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

Georg-August-Universität Göttingen
(founded in 1737)

Discussion Papers

No. 177

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Evidence from Indonesian households

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June 2015

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Inequality in emissions: Evidence from Indonesian households

Mohammad Iqbal Irfany[1]

Abstract

Although the literature on emission inequality is abundant, this study will differentiate itself by focusing on emission inequalities at the household level due to the disparity in household expenditure profiles. We further separate measures on emission inequality based on household characteristics as well as decompose it into sources of emission. Employing a common application for analyzing inequalities, results show that as per capita expenditure increases, within quintiles emission inequality tends to decline until the middle quintiles but then further increases in expenditure level and worsens emission inequality until the richest household. The decomposition of inequality based on emission sources suggests that energy-transportation dominantly contributes of the overall emission inequality.

Keywords: carbon footprint, household, inequality

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1 Introduction

Human activity is one the leading contributors to the rise in global emissions, particularly since the industrial revolution. The idea of the relationship between economic development and environmental degradation is suggested by the Environmental Kuznets Curve (EKC) hypothesis, that proposes that in the early stage of development environmental degradation surges until reaching its peak, then a further increase in economic affluence would lead to a decline in environmental degradation. For that reason, the investigation of the driving forces as well as the evolution of CO_2 emission levels are important and thus have been becoming of great interest to both research and policy perspectives.

However, different levels and patterns of development in countries or groups of economic actors lead to a disparity in the figures of environmental degradation. Of particular evidence is the fact that the inequality in emissions across countries (or regions) is enormously huge. For instance, the World Bank (2013) reports that in the 1980s developing countries in East Asia emitted only 1.27 tons of CO_2 per capita compared to the European countries that emitted about 5.75 tons/capita. In 2009 however there was a huge change in the emission disparity as the CO_2 emission per capita in East Asia jumped to 4.59 tons while Europe increased to just around 7.22 tons of CO_2 emission.

More importantly, many studies, such as Heil and Wodon (1997) and Clarke-Sather et al. (2011), proclaim that the inequality in emissions between developed and developing countries has been one of the huge challenges hampering the process of forging international agreements towards reducing green house gas (GHG) emissions. One particular reason for this is that developed countries believe that restraining their emissions will disrupt their economy. Conversely, developing and emerging economies argue that their growth should not be limited by any climate mitigation policies, as their historical levels of carbon emissions have been lower (Heil and Wodon 1997; Duro and Padilla, 2006). These contradictory arguments challenge the mitigation of global climate policies.

Notwithstanding the fact that the emission inequality problem is somewhat global or regional, it could be also relevant to investigate the issue at the micro level across households. Given this, this study tries to measure the CO_2 inequality as well as decompose the inequality from the household/micro perspective. The analysis of emission inequality could be valuable in the discourse of carbon inequality, particularly to the discourse on climate change. The measure and degree of inequality in CO_2 emissions across households show what degree of "responsibility" emitters have from the household perspective.

Some particular motivations of this study are: to discover whether the apparent stability in household (cross-sectional) emissions could coincide with the unequal expenditure distribution, as well as to investigate the drivers of its distributions. Similar to the emission inequality in the macro analysis concerning household distribution, we apply several measures of inequality to synthesize the amount of inequality at the household level. In addition to determining the level of inequality, we will also disaggregate and decompose inequality into subgroups of observations as well as into sources of emission. Among the major reasons to decompose household emission inequality are: (i) allowing us to identify whether the change in emission inequality is fueled by a reduction in the emission gap between household affluence, or whether its difference is due to the homogeneity of households' lifestyles within the same group; (ii) allowing us to understand which subgroups (and source of emissions) dominantly contribute to the overall emission inequality. Finally, to see whether household expenditure or emissions is more unequal, we will compare the dispersion and inequality decomposition of the two variables to investigate measures and drivers of such inequality.

2 Literature reviews

Various studies have been conducted to investigate emission inequalities that are mainly focusing on the international (e.g. Heil and Wodon, 1997; Hedenus and Azar, 2005; Padilla and Serrano, 2006; Cantore and Padilla, 2010) as well as the regional level (e.g. Alcantara and Duro, 2004; Padilla and Duro, 2013; Clarke-Sather et al. 2011). In general, these studies have taken into account the characteristics of the emission distribution and have dealt with the arrangement in international and national emissions inequality.

In an international context, Heil and Wodon (1997) analyze cross-countries CO_2 emissions inequality between poor and rich countries. Employing the Gini index, results found that the inequality in GHG emissions remained high during the period 1960-1990 and the between group component accounted for half of the per capita emissions inequality. Padilla and Serrano (2006) applied conventional applications of inequality to measure CO_2 emissions inequality, and employ the Theil index decomposition to investigate the contribution of four income country groups to the overall inequality in CO_2 emissions. They found that while overall CO_2 emissions inequality lessens over time, the low-income countries experience an increase in inequality. Employing the concentration indices of emissions (cross country emission inequality ordered by increasing value of income, which was proposed by Kakwani et al. (1997)), they found it has diminished less than the conventional measure in emission inequality. Duro and Padilla (2006) decompose the Theil index of emissions by using Kaya factors to find what contribution the factors had on per capita CO_2 emissions, CO_2 intensity, energy intensity and per capita income. They found that the CO_2 emissions inequality was mainly attributed to the difference in per capita income levels. Recently, an investigation of the international inequalities in ecological footprint was conducted by Duro and Teixidó-Figueras (2013), that primarily suggested that the global emission inequality was largely explained by “between groups” inequalities rather than “within group” component.

From the regional context, a study on the energy intensities inequality among OECD countries by Alcantara and Duro (2004) revealed that the decline in energy intensities differences was mainly due to “between-group component inequalities” rather than “within group inequalities”. Similarly, Padilla and Duro (2013), who only focused on the European Union case, employed the same method of decomposing emission inequality of using the Kaya factor. They found that per capita output is the most important factor of emission inequality. In other words, evidence from the European Union is consistent with the global context. Furthermore, there was a significant decline in emission inequality, which is primarily contributed by the declining contribution of energy intensity inequality and reduction of output inequality between country groups.

In the case of provincial level analysis, Clarke-Sather et al. (2011) primarily intend to investigate whether the Chinese provincial-level of CO_2 inequality mirrors the international pattern. They found that global evidence of CO_2 emission inequality was not reflected in the provincial context, as the contribution of "within group inequality" (i.e. intraregional inequality) was larger than the "between group" inequality component. This means that the variations of CO_2 emissions between regions in China are lower than the variation within any particular provinces. Their results contradict Heil and Wodon (1997), Padilla and Serrano (2006) and Levy et al. (2009) findings that indicated between group inequalities are the major contributors to total emission inequality in the international context.

3 Methodology and data

3.1. Basic measures of emission inequality

Imagine we have distribution of emission, $e = (e_1, e_2, e_3, \dots, e_N)$, for N individuals which has the mean $\mu = \frac{1}{N}\sum_{i=1}^{N} e_i$. For this distribution, emission inequality can be defined as a I(e) function which determines how unequal this emission distribution is. Several methods are commonly applied to measure inequality, each of which possesses their own benefits and drawbacks. This study will use the Gini and the Theil index, which will be applied to find the level of inequality in the emission and expenditure distributions.

One of the most popular inequality measures, the Gini coefficient, is defined as the area between the absolute equality line and the Lorenz curve. It is easily and readily understandable as it has a value from 0 (means perfect equality) to 1 (means perfect inequality). We calculate the household Gini coefficient of household emission using the following formula:

$$G(c) = \left(\frac{2\sum_{i=1}^{N} i * c_i}{N\sum_{i=1}^{N} c_i}\right) - \left(\frac{N+1}{N}\right) \qquad (1)$$

N and c_i refer to the total number of households (observations) and per capita emissions, respectively.

The Theil index measures a weighted entropy index and can be fully decomposable into subgroups of observations or other factors. This decomposability is beneficial as it allows us to study the composition of the index by factors or sources. This index can be calculated using the following formula:

$$T(c) = \sum_{i=1}^{N} p_i \ln(\frac{\bar{c}}{c_i}) \quad (2)$$

where p_i is the proportion of individual i to the overall individuals in the (group) sample, $\bar{c}$ is the mean of per capita emission. As mentioned, if our overall number of observations is divided into several groups (in our case, per capita expenditure quintiles, regions, educational attainment, number of household members, gender and age of household head), the overall emission inequality can be expressed as a sum of two terms called the ‘within group inequality’, $T(c)_w$, and the ‘between group inequality’, $T(c)_b$, as follows:

$$T(c) = T(c)_w + T(c)_b \quad (3)$$

The within-group inequality measures how much per capita emission inequality is due to the variations between the individuals in each of these groups, while the between group inequality quantifies to what extent emission inequality is due to the differences in the average emission amount of each subgroup. Equation (3) can be re-expressed as follows:

$$T(c) = \sum_{g=1}^{G} p_g T(c)_g + \sum_{g=1}^{G} p_g \ln(\frac{\bar{c}}{c_g}) \quad (4)$$

The first term, which represents the within group inequality, is a weighted sum of subgroup inequality values, while the latter term indicates the between group component of inequality. p_g is the household proportion in group g, $T(c)_g$ represents the internal Theil coefficient of household emission in group g, and c_g denotes the household emission in group g.

3.2. Concentration index of emission vs. expenditure Gini

Intuitively, we can directly compare the amount of emission inequality to the amount of expenditure inequality just comparing their Gini indices. However, one particular drawback of direct comparison is a different ranking criterion since the emissions Gini index is basically computed using the ranks of individuals based on their emissions, while the expenditure Gini index is constructed using the ranks of households based on their expenditure rank. To solve this, we can apply another index, modified from Kakwani et al. (1997), which basically compares the concentration of emissions and expenditure using the same rank ordering based on expenditure. In other words, this can be regarded as emissions inequality conditional on expenditure. Among the previous studies that employed this similar method were Cantore and Padilla (2010) and Padilla and Serrano (2006). We basically calculate the Kakwani index by subtracting the household expenditure Gini, $\mathrm{G(Exp)}$ from the quasi-Gini index of CO_2 emissions, $\mathrm{qG(c)}$, as follows.

$$\mathrm{G(Exp)_i} = \left[\frac{2\sum_{i=1}^{N} i.\mathrm{Exp}_i}{N\sum_{i=1}^{N}\mathrm{Exp}_i}\right] - \sum_{i=1}^{N} i.\, c_i \qquad (5)$$

where $\mathrm{Exp_i}$ is expenditure of i-th individual (which were ordered by their per capita expenditure).

$$\mathrm{qG(c)} = \left[\frac{2\sum_{i=1}^{N} i.c_i}{N\sum_{i=1}^{N} c_i}\right] - \left(\frac{N+1}{N}\right) \qquad (6)$$

where c_i refers to the emissions of the i-th individual, but ordered by per capita expenditure. The Kakwani index is then computed by the following formula:

$$K = \mathrm{qG(c)} - \mathrm{G(Exp)_i} \qquad (7)$$

which measures the difference between the concentration of household emissions and household expenditure inequality. A positive number of K indicates that CO_2 emissions are more concentrated along the expenditure distribution (less equally distributed than expenditure), and vice versa.

3.3. Inequality decomposition into emission sources

Although the Gini index cannot be decomposed into 'between' and 'within' group, we can decompose this index into sources of emissions using the application suggested by Lerman and Yitzhaki (1985) and Stark et al. (1986), employing the following steps. We initially need to divide the overall amount of emissions by the number of households and then rank the households from the lowest to the highest emitter. Then we compute the Gini index of the overall emission, $G(c)$, using another expressions as follows:

$$G(c) = \frac{2}{N\mu} Cov(c, r) \quad (8)$$

where c is the per capita CO_2 emission, μ is the mean of per capita CO_2 emissions for all N observations (in kg of CO_2) from all emission sources, and r is the rank of the individual according to their emissions.

Modifying (8), the Gini index of the i-th source of emissions, $G(c)_i$, can be computed as follows:

$$G(c)_i = \frac{2}{N\mu_i} Cov(c_i, r_i) \quad (9)$$

where c_i is the per capita emission amount in that particular expenditure category, μ_i is the average per capita emission amount of the i-th emission source, and r_i denotes the corresponding rank of the individual in that emissions source.

The overall Gini index of the overall per capita CO_2 emission amount can be derived from the above individual Gini index of emission source, as follows:

$$G(c) = \sum_i S_i R_i G(c)_i \quad (10)$$

where $S_i = \frac{\mu_i}{\mu}$ is the share of a particular emission source in overall emissions, $R_i = \frac{Cov(y_i,r)}{Cov(y_i,r_i)}$, is the rank correlation ratio of the covariance between the amount of emissions from a particular emission source and the overall emission rank ($Cov(y_i, r)$) to the covariance between the amount of emissions in that particular source and the emission source rank, $(\mathrm{Cov}(y_i, r_i)$.

Therefore, we can then estimate what effect a small change has in a particular inequality has on the total inequality given the equation (10), which shows that the overall emission inequality is a product of the three terms, including (i) the share of the average emission amount of a particular source has in total emissions, S_i, (ii) the correlation between the i-th emission source and its rank in overall emission, R_i, and (iii) the emission source Gini, $G(c)_i$.

In addition, we can measure what marginal effect of a percentage change in the emission source has on the total emission inequality. This will allow us to calculate what kind of an effect a marginal change in a particular emission source will have on overall emission inequality. We modified the method proposed by Lerman and Yitzhaki (1985) and Stark et al. (1986). Suppose we have an exogenous change in i emission source by a factor, say h, such that $c_i(h) = (1 + h)c_i$, we can then capture the change as:

$$\frac{\partial G(c)}{\partial h} = S_i[R_i G(c)_i - G(c)] \quad (11)$$

Dividing (11) by $G(c)$ yields the following formula:

$$\frac{\frac{\partial G(c)}{\partial h}}{G(c)} = \frac{S_i R_i G(c)_i}{G(c)} - S_i \quad (12)$$

which implies that the relative effect (change) of a percentage in i emission source to the total inequality equals the relative contribution of i emission source to the overall emission inequality minus the relative share of emissions from source i in the total emission amount.

3.4. Data

We use the data on carbon emission from the Global Trade Analysis Project-Environmental Account (GTAP-E), which contains CO_2 emissions from energy and cement production but does not include emissions from land-use change, which is also an important factor for the Indonesian case. These emissions are then incorporated with the Indonesian Input-Output (IO) table, and the Indonesian household expenditure survey (Susenas) from the 2005 and 2009 survey. This method is convenient for describing and explaining the environmental impact of different household types (Kok et al., 2006).

We combine the IO analysis with GTAP-E to calculate the cumulative sectoral carbon intensities, which account for the direct and indirect emissions of any particular economic sectors. Expenditure amounts on consumption items in Susenas are multiplied with the corresponding emission intensity from the IO-GTAP computation. Then by summing the CO_2 emissions from any particular consumption category we get the household carbon footprint. The method used in deriving the household carbon footprint follows the concept of the consumer responsibility model (Suh, 2009).

Technically, the total households' CO_2 emission can be computed by summing up the direct (c_{dir}) and indirect (c_{ind}) emissions, as follows:

$$\mathrm{c_{hh}} = \mathrm{c_{dir}} + \mathrm{c_{ind}} \qquad (13)$$

while the direct emissions consist of domestic energy consumption and transport, the indirect emissions account for emissions embodied in the consumption related to household operations, food expenditures, service-oriented goods and other expenditure items. The indirect emissions are calculated by tracing the emissions of a certain household expenditure item down to its intermediates in the IO table, employing the methods of IO analysis in estimating the embodied carbon emissions (e.g. Parikh, et al. 1997; Lenzen 1998; Bin and Dowlatabadi 2005; Kok et al. 2006). The sectoral CO_2 emission intensities, $\mathrm{EI_j}$, can be computed by using the following formula:

$$\mathrm{EI_j} = \mathrm{e}'(\mathrm{I} - \mathrm{A})^{-1}\mathrm{y} \qquad (14)$$

$\mathrm{EI_j}$ is the carbon intensity of each economic sector in the IO table, e is a vector of carbon coefficients taken from the GTAP (Lee 2008). A is the technical coefficients, while$(\mathrm{I} - \mathrm{A})^{-1}$ is widely known as the Leontief inverse; y is the vector of final demand for commodities. We then match j carbon intensity (14) with the i consumption categories taken from household expenditure as follows:

(15)

We found that the average Indonesian carbon footprint[2] in 2005 were 698 kg CO_2/capita and increased to 898 kg CO_2/capita in 2009 (expenditure deflated, 2005=1). When disaggregating across expenditure quintiles, there is a huge disparity in emissions across affluence quintiles (**Figure 1**), which indicates that there are large differences between the household carbon footprints across different household affluence level. For instance, the per capita emission amount of the richest quintile is almost seven times as high as the carbon footprint of the poorest quintile, and still about three times as high as the level of the third quintile (middle affluence group). Considering such large differences of household emission, it is sensible to analyze emission inequality of different household affluence as can be explained further in the following sections.

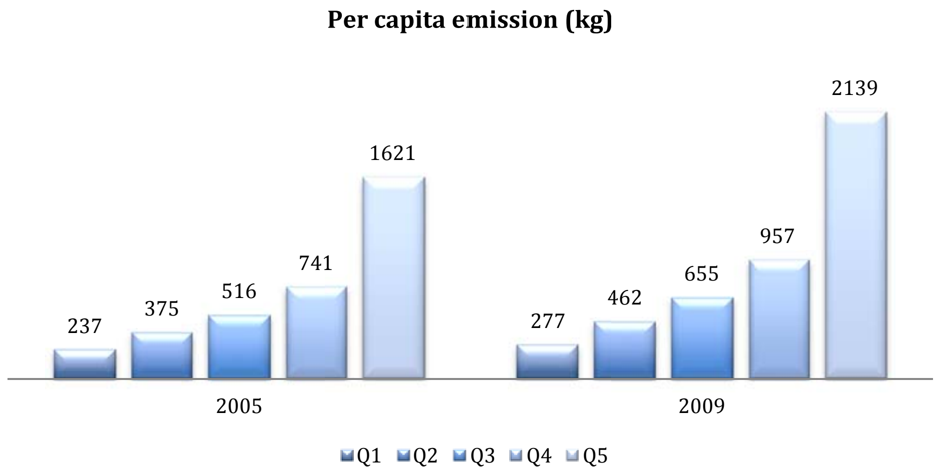

Figure 1. Per capita emission by affluence quintile (2005 and 2009)

[2] The CO_2 emissions are scaled up to national account expenditure.

4 Results and discussions

4.1. Household characteristics and emission share

We begin with providing a simple measure of inequality by computing the share of per capita emission from the overall figures, as shown in **Table 1**. First, by classifying observations into five quintiles based on per capita expenditure, it is clearly shown that the average per capita emission contribution increased in line with the rise in expenditures. In the 2005 survey, the richest quintile contributed about 46% of total emissions (48% in 2009) compared to the fourth quintile at 21% (21%), the third quintile at about 15% (15%), the second quintile at about 11% (10%), and the poorest quintile at about 7% (6%). In other words, the individuals from the richest household emit more than 7 times (8 times) the amount that the first and the second quintile emit. In general, these figures clearly suggest similar patterns of the share of emission among household groups in both surveys.

Table 1. Per capita emission and emission share

	Mean of Per capita emission (kg CO2)		Share of per capita emission (%)		% of observations	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**
Affluence						
Poorest	237	382	6.80	6.17	20	20
2nd	375	638	10.75	10.29	20	20
Middle	516	904	14.77	14.59	20	20
3rd	741	1321	21.24	21.32	20	20
Richest	1,621	2952	46.44	47.64	20	20
Location						
Rural	489	952	31.81	35.03	62.52	64.72
Urban	1047	1766	68.19	64.97	37.48	35.28
Education						
Did not grad	570	1113	13.01	16.32	19.06	17.51
Elementary	577	1114	13.17	16.34	43.34	41.91
Secondary	680	1191	15.52	17.46	16.69	16.62
High school	940	1468	21.45	21.52	16.62	17.98
At least college	1615	1934	36.85	28.36	4.30	5.98
If s/he is member of x persons HH						
1	1408	4767	24.51	38.28	1.31	1.53
2	1035	2336	18.02	18.76	5.98	6.79
3	830	1589	14.45	12.76	15.91	17.03
4	733	1242	12.76	9.97	24.55	25.03
5	656	1010	11.42	8.11	21.04	20.83
6	581	850	10.11	6.83	14.4	13.57
7+	501	659	8.73	5.29	16.81	15.21
Gender						
Male	706	1213	50.59	48.95	50.23	50.13
Female	690	1265	49.41	51.05	49.77	49.87
Age						
<30	656	1129	22.47	20.45	59.44	55.44
30-44	736	1262	25.18	22.85	20.21	22.1
45-64	796	1424	27.26	25.79	15.83	17.31
65+	733	1706	25.09	30.90	4.52	5.15
Per capita emission (No of obs.)	**698**	**1239**			**1052091**	**1155566**

Comparing locations, in both surveys we can see that the per capita emission of urban households is more than double the amount of those who are living in rural areas. The contribution of urban household to overall emission in 2005 was about 68% (65% in 2009). Comparing the two years, urban households decreased their share of emissions (from 68% to 65%), while per capita emission of rural households had a slight increase in their contribution to total emissions.

Classifying observations according to educational attainment, the figure has a similar pattern to the affluence classification. The contribution of 'at least college’ graduates was higher than lower educational attainments. Someone who had 'at least college' contributed about 38% in 2005 (27% in 2009), compared to elementary school graduate at about 13% (16%). Comparing the two years, we can see there was an increasing pattern in the share of emissions from 'did not graduate' to 'high school graduate', while 'at least college graduate' group has a decreasing emission share pattern.

Comparing emissions according to the number of household members, there have been decreasing patterns of per capita emission share from those who are a member of a small family to those who are a member of a large family. If s/he has 2 households member, for instance, per capita emission is about 18%, compared to the share of per capita emission from an individual, which is 7 or more times the amount per household member. This would hint that the population effect has a negative effect on lower per capita emission amounts, the effect becoming smaller as the per capita emission amount increases.

Comparing gender of household head, the emission share of those who are headed by a female is slightly lower than male-headed households. However, comparing between the two surveys, there was a slight increase in the emission contribution of female household heads, so the contribution to CO_2 emissions of female and male headed households are slightly more equal in 2009. Finally, when categorizing households by the age of the household head, we not-surprisingly found that there is an 'inverted U-shape’ of the emission share of households, as the share increased until the age of 64 and then lowered after 65 years of age.

4.2. Emission inequality measure by household characteristics

This section will analyze the disparity in emissions among households through employing the Gini and Theil indices**.** Classifying observations by their affluence, the conditional Gini coefficient indicates that both in 2005 and 2009 the emission inequality within quintiles has a U-shaped pattern when moving from the lowest to the highest expenditure quintiles (see **Appendix Table A.2)**. This within-group inequality measure decreases until the 4th quintile, however after the third quintile emission inequality worsens and increases up until the richest household group (**Figure 2**). Among all quintiles, it is clearly shown that the richest household group is the most unequal group in their per capita emission. It can be argued that this is due to variations in consumption preferences (lifestyle), which could determine emission inequality in addition to the richer household (particularly richest quintile) has larger range of expenditures. Comparing the two surveys, emission inequality in 2009 is less than in the 2005 survey, not only for the entire group of surveyed households but also at each affluence level. In addition, we can see that the 'within-quintile' emission inequality was the dominant contributor (about 70%) to overall inequality.

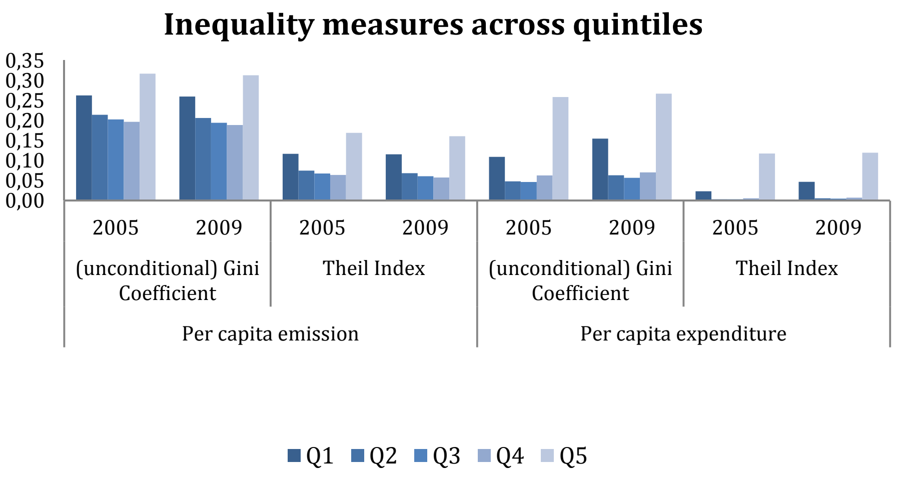

Figure 2. Emission inequality measures across quintiles

Based on educational attainment, we found that the most unequal group is observed amongst households headed with someone who has ‘at least college graduate’. Apart from decreasing inequality pattern from without formal education to elementary school graduate, there is an increasing pattern of inequality with respect to higher educational attainment. In addition, the Theil index decomposition indicates that the emission inequality is dominantly attributed to the within group component. The above figures could hint that formal education attainment does not likely change the consumption preferences towards less carbon intensive expenditure items. The more educated a household becomes, the greater the income attained and the more money that is spent by the household.

Classifying observations based on the number of household members, we observe an U-shape pattern of inequality moving from the least to the biggest household size. There is a decreasing pattern of per capita emission inequality from group of one family member to three members, and it increase from 4 household member groups to the largest household size. A possible explanation could be that it is related to the sharing of resources (energy use) among household members. If a small household generally has a higher per capita energy use, then the emission inequality could be higher. In larger sized households, resources could be shared, thus lowering per capita energy use that would cause emission inequality to decrease. Finally, from the gender classification, we found that in both surveys the male-headed households were more unequal than the female-headed households. We also found an increasing pattern of emission inequality based on the age of the household head. Younger household heads have a lower emission inequality.

4.3. Emissions inequality and its relationship with the expenditure distribution

We compare the inequality distribution of per capita emissions to the inequality distribution of per capita expenditure instead of solely analyzing the emission inequality itself. Comparing both figures allows us to evaluate whether the emission distribution is more or less equal than the expenditure distribution. This section compares the computation of emission inequality with the same measure and rank as the expenditure inequality. **Table 2** shows a descriptive analysis of the per capita emissions contribution of all of the household affluence levels to from both surveys.

Table 2. Per capita emission vs. per capita expenditure: Contribution to total (%)

	2005		2009	
	Per capita emission	Per capita expenditure	Per capita emission	Per capita expenditure
Poorest	6.80	7.75	6.17	5.98
2nd	10.75	11.51	10.29	10.30
Middle	14.77	15.20	14.59	14.64
4th	21.24	20.98	21.32	21.26
Richest	46.44	44.56	47.64	47.83

In the 2005 survey, the richest quintile is responsible for about 46% (45% in 2009) of total emissions compared to the fourth quintile that contributes about 21% (21%), the middle affluence group contributes about 15% (15%), the 2nd quintile about 11% (12%), and the poorest group contributes about 7% (8%). In other words, the richest group emits (in per capita terms) more than 7 times (8 times in 2009) the amount of the poorest household. Similarly, the pattern of the per capita expenditure shares (to total expenditure) is comparable to the emissions. In 2005 the most affluent household quintile emitted about 48% of total emissions compared to the poorest household group at 6%. Finally, comparing the expenditure shares, in both surveys the emission shares were generally higher than the expenditure shares in the two richest groups, which is opposite from the three lowest quintiles. In other words, the emissions are more concentrated relative to emission shares in the top two quintiles than the lower quintile. It also means that emission inequality is slightly larger than expenditure inequality.

In addition to the application of the ‘conventional’ Gini index, we can also measure emission inequality by employing the concentration index of CO_2 emissions, which is modified from Kakwani et al. (1997). This method basically measures the inequality in emissions by employing the Gini index, but we ranked household CO_2 emissions in the distribution according to their expenditures, which is widely called quasi-Gini or the concentration index. We then compared this emission concentration index with the expenditure Gini index. The Kakwani index measures to what extent the distribution of emissions is greater than the distribution of expenditure. Applying this index, we can measure the level of ‘regressivity’ or ‘progressivity’ of the emission distribution across observed subgroups (Padilla and Serrano, 2006).

Table 3 predicts the concentration index of per capita emissions versus the Gini index of per capita expenditure. We found that moving from the lowest to the highest quintile the evolution of both indices generally diminished, except from the first to the second quintile. For the overall households, surveys in 2005 and 2009 tell different story. In 2005, the overall Kakwani index had positive sign, which indicates that CO_2 emissions are more concentrated (less equally distributed) than expenditure. In contrast, the Kakwani index of the 2009 survey has negative value (but the sign is quite small), which indicates plotted CO_2 emission distribution conditional on expenditure is slightly less concentrated than expenditure distribution. If we take into account the movement of this index when moving from the poorest to the second quintile, we can see a conflicting figure. In 2005 the Kakwani index had a decreasing figure, i.e. un-equalizing emissions relative to expenditure, while in 2009 there was an increasing figure of Kakwani index, i.e. equalizing emission relative to expenditure distribution. In general however, the emissions were more unequal than expenditure.

Table 3. Concentration of CO_2 vs. expenditure Gini

	Unconditional Gini index of per capita emission		**Quasi Gini Index of per capita CO2**		**Gini index of per capita expenditure**		**Kakwani Index**	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Poorest	0.262	0.260	0.129	0.142	0.109	0.155	**0.020**	**-0.013**
2nd	0.214	0.206	0.056	0.063	0.048	0.063	**0.008**	**0.000**
Middle	0.203	0.194	0.053	0.059	0.047	0.057	**0.006**	**0.002**
4th	0.196	0.188	0.070	0.071	0.063	0.070	**0.007**	**0.001**
Richest	0.317	0.313	0.257	0.264	0.259	0.267	**-0.001**	**-0.003**
Overall	0.430	0.442	0.390	0.409	0.362	0.411	**0.028**	**-0.002**

Quasi Gini Index is based on Concentration Index of CO_2 emissions, i.e. Gini index of CO2 emissions ranked by household expenditure (Kakwani, et al.,1997).

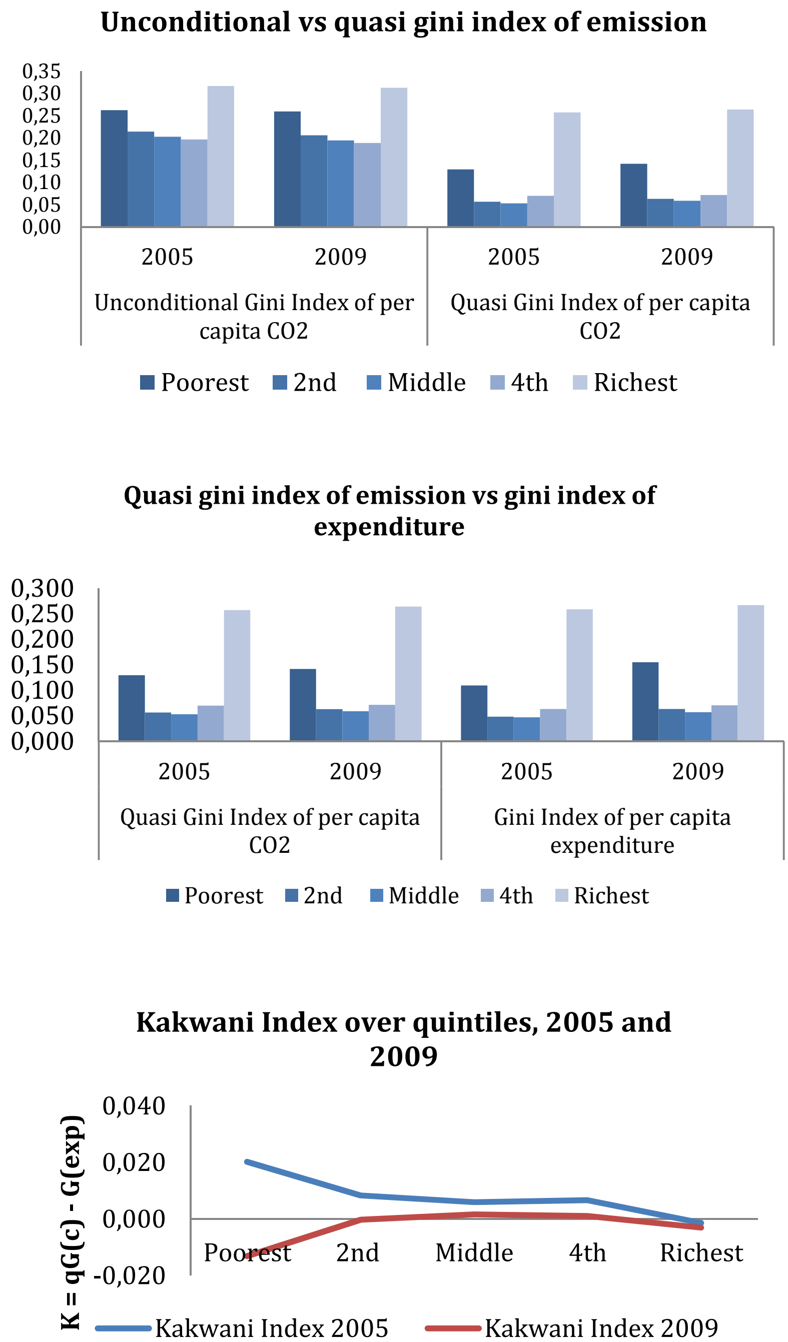

Figure 3. Emission vs. expenditure inequality

4.4. Decomposition and simulation of CO_2 inequality by emission sources

This section provides the analysis of emission sources (expenditure categories) to determine how they contributed to changing the inequality in emissions as well as the analysis of the marginal effects of a percentage change in emission sources that will determine the overall emission inequality. It can be seen from **Table 4** that fuel-light contributes more than half of overall emissions, followed by transportation, which accounts for 6-8% of the overall emissions. This clearly suggests that these two emission sources (expenditure groups) enormously contributed to the overall emission level. Hence, changing people's preferences of them will contribute to the behavior of overall emissions. In other words, a different distribution of household emissions can be traced from the composition of household consumption of these two carbon intensive categories.

Table 4. Gini decomposition by per capita emission source

Emission source	Share of emission source (*Sk*)		Gini of emission source (*Gk*)		Correlation to total CO2 (*Rk*)		$Share = \frac{S_k G_k R_k}{G}$		$\%\ change = \frac{S_k G_k R_k}{G} - S_k$	
	2005	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**	**2005**	**2009**
Cereal	0.015	0.016	0.261	0.379	0.013	0.403	0.000	0.005	-0.015	-0.010
Vegetable and fruit	0.038	0.040	0.381	0.434	0.637	0.711	0.021	0.028	-0.016	-0.012
Oil and fat	0.007	0.007	0.343	0.402	0.379	0.547	0.002	0.004	-0.005	-0.004
Beverage	0.058	0.063	0.509	0.551	0.733	0.736	0.050	0.058	-0.008	-0.005
Egg, fish, meat, dairy	0.064	0.068	0.487	0.551	0.610	0.707	0.044	0.060	-0.020	-0.008
Tobacco	0.024	0.025	0.578	0.623	0.314	0.448	0.010	0.016	-0.014	-0.009
Fuel and light	0.593	0.564	0.469	0.468	0.956	0.951	0.618	0.568	0.025	0.004
Telecommunication	0.011	0.012	0.882	0.736	0.844	0.795	0.018	0.016	0.008	0.004
Transportation	0.064	0.082	0.721	0.659	0.771	0.790	0.083	0.096	0.019	0.015
Health	0.005	0.006	0.757	0.774	0.582	0.599	0.005	0.006	0.000	0.000
Education	0.008	0.010	0.783	0.775	0.575	0.623	0.008	0.011	0.000	0.001
Toiletry	0.007	0.006	0.460	0.474	0.737	0.769	0.005	0.005	-0.001	-0.001
Clothes	0.016	0.017	0.509	0.532	0.627	0.708	0.012	0.014	-0.004	-0.003
House and durable goods	0.045	0.042	0.881	0.889	0.760	0.753	0.069	0.063	0.025	0.022
Services and rent	0.030	0.031	0.634	0.635	0.789	0.786	0.035	0.035	0.005	0.004
Taxes	0.001	0.002	0.844	0.817	0.754	0.753	0.002	0.002	0.001	0.001
Recreation, ceremony	0.016	0.013	0.854	0.904	0.523	0.544	0.017	0.014	0.001	0.002
Per capita CO2			0.430	0.442						

Applying the modified methods of Lehman and Yitzhaki (1985) and Stark et al. (1986), we compute the decomposition of the Gini coefficient, which allows us to estimate the marginal effects of each of the consumption categories on the overall emission inequality. A positive (negative) marginal effect indicates that an increase in any emission source leads to un-equalizing (equalizing) total household emissions, cateris paribus. We found that from the household cross-sectional analysis, it is noticeable that a 1% increase in the emissions of fuel-light leads to an increase the total emission inequality to about 0.25% in 2005 (0.04% in 2009). In other words, a rise in the share of emissions from this category will increase the overall emission inequality (i.e. the distribution of CO2 emissions become more unequal). In contrast, an increase in emissions from cereals will have equalizing effect of emissions.

In terms of direction, we found that emissions from food, toiletry, and clothes-related expenditures have an equalizing effect on the distribution of overall emission inequality. On the other hand, an increase in emissions from fuel-light, transportation and services will have a worsening effect on emission inequality. This finding is consistent with the fact that as income rises; the food-related expenditure share decreases, causing people to spend more on durables and services. When households become affluent, they tend to consume more energy, services and durables goods, which leads to an increase in the inequality level of emissions from these sources, contributing to more unequal emissions (particularly in the richest group).

The above observation is also supported by the individual Gini index of each emission source. In general, the Gini index of fuel-light emissions is similar to the overall emissions of the Gini. Moreover, emissions from services-durable goods (Gini index range from 0.63 to 0.89) are less equally distributed than food-related emissions. For instance, in 2005, the Gini indices of house, durables, telecommunication, recreation and ceremony are closed to 0.88 while the Gini coefficient of cereals, vegetables and fruits was only around 0.26-0.38. Compared to the overall emissions (Gini index of about 0.43-0.44), emissions from transportation are more unequal, at around 0.66 (2009) and 0.72 (2005) while fuel-light, along with beverage and toiletry, have a middle figure of Gini index (0.46-0.47).

It is also fruitful to compare the figure of the emission inequality decomposition with the inequality decomposition of expenditure sources (**Table 6**). We found that fuel-light expenditures no longer have a large contribution to overall expenditure inequality (only about 6%). The biggest portion is services, beverage and egg-fish-dairy products.

Table 5. Gini decomposition by per capita expenditure category

Expenditure category	Share of expenditure (*Sk*)		Gini of exp category (*Gk*)		Correlation to total expenditure (*Rk*)		$Share = \frac{S_k G_k R_k}{G}$		$\%Change = \frac{S_k G_k R_k}{G} - S_k$	
	2005	2009	2005	2009	2005	2009	2005	2009	2005	2009
Cereal	0.126	0.123	0.255	0.376	0.247	0.588	0.022	0.066	-0.104	-0.057
Vegetable and fruit	0.082	0.079	0.379	0.432	0.712	0.771	0.061	0.064	-0.021	-0.015
Oil and fat	0.025	0.023	0.343	0.402	0.520	0.650	0.012	0.015	-0.013	-0.008
Beverage	0.146	0.142	0.451	0.499	0.816	0.818	0.148	0.141	0.002	-0.001
Egg, fish, meat, dairy	0.132	0.126	0.452	0.513	0.768	0.805	0.126	0.127	-0.006	4.0E-04
Tobacco	0.077	0.073	0.576	0.622	0.468	0.569	0.057	0.063	-0.020	-0.010
Fuel and light	0.064	0.057	0.469	0.468	0.769	0.785	0.064	0.051	0.000	-0.006
Telecommunication	0.028	0.029	0.882	0.736	0.853	0.812	0.058	0.042	0.030	0.013
Transportation	0.046	0.054	0.721	0.659	0.757	0.785	0.069	0.068	0.023	0.014
Health	0.020	0.024	0.759	0.775	0.653	0.665	0.027	0.030	0.007	0.006
Education	0.032	0.035	0.783	0.775	0.545	0.684	0.037	0.045	0.006	0.010
Toiletry	0.028	0.024	0.460	0.474	0.735	0.794	0.026	0.022	-0.002	-0.002
Clothes	0.034	0.032	0.509	0.532	0.664	0.766	0.031	0.032	-0.002	-3.0E-04
House and durable goods	0.036	0.031	0.881	0.889	0.778	0.745	0.068	0.050	0.032	0.019
Services and rent	0.134	0.127	0.614	0.604	0.856	0.841	0.194	0.157	0.060	0.030
Taxes	0.010	0.011	0.822	0.792	0.760	0.757	0.017	0.017	0.007	0.005
Recreation, ceremony	0.015	0.011	0.854	0.904	0.563	0.559	0.020	0.013	0.005	0.002
Per capita expenditure			0.362	0.411						

We further aggregate the emission source and expenditure sources as shown in **Table 5** and **Table 6** into four major emission (expenditure) categories, namely food, energy and transportation, housing operation and durables, and services[3]. We then compute the same application to get a deeper understanding of the sources of inequality in emissions and expenditure. The results are summarized in **Figure 4**. We can see that there was an increase in the emission and expenditure inequality measure from 2005 to 2009. However, we observed a different story about the contributors to the inequalities in emissions and expenditure. For the emission inequality contributors, it is noticeable that in both years, energy-transport is responsible for more than two-thirds of the overall emission inequality, followed by services and household operations, so if we get rid of the disparity in the energy-transport emission, then the overall emission inequality will reduce by the same amount. For expenditure inequality, we found that the main contributors to inequality are food (mainly beverages) and services.

[3]"Food" refers to emission from cereals, vegetables and fruits, oil and fats, eggs fish, meat and dairy, and tobacco; "Energy and transportation" captures the emission from fuel-light and transportation; "Housing operations and durables" represents emission from house operation and durables, toiletry, and telecommunication; "Services" represents emission from health, education, services sectors and rent, tax and redistribution, and recreation and ceremony.

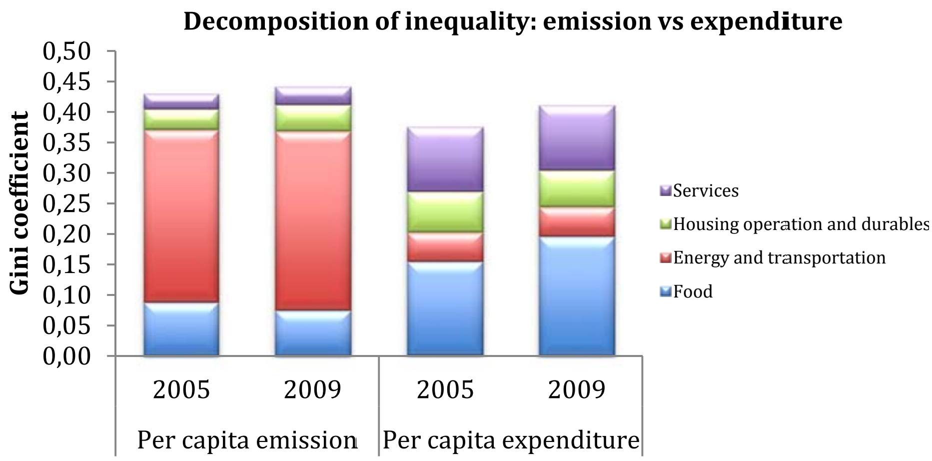

Figure 4. Sources of inequality: emission vs. expenditure

5 Summary: does it matter for policy?

This study investigates the dispersion in per capita CO_2 emissions by employing various measures of inequality and then comparing the differences between the emission and expenditure inequality indices. We also decompose emission inequality based on household affluences, socio-demographic factors as well as sources of emissions to assess the patterns and drivers of inequality. Disaggregating emission inequality into any particular within-inequality based on different household characteristics assumes that different characteristics would have different within-inequality measure in emissions. And decomposing inequality by emission sources aims to measure the contribution of emission shares and to study the marginal effects of changes in different emission sources to the change in overall emission inequality.

Similar to the evidence in the international and regional context, we found that as per capita expenditure increases, emission inequality tends to decline until the middle household affluence group, but then increases and worsens emission inequality until the richest group, which is the most unequal group in terms of the within-inequality measure of emissions. This evidence could hint that the variation in consumption preferences (lifestyle), particularly toward emission-intensive items, determines overall emission inequality. Similar to the inequality measure based on household affluence, the emission inequality figure based on educational attainment has a similar pattern. Classifying observation according to the number of household members, we observe an

U-shaped pattern of inequality figures from the smallest to the largest household size group. Based on location, the per capita emissions in urban areas are observed to be more unequal than the figure from rural households. Based on gender, we found that the group of male-headed households is more equal than the female-headed group. Based on the age of household head, we found younger household head groups have a lower emission inequality. In addition, dividing observation based on their affluence, we found a dominant contribution of 'between group' component of inequality compare to between-group component. However, classifying based on non-expenditure characteristics, we found that "within-group inequality" dominates overall inequality. Comparing inequality measures between the emission and expenditure distribution, it is clearly shown that moving from the least to the most affluent groups, the evolution of both indices generally diminished, except for the first to the second quintile. It is generally suggested that CO_2 emissions are more concentrated (less equally distributed) than expenditure. The decomposition analysis of inequality based on emission sources suggests that in both years, energy-transport emissions was responsible for more than two-thirds of the overall emission inequality. It is then noticeable that the change in overall emissions can be reflected by dominant contribution of energy-related emission source and to some extent attributed to a rise in the share of emissions from services, durable goods and luxury. The decomposition of the emission and expenditure inequality suggests a different story about the contributors to inequalities in emission and expenditure. While the largest contributor to emission inequality is energy-transport (following by services and household operations), food (mainly beverages) and services are the largest contributors to the expenditure inequality.

Although there are only a limited number of empirical studies related to household emissions inequality, we could compare this study to international (cross-country), national and regional perspectives to investigate whether our household level analysis mirrors the results from more macro perspectives. One piece of evidence suggests that emission inequality is dominantly explained by the between-affluence component, which is reasonably consistent with Clarke-Sather et al. (2011) for a provincial-level analysis in China. Other studies (e.g. Padilla and Serrano, 2006, Levy et al. 2009; Duro and Padilla, 2006) report that inequality between groups of different income levels largely explains the overall emission inequality. Our findings then suggest that the level of affluence dominates the emission inequality, although non-income characteristics might also contribute to the overall emission inequality.

The improvements in the standard of living of poor households may initially promote a declining the emission inequality, as indicated by the decomposition of inequality across per capita expenditure quintiles. Yet a balanced development has to be sought out as growth in the higher quintiles, particularly the two richest quintiles will then push emission inequality wider. Therefore, rising environmental awareness has to be taken in line with providing households with greener consumption items, and providing better green infrastructure, including better public transportation. Carbon tax could be also introduced, in line with gradual reduction (and better targeting of) energy subsidies. Another important strategy in reducing emission inequality is the effort towards the improvement of energy efficiency to encourage households, at any level of affluence, to consume carbon-efficient expenditure items that will not merely reduce the emission level but also reduce the emission inequality.

Acknowledgement

I thank to Prof Stephan Klasen for valuable supervisions and comments.

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Appendix

Table A.1. Descriptive analysis: 2005 and 2009

2005	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Overall**
Total HH expenditure (Rp 000)	6,433	8,519	10,500	13,600	26,700	13,100
Per capita expenditure (Rp 000)	1,130	1,677	2,215	3,058	6,495	2,915
CO2 emission (kg)	1,323	1,875	2,413	3,283	6,669	3,113
Per capita CO2 (kg)	237	375	516	741	1,621	698
HH size (persons)	5.76	5.09	4.73	4.45	4.16	4.84
N of observation	210,420	210,419	210,416	210,420	210,416	1,052,091

2009	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Overall**
Total HH expenditure (Rp 000), deflated	6,685	10,072	12,826	16,739	29,348	15,145
Per capita expenditure (Rp 000), deflated	1,123	1,935	2,750	3,995	8,986	3,751
CO2 emission (kg)	1,614	2,370	3,037	3,989	7,011	3,604
Per capita CO2 (kg)	277	462	655	957	2,139	898
HH size (persons)	6.06	5.22	4.68	4.20	3.48	4.73
N of observation	231,119	231,116	231,105	231,113	231,113	1,155,566

Note: Based on per capita level analysis. The CO_2 emissions are scaled up to national account expenditure. Quintile classification is based on the household per capita expenditure distribution. Quintile 1 refers to the poorest quintile. Expenditure in 2009 is deflated (2005=100).

Table A.2. Inequality measures of per capita emissions and per capita expenditure, by subgroup (HH characteristics) indices

	Per capita emission				Per capita expenditure			
	(unconditional) Gini Coefficient		Theil Index		(unconditional) Gini Coefficient		Theil Index	
	2005	2009	2005	2009	2005	2009	2005	2009
Affluence								
Q1	0.262	0.260	0.117	0.115	0.109	0.155	0.023	0.047
Q2	0.214	0.206	0.075	0.069	0.048	0.063	0.003	0.006
Q3	0.203	0.194	0.068	0.061	0.047	0.057	0.003	0.005
Q4	0.196	0.188	0.064	0.058	0.063	0.070	0.006	0.007
Q5	0.317	0.313	0.169	0.161	0.259	0.267	0.118	0.119
Within group (%)			*0.098 (31%)*	*0.093 (28%)*			*0.031*	0.037
Between group (%)			*0.220(69%)*	*0.245 (72%)*			*0.185*	0.249
Location								
Rural	0.372	0.406	0.236	0.283	0.294	0.372	0.142	0.233
Urban	0.397	0.425	0.267	0.309	0.370	0.417	0.226	0.294
Within group (%)			*0.248(78%)*	*0.292*			*0.174*	*0.254*
Between group (%)			*0.071(22%)*	*0.046*			*0.042*	*0.032*
Education								
did not grad	0.405	0.435	0.281	0.327	0.329	0.400	0.177	0.269
elementary	0.398	0.427	0.271	0.314	0.320	0.393	0.169	0.261
secondary	0.405	0.427	0.280	0.315	0.336	0.396	0.186	0.265
high school	0.405	0.439	0.285	0.335	0.357	0.416	0.210	0.294
at least college	0.426	0.472	0.318	0.390	0.409	0.456	0.281	0.356
Within group (%)			*0.279(90%)*	*0.325(71%)*			*0.185*	*0.275*
Between group (%)			*0.040(10%)*	*0.013(29%)*			*0.031*	*0.011*
Household members								
1	0.427	0.394	0.319	0.264	0.404	0.369	0.272	0.231
2	0.417	0.381	0.297	0.245	0.365	0.351	0.219	0.206
3	0.392	0.378	0.260	0.241	0.331	0.347	0.179	0.202
4	0.405	0.381	0.278	0.245	0.338	0.348	0.187	0.203
5	0.420	0.387	0.302	0.255	0.350	0.350	0.203	0.206
6	0.424	0.394	0.306	0.264	0.348	0.354	0.199	0.211
7+	0.442	0.404	0.334	0.278	0.355	0.357	0.208	0.215
Within group (%)			*0.279(90%)*	*0.254(75%)*			*0.197*	*0.207*
Between group (%)			*0.040(10%)*	*0.083(25%)*			*0.019*	*0.079*
Gender of HH-head								
Male	0.428	0.438	0.315	0.332	0.360	0.281	0.213	0.408
Female	0.432	0.445	0.322	0.342	0.364	0.291	0.218	0.415
Within group (%)			0.318(99%)	0.337(99%)			0.216	*0.286*
Between group (%)			7.0E-05(1%)	2.2E-04(1%)			1.0E-05	*1.8E-04*
Age								
<30	0.425	0.432	0.311	0.323	0.356	0.398	0.208	0.269
30-44	0.428	0.433	0.316	0.323	0.366	0.403	0.220	0.275
45-64	0.443	0.448	0.339	0.348	0.375	0.422	0.233	0.303
65+	0.415	0.471	0.296	0.390	0.351	0.455	0.203	0.356
Within group (%)			0.316(99%)	0.331(98%)			0.214	*0.280*
Between group (%)			0.003(1%)	0.007(2%)			0.002	*0.006*
OVERALL	0.430	0.442	0.318	0.338	0.362	0.411	0.216	0.286