Jie Li (USA), Yan Wang (China)

Income, lifestyle and household carbon footprints (carbon-income relationship), a micro-level analysis on China's urban and rural household surveys

Abstract

In this paper, 2002 household survey data of China are used to calculate household and individual CO_2 emissions. The lifestyle approach (consumption approach) is applied to obtain carbon emissions from household expenditure information. The averaged per capita household CO_2 emissions results are, then, used to analyze the pattern of households-level lifestyles and carbon footprints, the existing carbon inequality in China and to calculate income elasticity of individual CO_2 emissions. Average household per capita CO_2 emissions of 1.68 tons are obtained for all the surveyed households, 3.17 tons for urban residents and 0.88 tons for rural households. Simulation results indicate that income level (expenditure on consumption used in the models) is the most important factor that causes carbon emission inequality. For income elasticity of CO_2 emissions (β), when other factors controlled, we estimated a 0.61 elasticity for urban, 0.92 for rural residents, and 0.84 for all the households together. Other factors that can significantly affect the micro carbon-income (C-I) relationship are household head education, households head age, households size, and geographic factors. Similar to the results from former researches on other countries, education and age have positive effects on per capita household emissions, while the effects of household size are negative. In addition, rural-urban and north-south differences are both extremely huge. This microdata analysis on Chinese household carbon emissions provides a close look at how different people with different lifestyles have different carbon footprints. In this research, only CO_2 emissions from fuel combustion (energy use) are taken into consideration. CO_2 emissions from other chemical processes, such as cement production, are not included. Also, this research is only on CO_2 emissions. Other greenhouse gases (GHGs) are not considered.

Keywords: carbon footprint, household survey, direct and indirect CO_2 (carbon dioxide) emission, lifestyle approach, income elasticity of CO_2 emissions, inequality, urban, rural, China.
JEL Classification: Q4, Q5.

Introduction

People have been interested in the relationship between development and CO_2 emissions, which is considered the most important GHG, since concerns on global warming and CO_2 (a much longer history for energy consumption). In terms of using what variables to describe development and CO_2 emissions, there are different choices. There are mainly two perspectives. One is production perspective, and the other is consumption perspective. To describe income or affluence, GDP/cap can be used at the macro-level, and household per capita income and expenditures at the micro-level. GDP/cap is mainly production-orientated and, on the other hand, household income and expenditures focus on consumption. As to CO_2 emissions, it is more complicated. If we consider at the macro-level, national or regional, the total emissions usually include those both from production and from consumption. National or regional CO_2 emissions are usually calculated, top down, from both energy consumption, which includes industrial, transportation, commercial and residential sectors, and industrial processes, which are mainly the cement and iron-and-steel subsectors. Such top-down method is called the "sectoral approach". In all the sectors, residential sector is the one that is most clearly related with consumption. Even though, more often than less, it is the utility company rather than the consumer, who is considered as responsible to the CO_2 emissions of the electricity used at home. CO_2 emissions can be also calculated bottom up. Starting from individual expenditures, consumption of any good and service can be converted into CO_2 emissions either direct or embedded (by economic input-and-output (I-O) table). This is a micro-level CO_2 emissions calculation method, the so-called consumer lifestyle approach (CLA). It is a pure consumption perspective, providing a better way to reveal the impact of consumer activities on CO_2 emissions.

"Lifestyle is a way of living that influences and is reflected by one's consumption behavior" (Bin and Dowlatabadi, 2005).

Lifestyle research studies energy requirements and environmental impacts from the perspective of consumption. As scientific evidence on climate change becomes conclusive and the deadline for the next generation of international agreement approaches, increasing attentions, are attracted to topics like energy consumption and carbon emissions. For the purpose of future emission projection, international negotiation, and/or environmental regulation, micro-level CO_2 emissions, which are connected to household consumption and affected by lifestyle, are obtaining more and more attention, especially at current stage, where justice plays a pivotal role in international negotiations. Research on carbon emissions requirements of household consumption has become one of the well-studied areas of climate change. It is also of enormous importance to sustainability study. In addition, better understanding of the (C-I) nexus from the micro-level can help improve CO_2 emission projection, shed more light on analysis for carbon mitigation policies, and therefore underpin international climate negotiation.

CO_2 is the most important GHG, and fossil energy use is its major source of anthropogenic emissions. People consume energy and emit CO_2 in their daily life, directly or indirectly, through consuming various goods and services. As income increases, it is human nature to improve their living standards. After minimum food and clothing requirements are satisfied, people will eat relatively more meat and dairy in their diet, buy more clothes, live in a bigger house, switch from bicycle to public transportation and then private cars, spend their spare money on better services and entertainments, and can spend more on health care, and so on (with increasing share of goods transported from far away). As a country develops, it also needs to improve its public services and infrastructures. All these hinge on increasing energy consumption and CO_2 emissions. Also, people at different income levels have different lifestyles; therefore, different patterns of consumption and related CO_2 emissions.

For China, the fastest growing developing country with such a huge population, its future CO_2 emission is extremely important information for the world. Huge differences exist in lifestyle, therefore, patterns of consumption and CO_2 emissions, between rural and urban households and among household at various income levels. At the same time, China is experiencing fast and unprecedented urbanization. The living standards of both rural and urban population are improving continuously and rapidly, with simultaneous increase of energy demand and CO_2 emissions. How different are individual's emissions? What is the carbon inequality in China? What are the important factors causing and affecting the inequality? These are the factors than should be taken into climate policy consideration by any policy maker, who cares about the welfare of the poor and reducing poverty and inequality.

What kind of lifestyle will Chinese people take as they get wealthier? There are quite diverse examples available from developed countries around the world. Even at very similar stages of development, people in different regions and countries lead quite distinct lives. What kind of example Chinese people take as they get rich will make a huge difference in its energy consumption and CO_2 emission contribution to the world. This research can help answer questions what are the differences between the rich and the poor, rural and urban households in CO_2 emissions, and so on. Therefore, this research will render more evidence to improve future CO_2 emissions projection and help provide policy recommendations for constructing an energy-saving, low-carbon economy. In addition, based on the results of this paper further researches can also be done to analyze the impacts of possible carbon mitigation policies on different income groups and on groups with different interests. A good climate policy should be able to reduce GHG emissions effectively and at the same time to make sure the poor and the most vulnerable groups are taken good care of. Inequality can be reduced, rather than being exacerbated, while we fight climate change. Micro-level study can help take environmental justice into policy consideration, especially in a society like China, where harmony is the theme of national development.

Survey data provide income, expenditure, demographic information, and living conditions, and so on for different regions at the household level. The amount of energy consumption and carbon emissions (both direct and indirect) can then be calculated from the amount of money spent on each category of good and services and other supporting information, based on proper assumptions and approximation. The detailed information of energy consumption and CO_2 emissions for household groups with different income and demographic features, that survey data can provide, can never be replaced by aggregate or averaged data (macrodata). However, it is exactly the detailed information that is of great importance for policy making and execution, especially if we take the welfares of different interest groups into serious consideration.

In this paper, the lifestyle approach is applied to calculate individual CO_2 emissions due to household consumption. The data from the 2002 surveys of China's rural and urban households are combined with the 2002 national input-output table to convert expenditure information into carbon emissions. This research provides quantitative analysis on direct and indirect CO_2 emissions of around 16,000 (9200 rural and 6800 urban) households. Carbon emission distributions and carbon inequality are also analyzed for the surveyed population. In addition, econometric models are designed to estimate the income elasticity of individual CO_2 emissions, and the effects of other factors on the C-I relationship. The simulation results are then compared with former similar researches on other countries.

This research tries to answer the following research questions:

1. How do the consumption patterns differ across income groups for both rural and urban household and between rural and urban household of China?
2. What is the carbon inequality in China? How are the distributions of individual CO_2 emissions like for China?
3. Who are the high emitters and who are the low emitters?
4. What is the north-south/urban-rural difference in per capita household CO_2 emissions?
5. How income affects carbon emissions?
6. What are the scale and patterns of per capita household CO_2 emissions for different income groups?
7. What are the income/expenditure elasticity coefficients of CO_2 emissions for China's rural and urban households? What are the major demographic factors that can significantly affect the C-I relationship, and how?

Lifestyle research studies environmental issues from a consumption perspective. In recent years, increasing research attention has been switched from "production process" to the "concept of lifestyles/domains of consumption" (Reusswig et al., 2003). After the earliest work by Herendeen in the 70s (Herendeen, 1978), the similar research method has been applied continuously by scholars to different countries. As the climate change issue gets increasing attention, more studies have been performed on household energy requirements and household CO_2 emissions.

A large amount of work has been done for developed countries most of which is on household energy requirements. From the literature reviewed, these developed countries, not exhausted, are Australia (Lenzen, 1998), Denmark (CO_2 emissions) (Munksgaard et al., 2000; Wier et al., 2001), Japan (energy) (Lenzen et al., 2006), Netherlands (Vringer and Blok, 1995), New Zealand (Peet et al., 1985), Norway (CO_2 emissions) (Herendeen, 1978; Peters et al., 2006), Spain (CO_2 emissions) (Roca and Serrano, 2007) and the USA (energy and CO_2) (Herendeen and Tanaka, 1976; Herendeen et al., 1981; Weber and Matthews, 2008). Very limited studies have been done for developing countries. There is some research on Brazil (energy requirements) (Cohen et al., 2005; Lenzen et al., 2006) and a lot of work for India (CO_2 emissions) (Murthy et al., 1997a; Murthy et al., 1997b; Parikh et al., 1997) (energy requirements) (Pachauri, 2002; Pachauri, 2004), one of the very few developing countries with first class survey data available. In contrast, similar work for China is still missing. This is not commensurate with the important role China plays in the international arena of climate change. The absence of micro-level research on Chinese household is mainly because the raw data of household surveys are not easy to get. This research is going to meet this gap. It will also provide a detailed comparison of lifestyles and CO_2 emissions between Chinese rural and urban households. The following is a detailed review on several important papers on this topic.

Although, there is increasing literature on energy and CO_2 issues of China, comprehensive work with micro-data is still in absence. Two very recent papers on lifestyle and energy consumption, and CO_2 emissions were found when our research was under progress. One is a 2007 paper that analyzes the impact of lifestyle on energy use and CO_2 emissions for China with aggregate national data. It calculates the total energy consumption and CO_2 emissions caused by residential consumption of both rural and urban households. The national-averaged rural and urban lifestyles are compared. The impacts of income are not taken into consideration, nor are those of regional, demographic characteristics (Yi-Ming Wei et al., 2007). The other is the 2008 paper by Shonali Pachauri and Leiwen Jiang (2008). This paper mainly focuses on household energy transition in India and China. Since its major interest is on transition, it only analyzed direct residential energy use. This paper analyzes and compares between China and India the transition of national aggregate energy consumption and household (both rural and urban) direct energy use for different income groups. However, neither indirection energy requirements nor CO_2 emissions are analyzed. For the analysis of China, this paper uses 1999 survey data for rural households and 1992, 1996, 1999, and 2001 are used for urban households. Therefore, only 1999 data are used for urban and rural comparison.

This paper is organized as follows. The introduction Section provides some background information and reviews literature on lifestyle CO_2 emissions research. In Section 1 the raw data are introduced, and information on features of the surveyed population is also analyzed from the raw data. Parameters selected and assumptions made for the CLA are provided in details in Section 2. Section 3 contains the results. It is presented in two subsections: descriptive results are mainly in figures and statistical numbers, while the elasticity is estimated by econometric models. The last Section concludes.

1. Data

Data, used in this research, are from the household surveys performed in 2003 by Institute of Economics Chinese Academy of Social Sciences and National Bureau of Statistics (NBS) of China (rural household survey team and urban household survey team). The surveys covered the demographic, employment and income information of each member of the households and information on expenditure (especially consumption), ownership of major durable goods, and living conditions of each household as a whole in 2002. Different surveys were designed for rural, urban, and rural-urban migrant households respectively, according to their quite distinct lifestyles. The surveys are designed to study income, employment, and expenditure issues, therefore to provide pertinent policy recommendations to the governments. The questionnaires have a very detailed coverage on information of household expenditures and living conditions that are particularly important for this study. This Section provides a review of the raw data from the surveys for rural and urban households. Through this Section, readers can obtain an overall impression of the demographic features, income levels, expenditure patterns, and living conditions of the surveyed population.

The urban survey covers 12 provinces/municipal cities, where over 6800 households from 77 cities or districts are surveyed. The rural survey covers 22 provinces/municipal cities from which 920 villages of 122 counties are sampled. Of each village, 10 households are selected and surveyed. For details of the survey coverage, please refer to Appendix A.

As official urban surveys in China, cities and counties are selected first by strata sampling. Cities are divided into different categories, according to their geographic location and size. In each category, cities are ranked by average salary and cumulative population is calculated at the same time. The required number of cities is drawn according to the proportion of population. Then, households are selected from each sample city and county by combined two-phase-multi-stage sampling. In the first phase, samples are drawn through multi-stage sampling method. At the first stage, the survey streets are drawn; at the second stage survey neighborhood communities are drawn; survey households are drawn at the third stage. In middle and small cities, the first stage is omitted. Households in the first phase sample (the large sample) are surveyed for information of household size, employment, income, and so on. Based on this information, households are divided into groups. A small sample (the second phase sample) is drawn from these groups proportionally. Households in the small sample are called "frequently-surveyed households", which perform bookkeeping survey. The first phase sample is surveyed every three years to provide sampling framework for the second phase. For cities, 1/3 of the frequently-surveyed households are required to be replaced every year. Therefore, every 3 years the whole second phase sample is replaced. For counties, in the year right after the first phase sample survey, which takes place every 3 years, at least 2/3 or all the frequently-surveyed sample should be replace in one time. For rural survey, a large sample is drawn by systematic sampling. Villages in the large sample are ranked by per capita income, and meanwhile cumulative population is calculated. Then, from the large sample a small sample of villages is drawn with symmetrical systematic sampling method. Then, systematic sampling is used again to drawn 10 households randomly from each village of the small sample.

According to Martin Ravallion and Shaohua Chen, "while NBS has selectively made the microdata (for some provinces and years) available to outside researchers, the complete data are not available to us for any year" (Ravallion and Chen, 2007). The survey data, used for this research, are via personal contact introduced by Shaohua Chen, a senior statistician in the development economics research group of the World Bank. This is the latest household survey data of China with such a big size of sample available to the public. At present, each year China NBS surveys 68,000 samples in rural areas and 30,000-40,000 in urban areas. The data, used for this research, account for about 1/7 to 1/6 of the whole survey and represent all regions of China. We have to admit that, given the huge population of China, it is almost not possible to perfectly represent the whole country's situation by a sample of about 1 million households. Figure 1 (see Appendix A) is average urban per capita household disposable income of each province of China in 2002 ranked in ascending order. The urban survey data are available for 12 provinces: Anhui, Gansu, Shanxi, Henan, Liaoning, Sichuan, Hubei, Chongqiong, Yunnan, Jiangsu, Guangdong, Beijing. The rural survey covers 22 of all the 31 provinces. Therefore, although the data, used in this research, are partial, they cover a large enough geographic area (Figure 11 in Appendix B) and represent the provinces of various income levels. Given the limited availability of the raw data of China's national surveys, our study should be comparatively good enough to provide a sketch of and shed the first light on carbon footprints of Chinese households at the microlevel.

2. Methodology

2.1. The consumer lifestyle approach. The consumer lifestyle approach is a method to calculate household energy and carbon footprint from the side of consumption. Usually household energy requirements or consumption are divided into two major categories: direct energy requirements and indirect (embedded) energy requirements. Accordingly, carbon emissions are also calculated from these two categories: direct emissions (carbon emissions from direct energy use) and indirect (embedded) emissions. Direct energy requirements (carbon emissions) include mainly home energy use (electricity, natural gas and so on for lighting, cocking, heating, etc.) and fuels for personal travel (public transportation is considered as indirect emissions from service). Indirect energy requirements (carbon emissions) include all the energy (carbon) embedded (energy consumed and carbon emitted in the production and processing chain of consumer goods and provision of services) in all the goods and services that are consumed. The economic input-output table is used to calculate the energy intensities and carbon intensities (kg of carbon/RMB) for all the major good and service sectors in the economy. Household expenditure categories, listed in the survey questionnaire, are then matched to the industrial sectors to calculate from expenditure to embedded CO_2 emissions. This is a good method to study how variations in lifestyles people take at the microlevel cause different individual carbon emissions. It can also provide much more detailed and meaningful information for future emission projection, mitigation policy, and even poverty and inequality reduction. However, to calculate household CO_2 emissions from this method effectively, high-quality data of household survey and input-output table are essential. Proper assumptions are also crucial to make sure all consumption converted into emissions with least errors.

As summarized above, there is already a large amount literature on many developed countries: Brazil and India. Some of the literature provides very detailed introduction to this method (Lenzen et al., 2006; Wier et al., 2001; Pachauri, 2002).

Due to constraints of data quality and availability, also with consideration of the purpose of this research, several major assumptions are made here. First, the 2002 national economic input-output table is used to calculate carbon intensity coefficients, which are used for all the rural and urban households from different provinces. This is the same as how Lenzen et al. (2006) did in their paper[1]. Although provincial input-output tables are also available because the data are collected and processed by different provincial statistical units, data discrepancy may bring more errors then accuracy, which may make the results of CO_2 emissions less informative and harder to explain. Also, people consume goods produced and travel all over the country. It is really impossible to tell which part of consumption is provided or produced locally. Second, different assumptions are made for rural and urban households in detailed calculation. This is mainly because different questionnaires are designed for rural and urban surveys respectively, according to distinct sources of income and categories of expenditures. Third, the whole survey sample is used to represent the whole countries' situation. This is mainly because the sample has a large enough geographic coverage throughout all the regions and it also has a very good representation of all income levels in China (see Section 1 for details.) Fourth, averaged per capita values, such as income, expenditure, and CO_2 emissions, are calculated from total values of each household divided by the size of the household (population in the household).

Specific assumptions are made and parameters are selected for direct emissions from domestic electricity, fuel use, heating, and personal travel. Based on the approximation, direct CO_2 emissions are calculated from physical and/or monetary values collected by the surveys.

3. Results

Based on the methodology, parameters, and assumptions introduced in last Section, household CO_2 emissions are calculated for each category of direct and indirect energy consumption and then summed up. Per capita households CO_2 emissions are defined as the total household emissions averaged over the total population in the household (household size). All the emissions are annual, more accurately the emissions in the year of 2002. In this Section, per capita household CO_2 emissions from the urban and rural surveys will be analyzed. The first subSection contains some descriptive analysis of statistical information on emissions of different groups of households, which are urban households, rural households, northern households, southern households, and household groups divided by emission levels and by income levels. In this subsection, the composition of total per capita household emissions in terms of direct versus indirect emissions and in terms of consumption categories is also discussed for the various groups.

The surveys were performed for rural and urban households separately with different questionnaires. Therefore, the households are automatically divided into rural groups and urban groups. In addition, one

[1] "The assumption in this approach is that products, purchased by regional households, are produced regionally and nationally using the same production recipe" (Lenzen et al., 2006, p.186).

very important factor of energy consumption and carbon emissions is home heating. The differences of household heating between the north and the south exist not only in the amount of energy used, but more importantly in the forms of heating. In the north, almost all urban households have collective district heating systems, while on the other hand there is almost no collective heating system available at all in the south. Rich households may heat their houses with air conditioners in cold days. For rural households, there is no collective heating system available. They need heat their houses by whatever fuels are available and affordable. Hence, the geographic, to some extent de facto, location, whether the household is in the north, is another factor used to define groups.

To take a closer look at what is inside the carbon distribution, after a discussion on the general distribution and inequality, the surveyed households are then divided into 4 groups (next to each other), the bottom 10%, the lower 40%, the upper 40%, and the top 10%, according to their emission levels. By analyzing the composition of each emission group, we can find out who are the high emitters, on the other end, who are the low emitters, and their contribution to the total.

Then, to study the relationship between emissions and income, both the rural and urban households are divided into 4 groups by their income levels, respectively. This is the same as what is done in the previous Section. The statistical income and expenditure information is given in Table 15 (see Appendx C) in the units of both RMB and USD. The grouping method is the same for both emissions' groups and income groups. What is different is just one uses emissions as the grouping measure, while the other uses income.

In the second subsection, econometric models are designed to estimate the income elasticity of CO_2 emissions at the microlevel. Regressions are run for total emissions, direct emissions, and indirect emissions for models with and without other possible factors included and for both rural and urban households separately. The two sets of data are also put together. Similar simulations are run for the dataset that includes all rural and urban data to calculate the overall elasticity of CO_2 emissions. Thereafter, results from this study are compared with other former similar researches done for other countries.

3.1. Descriptive results. This Section is organized as follows.

3.1.1. What is the magnitude of individual carbon emissions of Chinese households in 2002? Calculated from the survey data with consumer's lifestyle approach, Figure 2 (see Appendix A) is a summary of emission levels of different households groups in China in 2002. Average per capita CO_2 emissions (weighted with households population), composing of direct and indirect emissions are calculated for urban, rural, northern urban, southern urban, northern rural, and southern rural households. In average, the urban households emitted 3.17 tons of CO_2 per capita in the year of 2002 and rural households emitted 0.88 tons of CO_2 per cap. The north-south difference for urban households is huge, which is about 1.6 tons of CO_2, and the difference is mainly from direct emissions of heating. The north-south discrepancy in rural households is much smaller with the north emitting, a little more directly and the south emitting, a little more indirectly. There is not much difference in indirect emissions between the northern urban and southern urban households. If we put all the urban and rural data together, we can get average CO_2 emissions of 1.68 tons per cap in total of which about 1 ton is from indirect emissions. In average, indirect emissions account for about 60% of total emissions with the lowest share of northern urban households which is 46% and the highest share of southern urban households which is as high as 78%. For more detailed information on averaged physical values of and the share of direct and indirect emissions of different groups of households, readers can refer to Table 14 in Appendix C. For all the groups in Figure 2, northern urban has the highest average emissions, 4.08 tons per cap, which is just the level of world average per capita emissions.

What is the magnitude of per capita CO_2 emissions of China calculated from macro/production data? How do our results of micro/consumption-based emissions look like when comparing with the macro data? Averaged per capita CO_2 emissions of macro data from various sources are plotted in Figure 3 (see Appendix A).

The international energy agency (IEA) data and environmental investigation agency (EIA) data are broadly accepted as authoritative national CO_2 emissions internationally. The provincial CO_2 data are new and not published. However, both of the two series are calculated from energy data of NBS of China, and they are very similar. The national average from provincial data are average of provincial per capita emissions (macro data) weighted by population of each province. There is clearly a gap between the national data (EIA and IEA) and the provincial data (both provincial 1 and provincial 2), especially after 2000. As it is well-known, there are always gaps between China's national and provincial data. However, it is really hard to ignore the huge gap in national CO_2 emissions. In 2005, the difference between national and provincial data is about 1

tCO_2/cap, which means a gap of around 1.3 $GtCO_2$ in national total emissions. Which is closer to the real carbon emissions in China? Since we have the micro CO_2 data calculated from household surveys, I am going to compare the micro and macro data of 2002.

In Table 1 there is comparison of our micro emission result with averaged macro emissions in 2002. The share of urban population in the survey, I used, is 35%, while the urbanization rate in China in 2002 was 39%. So, the averaged per capita household emissions are recalculated for national average to adjust the urbanization error. The averaged 1.68 tCO_2/cap is then adjusted to 1.78 tCO_2/cap. Our micro result, the averaged per capita households CO_2 emissions from consumption, accounts for about 1/2 (52%-55%) of macro emissions (averaged national total), calculated from provincial data, and about 2/3 of the macro data of EIA and IEA. For a fast developing country, like China, which consumes a lot of energy on public infrastructure construction and fixed capital investment, the share of consumption in total energy, consumption is lower than in developed countries. The relatively low national emissions provide relative high share of CO_2 emissions from household's consumption in total. If here we believe in the microdata which are based on real household surveys, with all the confidence in assumptions and parameters of our calculation, it is reasonable to claim that the aggregate national data are questionable. The provincial data are more believable. In another word, the EIA and IEA data underestimate China's total CO_2 emissions, by around 20% starting from 2000. One piece of evidence supports the fact that the decreasing national averaged per capita emissions between 1996 and 2002, in Figure 3, are not reasonable, since the economic growth rate during the same period is in average still above 8%. However, if we trust the EIA and IEA data, then our microdata calculation overestimates the per capita household CO_2 emissions by around 0.4 tons.

3.1.2. What is the carbon inequality? Figures 4(a), 4(b), and 4(c) (see Appendix A) are histograms of urban, rural, and urban + rural total per capita households CO_2 emissions weighted with household size as frequencies. The *x* axes are per capita CO_2 emissions, and *y* axes are probability density. The brown bars are histograms of the raw data of CO_2 emissions. The curves are sketch fits of the two distributions with lognormal distribution models. The numbers in the upper right corner are number of household (HH) and number of population of these households (Pop). Lognormal distribution, which is one of the most popular models used for income distributions, can fit the individual CO_2 emission distributions very well here. Mu is parameter μ and sigma is σ of lognormal distribution. Comparing with the urban distribution, the rural one is not fitted as well. It is mainly because that there are a very large amount of rural households which use biomass that is considered as zero emission as the major fuel and also a very significant amount households that use commercial energy. The dramatic differences in types of energy use cause the discreteness and bad fit of CO_2 emission distribution. Histogram in 12(c) is not fitted, because visually it is not a lognormal distribution mainly due to the huge discrepancy between rural and urban population. It is a combination of two lognormal distributions with a high peak in the left end contributed by the large low emitters from rural area. This, in fact, indicates that it is more reasonable to treat the rural and urban population separately when simulating China's individual carbon distributions, than using one lognormal distribution for the whole population.

In order to study carbon inequality, Gini coefficients are calculated and Lorenz curves are plotted for urban and rural emissions (total, direct, and indirect emissions) for both the north and the south. Gini coefficients are in Table 2 (see Appendix A) and Lorenz curves are in Figure 12(a-f) (see Appendix C). Over all, carbon inequality among rural households, whose Gini is around 0.45, is much higher than among urban households, whose Gini is around 0.30. The higher Gini coefficients among rural households exist in direct, indirect, and total emissions. Inequality in direct emissions is much bigger than in indirect emissions, especially among rural households. For urban households, the inequality of direct emissions comes mainly from the difference between the north and the south, which is caused by heating. For rural households, the direct emissions inequality should come mostly from the critical distinction between the use of biomass and commercial energy. In addition, different from urban inequality, the north-south difference in direction emissions of rural households is not as big, and the inequality of total emission of all rural households (both the north and the south) is smaller than that of the northern rural households. In their working paper, Kahrl and Roland-Holst calculated the world carbon inequality by weighing the national averaged emissions with national population. They got a Gini coefficient of 0.52 for the year of 2004 and 0.64 for cumulative emissions from 1904 to 2004 (Kahrl and Roland-Holst, 2007). Comparing with the world carbon inequality, China's carbon inequality among urban households is relatively small, while, on the other hand, the inequality among all households is comparable with the world inequality.

Except for the northern urban households, the Lorenz curves of total emissions lie between those of direct and indirect emissions and they are also far from those of direct emissions and close to indirect ones (Figure 12). This is mainly because indirect emissions overall dominate the total. As to the northern urban households, that the inequality of total emissions is the smallest, means the lowest indirect emitters, are not the lowest direct emitters. The truth may be that the lowest indirect emitters are usually the poorest. However, the poorest might have more direct emissions than other low income households. This is mostly because the poorest in cities may have no access to centralized heating system or pipeline gases, which forces them to use the dirtiest fuel, coal briquettes, for domestic heating and probably even cooking.

3.1.3. Who are the high- and low- emitters? By dividing households into different groups based on their emission levels, in this Section we are going to take a look at the inequality within the carbon distributions in detail. Rural and urban households are put together and then divided into 4 groups by the 10^{th}, 50^{th}, and 90^{th} percentiles: the bottom 10% lowest emissions households, the next lower 40%, the upper 40%, and the top 10%. The 4 groups are next to each other and add up to 100% (see Table 3, Appendix A).

The top 10% high-emission households have averaged per capita CO_2 emissions of 6.3 tons. The bottom 10% emits only 0.2 tCO_2/per. The 10% households which account for 7.6% of the total surveyed population contribute to 28.3% of the total emissions, while the bottom 10% representing 13% of the population only emit 1.6% of the total. The top 50% households (43% of the population) all together account for 80% of the total emissions. The top 10% emitters expend more then 10 times of the bottom 10%.

Figure 5 (see Appendix A) decomposes the population share in each carbon-emission group. 90% (around 70% in north and 20% in south) of the residents in the top 10% households are urban, which leaves only 10% of them rural. In the upper 40% group, southern urban residents have the largest share and share of rural residents' increases to 30%. All of the bottom 10% and more than 90% of the lower 40% are rural residents.

3.1.4. Relationship of emission patterns with income (*Composition of total per capita household CO_2 emissions for different income groups*). Because dramatic discrepancies of direct emissions between the north and the south from heating, and between the rural and the urban caused by large share of biomass in domestic energy use in rural areas, comparisons of direct emission composition are made for different income groups of the north, the south, the urban, and the rural households respectively. Figures 6(a) and 6(b) (see Appendix A) are the compositions of averaged direct CO_2 emissions of each income group of urban and rural households.

For urban households in Figure 6(a), both in the north and in the south, total direct emissions as a whole, and direct emissions from electricity and heating in particular increase very fast along income groups, while on the other hand the absolute amount for the north and the share for the south of emissions from direct fuel use at home decrease as income increases. Private travel still accounts for only a very small share of total emissions, which leaves a huge space to grow. However, in percentage direct emissions from private travel are escalating with income. In the north, heating dominates. It accounts for about 60% of the total direct emissions in average. The bottom 10% has the lowest share of emissions from heating but much a larger share from direct domestic fuel use. This is because the poorest have the least access to collective heating system and have to use fuel directly at home for heating. In the south, from low income groups to high income groups emissions from direct fuel use almost do not change. However, meanwhile, emissions from electricity increase both in absolute value and in relative share. This, together with the information of the north, can be deciphered as urban residential demands for direct fuel use have more or less been saturated. In contrast, it is not the case for electricity and heat.

Similar to urban households, rural per capita household direct emissions in Figure 6(b) also increase along income ladders. But the increase is much steeper. For both southern and northern rural residents, the top 10% emit more than twice as the upper 40%. This may indicate a bigger income elasticity of CO_2 emissions in rural households. The dramatic increase of direct emissions along income levels of southern households mainly comes from the increase of electricity consumption, while for the north both electricity and domestic direct fuel use are important factors of increase. In south, emissions from fuel dominate emissions of low income groups. However, as income increases, the share of emission from electricity increases to more than 70%. As rural people get rich, a lot more electricity will be in demand in the future. In north, emissions from direct fuel use have the largest share of averaged direct emissions of all income groups. Different from all the other groups, northern rural group is the only one whose emissions from fuel increase all the way along income levels, and most of them are from coal. At current stage, there is still no alternative for coal to avoid the increase in emissions from rural direct domestic fuel use. Although rural households' total emissions are still very low and they should not be put under the pressure of carbon mitigation without jeopardizing their development, a cleaner way of domestic fuel use should be introduced to them for the, even if only, purpose of reducing indoor air pollution now (and CO_2 emissions in the future).

To compare between rural and urban direct emissions, Figures 6(a) and 6(b) (see Appendix A), the south-north discrepancy of urban households is much larger than that of rural households. Therefore, urbanization in northern China will need much more energy and emit a lot more CO_2 than in south.

In addition, for both rural and urban households, at every income level direct emissions from electricity of northern households are always higher than those of the north. Intuitively, this is not quite reasonable. In south, it is much hotter in the summer when more electricity is needed for cooling, and, it also can be very cold in winter. With almost no collective heating system, more electricity is demanded for heating too. Figure 7 (see Appendix A) indicates that it is true that for each income level urban residents in south do consume more electricity than those in north. The relatively lower CO_2 emissions are mainly due to lower carbon intensity in the electricity generated there mainly due to relatively large share of hydropower. The situation is similar for rural households.

In terms of emission from direct fuel use, also for both rural and urban households and for all, except for the top 10% urban households, for each income group, northern residents always have a higher value of averaged per capita emissions. The reason for this is not only that the north need more fuel for heating, but also their mix of domestic fuel use is more carbon intensive. Figures 8(a) and 8(b) (see Appendix A) compare the south-north shares of different fuels used at home for urban and rural households, respectively. Coal shares are much larger fraction of domestic fuel use in northern households, especially in rural areas.

From Figure 2 (see Appendix A) we can tell that there is no obvious difference between the north and the south in indirect emissions, so it is clearer to just present and compare the composition of indirect emissions of urban and rural household groups by different income levels without breaking them down into south and north. The indirect emissions in absolute value and in percentage share are decomposed into each consumption category for various groups in Figures 9(a) and 9(b) (see Appendix A). The consumption categories are: (1) food and beverage; (2) clothes; (3) transportation (public transportation and emissions embedded in vehicles) and communication; (4) health care; (5) education, culture, and entertainment; (6) housing and household effects; (7) other goods and services.

In Figure 9(a), on average an urban resident emits around 4 times as much as a rural resident CO_2 indirectly. Indirect emissions of all the categories, even from the basic needs of eating and clothing, increase fast along the income groups from the bottom 10% to the top 10%. For both rural and urban households, the top 10% averaged per capita emissions are about 5 times as high as those of the bottom 10%. The major 3 emissions categories are food, transport and communication, and housing and household effects.

In terms of relative share of the total indirect emissions, Figure 9(b) indicates that the most important category for urban households is housing and household effects. However, for rural households emissions from food account for the largest share of low income groups, transport and housing dominate emissions of the higher income groups. For both rural and urban residents, there is very significant increase of fractions of emissions from transport and communication with income. As to the categories of health care and education, their shares keep increasing with income in urban, while almost consistent in rural, indirect emissions. As income increase from the bottom 10% to the top 10%, housing of urban households and food of rural households are those categories whose shares decrease. And there is not much change in the share of emissions from clothing.

In order to provide more quantitative information on the inequality in income, expenditures, and carbon emissions, existing among the surveyed household, comparisons between the top 10% group and the bottom 10% group of urban and rural households are shown in Table 4 (see Appendix A). For total and direct emissions, the comparisons are made for the north and the south separately. The ratio of the top 10% to the bottom 10% are listed in the last column.

The largest ratios exist in per capita income: 11.4 for rural households' pure income and 7.9 for urban households' disposable income. Ratios of direct and total emissions of southern rural residents and urban expenditures are 5.6, 5.9. 6.2. Then the third ladder contains rations between 4 and 5 (4.3, 4.4. 4.5, 4.8, 4.9), which are shown in Table 4.

As mentioned before, carbon inequality among rural households is much bigger than that among urban households. And, inequality in south rural is higher than in north rural.

3.2. Elasticity estimation. The model, used in simulations here is, as below:

$\ln(c) = \alpha + \beta \ln(I) + \gamma_i X_i,$

where, c is per capita household CO_2 emissions (total, direct, or indirect), I is per capita household total expenditures on consumption (representing income), and X_i presents other factors such as education level of household head, household size and so on. The key parameter of interest in this research is β, the income elasticity of CO_2 emissions.

Figures 10(a) and 10(b) (see Appendix A) are scattering of household per capita carbon emissions against income and expenditure. Both the y axes and x axes are in log scale. For income, still, rural income is pure income and urban income is disposable income. All the surveyed households are plotted in both of the two figures. Overall, we can see a linear relationship between the logarithm of income (expenditure) and logarithm of carbon emissions. However, the scattering of carbon emissions against income is more widely distributed. The direct and indirect emissions against income and expenditure are plotted for both rural and urban households (see Figure 14 (a-f), Appendix D).

Table 5 (see Appendix A) explains each of the explanatory variables that may affect the β coefficient of C-I relationship. In the regressions, to avoid multicollinearity, *Dhhs*4 (household size of 4) which is a prevail both rural and urban household size, *Dedu*1, *Dage*1, and *Dprovince*1 are dropped. Therefore, coefficients of other dummies from the same dummy group provide the differences comparing with this dropped one.

3.3. Regression results. Tables 6-8 (see Appendix A) are shown simulation results of urban, rural, and urban-plus-rural households, respectively. Regressions are run for per capita household total, direct, and indirect CO_2 emissions. In the three Tables, coefficient and t-statistics of each explanatory variable are provided for each regression. Except for total emissions, for which one more regression is run with no any other factors included, all the other simulations include all the significant variables considered to be relevant. When other factors controlled, income elasticity of emissions is reduced somewhat for all the three sets of data. These factors are household head education, household size, household head age, urban effect, and geographic effect. All the regressions are weighted with household size (as a frequency weight).

For comparison, regressions are also run with I represented by per capita household income (pure income for rural households and disposable income for urban households, all other variables remained the same. Regression results are compared with results of Tables 6-8 in Table 16 in Appendix D. Only the elasticity coefficients and R^2 under different models are compared. The reasons, why in the end the regression results, presented here, are against expenditure, are: (1) they have much higher R^2 values, especially for rural households; (2) expenditures are defined the same for rural and urban households (different rural-urban income definition makes the results hard to compare); (3) as discussed in the data Section 1, when reporting pure income in rural survey there are a lot of problems, which may cause on average expenditure of the bottom 10% households higher than income; (4) to get in line with other similar research. Expenditure is a better variable to describe people's living situations. That is why, should be why most similar research has chosen expenditure as I to estimate the elasticity.

3.4. Income elasticity of emissions. The income elasticity of CO_2 emissions, which is of the most interest of this research, is collected in Table 9 (see Appendix A) from all the regressions for the three sets of data in Tables 6-8, together with 16 results (elasticity of both energy and CO_2 emissions) of similar former researches from 12 published papers. This research obtains an elasticity coefficient of 0.61 for urban households, 0.92 for rural households, and of 0.84 for all the households together. To compare with former researches, the elasticity of urban total emissions, which is almost at the lowest end of all the results, has a value close to that of Japan, India (Shonali Pachauri, 2004), and the lower boundary of the U.S. (Weber and Matthews, 2008). The elasticity of rural total emissions, which is relatively high, is similar to that of Brazil, Denmark (Wier, 2001), and Spain. When all the urban and rural data are put together, the elasticity has a medium value and is most alike to that of Denmark and India (Lenzen, 2006), the Netherlands, and the U.S. (Herendeen and Tanaka, 1976).

As to the effects of other factors, both education and age of household head, have positive effects on per capita household CO_2 emissions. On the other hand, household size has a very significant negative effect. In addition, both the variable *Durban* and *Dnorth* have positive coefficients and are significant in most simulations in Tables 6-8. These results, in the general direction, are in line with conclusions of former researched summarized in Table 9. The magnitudes of each factors' effects in different models for different groups of households are quite different. The effects of these factors are analyzed as follows.

The elasticity of urban direct emissions is very low, 0.37. Why? First, there are historical reasons. China developed from a socialistic, highly planned economy and only started the reform and openness since the end of 1970s. Most urban households lead quite uniformed lifestyle. They live in 2- or 3-bedroom apartments, with pipeline gases and electricity, and collective heating for northern households. While all these direct energy consumptions are mainly to satisfy people's basic needs, there are no big changes in direct emissions with income. In 2002, private transportation, which is a very important factor to affect individual direct carbon emissions, has not really taken off in China. As urban people get richer, even with policy intervention, this elasticity will increase with people's increasing demand for mobility. And, there is almost no biomass use in cities. This makes it different from rural situation. These reasons can also help to explain why the R^2 in regression for urban direct emissions is so low, when no other factors are included. Urban direct emissions are mainly affected by other factors than *I*.

3.5. Positive effect of education. The levels of education of household heads are divided into 6 groups and represented by 6 dummy variables, as explained in Table 5 (see Appendix A). In all the simulations, *Dedu*1 is dropped. So, coefficient of each of the rest education dummy variables provides its difference with the illiterate/semiliterate group. The results of urban households (Table 6, Appendix A) indicate that the households, whose heads have junior middle school education in average emit 4.4% more total CO_2 per cap, than those, whose heads have only illiterate/semiliterate or elementary education (since *Dedu*2 is not significant here), other factors controlled. Household heads with high school education emit 6.9% more, 11.1% and 14.6% more, respectively for junior college and college-and-graduate education. Similar features can be found in direct and indirect emissions, with bigger effects on direct emissions, of both rural and urban households, with overall bigger effects among rural households. People with higher education tend to emit consistently more CO_2, even with income/expenditure controlled. It seems that people are not educated to be more environmentally friendly, but instead to pursue lifestyles that are more energy/carbon intensive.

3.6. Negative effect of household size. It is relatively easier to understand the negative effects of household size. Larger households share more common consumption. To make the coefficients provide meaningful comparison, household size of 4 (*Dhhs*4) is dropped as a baseline to compare to. For urban total emissions (Table 6), all other conditions the same, one-person households emit 51% more than 4-person household per capita. 2-person and 3-person households emit 24% and 6.4% more, respectively. In comparison, the difference between 5-person and 4-person households is not significant, and 6-person households emit 7.1% less. Household size has effects with similar trends but a relatively larger scale on direct and smaller scale on indirect emissions than on total emissions.

For rural households (Table 7, Appendix A), because there are very few households of size 1 or 2, coefficients of *Dhhs*1 and *Dhhs*2 are not significant for total and direct emissions. In terms of total per capita carbon emissions, 3-person households emit about 5.9% more, and 5-person, 6-person, and 7-plus-person households emits 1.3% (t = 1.84, only significant at 10% level), 4.4%, and 9.8% less respectively, also comparing with 4-person households. In the simulation of direct emissions, only *Dhhs*3 and *Dhhs*7 are significant. The household size effects are more significant on indirect emissions for rural households.

In Table 8 (see Appendix A), where the simulations include all the rural and urban data, the coefficients provide averaged and more general information on the effects of each independent variable. In general, comparing with 4-person households, households with 1 to 3 residents emit around 24%, 9.4%, and 3.8% more CO_2 in terms of per capita total emissions, while on the other hand, those with 5, 6, and 7 and more people emit respectively 2.9%, 6.9%, and 12.8% less. More coefficients with similar pattern are listed in the Table for direct and indirect emissions.

3.7. Positive effect of household head age. The effect of household head age is overall positive, which indicates that households, whose heads are older, emit more CO_2 per cap. Why? First, old people may spend more time at home, since most of them are retired. This means more electricity and other domestic fuel consumption. Second, elder people have less tolerance of extreme coldness and heat. Therefore, more energy is needed for heating and cooling. Third, older couples have, if any, relatively older kids who, comparing with younger kids, spend more money with more CO_2 embedded in their expenditures. In the simulations, *Dage*1, the youngest group is dropped.

For both urban and rural households, *Dage*2 (40-47) is only significant in direct emission models. Other conditions the same, individuals, whose householders are at the age between 47 and 54, emit 3.7% more CO_2 per cap in total, and 6.9% more for the householders whose heads are 55 or older than the younger ones (less than 47). Older households emit much more direct than indirect emissions, comparing with younger ones. Information from the rural simulations is mixed. Although the coefficients of household head age are positive, the coefficients of the oldest group (*Dage*4) are smaller than those of *Dage*3.

Table 8 (see Appendix A) provides more and clearer information on the effect of household head age. The *Dage*3 and *Dage*4 groups emit around 12% and 18% more per cap directly, around 3% more indirectly, and 5.2% and 6.5% more in total than the groups with younger householders, assuming all the other conditions the same. The age effects on direct emissions are relatively larger.

3.8. Positive effect of urban and north, very significant provincial effects. In addition, there is no doubt that the north dummy always has positive coefficients in all the models. And, in Table 8 which includes both rural and urban households, the urban dummy is also significantly positive, even though income has already been controlled. With all the other situations controlled, per capita urban household CO_2 emissions are 40% higher in total, of which around 70% more is in direct and 38% is in indirect emissions. At the same time, in all simulations except the first one in Tables 6-8, province dummies are also included. Province dummy of Beijing is dropped in the models. Almost all of the province dummies are statistically significant, positive or negative. These coefficients carry the information that is locally specific and not present by other independent variables, such as price levels, natural resource endowment, living habitsand so on.

Conclusion

After all the calculation and analysis, this research finds that the average annual household per capita CO_2 emissions of Chinese urban and rural households from consumption in 2002 are about 3.2 tons and 0.9 tons, respectively. The averaged emissions of all the households together, with a similar rural-urban ratio as that of the country's rural-urban population, are 1.7 tons per capita. The northern urban households have an averaged emission level as high as 4.1 tons/cap. In all, emissions from direct energy use account for 40%, and indirect energy use emit the rest 60%. Households in north have a much larger share of direct emissions due to huge energy demand for heating. The most important direct emissions in north are from heating for urban households and from direct domestic fuel use for rural households. On the other hand, in south, except for the bottom 10% income groups (rural and urban), the biggest share of direct emissions is from electricity use. In indirect emissions, house and household effects and transport and communication are the two most important categories. As income increases, the share of emissions from transport, both directly (private travel) and indirectly (transport and communication category), grows the fastest. And the growth is faster in rural areas.

In terms of carbon inequality, China's overall inequality (0.51 in 2002) is in the same order of the world's level (0.52 in 2004). The inequality mainly comes from income inequality and the rural-urban discrepancy. North-south difference is another important factor, but not as prominent. In addition, inequality among rural households is a lot higher than that among urban households, 0.46 vs. 0.31. However, the north-south difference in rural areas is not as huge as that in urban areas. For any group of households, inequality in direct emissions is always much higher than that in indirect emissions. This is due to not only the amount of energy directly consumed, but also the different forms of energy used.

Simulation results indicate that income level (expenditure on consumption used in the models) is the most important factor that causes carbon emission inequality. The income elasticity of household per capita CO_2 emissions, β, is the most significant coefficient and expenditure itself can explain a very large part of the total emissions (very big R^2 in simulations with only expenditure as the independent variable). With all the other available conditions the same, β is 0.92 for rural households, 0.61 for urban households, and 0.84 for all the households together. These values are in the reasonable range of results of existing researches. Other factors that can affect the micro C-I relationship are household head education, households head age, households size, and geographic factors. Similar to the results from former researches on other countries, education and age have positive effects on per capita household emissions, while the effects of household size are negative.

Urban, north and province effects. With all the other factors controlled, *Durban* and *Dnorth* always have very significant positive coefficients. In Table 8, where all the urban and rural data are included in the simulations and both *Durban* and *Dnorth* are explanatory variables, the two coefficients are almost the same, around 0.40, with *Durban* having a larger *t*-value. This means all other factors the same, urban households and households in north emit 40% more CO_2 in per capita terms. In addition, in all the simulations almost all of the province dummies are statistically significant. Locally specific features have a very significant effect on individual carbon footprints. And these features are out of individuals' capability of control. Besides income/expenditure inequality, geographic and administrative location factors should also be taken into climate policy consideration not only at the burden allocation stage but also at the implementation stage and in the adaptation policies.

The data, used in this research, are from 2002, which is a bit old given the fast development of China's economy and increase of CO_2 emissions. However, this is the most recent survey data that are available in such a large scale. This paper provides the first of this kind of studies for China, which sets up the base for future comparison when more recent data in comparable scale and quality are available. Just by setting up one simple assumption, we can use the latest national averaged per capita emissions to estimate household emissions from consumption. Supposing that averaged per capita household emissions from consumption account for 2/3 of the total national average (4.9 tons/cap according to IEA), as what we found in Figure 3 (see Appendix A), in 2008 China household carbon footprint from consumption is 3.27 tons/cap. Detailed calculation is needed to make comparison in structural changes, therefore, to find out development trend over time.

References

1. Bin, Shui and Hadi Dowlatabadi (2005). Consumer lifestyle approach to U.S. energy use and the related CO_2 emissions, *Energy Policy*, 33, pp. 197-208.
2. Chakravarty, Shoibal et al. (2009). Sharing global CO_2 emission reductions among one billion high emitters, *PNAS*, Vol. 106, No. 29, pp. 11884-11888.
3. Cohen, C, Lenzen M, and Schaeffer R. (2005). Energy requirements of households in Brazil, *Energy Policy*, 33(4), pp. 555-562.
4. DRC (Development Research Center) of the State Council of People's Republic of China (2003). China fuel efficiency background report.
5. Herendeen, R. and Tanaka J. (1976). Energy cost of living, *Energy*, 1, pp. 165-178.
6. Herendeen, R. (1978). Total energy cost of household consumption in Norway, 1973, *Energy*, 3, pp. 625-630.
7. Herendeen, R. et al. (1981). Energy cost of living, 1972-1973, *Energy*, 6, pp. 1433-1450.
8. IPCC (2006). IPCC guideline for national greenhouse gas inventories, *Energy*, Vol. 2.
9. Kahrl, Fredrich and David Roland-Holst (2007). Carbon inequality, Research Paper No. 07090701 of University of California, Berkeley.
10. Lenzen, M. (1998). Energy and greenhouse cost of living for Australia during 1993/94, *Energy*, 23 (6), pp. 497-516.
11. Lenzen, Manfred et al. (2006). A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan, *Energy*, 31, pp. 181-207.
12. Munksgaard et al. (2000). Impact of household consumption on CO_2 emissions, *Energy Economics*, 22 (4), pp. 423-440.
13. Murthy, N.S., M. Panda, and J. Parikh (1997a). Economic growth, energy demand and carbon dioxide emissions in India 1990-2020, *Environment and Development Economics*, 2, pp. 173-193.
14. Murthy et al. (1997b). Economic development, poverty reduction and carbon emissions in India, *Energy Economics*, 19 (3), pp. 327-354.
15. MWR (Bureau of Rural Hydropower and Electrification Development, Ministry of Water Resource) (2007). Record of major events, http://www.shp.com.cn/news/info/2007/11/9/1126024556.html.
16. NBS of China (2004). *Price yearbook of China 2003*.
17. NBS of China (2006). *China energy statistical yearbook 2005*.
18. Pachauri, Shonali (2002). Direct and indirect energy requirements of households in India, *Energy Policy*, 30, pp. 511-523.
19. Pachauri, Shonali (2004). An analysis of cross-sectional variations in total household energy requirements in India using micro survey data, *Energy Policy*, 32, pp. 1723-1735.
20. Pachauri, Shonali and Leiwen Jiang (2008). The household energy transition in India and China, *Energy Policy*, 36, pp. 4022-2035.
21. Parikh et al. (1997). Consumption patterns by income groups and carbon-dioxide implications for India 1990-2010, *International Journal of Global Energy Issues*, 9 (406), pp. 237-255.
22. Peet, N.J. et al. (1985). Energy in the New Zealand household, 1974-1980, *Energy*, 10 (11), pp. 1197-1208.
23. Peters, G.P. et al. (2006). Environmental impacts and household characteristics, an econometric analysis of Norway, 1999-2001, In: Tukker, A. (Ed.) Sustainable Consumption Research Exchange Launch Conference, Wuppertal, DE, pp. 292-307.
24. Ravallion, Martin and Shaohua Chen (2007). China's (uneven) progress against poverty, *Journal of Development Economics*, 82, pp. 1-42.
25. Reusswig, Fritz, Hermann Lotze-Campen, Katrin Gerlinger (2003). Changing global lifestyle and consumption patterns: the case of energy and food, Potsdam Institute for Climate Impact Research (PIK) and Global Change & Social Systems Department; http://www.unescap.org/esd/environment/mced/tggap/documents/2RPD/bgm/Global%20 lifestyle20and%20 consumption%20pattern.pdf.
26. Roca, Jordi and Mònica Serrano (2007). Income growth and atmospheric pollution in Spain: an input-output approach, *Ecological Economics*, 63, pp. 230-242.
27. Vringer, K. and Blok, K. (1995). The direct and indirect energy requirements of households in the Netherlands, *Energy Policy*, 23 (10), pp. 893-910.
28. Weber, Christopher L. and H. Scott Matthews (2008). Quantifying the global and distributional aspects of American household carbon footprint, *Ecological Economics*, 66, pp. 379-391.
29. Wei, Yi-ming et al. (2007). The impact of lifestyle on energy use and CO_2 emission: an empirical analysis of China's residents, *Energy Policy*, 35, pp. 247-257.
30. Wier, M., Lenzen, M. et al. (2001). Effects of household consumption patterns on CO_2 requirements, *Economic Systems Research*, 13 (3), 259-274.

Appendix A

Table 1. Micro vs. macro emissions of 2002

Source	Per capita CO_2 (tCO_2/cap)	Share of micro in macro
From provincial data - 1	3.43	52%
From provincial data - 2	3.25	55%
IEA - sectoral approach	2.60	68%
EIA	2.68	66%
Micro result (our result)	1.68→1.78	

Table 2. Gini coefficients (weighed with HH size)

		Total emissions	Direct emissions	Indirect emissions
Urban HH	North	0.28	0.35	0.31
	South	0.28	0.40	0.29
	All	0.31	0.52	0.30
Rural HH	North	0.48	0.69	0.36
	South	0.44	0.68	0.39
	All	0.46	0.70	0.38
All HH	North	0.53		
	South	0.46		
	All	0.51		

Table 3. Statistics of different emission household groups

Emission groups of HH	tCO_2/cap	Share of total population	Share of total emissions	Annual expenditures on consumption (RMB/cap)
Top 10%	6.3	7.6%	28.3%	9,974
Upper 40%	2.5	35.6%	51.8%	4,831
Lower 40%	0.7	44.0%	18.3%	1,727
Bottom 10%	0.2	12.8%	1.6%	864

Table 4. Top 10% vs. bottom 10% (income group)

		Bottom 10%	Top 10%	Ratio of top 10% over bottom 10%
Total emissions (kg CO_2/cap)	All urban	1807	5667	3.1
	Northern urban	2346	6798	2.9
	Southern urban	1327	4841	3.6
	All rural	424	2035	4.8
	Northern rural	519	2235	4.3
	Southern rural	332	1945	5.9
Direct emissions (kg CO_2/cap)	Northern urban	1523	2879	1.9
	Southern urban	388	897	2.3
	Northern rural	237	1136	4.8
	Southern rural	101	629	6.2
Indirect emissions (kg CO_2/cap)	Urban	884	3934	4.4
	Rural	256	1249	4.9
Income (disposable RMB)	Urban	2475	19597	7.9
Income (pure RMB)	Rural	691	7892	11.4
Expenditures on consumption (RMB)	Urban	2387	13296	5.6
	Rural	975	4342	4.5

Table 5. Definition of independent variables

Independent variables	Dummies	
ln(*I*)		Natural logarithm of per capita household total expenditures
HHS		Household size (household population)
Dhhs	Dummies of HHS	
	*Dhhs*1	=1, if HHS = 1
	*Dhhs*2	=1, if HHS = 2
	*Dhhs*3	=1, if HHS = 3
	*Dhhs*4	=1, if HHS = 4
	*Dhhs*5	=1, if HHS = 5
	*Dhhs*6	=1, if HHS = 6
	*Dhhs*7	=1, if HHS >= 7
Education		Education of household head
Dedu	Dummies of education	
	*Dedu*1	=1, if education = 1, illiterate or semiliterate
	*Dedu*2	=1, if education = 2, elementary school
	*Dedu*3	=1, if education = 3, junior middle school
	*Dedu*4	=1, if education = 4, high school and equivalent
	*Dedu*5	=1, if education = 5, junior college
	*Dedu*6	=1, if education = 6, college and postgraduate
Age		Age of household head
Dage	Dummies of age	Grouped by quartiles
	*Dage*1	=1, if age < 39
	*Dage*2	=1, if 40 < Age < 47
	*Dage*3	=1, if 48 < Age < 54
	*Dage*4	=1, if age >= 55
Durban		=1, if urban household (in the urban survey)
Dnorth		=1, if in the north of China
*Dprovince**		Dummy of each province

Table 6. Simulation results of urban households

Variable	Total				Direct				Indirect			
	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics
ln(*C*)												
ln(*I*)	**0.634**	120.30	**0.610**	116.26	**0.377**	29.95	**0.368**	35.43	**0.816**	210.94	**0.768**	178.72
*Dedu*2				NS			**0.139**	1.95			**-0.049**	-6.46
*Dedu*3			**0.044**	4.74			**0.184**	2.68				NS
*Dedu*4			**0.069**	7.38			**0.188**	2.74			**0.013**	3.22
*Dedu*5			**0.111**	10.92			**0.227**	3.30			**0.049**	9.42
*Dedu*6			**0.146**	12.47			**0.291**	4.16			**0.074**	11.67
*Dhhs*1			**0.508**	12.61			**0.742**	9.08			**0.322**	9.56
*Dhhs*2			**0.243**	30.06			**0.362**	21.66			**0.151**	23.21
*Dhhs*3			**0.064**	11.30			**0.086**	7.17			**0.040**	8.21
*Dhhs*5				NS				NS			**0.025**	3.32
*Dhhs*6			**-0.071**	-3.23			**-0.138**	-3.65			**-0.047**	-2.59
*Dhhs*7			**0.186**	9.25			**0.147**	3.64			**0.212**	5.31
*Dage*2				NS			**0.075**	5.50				NS
*Dage*3			**0.037**	6.81			**0.143**	10.17			**0.010**	2.40
*Dage*4			**0.069**	10.97			**0.194**	12.53			**0.032**	6.88
Dnorth			**0.610**	45.22			**1.439**	56.13				NS
*Dprovince**				Overall significant				Overall significant				Overall significant
Intercept	**2.496**	54.48	**2.329**	53.56	**3.393**	31.26	**2.756**	23.74	**0.455**	14.33	**0.726**	20.64
R^2	**0.4404**		**0.7110**		**0.0432**		**0.6121**		**0.8016**		**0.8180**	

Notes: All regressions are weighted with HHS; NS: coefficients which are not significant at 10% significance level.

Table 7. Simulation results of rural households

Variable	Total				Direct				Indirect			
	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics
ln(*C*)												
ln(*I*)	**0.954**	194.07	**0.922**	165.61	**1.066**	90.80	**1.107**	83.62	**0.885**	200.60	**0.777**	147.36
*Dedu*2			**0.047**	4.20				NS			**0.051**	6.53
*Dedu*3			**0.118**	10.86			**0.167**	10.23			**0.092**	12.21
*Dedu*4			**0.123**	10.22			**0.165**	7.79			**0.126**	14.82
*Dedu*5			**0.289**	6.94			**0.358**	3.74			**0.210**	7.68
*Dedu*6				NS				NS			**0.107**	2.85
*Dhhs*1				NS				NS			**0.134**	1.67
*Dhhs*2				NS				NS			**0.044**	4.08
*Dhhs*3			**0.059**	7.39			**0.094**	5.10			**0.062**	10.41
*Dhhs*5			**-0.013**	-1.84				NS			**-0.023**	-4.52
*Dhhs*6			**-0.044**	-5.05				NS			**-0.046**	-6.83
*Dhhs*7			**-0.098**	-7.97			**-0.069**	-2.43			**-0.088**	-10.23
*Dage*2				NS			**0.075**	4.00				NS
*Dage*3			**0.060**	8.84			**0.084**	4.48			**0.029**	6.07
*Dage*4			**0.058**	7.56			**0.090**	4.35			**0.011**	1.86
Dnorth			**1.024**	31.30			**2.644**	34.74			**0.443**	21.43
*Dprovince**				Overall significant				Overall significant				Overall significant
Intercept	**-0.558**	-15.27	**-0.924**	-21.29	**-3.022**	-34.80	**-5.010**	-48.99	**-0.456**	-14.14	**0.012**	0.31
R^2	**0.5188**		**0.6054**		**0.1756**		**0.3454**		**0.6545**		**0.6991**	

Note: see notes in Table 6.

Table 8. Simulation results of ALL households (urban + rural households)

Variable	Total				Direct				Indirect			
	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics
ln(c)												
ln(I)	**1.023**	376.85	**0.839**	196.19	**1.155**	178.93	**0.900**	89.57	**0.998**	483.36	**0.781**	205.16
*Dedu*2			**0.044**	3.99			**0.059**	2.21			**0.047**	6.49
*Dedu*3			**0.125**	11.89			**0.231**	9.04			**0.099**	14.16
*Dedu*4			**0.127**	11.49			**0.200**	7.42			**0.124**	16.61
*Dedu*5			**0.125**	9.91			**0.112**	3.74			**0.153**	18.00
*Dedu*6			**0.116**	8.46			**0.079**	2.42			**0.168**	18.35
*Dhhs*1			**0.237**	5.17			**0.252**	2.68			**0.264**	7.38
*Dhhs*2			**0.094**	10.76			**0.096**	4.84			**0.105**	17.32
*Dhhs*3			**0.038**	6.81			**0.049**	3.71			**0.042**	10.37
*Dhhs*5			**-0.029**	-4.48			**-0.044**	-2.82			**-0.018**	-3.98
*Dhhs*6			**-0.069**	-8.22			**-0.091**	-4.34			**-0.048**	-7.69
*Dhhs*7			**-0.128**	-10.96			**-0.175**	-6.09			**-0.084**	-10.49
*Dage*2				NS				NS				NS
*Dage*3			**0.052**	10.33			**0.118**	9.77			**0.026**	7.26
*Dage*4			**0.065**	11.32			**0.148**	10.88			**0.027**	6.73
Durban			**0.401**	58.79			**0.694**	42.70			**0.378**	69.56
Dnorth			**0.393**	20.70			**1.310**	37.24			**0.286**	22.93
*Dprovince**				Overall significant				Overall significant				Overall significant
Intercept	**-0.980**	-45.14	**0.156**	4.55	**-3.519**	**-68.22**	**-2.259**	-28.02	**-1.216**	-74.88	**0.040**	1.42
R^2	**0.7078**		**0.7858**		**0.3391**		**0.532**		**0.8359**		**0.8682**	

Note: see notes in Table 6.

Table 9. Income elasticity of CO_2 emissions with other factors controlled

Country	Reference	Year	Energy	CO_2 emissions
Australia	Lenzen (1998)	1993-94	0.74	0.70
Australia	Lenzen et al. (2006)	1998-99	0.78	
Brazil	Lenzen et al. (2006)	1995-96	1.00	
Denmark	Wier et al. (2001)	1995	0.90	0.90
Denmark	Lenzen et al. (2006)	1995	0.86	
India	Shonali Pachauri (2004)	1993-94	0.67	
India	Lenzen et al. (2006)	1997-98	0.86	
Japan	Lenzen et al. (2006)	1999	0.64	
Netherlands	Vringer & Blok (1995)	1990	0.83	
New Zealand	Peet et al. (1985)	1980	0.40	
Norway	Herendeen (1978)	1973	0.72	
Norway	Peters et al. (2006)	1999-2001		0.88
Spain	Roca & Serrano (2007)	2000		0.91-0.99
U.S.	Herendeen & Tanaka (1976)	1960-61	0.85	
U.S.	Herendeen et al. (1981)	1972-73	0.78	
U.S.	Weber & Matthews (2008)	2004		0.60-0.80
China (Urban)	Our results	2002	Total	**0.61**
			Direct	0.37
			Indirect	0.77
China (Rural)			Total	**0.92**
			Direct	1.11
			Indirect	0.78
China (All)			Total	**0.84**
			Direct	0.90
			Indirect	0.78

Notes: Based on the reviews done by Wier (Wier et al., 2001), Lenzen (Lenzen et al., 2006), Peters (Peters et al., 2006) and Chakravarty (Chakravarty et al., 2009).

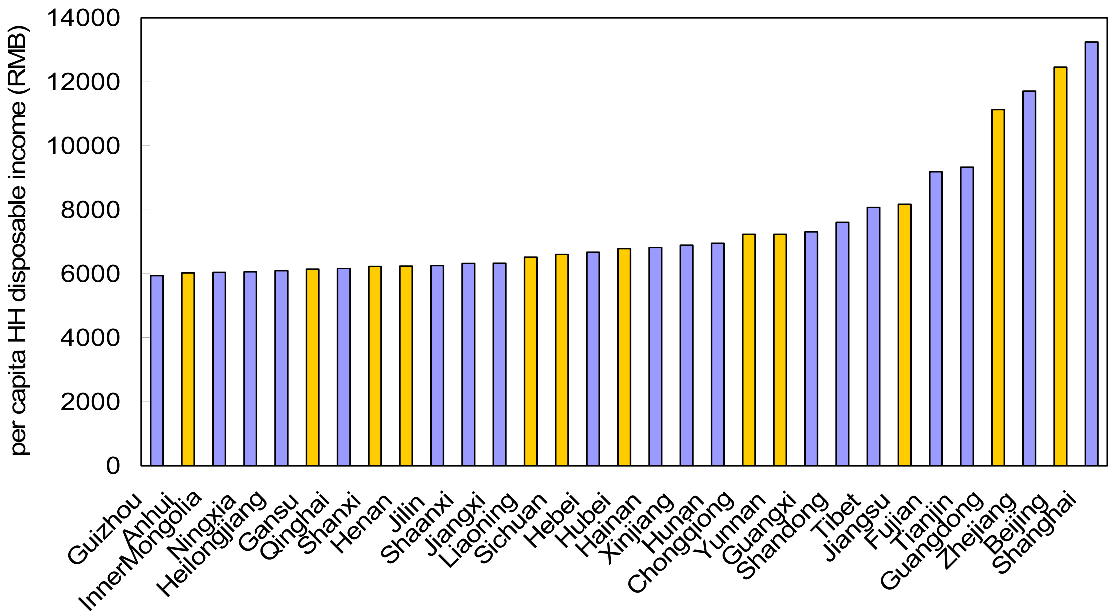


Fig. 1. Urban per capita household disposable income of all the provinces and municipal cities of China in 2002

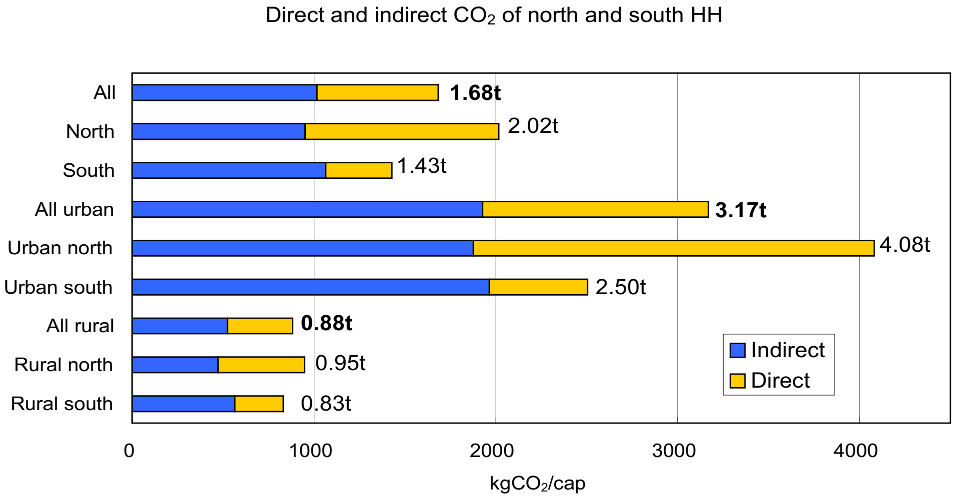


Fig. 2. Averaged per capita household CO_2 emissions of rural and urban households

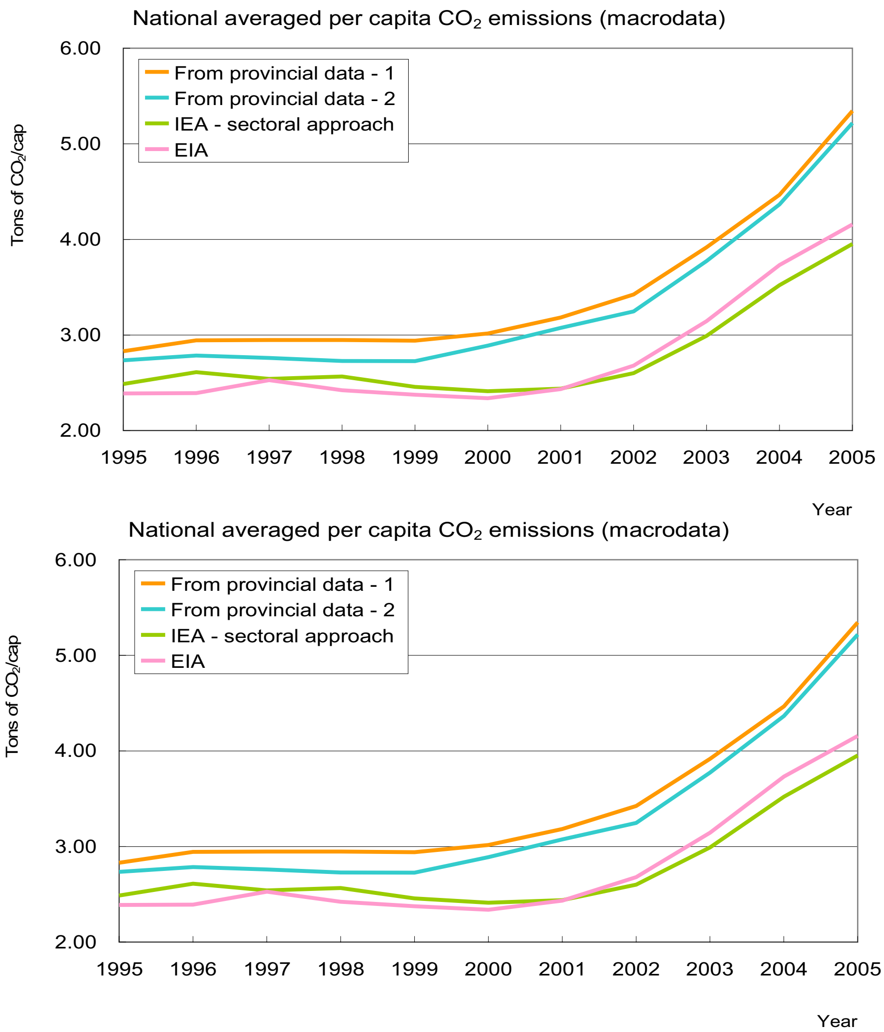


Fig. 3. Macro emission data[1]

[1] The "from provincial data - 1" and "from provincial data - 2" are national averaged emissions calculated from China's provincial aggregate energy data. The energy data are collected from provincial energy balance tables in different series of energy statistical yearbook of China and converted into CO_2 emissions by sectoral approach. Therefore, only emissions from energy combustion are included. "From provincial data - 1" is collected and calculated by Jing Cao, an assistant professor of Tsinghua University. And the data are obtained through Dr. Sivan Kartha, Senior Scientist of Stockholm Environment Institute. "From provincial data - 2" is collected and calculated by Jie Li. There slight differences between the two series of results maybe due to somewhat different approximation in the calculation processes. The "IEA – sectoral approach" is from IEA's database, per capita CO_2 emissions by sector Vol. 2008, which is calculated with China's national aggregate data by sectroal approach. The "EIA" data are from EIA's official website.

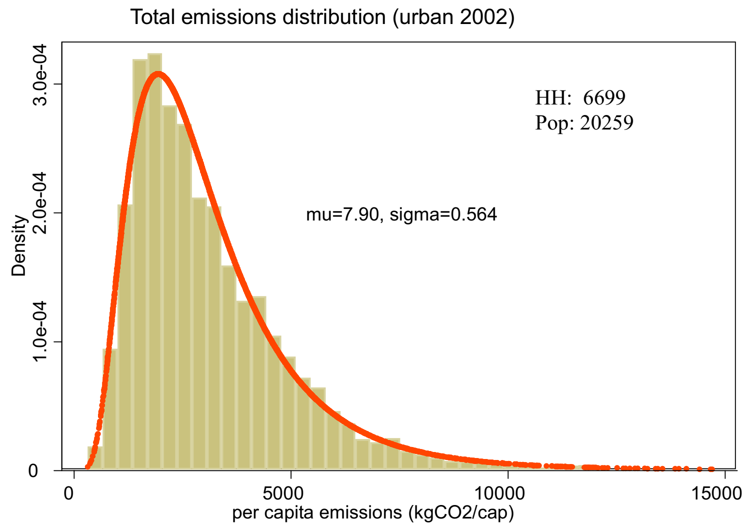


Fig. 4(a). Distribution of urban per capita households CO_2 emissions (weighted by HH size)

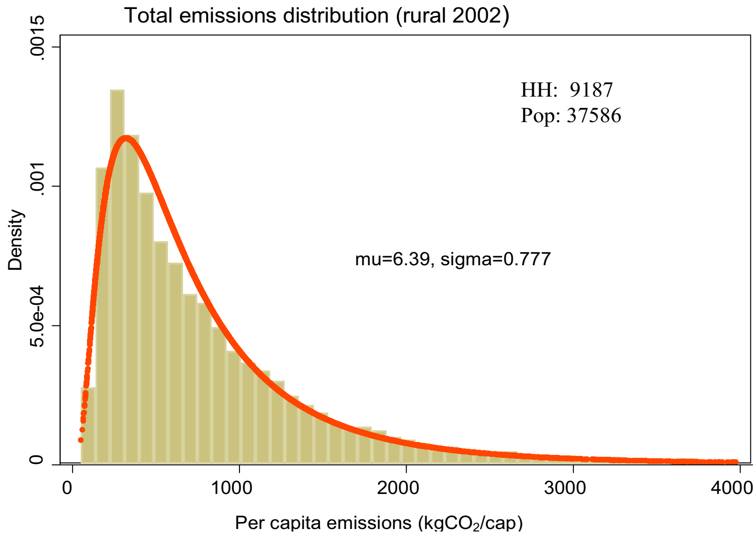


Fig. 4(b). Distribution of rural per capita households CO_2 emissions (weighted by HH size)

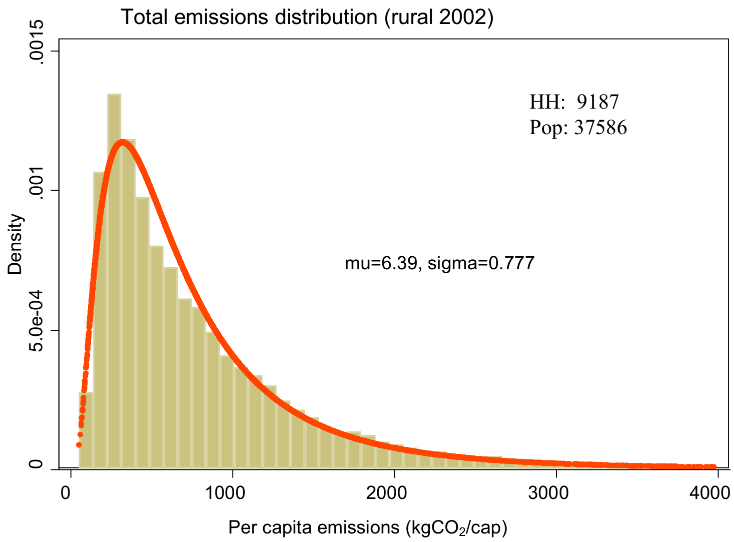


Fig. 4(c). Distribution of urban plus rural per capita households CO_2 emissions (weighted by HH size)

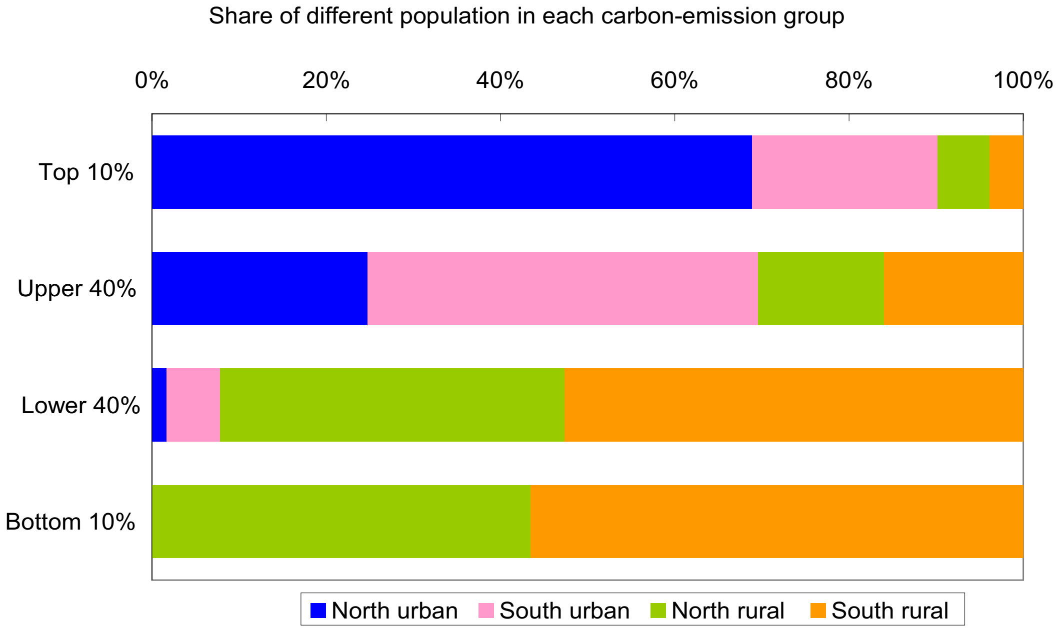


Fig. 5. Composition of each emission group

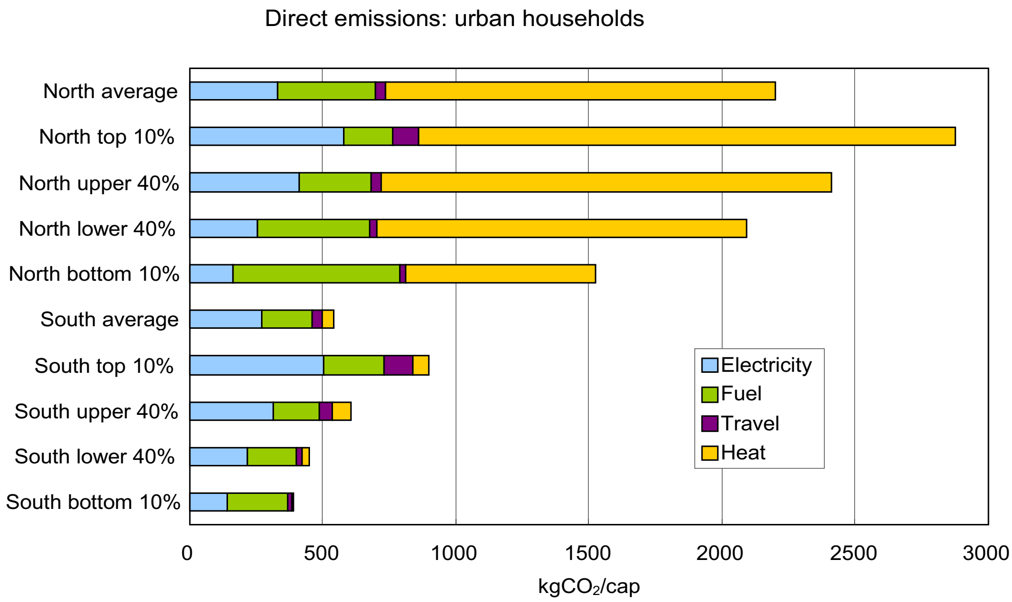


Fig. 6(a). Compositions of averaged direct CO_2 emissions of each urban income group

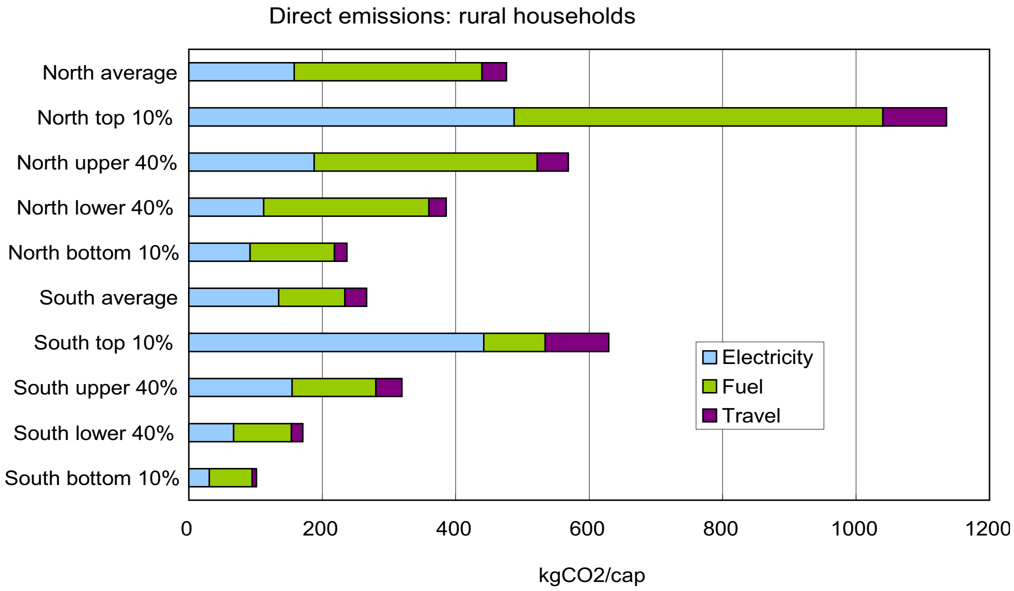


Fig. 6(b). Compositions of averaged direct CO_2 emissions of each rural income group

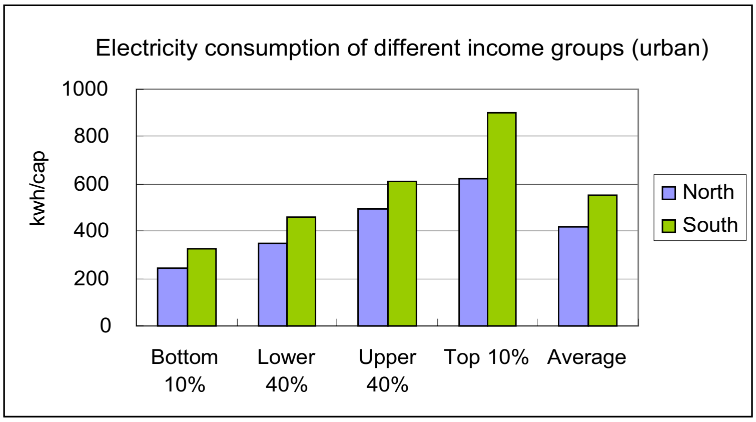


Fig. 7. Comparison of electricity consumption between the north and the south (Urban)

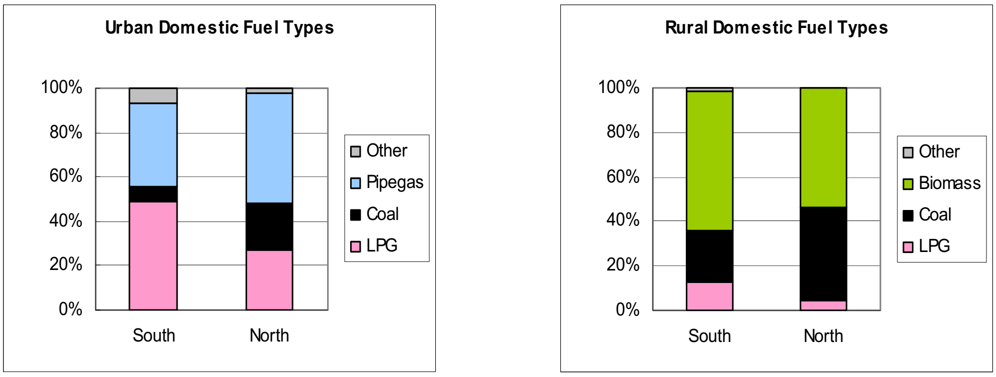


Fig. 8(a) and 8(b). Mix of domestic fuel use (urban and rural)

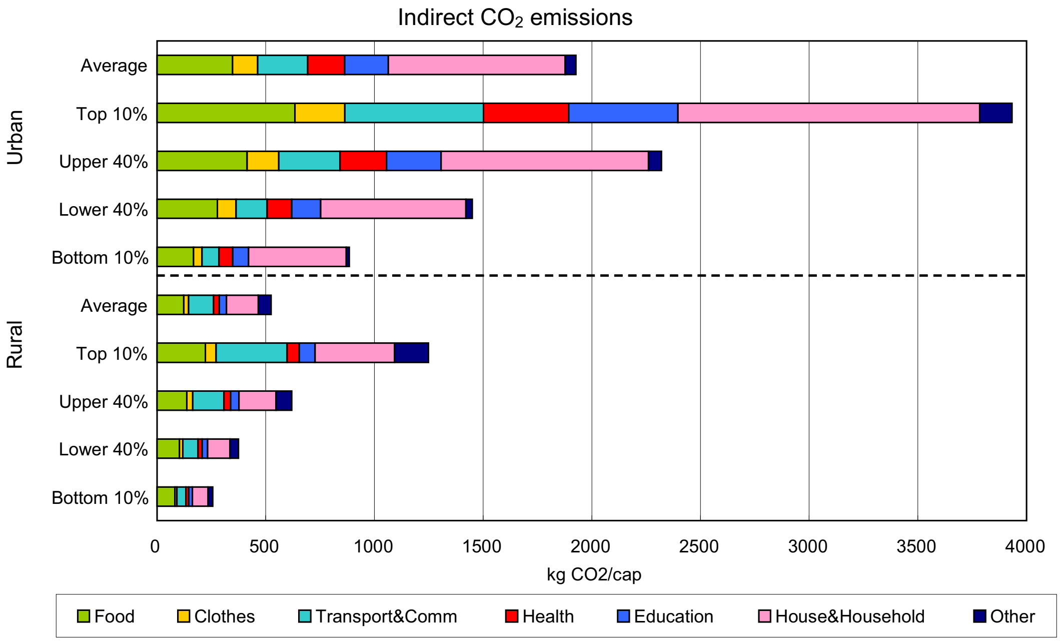


Fig. 9(a). Composition of indirect emissions of urban and rural households in percentage

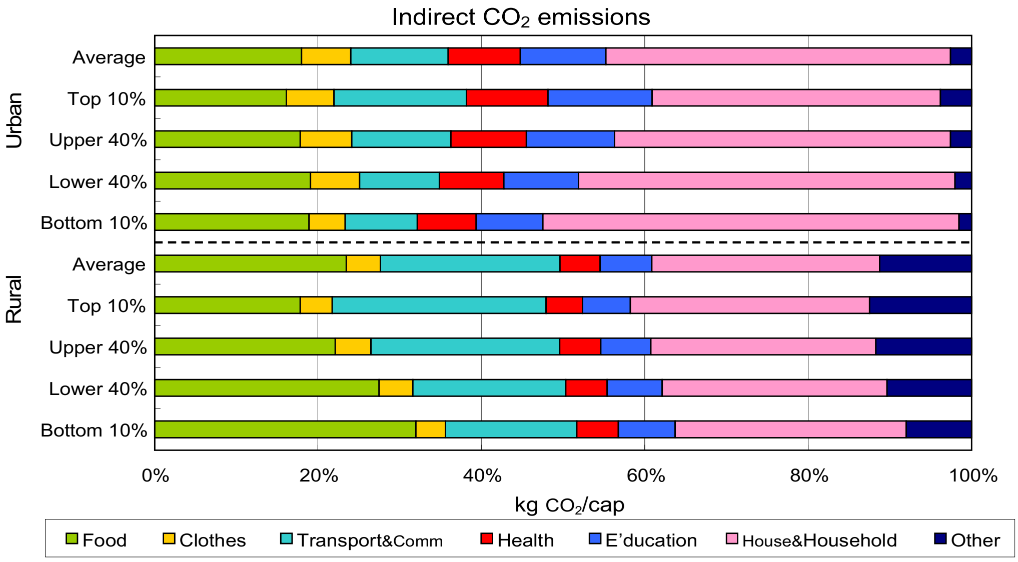
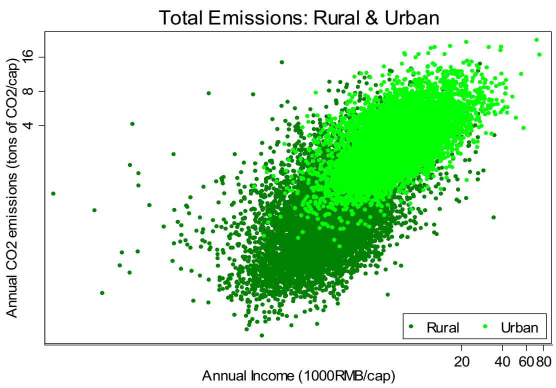


Fig. 9(b). Composition of indirect emissions of urban and rural households in percentage



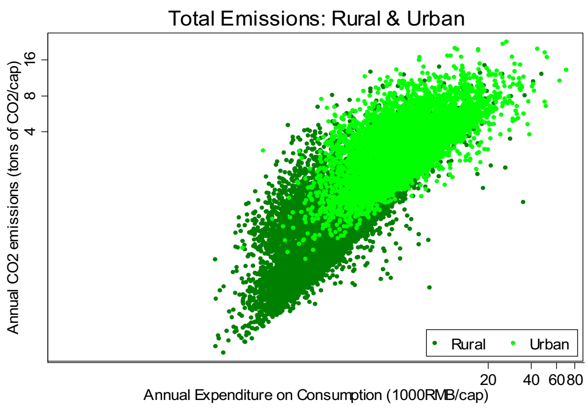


Fig. 10(a) and 10(b). Relationship of individual CO_2 emissions and income/expenditure

Appendix B

Table 10. Coverage of the urban survey

Code #[1]	Province/municipal city	Number of cities/ districts	Number of households	Northern or southern
11	Beijing	8	484	N
14	Shanxi	7	640	N
21	Liaoning	5	697	N
32	Jiangsu	9	729	S
34	Anhui	6	492	S
41	Henan	8	680	N
42	Hubei	7	672	S
44	Guangdong	8	544	S
50	Chongqing	2	279	S
51	Sichuan	6	585	S
53	Yunnan	8	636	S
62	Gansu	3	395	N
Total	12	77	6,833	

Table 11. Coverage of the rural survey (10 HH in each village, 9200 HH in total)

Code #	Province/municipal city	Number of counties	Number of villages	Northern or southern
11	Beijing	2	16	N
13	Hebei	5	37	N
14	Shanxi	6	40	N
21	Liaoning	6	45	N
22	Jilin	6	48	N
32	Jiangsu	5	44	S
33	Zhejiang	6	52	S
34	Anhui	5	44	S
36	Jiangxi	6	43	S
37	Shandong	7	63	N
41	Henan	7	53	N
42	Hubei	6	52	S
43	Hunan	5	45	S
44	Guangdong	7	53	S
45	Guangxi	5	40	S
50	Chongqing	2	20	S
51	Sichuan	6	50	S
52	Guizhou	6	40	S
53	Yunnan	5	26	S
61	Shaanxi	6	37	N
62	Gansu	5	32	N
65	Xinjiang	8	40	N
Total	9200	122	920	

[1] Official standard provincial codes used in China for surveys, provided by National Bureau of Statistics.

Fig. 11. Data coverage (the circles indicate where the urban survey is taken, and the red squares indicate, the provinces that the rural survey covers)

Table 12. Ownership of durable goods (per 1000 HH)

Urban	TV		Washing machine	Refrigerator	PC	Cell phone	Motorcycle	Automobile
Bottom 10%	104		87	66	3	17	11	3
Lower 10%	120		93	85	12	46	14	4
Upper 10%	137		99	96	33	89	20	12
Top 10%	160		106	102	58	134	26	51
Average	130		96	89	24	69	17	12
Rural	TV_color	TV_BW	Washing machine	Refrigerator	Air conditioner		Motorcycle	Automobile
Bottom 10%	42	54	19	6	0		13	0.0
Lower 10%	51	54	25	7	0		20	0.5
Upper 10%	69	46	40	18	2		36	0.8
Top 10%	98	34	59	46	16		62	15
Average	62	49	34	15	3		30	2

Table 13. Overview of the surveyed households' situations

		Mean	Standard dev.	1st quartile	Median	3rd quartile
Urban	Per capita HH disposable income (RMB) in 2002	**8040**	**5280**	**4620**	**6840**	**9900**
	Per capita HH disposable income ($PPP, WB)	2470	1620	1420	2100	3040
	Per capita HH disposable income ($PPP, Penn)	4140	2720	2380	3530	5100
	Per capita HH expenditure on consumption (RMB)	**6300**	**4480**	**3620**	**5220**	**7630**
	Per capita HH expenditure on consumption ($PPP, WB)	1930	1370	1110	1600	2340
	Per capita HH expenditure on consumption ($PPP, Penn)	3250	2310	1870	2690	3930
	Age of HH head	48	11	40	47	54
	Education of HH head	11	3.3	9	11	13
	HH size	3	0.79	3	3	3
Rural	Per capita HH pure income (RMB) in 2002	**2800**	**2410**	**1440**	**2190**	**3370**
	Per capita HH disposable income ($PPP, WB)	860	740	440	670	1030
	Per capita HH disposable income ($PPP, Penn)	1440	1240	740	1130	1740
	Per capita HH expenditure on consumption (RMB)	**2000**	**1950**	**1030**	**1490**	**2290**
	Per capita HH expenditure on consumption ($PPP, WB)	610	600	320	460	700
	Per capita HH expenditure on consumption ($PPP, Penn)	1030	1010	530	770	1180

Table 13 (cont.). Overview of the surveyed households' situations

		Mean	Standard dev.	1st quartile	Median	3rd quartile
	Age of HH head	46	10	38	46	53
	Education of HH head	7.2	2.5	5	8	9
	HH size	4.1	1.3	3	4	5

Notes: (all at current prices of 2002); PPP exchange rate of World Development Indicators from the World Bank: 1 USD = 3.26 RMB; PPP exchange rate of World Penn Table: 1 USD = 1.94 RMB, HH: household.

Appendix C

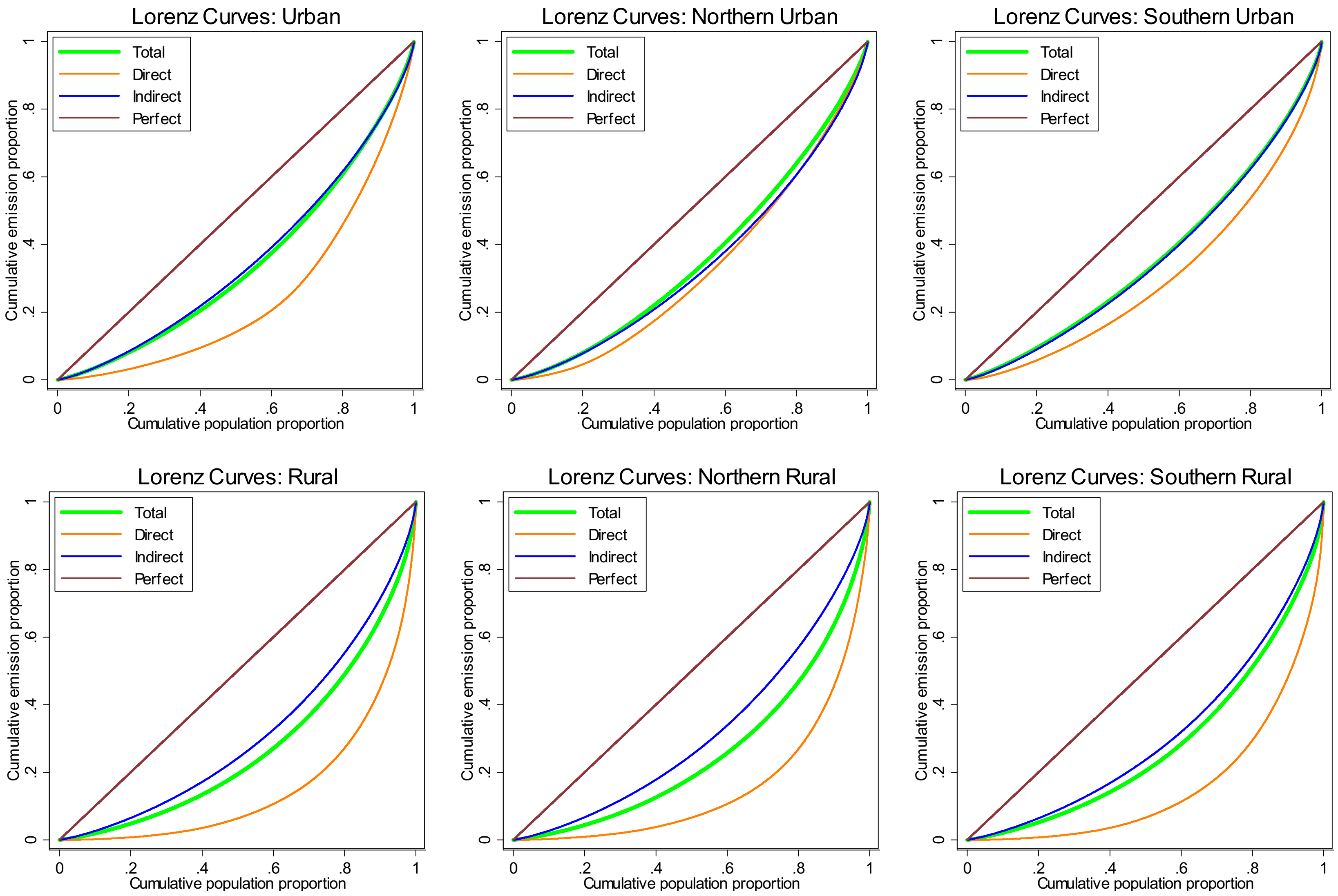
Table 14. Average per capita CO_2 emissions of the major groups of households (weighted with HH size) ($KgCO_2$/cap)

	Direct	Indirect	Total	% of direct	% of indirect
Rural south	266	565	831	32%	68%
Rural north	476	473	949	50%	50%
All rural	**359**	**524**	**883**	**41%**	**59%**
Urban south	540	1964	2504	22%	78%
Urban north	2203	1876	4080	54%	46%
All urban	1241	1927	3169	**39%**	**61%**

Table 15. Average per capita income and expenditure on consumption of the major groups

		Urban		Rural	
		Income	Expenditure	Income	Expenditure
RMB	Bottom 10%	2475	2387	691	975
	Lower 40%	5055	4370	1583	1371
	Upper 40%	9481	7437	3225	2199
	Top 10%	19597	13296	7892	4342
	Average	7678	6066	2612	1878
USD ppp WB [a]	Bottom 10%	759	732	212	299
	Lower 40%	1551	1341	485	420
	Upper 40%	2908	2281	989	675
	Top 10%	6011	4079	2421	1332
	Average	2355	1861	801	576
USD ppp Penn [b]	Bottom 10%	1275	1230	356	502
	Lower 40%	2604	2252	815	706
	Upper 40%	4884	3832	1662	1133
	Top 10%	10096	6850	4066	2237
	Average	3956	3125	1346	968
USD market [c]	Bottom 10%	299	288	84	118
	Lower 40%	611	528	191	166
	Upper 40%	1145	899	390	266
	Top 10%	2368	1606	953	525
	Average	928	733	316	227

Notes: (all at current prices of 2002); PPP exchange rate of World Development Indicators from the World Bank in 2002: 1 USD = 3.26 RMB; PPP exchange rate of World Penn Table in 2002: 1 USD = 1.94 RMB.



(a, b, c)

(d, e, f)

Fig. 12. Lorenz curves of urban and rural per capita CO_2 emissions (all, north, south)

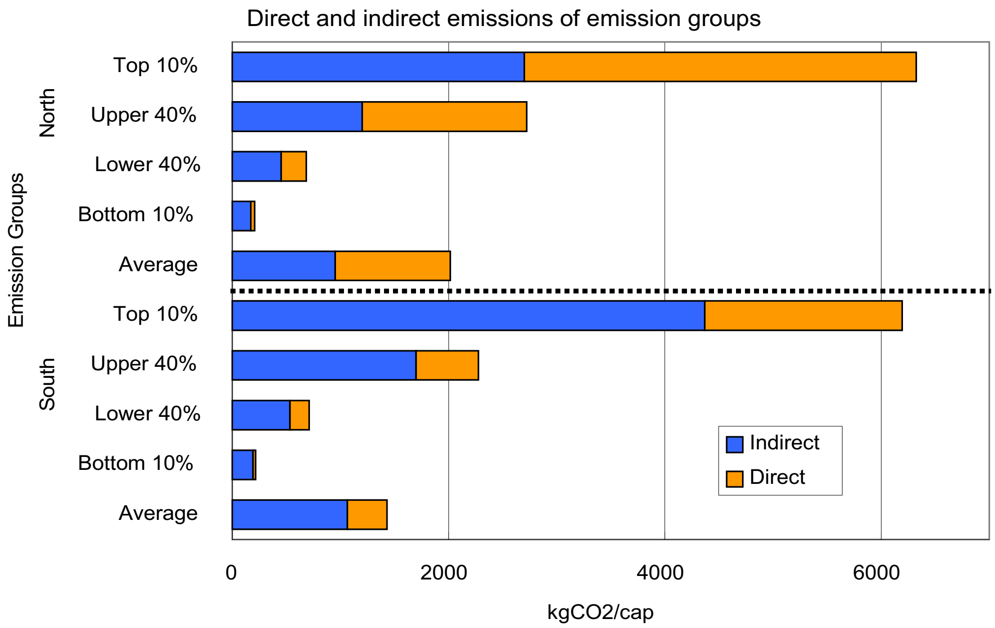
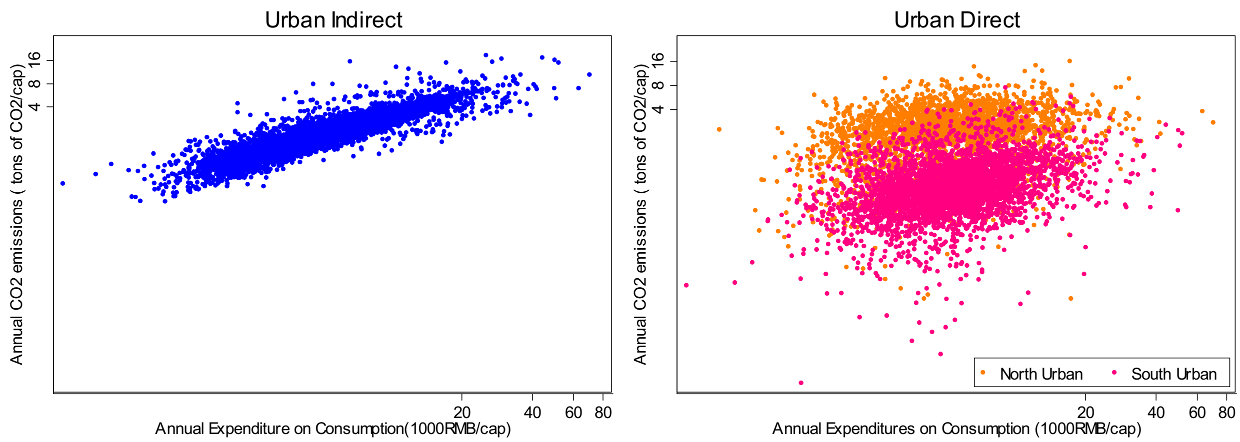
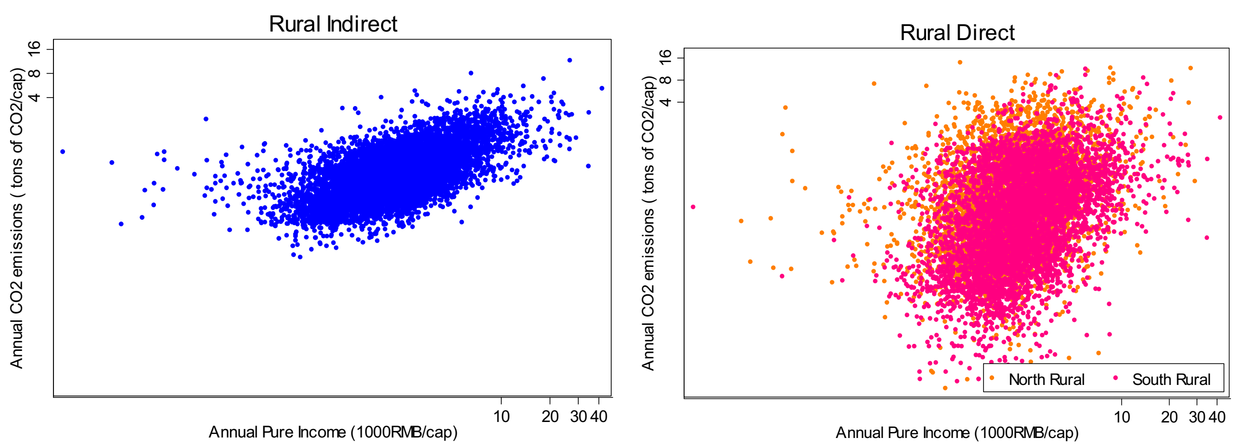


Fig. 13. Direct and indirect emissions of emission groups

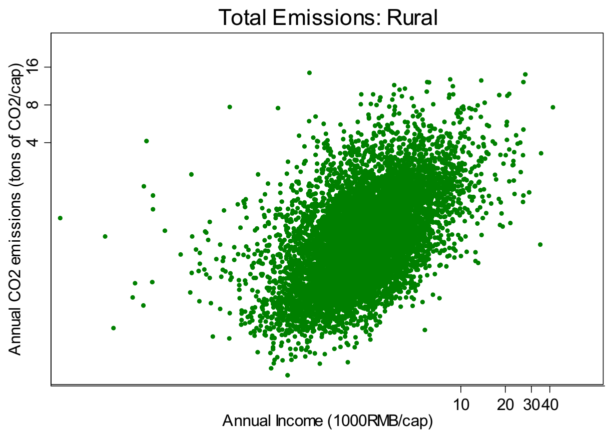
Appendix D



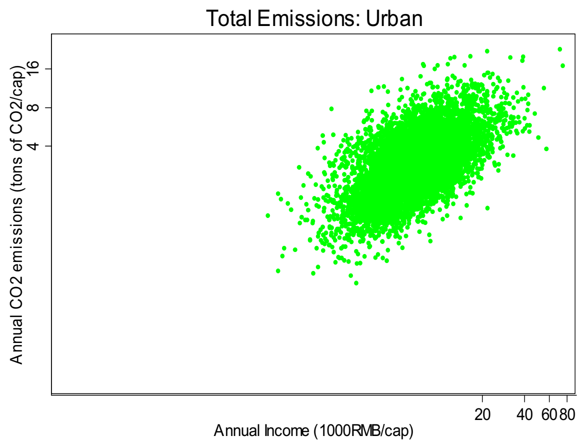
(a) (b)



(c) (d)



(d)



(f)

Fig. 14. Scatter of carbon against income (a-f)

Table 16. Comparison of regression results against different *I*: income vs. expenditure

		Total				Direct				Indirect			
		Income as the only independent variable		Other factors controlled		Income as the only independent variable		Other factors controlled		Income as the only independent vari-able		Other factors controlled	
		Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics	Coef.	t-statistics
Urban	ln(*I*)	**0.58**	101.99	**0.51**	85.59	**0.38**	29.53	**0.32**	29.13	**0.72**	154.71	**0.64**	111.59
	R^2	**0.35**		**0.61**		**0.04**		**0.60**		**0.60**		**0.64**	
Rural	ln(*I*)	**0.65**	95.24	**0.50**	64.61	**0.80**	66.23	**0.64**	47.07	**0.62**	104.00	**0.44**	68.57
	R^2	**0.29**		**0.39**		**0.12**		**0.27**		**0.38**		**0.49**	
Rural + urban	ln(*I*)	**0.91**	217.00	**0.52**	88.32	**1.06**	144.19	**0.59**	57.65	**0.89**	237.92	**0.50**	97.07
	R^2	**0.56**		**0.69**		**0.29**		**0.49**		**0.67**		**0.77**	
		Expenditure as the only independent variable		Other factors controlled		Expenditure as the only independent variable		Other factors controlled		Expenditure as the only independent variable		Other factors controlled	
Urban	ln(*I*)	**0.63**	120.30	**0.61**	116.26	**0.38**	29.95	**0.37**	35.43	**0.82**	210.94	**0.77**	178.72
	R^2	**0.44**		**0.71**		**0.04**		**0.61**		**0.80**		**0.82**	
Rural	ln(*I*)	**0.95**	194.07	**0.92**	165.61	**1.07**	90.80	**1.11**	83.62	**0.89**	200.60	**0.78**	147.36
	R^2	**0.52**		**0.61**		**0.18**		**0.35**		**0.65**		**0.70**	
Rural + urban	ln(*I*)	**1.02**	376.85	**0.84**	196.19	**1.16**	178.93	**0.90**	89.57	**1.00**	483.36	**0.78**	205.16
	R^2	**0.71**		**0.79**		**0.34**		**0.53**		**0.84**		**0.87**	