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# Income inequality and carbon dioxide emissions: The case of Chinese urban households

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ABSTRACT

This paper draws on Chinese survey data to investigate variations in carbon dioxide emissions across households with different income levels. Rich households generate more emissions per capita than poor households via both their direct energy consumption and their higher expenditure on goods and services that use energy as an intermediate input. An econometric analysis confirms a positive relationship between emissions and income and establishes a slightly increasing marginal propensity to emit (MPE) over the relevant income range. The redistribution of income from rich to poor households is therefore shown to reduce aggregate household emissions, suggesting that the twin pursuits of reducing inequality and emissions can be achieved in tandem.


## 1. Introduction

China's recent rise to the unenviable position as the world's largest emitter of carbon dioxide has coincided with a far more enviable economic growth record during the last three decades, albeit one that has generated significant income inequalities in a range of dimensions. Chinese leaders are challenged by the simultaneous needs to 'build a resource efficient and environmentally-friendly society' and to ensure that growth is more equitable, both of which are integral to 'building a harmonious society' as outlined in the Eleventh Five-Year Plan (2006–2010) and reiterated in the Twelfth Five-Year Plan (2011–2015). It is far from obvious how best to tackle this combination of challenges from a policy perspective, even when narrowing the analysis down to a particular disadvantaged region, sector or group within the Chinese economy. Transferring income from rich to poor households, for example, would obviously reduce inter-household income inequality, but what would be the consequences for the aggregate carbon dioxide emissions of Chinese households (let alone of China at large)? Policy decisions would be considerably easier to make if income redistribution turned out to be environmentally friendly as well.

This paper demonstrates that this may well be the case for China's urban household sector. To establish this point, we utilize China's Urban Household Income and Expenditure Survey (UHIES) 2005 to investigate variations in per capita carbon dioxide emissions (henceforth emissions[1]) across urban households with different income levels.[2] Cross-country time-series analyses of the relationship between emissions and income have provided evidence of a diminishing marginal propensity to emit (MPE) as income rises (Heil and Selden, 2001; Holtz-Eakin and Selden, 1995; Ravallion et al., 2000). Critically, as shown by Ravallion et al. (2000), a diminishing MPE implies a trade off between inequality-improving income redistributions and aggregate carbon dioxide emissions, whereas an increasing MPE implies a win–win case in which inequality reductions go hand in hand with aggregate emission reductions.

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[1] All subsequent reference to "emissions" in this paper implies "carbon dioxide emissions". By focusing on carbon dioxide only, we overlook other greenhouse gasses (GHGs), such as methane, nitrous oxide and chlorofluorocarbons. While these other GHGs may be equally, or even more, important for certain environmental problems, data restrictions prevent a more holistic analysis at this stage.

[2] The UHIES was conducted by the National Bureau of Statistics in 31 provinces. The data we have access to cover 16 provinces. The survey only samples urban permanent households (households with urban *household registration* or *hukou*).

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Ravallion et al. (2000: p. 653) acknowledge that consumer demand is 'the most likely source of non-linearities in the effect of higher incomes on emissions, particularly given that the latter depend in large part on what goods are consumed within the economy'. They also make the critical observation that direct consumer demand for energy (i.e. fossil fuels) is only part of the story since 'many goods which do not require fossil fuel combustion as part of their consumption do require it for production. Both the direct and indirect demands are relevant to carbon emissions' (p. 653). Yet after making this observation, they then use estimates of national-level emissions based on fossil fuel use and cement production to calculate per capita emissions, which do not take consumers' indirect energy demand into account. Taking a consumer-based approach, numerous recent studies have highlighted how important this indirect energy consumption—and hence indirect emissions generation—can be. Wei et al. (2007), for example, attempt to quantify the direct and indirect energy requirements and related carbon emissions of Chinese urban and rural residents between 1999 and 2002, and show that 71% of urban household energy is consumed indirectly. Pachauri and Spreng (2002) show that indirect energy requirements account for close to half of the total energy consumption of Indian households, while Cohen et al. (2005) show that 61% of household energy is indirectly consumed in Brazil.[3] When a more comprehensive measure of indirect emissions is included in each consumer's total emissions, it is far from clear that the MPE will still be diminishing, whether in cross-country time-series or single country cross-sectional analyses.[4]

The paper is structured as follows. Section 2 describes the methodology and data used to calculate each household's per capita energy consumption and emissions and presents the key results depicting the relationship between these two variables and per capita income. Our econometric analysis is presented in Section 3, followed by a consideration of the impact of income redistribution on aggregate household emissions in Section 4. Section 5 concludes.

## 2. Per capita energy consumption and emissions of Chinese urban households

Emissions are embodied in energy, which each household consumes directly, in the form of coal, petroleum, natural gas and electricity, and indirectly via the energy inputs used in the production of all other goods and services that the household consumes.[5] Each household's direct energy consumption is relatively easy to calculate, as long as the physical quantity of consumption of each direct energy source can be observed. These physical quantities can be converted into net calorific values (expressed in joules) and summed across all sources. Each of these energy sources has a different emission factor, which is country and sector specific. Each household's direct energy consumption can thus be converted into its direct emissions by multiplying the net calorific value of each energy source by its emission factor and summing across all sources.

'Indirect' energy consumption, and therefore indirect emissions, can be calculated in a number of ways. Process analysis assesses the emissions generated throughout the lifecycle of a product, from the commencement of production through to distribution, storage, transport, waste and recycling. This method appears to have been used only for European analysis where such detailed data is available.[6] Less data-intensive methods rely on input–output (IO) analysis to identify the energy embodied in a unit value of production for each sector. The resulting embodied energy intensities reflect not only the energy used as direct inputs into the production of each good, but also the energy used in the intermediate inputs that are used in the production of that good, and the energy used in the intermediate inputs of those intermediate inputs, and so on.[7] These sector-level intensities can be combined with household expenditure on each sector to calculate the indirect energy consumption of each household, in what Kok et al. (2006) call the 'IO plus household expenditure' method.[8] This method is much more commonly used for practical reasons and is the method adopted here.

In particular, household *k*'s total energy consumption per capita is the sum of its direct energy consumption per capita and its indirect energy consumption per capita. In order to calculate the latter, we first calculate the direct energy intensities associated with each sector and then use IO data to calculate the associated indirect energy intensities, which are given by:

$$\mathbf{I^E} = \mathbf{D^E}(\mathbf{I}-\mathbf{A})^{-1}$$

where $\mathbf{I^E}$ is a vector of indirect energy intensities in each sector, $\mathbf{D^E}$ is a vector of direct energy intensities in each sector and $\mathbf{A}$ is the inter-industry matrix of direct input coefficients. Given the 42 sector IO data used below, $\mathbf{A}$ is a 42 by 42 matrix of direct input coefficients, where $a_{ij}$ $(i, j = 1,2,\ldots,42)$ is the value of industry *i* used in the production of one yuan of industry *j*'s output. Multiplying the Leontief inverse matrix $(\mathbf{I}-\mathbf{A})^{-1}$ by the direct energy intensity vector, $\mathbf{D^E}$, yields a vector of indirect energy intensities for each sector. In turn, multiplying $\mathbf{I^E}$ by a vector of household expenditure per capita on each good, $\mathbf{y_k}$, gives each household's indirect energy consumption per capita. Thus household *k*'s total energy consumption per capita can be expressed as:

$$TE_k = DE_k + IE_k = \sum_{i=1}^{4} DE_{ik} + \mathbf{I^{E\prime}}\mathbf{y_k} \quad (1)$$

where $DE_k$ and $IE_k$ are household *k*'s direct and indirect energy consumption per capita respectively and $DE_{ik}$ is household *k*'s direct consumption of energy *i* per capita.

Likewise, in order to calculate indirect emissions, we first need to calculate the direct and indirect emission intensities associated with each good:

$$\mathbf{I^C} = \mathbf{D^C}(\mathbf{I}-\mathbf{A})^{-1}$$

where $\mathbf{I^C}$ is a vector of indirect emission intensities in each sector and $\mathbf{D^C}$ is a vector of direct emission intensities in each sector. Household *k*'s total emissions per capita can then be expressed as:

$$TC_k = DC_k + IC_k = \sum_{i=1}^{4} f_i DE_{ik} + \mathbf{I^{C\prime}}\mathbf{y_k} \quad (2)$$

where $DC_k$ and $IC_k$ are direct and indirect emissions per capita respectively and $f_i$ is the emission factor for energy *i*.

[3] See also Kerkhof et al. (2009) on the Netherlands, UK, Sweden and Norway, Lenzen et al. (2006) on Australia, Brazil, Denmark, India and Japan, Baiocchi et al. (2010) on the UK, and Lenzen et al. (2004) on Sydney.

[4] This is not to suggest that Ravallion et al. (2000) should have tried to do this. Given the effort and data required to construct household-level indirect energy and emissions data for a single country in a single year, compiling accurate and consistent cross-country time series data of this kind simply isn't an option. Kerkhof et al.'s (2009) four-country, two-year comparative analysis is impressive enough.

[5] The definition of 'direct' energy requirements used here excludes biomass fuels such as firewood and crop stalks, which constitute a major source of energy in developing, rural areas: according to Pachauri and Jiang (2008), 60% of rural Chinese use traditional biomass fuels for their heating and cooking needs. However, they also note that urban Chinese households—the focus of this paper—use almost no biomass fuels, so this definition seems appropriate in this case.

[6] See Reinders et al. (2003) for example.

[7] In contrast, Wei et al. (2007) appear to use only the direct energy inputs in the production of each good in their intensity calculations, which they then use to calculate each consumer's indirect energy consumption. By ignoring the IO table, this method understates the importance of indirect emissions. This less comprehensive method was also used in Golley et al. (2008).

[8] To complicate matters, different authors use different names for the same method. For example, Kok et al.'s 'IO plus household expenditure' method is Bin and Dowlatabadi's (2005) 'environmental IO life-cycle analysis' and Weber and Perrels's (2000) 'mixed monetary energetic approach'. This is basically the method used by Pachauri and Spreng (2002), Pachauri (2004), Cohen et al. (2005), and Kerkhof et al. (2009), among others.