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The effects of urbanization, consumption ratio and consumption structure on residential indirect CO_2 emissions in China: A regional comparative analysis

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HIGHLIGHTS

- The residential indirect CO_2 emissions display regional difference.
- We decompose the urbanization variable from the SDA model.
- Urbanization increases residential indirect CO_2 emissions in China.
- Consumption structure increases residential indirect CO_2 emissions in China.

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ABSTRACT

Based on analysis of input–output energy and household expenditure data (IO-EA-expenditure), this paper calculates China's indirect carbon emissions from residential consumption in 2002 and 2007, by region. Then a new Structural Decomposition Analysis (SDA) model is proposed to investigate the regional variations of impacts of urbanization, consumption ratio and consumption structure on residential indirect CO_2 emissions in China during 2002–2007. As the results suggest, expansion of urbanization and upgrade of consumption structure play important roles in the growth of residential indirect emissions. Transformation of consumption ratio, contributing the most to emissions in the eastern region, reduces indirect emissions in all regions to a certain extent. The persistent decline of carbon emission intensity still contributes significantly to the decrease in emissions and the rise of per capita consumption plays a dominant role in the growth of residential indirect emissions. Based on empirical results, this article provides policy suggestions which can help reduce China's residential indirect CO_2 emissions.

1. Introduction

According to the Key World Energy Statistics from the IEA [1], 6.2 billion tons of carbon dioxide emissions in China and it accounted for 21% of global carbon dioxide emissions in 2007, which makes it the world's largest emitter, and residential energy consumption (REC) has been sharply increasing since the year 2002. In 2010, REC is 345.58 million ton coal equivalent (tce), compared to 171.62 million tce in 2002. REC is still the second largest energy consuming sector (10%) in China, after industry which in China is responsible for 71.5% of energy use [2–5]. Calculations of household energy requirements and related carbon emissions show that a major part of energy requirements and related carbon emissions in the economy of a country is allocated to the household sector and that indirect CO_2 emissions are becoming more and more important. For example, approximately 45–55% of total energy use is caused by consumers' activities for personal transportation, personal services and homes in Sweden [6]; the building sector accounts for the largest share of the total EU final energy consumption (42%), and greenhouse gas emissions (35%) [7,8]; about 40% of CO_2 emission in Japan is related to the final demand for consumption [9]; household energy consumption comprises 75% of the total energy consumption in India [10]; 80% of American energy consumption and CO_2 emissions are attributed to consumer behaviors and related economic activities and the indirect effects are twice those of direct actions [11]; 52% of Korean energy

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Nomenclature

Acronyms

CLA	Consumer Lifestyle Approach
CPC	national congress of the communist party of China
IDA	Index Decomposition Analysis
IEA	international energy agency
IO	input–output
IO-EA-basic	input–output energy analysis based on national accounts
IO-EA-expenditure	input–output energy analysis combined with expenditure data
IO-EA-process	input–output energy analysis combining with process
IPCC	intergovernmental panel on climate change
LMDI	Logarithmic Mean Divisia Index
NBS	National Bureau of Statistics
QMRIO	quasi-multi-regional input–output
REC	residential energy consumption
SDA	structural decomposition analysis

Symbols

$\overline{Y}_i$	per capita consumption of residents *i*
$\overline{Y}_c$	per capita consumption effect
x_i	independent variables
$g(\Delta x_i)$	the effect of changes in x_i on Δy
$(I–A)^{-1}$	Leontief inverse square matrix
A	direct consumption coefficients matrix
CE	CO_2 emissions
CI	vector for emission intensity
E_{ij}	consumption of fuel type *j* by sector *i*
f_j	CO_2 emissions factor of fuel type *j*
I	identity matrix
IC	vector for indirect CO_2 emissions
M_c	consumption structure effect
P	population effect
P_i	population of residents *i*
S_c	consumption ratio effect
U_c	urbanization effect
Y	residential consumption
Y_{ij}	consumption expenditure on sector *j* by residents *i*

requirements are accounted for by households energy requirements, more than 60% of which are indirect [12]; most of China's household energy consumption is indirect [13]. Therefore, studying the residential indirect CO_2 emissions is of vital importance and can help the government make related emission-cutting policies from the perspective of consumption.

The 18th CPC National Congress pointed out that the new-typed urbanization is a major means of carrying out strategic adjustments of the economic structure. On the one hand, urbanization can boost domestic demand, which in turn significantly boosts consumption of food, clothing, education and cultural entertainment and transportation and communications in China. On the other hand, urbanization is likely to affect energy demand and CO_2 emissions because of the change in consumption structure and consumption ratio [14,15]. Therefore, by studying the effects of urbanization, consumption ratio and consumption structure on residential indirect CO_2 emissions, we can provide some suggestions for China's policy makers to achieve the targets of emission reduction. At the same time, as China has a vast territory and its regions are hugely diverse in terms of consumption level and urbanization, a regional comparative analysis is helpful for the government to lead to a road of efficient, low-carbon and new urbanization in tune with needs of different regions.

Residential energy consumption can be divided into direct and indirect energy usage. The direct energy requirements of households are defined as the consumption of energy carriers (coal, petroleum, natural gas and electricity) purchased directly by households for space heating, heating tap water, lighting, appliances, cooking and motor fuel, etc. Indirect energy requirements of households consist of the energy required for production of goods and services and energy needed by the energy supply system for production of this energy from primary energy. Meanwhile, CO_2 emissions are also separated into direct and indirect emissions [16,17].

CO_2 emissions caused by residential consumption have become a point of focus worldwide. Many studies have examined factors affecting residential CO_2 emissions. The major factors mainly include emission intensity, household income, per capita consumption and population. Vringer and Blok [18] calculated both direct and indirect household energy requirements in the Netherlands, and they also attempted to quantify the effects of household income and expenditure, age and the number of household members on the total energy requirements of households. Weber and Adriaan [16] developed an enhanced input–output model to analyze and quantify the impacts of lifestyle factors on current and future energy demands such as household types, household characteristics and consumption of households. Pachauri and Spreng [10] calculated indirect energy requirements of India in three different years by using a 115 sector classification of IO tables and proved that the main driving force of the increase of total household energy consumption have been: the growing expenditure per capita, population and increasing energy intensity. Reinders et al. [19] evaluated the household energy consumption of 11 EU member states on the basis of household expenditure and the energy intensity of the consumed goods and found that the indirect energy requirement is linearly related to the total household expenditure. Using micro level household survey data from India, Pachauri [20] built an econometric model to analyze the factors causing variations in energy requirements across households for the year 1993–1994. Results showed that total household expenditure or income level is the most important explanatory variable. On the basis of a generalized input–output model, Cohen et al. [21] calculated the energy embodied in goods and services purchased by households of different income levels in 11 capital cities of Brazil and found that the total energy intensity of household expenditure increased with the rise of the income level. On the basis of a quasi-multi-regional input–output (QMRIO) model, Druckman and Jackson [22] calculated CO_2 emissions that arose from energy used in the production of goods and services in the UK. Results showed that although absolute decoupling occurred between household expenditure and CO_2 emissions in the early 1990s, since then the decoupling has been nominal. Cellura et al. [23] applied the extended IO model to investigate the energy consumed and gases emitted in the process of satisfying the final demands of Italian households from 1999 to 2006. They used SDA to discuss the influences of emission intensity, Leontief and final demand on the changes of indirect emissions of Italian households. Zha et al. [24] used the LMDI (Logarithmic Mean Divisia Index) decomposition analysis to investigate factors that may affect the changes of the CO_2 emissions. It is found that energy intensity and income effects contribute the most to the changes of residential CO_2 emissions, respectively. Zhang and Guo [25] employed the LMDI to investigate the influencing factors of China's residential commercial energy consumption, finding that income