CO2 emission induced by household consumption in China

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Abstract: Household consumption is one of the important factors to induce CO2 emission. Change in lifestyle and increase in living expenditures with income growth may lead to increase in CO2 emission. This paper calculated the inventory of CO2 emission in China based on input-output model, and then estimated CO2 emission induced by urban and rural household consumption based on statistic data of household living expenditure from 1995 to 2004 in China. The results show that from 1995 to 2004, CO2 emission per capita induced by household consumption has increased from 911kgCO2 to 1,564kgCO2. The ratio of consumption-induced CO2 emission to total CO2 emission has risen from 37% to 45% in the past decade. The CO2 emission induced by indirect energy consumption has increased from 641kgCO2 to 1,193kgCO2, and the ratio of indirect emission to total emission has risen from 70% to 76% during same period. CO2 emission per capita induced by urban household consumption has increased from 1,583kgCO2 to 2,498kgCO2. CO2 emission per capita induced by rural household consumption has grown from 636kgCO2 to 894kgCO2. A significant regional difference in CO2 emission induced by of household consumption can be observed. In 2004, CO2 emission per capita induced by household consumption in Shanghai is 4,499kg, while it in Yunnan is only 745 kgCO2. CO2 emission per capita induced by urban household consumption in Shanghai is 4,680kg, while it induced by rural household consumption in Yunnan is only 580kgCO2. The former is 8 times of the latter. CO2 emission increases with growth in income.

Change in lifestyle has driven significant increase in CO2 emission. CO2 emission per capita induced by housing expenditure has increased from 399kgCO2 to 521kgCO2 during 1995-2004. CO2 emission per capita induced by transport expenditure has increased from 33kgCO2 to 189kgCO2. Especially increase in private transport expenditure and house building expenditures are key driving factors to induce growth of CO2 emission. There are large differences in CO2 emission induced by changing lifestyle between urban and rural areas and cross provinces. In 2004, CO2 emission per capita induced by housing expenditure in Shanghai is 1,927kgCO2, while it in Hunan is only 613kgCO2. CO2 emission per capita induced by transport expenditure in Guangdong is 509kgCO2, while it in Gansu is only 17kgCO2. It can be expected that households in low-income regions will increase consumption to improve their livings with income growth in future. Although it may induce much more CO2 emission, a reasonable level of CO2 emission is needed to satisfy human basic needs and to improve household livelihood. A noticeable fact is that CO2 emission per capita induced by household consumption in developed areas of China has reached at a quite high level. Adjustment in lifestyle towards low-carbon society is required urgently.

Key words: CO2 emission induced by household consumption, changing lifestyle, inventory of CO2 emission, input-output model, China

1 Introduction

Household consumption is one of important factors of inducing energy consumption and CO2 emission. Home energy use may directly cause CO2 emission. On the other hand, because

many energy is embodied in goods and services, Consumption of living commodities and service may result in indirect CO2 emission. The income growth, the improvement of living standard, the increasing amount of home appliance, housing and private transportation, have driven the indirect energy consumption and increased the amount of indirect CO2 emission. It is evident that in Europe and the United States, the ratio of CO2 emission induced by consumption to the total yearly CO2 emission is about 40-50% (Bin S, Dowlatabadi H, 2005; Cohen,2005;Lenzen,1998;Park and Heo et al,2007;Reindersa.,K.andVringerb.,K. Blok,2004;Vriner and Block,1995). To deal with global climate change, international community is sparing no effort promoting the development of "low-carbon economy". The so-called "low-carbon economy" is based on low energy consumption, low pollution, and low-emission. Therefore, energy saving and emission reduction should be also emphasized in household consumption and lifestyle.

China has become the second largest CO2 emission, A drastic change in lifestyle is undergoing with income growth. It has been observed that increase in household consumption has driven growth in energy consumption and CO2 emission in the past decades (Wei, 2007a, 2007b). However, there is significant disparity in consumption across different income groups and different regions in China. Therefore, the effects of income differences and regional disparity on CO2 emission induced by consumption should be taken into account.

This paper aims to estimate CO2 emission induced by household consumption and then to provided insight on perspective for low-carbon society in China. In the first, coefficient of CO2 emission is calculated based on input-output analysis, and then CO2 emission induced by consumption of urban residents during 1995-2004 is estimated by using statistic data of household living expenditure. Secondly, difference in CO2 emission across different regions is compared. Thirdly, contribution of increasing housing and transport expenditure to CO2 emission is analyzed. Finally, future perspective of CO2 emission induced by consumption with income growth and regional development is discussed to draw policy implication for low-carbon society.

2 Methods and data

2.1 Methods

The general method used for estimating the CO2 emission of households is outlined in Lenzen(1998), Bin and Dowlatabadi (2005), Park and Heo (2007), input-output analysis and consumer lifestyle approach are the main methods in their works. In this paper we drew upon the work of them, the functions are as follows:

$$E = E^{ind} + E^{dir} = Q^{emb}Y + E^{dir} \quad (1)$$

$$Q^{emb} = Q^{dir}(I - A)^{-1} \quad (2)$$

$$C = (C^{emb} + C^{hh}) \times Y \quad (3)$$

$$C^{emb} = C^{dir}(I - A)^{-1} \quad (4)$$

$$C^{hh} = CO_2 coefficient \times Q^{hh} \quad (5)$$

$$C^{emb} = CO_2 coefficient \times Q^{dir}(I - A)^{-1} \quad (6)$$

E: energy use induced by residents consumption;

Q^{emb} : Indirect energy use of urban resident;

$(I - A)^{-1}$:Leontief inverse matrix;

Q^{dir} : direct energy intensity of sectors;

Q^{hh} : direct energy use of urban residents;

Y: the matrix of residents consumption;

C: CO2 emission by residents consumption;

C^{emb} : indirect CO2 emission by residents consumption;

C^{hh} : direct CO2 emission of residents

$CO_2 Coeifficient_m$: the carbon coefficient of fuel m.

The above-described functions are aimed at calculating indirect CO2 emission induced by consumption, while the method of direct CO2 emission is drew upon the research of Wei (2007).

2.2 Regions

According to various levels of economic development in different regions in China, 7 provinces areas have been selected from east to west, i.e. Northeast, Liaoning, North municipalities, Beijing, East, Shanghai, South coast, Guangdong, Central region, Hunan, Northwest, Gansu, and Southwest, Yunnan.

2.3 Data

Home energy, final energy use are all taken from China Energy Statistical Yearbook (1997-2005); the consumption expenditure of urban families is taken from the China Statistical Yearbook (1996-2005); Statistical Yearbooks of 7 provinces (1996-2005); Chinese Price and Urban household Survey Yearbook(1996-2005);40 sector Input-output table of China in 1997; 38 sector input-output tables of 7 provinces in 1997, 60 sector input-output tables in 2002.

To avoid double calculation, in this paper fossil energy such as coal, petroleum and natural gas are considered and included, hydropower, nuclear power and renewable energy are neglected. So the results may less than the actual emission. Carbon emission factors and fraction of oxidized carbon; which are shown in Table 1.

Table 1 Potential carbon emission factors of leading fossil fuels & their fraction of oxidized carbon[a]

Fuel	Potential carbon emissions factor(Kg carbon/106KJ)	Fraction of oxidized carbon
Coal	26.03	0.92
Crude oil	20.08	0.98
Natural gas	15.32	0.99

[a]National Development and Reform Commission of China.

3 Results

3.1 CO2 emission induced by consumption of residents in China

3.1.1 Trend in CO2 emission induced by consumption of residents in China

With the increase of the income and consumption, CO2 emission per capita induced by household consumption of China increases year by year. from Figs.1 and 2, respectively, it can be seen CO2 emission per capita induced by household consumption had increased from 911kg to 1564kg during 1995-2004. The ratio of consumption-induced CO2 emission to the total CO2 emission had risen from 37% to 45% in the past decade. CO2 emission per capita induced by urban household consumption has increased from 1,583kg to 2,498kg, CO2 emission per capita induced by rural household consumption has grown from 636kg to 894kg. CO2 emission induced by indirect energy consumption had increased from 641kg to 1193kg, and the ratio of indirect emission to the consumption-induced CO2 emission has risen from 70% to 76% during same period, direct CO2 emission was declined. Increase in CO2 emission per capita and indirect CO2 emission per capita by induced resident consumption indicates that the impacts of household consumption on CO2 emission are gradually strengthening. In future, with the increase in income, CO2 emission induced by consumption will continue to increase.

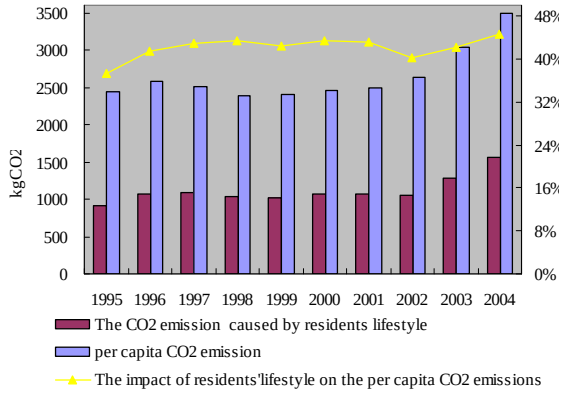

Fig.1 Ratio of consumption-induced CO2 emission to total CO2 emission during 1995-2004

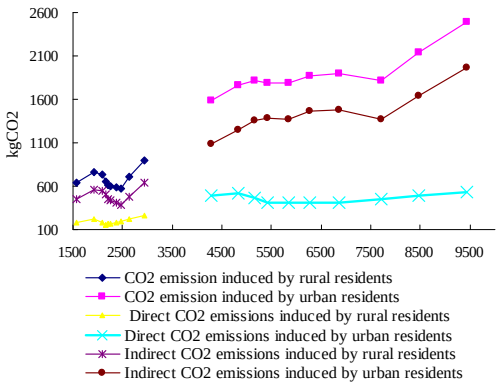

Fig.2 Direct and indirect CO2 emission per capita induced by consumption during 1995-2004

It is worth noting that, the speed of consumption increase lagged behind that of technical improvements. Even if the consumption increased, CO2 emission induced by consumption may

reduce. During 1997-2002, the intensity of CO2 emission was gradually declined, which lead to the decline of CO2 emission each year in the period. From 2003, the intensity of CO2 emission began to rise, so did the CO2 emission induced by consumption.

3.1.2 Difference in CO2 emission induced by household consumption-region

A significant regional difference in CO2 emission induced by household consumption has been observed. CO2 emission per capita in developed coast provinces had more rapid increase than that in developing inland provinces, and the difference of CO2 emission induced by consumption in different regions will increase when the income of urban residents in these regions are increasing. Fig.5 summarizes, in 1995, CO2 emission per capita induced by consumption of urban in Guangdong was 2,201kgCO2, while it was only 580 kgCO2 in Yunnan rural; In 2004, CO2 emission per capita induced by urban household consumption in Shanghai was 4,680kgCO2, while it was only 713 kgCO2 in Hunan rural; The former was 6.56 times of the latter. Difference in CO2 emission growth between coast provinces and inland provinces was caused by difference in income growth(Fig.3).

In addition, the CO2 emission intensity per output varies in different regions, so there are differences of CO2 emission per capita embodied in the consumption of urban residents in different regions even at the same level of income and consumption. According to input-output table and the China Energy Statistical Yearbook, the results show that the CO2 emission intensity gradually increased from east to west.

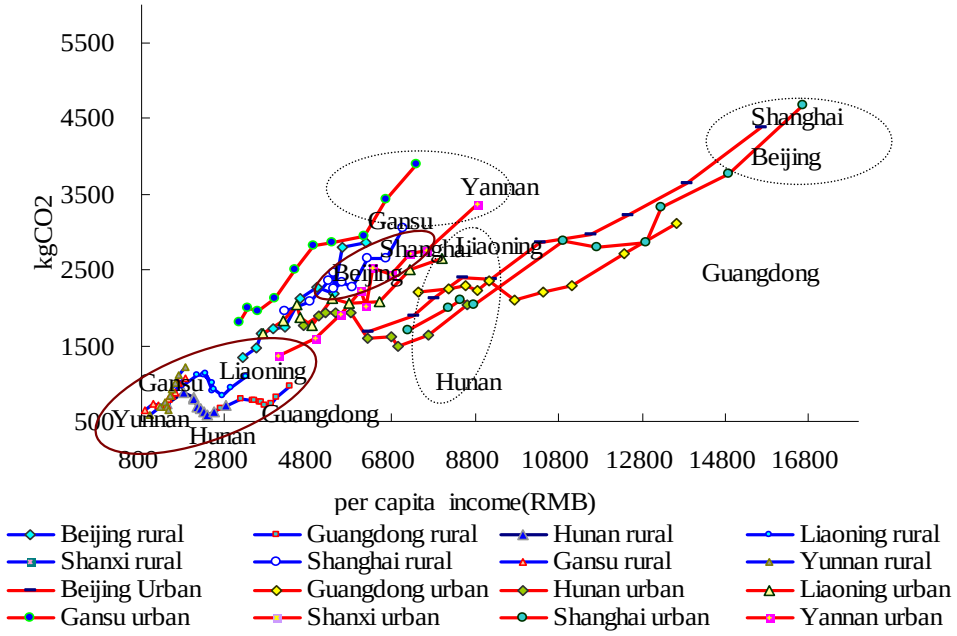

Fig.3 Consumption-induced CO2 emission in 7provinces in 2004

3.2 Contribution of changing housing and transport expenditure

3.2.1 Contribution of changing housing and transport expenditure to increase in CO2 emission induced by consumption in China

An important driving factor caused the increase of CO2 emission is the change in lifestyle. CO2 emission induced by the consumer behaviors, apparently increased from 1995-2004. CO2 emission induced by housing and transport is an important driving factor in CO2 emission increases induced by household consumption. Moreover, the expenditure of the housing and transportation must increase with the rising of the income in future, inevitably inducing more CO2 emission. in this section, we focused on the impact of changing housing and transport expenditure to increase in CO2 emission induced by urban household consumption. From Figs.4 and 5 it can be seen that, CO2 emission per capita induced by housing expenditure had increased from 680kg to 783kgCO2 during 1995-2004, and the ratio of it to CO2 emission induced by consumption was from 30% to 40%; CO2 emission per capita induced by transport expenditure had increased from 52kgCO2 to 249kgCO2. And the ratio of it to CO2 emission induced by consumption had risen from 3% to 10%. Especially, the increase in private transport expenditure and house building expenditure are key driving factors to the growth of CO2 emission.

During 1995-2004, per capita housing area of urban residents had risen from 16.3 m^2 to 25 m^2, an increase of 1.53 times. the number of family vehicle had risen from 0.19 per 100 households to 2.18 per 100 households, an increase of 11 times, the number of motorcycles from 6 per 100 households to 25 per 100 households; in accordance with CO2 emission per capita induced by consumption and per capita housing area, It is estimated when per capita housing area increases by one square meter, there will be 30kg CO2 produced. Assuming the same CO2 emission intensity, if the goal, addressed by the Ministry of Construction that per capita housing area of 35 square meters, is reached in 2020, 1050kg CO2 will be produced by housing, the number is 267kg more than that in 2004. Based on the result of complete CO2 emission coefficient and the data of the China Statistical Yearbook, it can be calculated that, when a vehicle is manufactured, there will be 35.67 tons of CO2 emission coming with the vehicle production; when a motorcycle is manufactured, 1.28 tons of CO2 emission. An estimate was obtained that a car can produce 0.24kg CO2 per kilometer and a motorcycle can produced 0.06kg CO2 per kilometer based on the number of National Bureau of Statistics. Assuming a car-travels 41 kilometers per day, with every less day of use in each week, there would be 480kgCO2 less CO2 emission per year per car.

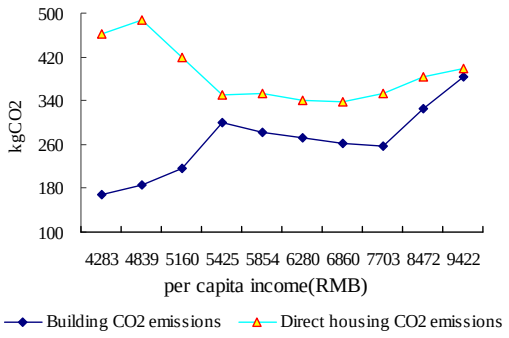

Fig.4 CO2 emission induced by housing expenditure in during 1995-2004

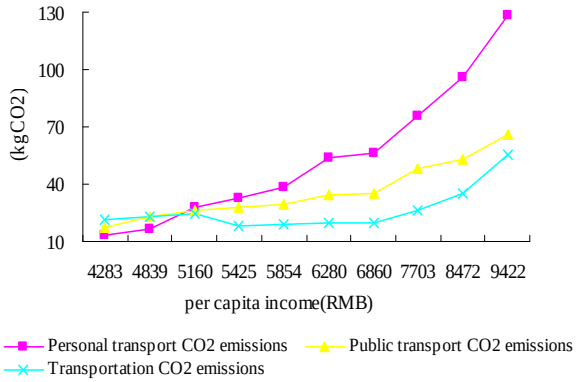

Fig.5 CO2 emission induced by transport China expenditure in China during 1995-2004

3.2.2 Difference in CO2 emission induced by housing and transport across regions

There is large regional discrepancy of CO2 emission induced by housing and transport across residents.CO2 emission induced by housing and transport expenditure in most of provinces increased with income growth, coast provinces increased more rapid than that of inland provinces. Regarding the CO2 emission per capita induced by housing expenditure during in 1995-2004, the emission was ranged from 523 kgCO2 to 1927 kgCO2 in Shanghai, while it was ranged from 439kgCO2 to 453kgCO2 in Hunan. With the increase of urban household income among provinces, the CO2 emission induced by transportation expenditure had significantly increased. Guangdong, Beijing and Shanghai were on the top of such provincial list, by both their emission amount and growth rate. Back to 1995, Guangdong had the highest amount of CO2 emission induced by transport expenditure – 87kgCO2, while Gansu in the bottom of the list – 17kgCO2, resulting in a difference of 5.1 times. In 2004, Guangdong remained the highest with 509kgCO2, while Hunan was in the bottom – 119kgCO2, a difference of 4.27 times. It has been a rapid growth of CO2 emission induced by transportation expenditure in high income areas, because of the rapidly growing demand for private vehicles in these areas: in 1997, it was 0.8 vehicle per household and 0.3 vehicle per household in Beijing and Guangdong, respectively; in 2004, these numbers had increased to 6.59 vehicle per household and 12.64 vehicle per household, with a 20 times increase in Guangdong. Besides, Guangdong had the highest amount of household motorcycles among provinces: from 1997 to 2004 it had increased from 37.23 per hundred household to 76.91 per hundred household; while from 4.54 to 7.28 in Liaoning and from 5.06 to 12.18 in Gansu, within the same period. So, it is very important to take measure to decrease the amount of CO2 emission as the expenditure of the housing and transportation increases. Such measures include the use of energy-saving materials and proper guidance for people to improve their awareness of energy saving.

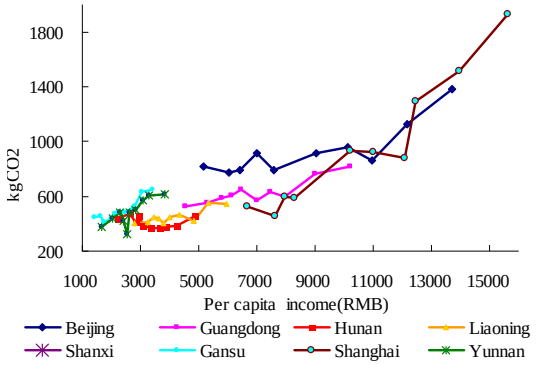

Fig.6 CO2 emission induced by housing expenditure in 7 provinces during 1995-2004

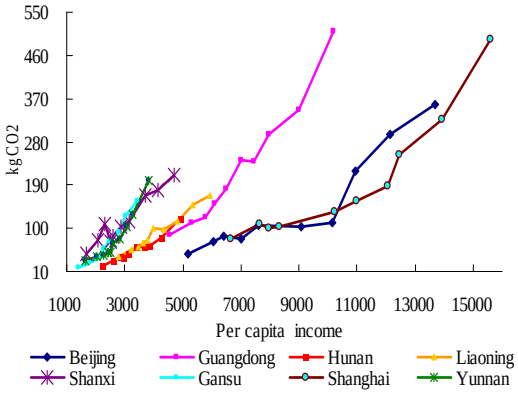

Fig.7 CO2 emission induced by transport expenditure in7 provinces during 1995-2004

3.3 Factor decomposition of CO2 emission induced by consumption

There are two determining factors for the change of CO2 emission amount per capita induced by urban consumption. They are: increase of consumption and expenditure, and technology improvement. In order to analyze the influence of the change of the technology on the decreasing decrease of the amount of CO2 emission induced by consumption, we decompose the amount of CO2 emission induced by consumption per capita. The result shows that the change of the technology mitigates the influence of the consumption expenditure to CO2 emission. The net increment of CO2 emission per capita induced by consumption was 916 kgCO2, and decreased by 755kgCO2, because of technology innovation; otherwise it would amount to 1670 kgCO2. The effect of technology innovation on CO2 emission amount varies for different income groups. In the higher income group, technology innovation resulted in more decreases of CO2 emission amount. There was 3688 kgCO2 decrease because of technology innovation in the highest income group, and only 281 kgCO2 in the lowest income group.

The velocity of the technology innovation differs in areas, the decrease of CO2 emission amount by technology innovation, shows different releasing effect on CO2 emission amount induced by consumption between more developed areas such as Shanghai or Guangdong and developing areas such as Liaoning or Hunan, it decreased by 619 kgCO2 in Shanghai, 959 kgCO2 in Guangdong, 1047 kgCO2 in Liaoning and 1176 kgCO2 in Hunan. In the less developed areas such as Gansu and Yunnan, CO2 emission amount increased. The low productivity led to the increase of CO2 emission induced by consumption, which was 24 kgCO2 in Gansu and 142 kgCO2 in Yunnan. The rapid development of the electricity industry in Beijing drives indirectly the increase of energy consumption and CO2 emission. So both the consumption and the technology have a positive effect on CO2 emission amount(Figs.8).

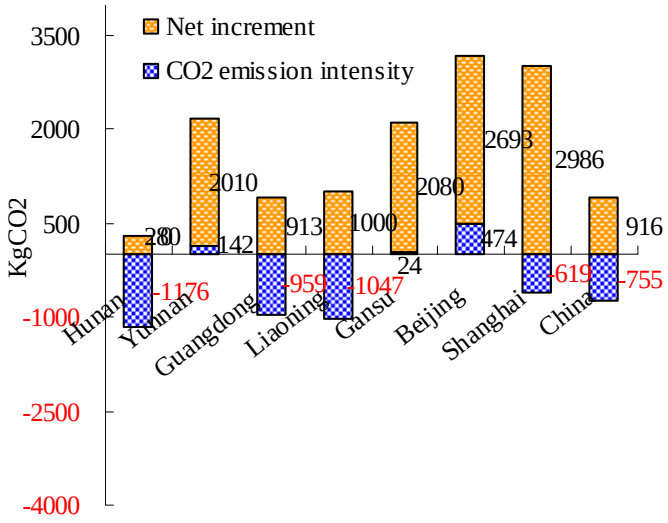

Fig.8 The impact of consumption and emission on CO2 emission increment in 7 provinces during 1995-2004

4 Findings and Perspectives

The results showed that with the increase in income and consumption, CO2 emission per capita induced by consumption of urban residents increased year by year. CO2 emission per capita induced by urban household consumption has reached at 2500kgCO2 in 2004. It is far away lower than OECD countries but quite higher than most of developing countries. The ratio of CO2 emission induced by urban household consumption to total CO2 emission has reached at 30% in 2004, it indicates that 30% of CO2 emission is to meet needs of urban household consumption in China.

There are great differences regarding CO2 emission induced by consumption, across different provinces. In 2004, Shanghai where the income was the highest, the CO2 emission amount induced by consumption had amounted to 4680 kgCO2 per capita, 3.85 times of Hunan province where the income was the lowest. CO2 emission per capita of developed regions had more rapid growth than that of developing regions. The results showed that growth in CO2 emission per capita induced by household consumption accelerated while income per capita reached at a relatively high level.

Housing and transportation expenditure are two key factors which induce CO2 emission. The housing and transport expenditure contributes about 40% of increase in CO2 emission induced by urban household consumption. For developed regions, housing and transportation expenditure contributed more to the increase in CO2 emission. The increase of both housing and private vehicle expenditure is the main factor which brought significant difference of the increased CO2 emission across different regions.

Finally, technology innovation and decline in energy intensity has greatly reduced the CO2

emission induced by consumption, and such effect is more evident in high income areas. From 1995 to 2004, technology innovation and decline in energy intensity reduced by 40% of CO2 emission induced by consumption. In east and mid provinces, with technology innovation, intensity of CO2 emission decreased, and the increased part of CO2 emission decreased by 600-1000kgCO2. In west areas, where technology is less advanced, CO2 emission increased slightly, both technology and the consumption level have a positive effect to the increase of CO2 emission.

The conclusion implies that with income increase and consumption improvement in future, CO2 emission induced by urban living expenditure, especially by developing regions, will increase continuously. China will face a big challenge to control CO2 emission while to enlarge consumption and to improve well-being. Following measures should be taken into account. On one hand, promoting technology innovation, adjusting the industrial structure and reducing the emission intensity are essential to control the CO2 emission induced by household consumption. On the other hand, strengthen the guidance of residents consumption patterns, especially the change of transportation style across the higher income groups and higher income regions for transition life style low-carbon economy. In the meanwhile, energy-saving building material and new energy development are important for the CO2 emission induced by household consumption.

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