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The relationship between consumption and production system and its implications for sustainable development of China

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ABSTRACT

Rapidly developing economy in China makes great improvement in human life quality. At the mean while, it brings great pressures on environment which has drawn broadly attentions all over the world. The 'problems of consumption' comes both from consumers and producers. Hybrid life cycle analysis method and structural decomposition analysis model were used in this paper to explore the interaction of consumption and production and how technology development and household consumption contributed to CO_2 emissions in the period of 1992–2002. The achievements of technology development in the last two decades reduced the emission intensity and technical coefficients which lowered the CO_2 emissions. But the household consumption has offset this technological contribution and resulted in the growth of CO_2 emission. Interaction analysis results showed that consumer's demand for energy-intensive product was an important driving force of pollution production. Household consumption in China contributed a lot to the expansion of manufacturing activities in the last two decades. We concluded that sustainable development could not be achieved if policy makers continuously emphasize the control of polluting industries. The government should simultaneously emphasize technological development and consumer policies to curb these emissions and induce more environmental conscious production and consumption patterns.

1. Introduction

People kept exploring the applicable path for sustainable development for decades and social responses to environmental problems have focused largely on the production side of economic activities. But evidences have shown that over the last decade, changes in consumption patterns have offset the environmental achievements from industrial technological improvement (UNEP, 2002; Spangenberg and Lorek, 2002; Princen, 2003; Clark, 2007). During the UNCED conference in Rio de Janeiro 1992, unsustainable consumption patterns, together with unsustainable production patterns were identified as the key driving forces behind the unsustainable development of the world. This became the starting point for international work directed to improving understanding of global consumption patterns and their environmental impacts (Lintott, 1998; Farah and Allely, 2003; Nansai et al., 2007).

Households are the mainly final consumption sectors which consist of the most part of gross domestic product. The households' consumption behavior can impact the environment directly and indirectly. The indirect impacts are associated with the production processes of commodities and services for households (Noorman, 1998). From a life cycle point of view, consumption behavior is not an isolated phase. The resources consumed as well as the pollution released from production process can be allocated to end-uses. Thus, the UNEP proposed a life cycle thinking when it brought forward the definition of sustainable consumption in 1994 (UNEP, 1994).

China is a rapid developing country with huge population. The human life quality in China has been great improved after taking the open-the-door policy. Along with income increase and living standard improvement, private consumption brings great pressures on the deteriorating environment which has drawn broadly attention all over the world (Liu and Diamond, 2005). The government is now facing a serious situation to balance the economy development and environmental protection. It is now widely accepted by managers that shifting from cleaner production practices to sustainable production and consumption economy activities is an indispensable path for achieving sustainable development in China (China's Agenda 21, 1994). It is essential to analyze the synergetic relations of production and consumption systemically to set out a course of action for sustainable development practices.

China is the second largest CO_2 emitter in the world and households is an important contributor of GHG emissions (Lenzen, 1998; Munksgaard et al., 2002; Lenzen and Dey, 2002). In this research, we chosen CO_2 emissions connected with energy consumption as an indicator to reflect the environmental impact

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Table 1
CO_2 emission factors of energy fuels.

Fuel	Emission factor (Tc/TJ)	Carbon oxidation rate (%)	NCV (MJ/t m^3, tce)	Emission factor (CO_2/TJ)
Raw coal	24.74	94.4	20908	90.65
Clean coal	24.74	94.4	26344	90.65
Other washed coal	24.74	94.4	8363	90.65
Coke		97	28435	74.02
Coke oven gas	20.2	99	16726	
Other gas	20.2	99	5227	74.02
Crude oil	20	98	41816	73.28
Diesel	20.2	98	42652	74.02
Fuel oil	21.1	98	41816	77.31
LPG	17.2	99	50179	63.02
Refinery gas	20	99	46055	73.28
Natural Gas	15.3	99	38931	56.06
Other petroleum products	20.2	98	41816	74.02
Other coking products	25.8	97	28435	94.54

Datasources: (1) Climate Change Country Study, 57–58; (2) Wu Zongxin, Chen Wenying. Coal based diversified clean energy strategy, 145–146; (3) 94.4 is lower than the IPCC default value, which is the estimation of industrial average value in China.

of household consumption. Using the hybrid life cycle analysis method and related mathematic models, we established an environmental extended input–output table of China by combing with energy statistic data and calculated the carbon dioxide (CO_2) emission intensities of production sectors in 1992, 1997 and 2002. Structural decomposition analysis was then used to calculate the contribution of technology development and lifestyle changes to the total consumption-related CO_2 emission changes from 1992 to 1997 and 1997 to 2002. The relationship of CO_2 emissions between consumption and production system was analyzed. The key points for Chinese sustainable consumption and production development were identified and discussed.

2. Methods, data sources and models

2.1. Hybrid life cycle analysis

There are two basic methods in compiling life cycle inventory: process analysis and input–output analysis (Suh et al., 2004). Process analysis is a bottom-up technique and input–output analysis is a top-down macroeconomic technique that uses sectoral monetary transactions matrix to describe the structure of an economy in terms of interactions among industries and between them and households (Lenzen, 2002). One of the most important applications of input–output analysis is to calculate the total input requirements for a unit of final demand. By doing this, one can assess not only the direct requirement in the production process of the analyzed sector itself, but also all indirect requirements resulting from intermediated product deliveries from other sectors (Hubacek and Giljum, 2003). Consumption is related with products, by using hybrid LCA, it is easy to analyze the interactions between consumption and production. Since the input–output analysis is based on publicly available data, the method is less time consuming than process analysis (Munksgaard et al., 2005).

2.2. Data sources and treatment of data

By combing the Chinese input–output table, energy statistical book and CO_2 emission factors, we calculated the CO_2 emission intensity of industrial sectors. The Chinese input–output table was published each five years in 1992, 1997 and 2002. There are 118 industrial sectors in 1992s input–output table, 124 sectors in 1997s table and 122 sectors in 2002s table. To make a consistent analysis, we aggregated the number of industrial sectors to 97 according to the Chinese National Standard.

Eighteen kinds of energy fuels used by 40 industrial sectors are compiled in the Chinese energy statistic books. These 40 sectors' energy consumption and related CO_2 emissions were disaggregated to 97 industrial sectors in input–output tables. The economic input–output table was linked with energy matrices based on some basic assumptions. The method of desegregation in this process is very important. More detailed methods are described in other references (Vringer and Blok, 1995; Lenzen et al., 2003; Sangwon, 2006; Hoekstra and Bergh, 2006). Allocations among sectors were based on the percentage of sector's price output to the total outputs of same group sectors.

The amount of CO_2 emission is determined by types of fuel, discharge coefficient of carbon and oxidation rate (Table 1). To avoid double counting, we only considered the primary fuels for constructing emissions data. For example, the emission of coal was calculated, but the secondary energy of coal, like electricity, was out of our consideration. During the calculation, energy loss should be considered. The amount of total energy losses was achieved in China energy statistics yearbooks. We divided the total energy losses into each sector according to the amount of total energy used by that sector. The indirect CO_2 emissions of household consumption are calculated by multiplying the sectoral cumulative CO_2 intensities with household expenditures.

2.3. Models

2.3.1. The basic input–output model

The basic concepts of input–output analysis were developed by Leontief in the last 60th. Expanded models with environmental multipliers have been widely used and discussed since then (Chapman, 1974; Gay and Proops, 1993; Duchin, 1992; Lenzen, 1998; Hertwich, 2005). The basic equation of input–output analysis is:

$$x = A_x + y \quad \text{or} \quad x = (I - A)^{-1} \tag{1}$$

where x is the elements of a matrix ($n \times n$) of intermediated demand of industries $j = 1,\ldots,n$ from industries $i = 1,\ldots,n$. y is the vector ($n \times 1$) of final demand from industrial sectors. Each column A_j is the requirements for one unit of output of sector. $(I - A)^{-1}$ is the key of input–output analysis, which is called Leontief inverse matrix.

2.3.2. Expand input–output model with CO_2 emission multiplier

Assuming the total CO_2 emission of industrial sector is T_i, the ratio of T_i to X_i can be defined as the direct CO_2 emission coefficient of sector i:

$$w_i = \frac{T_i}{X_i} \tag{2}$$