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Determinants of GHG emissions for a municipal economy: Structural decomposition analysis of Chongqing

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HIGHLIGHTS

- SDA includes the effects of both production and final demand.
- Explore the determinants of municipality-level emissions.
- Final demand drove GHG emissions growth.
- The change of intensity effect and production structure reduced GHG emissions.

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ABSTRACT

The prefecture-level municipality of Chongqing, in western China, is the largest and most populous city in China. Chongqing's uniqueness presents multiple challenges, including that greenhouse gas (GHG) emissions abetment requirement of the city is greater than that of other Chinese cities. This paper explores factors behind change in aggregate greenhouse gas (GHG) emissions in Chongqing, including differences at the sector level. We use a structure decomposition analysis (SDA) method to quantify sources of emissions growth. Results indicate that the crucial factors that drive GHG emissions reduction relate to intensities and input-output structure; and that the main driver of emissions growth was increasing final demand. The analysis also reveals that the mining and coal-washing sector and the metals melting and rolling sector were the main sources of GHG emissions in Chongqing.

1. Introduction

In recent years, concern for the environment has been rising. Consequently, public and academic researchers have devoted greater attention to the linkages between human activity and the environment. In the case of the growth of greenhouse gas (GHG) emissions, economic development is widely accepted as the dominant driver. China is the world's largest GHG emitter, since 2009 [1], and is the second largest economy in the world, but crucially also remains a developing country. The evolution of GHG emissions in China therefore deserves substantial attention.

According to the 13th National Five-Year Plan (2016–2020), by 2020 China aims to reduce CO_2 emissions per unit of GDP by 18% on 2015 levels, and to make great effort to reduce other GHG emissions. As the most highly populated city in China, Chongqing is important to these goals. One of the six legacy industrial bases in the country, Chongqing is one of China's fastest growing cities economically (Table 1). For more than a decade, and specifically since 2002, Chongqing's GDP growth rate has exceeded 10% per annum. In recent years, the municipality has maintained the highest annual economic growth rate in China, of 10.9% in 2014 and 11.0% in 2015 respectively. Located in the upper reaches of the Three Gorges Reservoir area, Chongqing is the only one of China's four provincial-level municipalities (the others being Beijing, Tianjin and Shanghai) that is located deep in China's interior. In general, the city faces greater challenges in creating an environmentally friendly economy than do these other Chinese cities.

Decomposition analysis is a widely used method in the literature for the study of the driving forces behind aggregate energy

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Table 1
List of top 10 most populous cities in China, 2014. *Data Source*: China city statistical yearbook 2015.

Population ranking	City	Population (10,000)	Administrative size (sq km)	Growth rate of gross regional product (%)
1	Chongqing	3366.8	82,374	10.90
2	Shanghai	1435.5	6340	7.00
3	Beijing	1324.9	16,411	7.30
4	Zhoukou	1230.4	11,961	9.10
5	Chengdu	1199.4	12,121	8.90
6	Nanyang	1178	26,509	8.50
7	Baoding	1145.3	22,185	6.00
8	Linyi	1101.8	17,191	10.10
9	Fuyang	1052.3	9776	8.65
10	Handan	1020.7	12,065	6.50

consumption change, GHG emissions, and industry-related energy efficiency or carbon emissions efficiency. There are two standard decomposition approaches. One is the index decomposition analysis (IDA) method; the other is the structure decomposition analysis (SDA) method. Multiple studies have applied the IDA approach to decompose the energy consumption or pollutants discharged, including Ang et al. [2], Wang et al. [3], Xu et al. [4], Robaina-Alves and Moutinho [5], Nie and Kemp [6], Xu [7] and Wang et al. [8]. This method's advantages include milder data requires and greater formulation flexibility. On the other hand, the IDA method can only address direct effects, but not the indirect effects, including the effect captured by the Leontief inverse matrix [9].

By contrast the SDA approach is better enabled to provide detailed economic structure decomposition [10], and can better elucidate the determinants of emissions, including both production and final demand effects. Application of the SDA approach to environmental issues can be traced back to the early 1970s [11]. Earlier SDA studies tended to focus on energy consumption, CO_2 emissions and other air pollutants in developed countries, see, for example, United States [12–14], Germany, the UK [15] and South Korea [16]. More recently, energy use in China has become a focus of many articles that use the SDA approach, including studies of energy intensity change during the period 1992 to 2004 [17]; the historical change in energy-related carbon intensity in China between 1992 and 2006 [18]; factors driving the increase in energy consumption from 1987 to 2007 [19]; drivers of China's energy intensity fluctuation over years 1997–2007 [20]; and past and forecasted drivers of change in CO_2 emissions from 1980 to 2030 [21].

Most studies exploring the determinants of emissions using the SDA method are applied at the national level. The method has rarely however, been applied to a provincial-level or city-level analysis [22,23]. This is mainly due to the fact that the SDA method requires time series input-output tables and also sectoral energy use data that are usually only complete at the national level. Since cities are increasingly the center of economic cycles and human activities, they should also become the focus of GHG emission research.

We identified some papers exploring the determinants of GHG emission of cities, but these did not use the SDA approach. For example, Hachem analyzed neighborhoods in the vicinity of Calgary, Alberta Canada, and found that adopting high-energy efficiency measures can reduce GHG emissions [24]. Chavez-Baeza and Sheinbaum-Pardo found that passenger road transport scenarios that may assist the Mexico city Metropolitan Area to lower GHG emissions [25]. Kim and Rahimi suggested that using plug-in electric vehicles has become an important component of GHG emissions reduction strategy in Los Angeles [26]. Zhang et al. found that type-approval fuel consumption for light–duty passenger vehicles could reduce GHG emissions in Macao [27]. Chen et al. found Macao's total energy consumption has decoupled from its economic growth [28]. Tan et al. studied Chongqing's GHG emissions for three industries via status-based trend prediction models [29].

Though such research can help to explore certain mechanisms for reducing GHG emissions, none comprehensively investigate the source of economic activity-related GHG emissions. Some researchers try to examine the GHG emission via SDA approach at the city level, with the aim of decomposing the key determinants of GHG emissions. For example, Wang et al. analyzed the driving forces of the increase of CO_2 emissions in Beijing over the period 1997–2010 [30]. Xia et al. clarified the underlying factors for the increment of GHG emissions in Beijing during the period 2007–2010 [31]. There are, however, few decomposition studies exploring the determinants of GHG emissions in Chongqing, despite that the city is a rapidly growing energy consumer and polluter.

Here we utilize the latest data and employ IO-SDA framework to quantify sources of GHG emissions growth in Chongqing. This study's main resulting contributions are as follows: Firstly, we identify the driving forces of the change in GHG emissions in Chongqing over the time period 2002–2012. This enriches the city-level GHG emission literature, even internationally. Secondly, we used the SDA approach to study the determinants of GHG emissions, therefore adopting a whole economy approach rather than a selective industries approach, which provides a global picture of emission change around economic activity. We also investigate the relative contributions of socio-economic factors, from both production and final demand perspective. Finally, we identify that the crucial factors that drive GHG emissions reduction relate to intensities and input-output structure; and that the main driver of emissions growth was increasing final demand. Since Chongqing is China's most populous city and also one of China's fastest-growing cities economically, study on the unique variation in GHG emissions of Chongqing can shed light on the GHG emissions reduction of extra-large and fast-growing cities, and also help to find a way to balance urbanization, industrialization and emissions reduction in China's less-developed cities.

2. Methodology and data

2.1. Input-output analysis

Input-output (I-O) techniques describe the interdependence among different economic sectors. The method provides a way to identify flows of products among sectors in monetary terms and to measure impacts of specified changes to economy activity. In addition to analysis of national economy structure, the I-O analysis method is widely used in analyzing environment issues as driven by technology and economic growth [32,33].

In a typical I-O analysis aggregate GHG emissions are expressed as follows:

$$G = \hat{T}X = \hat{T}Ly = \hat{T}(\mathrm{I} - A)^{-1}y \tag{2}$$

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