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Decomposition of energy-related CO_2 emissions in China: An empirical analysis based on provincial panel data of three sectors

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HIGHLIGHTS

- Both direct and indirect energy-related CO_2 emissions are considered.
- The driving factors are analysed at both the national and provincial levels.
- Economic output was the dominant positive driving factor.
- While energy intensity was the dominant negative driving factor.
- Driving factors in China show significant spatial characteristics.

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ABSTRACT

To grasp the characteristics of CO_2 emissions across provinces in China and to determine changes in the centre of gravity of CO_2 emissions over the 2000–2014 period, a gravity model is first used to examine the spatial distribution and centre of gravity of energy-related CO_2 emissions. Then, to explore the main factors driving CO_2 emission changes and to uncover feasible ways to reduce CO_2 emissions, this paper decomposes changes in energy-related CO_2 emissions into a population effect ($\mathbf{\Delta C}_P$), an economic output effect ($\mathbf{\Delta C}_Q$), an industrial structure effect ($\mathbf{\Delta C}_S$), an energy intensity effect ($\mathbf{\Delta C}_I$), an energy structure effect ($\mathbf{\Delta C}_M$) and a carbon dioxide emission coefficient effect ($\mathbf{\Delta C}_U$) at both the national and provincial levels based on the Log-Mean Divisia Index (LMDI) method. The results indicate that (1) energy-related CO_2 emissions rose by approximately 5.46 billion tonnes during the 2000–2014 period, with secondary industry accounting for approximately 80% of total CO_2 emissions. (2) Economic output (Q) was the dominant positive driving factor, and energy intensity (I) was the dominant negative driving factor. The population changes had a weak positive effect on CO_2 emissions, but the industrial structure effect and energy structure effect varied considerably over the years without showing clear trends. (3) Over multiple spatial scales, the contribution ratios of the factors varied significantly across provinces; in general, the positive driving effects outweighed the negative inhibiting effects. Based on these empirical findings, policy recommendations to further reduce CO_2 emissions are provided. The Chinese central and local governments should make full use of the important inhibiting factors, i.e., energy intensity and energy structure, and strive for breakthroughs in secondary sector.

1. Introduction

Global warming has become a serious issue worldwide. According to a report published by the International Panel on Climate Change (IPCC) [1], sharp growth in carbon dioxide (CO_2) emissions is the key factor causing global warming. Since it's economic reforms and liberalization, China's economy has experienced a long period of rapid development. This continuous social and economic development has been accompanied by soaring energy consumption and CO_2 emissions (as shown in Fig. 1). According to the World Bank, China overtook the United States as the world's largest energy consumer in 2009 [2,3]. In addition, China has become the world's largest CO_2 emitter [4]. The main source of CO_2 emissions in China is fossil energy [5,6], which is also the primary energy source. The ratio of fossil energy consumption to total energy consumption is more than 88% (as shown in Fig. 2).

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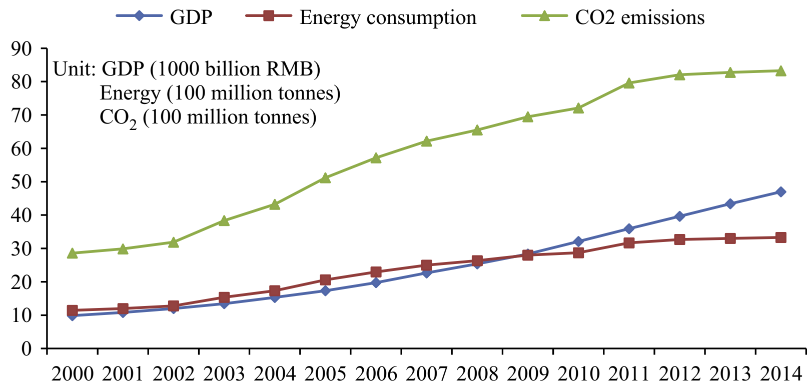

Fig. 1. Gross domestic product (GDP), fossil energy consumption and CO_2 emissions in China, 2000–2014.

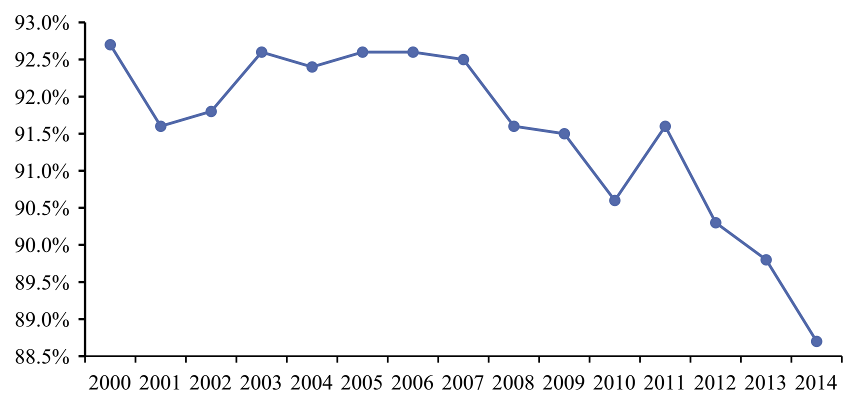

Fig. 2. Ratio of fossil energy consumption to total energy consumption in China, 2000–2014. Data source: National Bureau of Statistics of the People's Republic of China (NBSC).

Additionally, China, a middle-income country, is becoming a moderately developed country. Its continued population and economic growth, industrialization and urbanization have contributed significantly to increasing CO_2 emissions [7,8]. In 2014, China's CO_2 emissions reached 9.76 billion tonnes, accounting for 27.5% of total emissions worldwide [9].

Given China's goal of achieving sustainable economic development, the control and reduction of its CO_2 emissions is an urgent task. In November 2014, the *U.S.-China Joint Announcement on Climate Change* was released. China intends to achieve peak CO_2 emissions by approximately 2030 and to take pains to achieve it earlier, increasing the non-fossil-fuel share of primary energy consumption to approximately 20% by 2030. This announcement marked the first time that China proposed a concrete timeline for achieving peak CO_2 emissions; this goal presents a great economic development and ecological construction challenge. In July 2015, the Chinese government issued and submitted the *Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions* to the *United Nations Framework Convention on Climate Change*. In that report, China stated that by 2030, it would reduce its CO_2 emissions per unit of gross domestic product (GDP) by 60–65% of the 2005 level.

Achieving these targets requires finding effective and efficient ways to control CO_2 emissions, and the above goals are important forces driving China to formulate and implement additional CO_2 emission reduction policies. In this context, clarifying the evolution of China's CO_2 emissions and investigating the main factors driving CO_2 emissions would help policymakers institute emission reduction policies. Therefore, in this paper, we try to incorporate both direct and indirect CO_2 emissions into the provincial estimations. Thus, we first utilize a gravity model to determine how the centre of gravity of CO_2 emissions changed over the 2000–2014 period. Then, to reveal the main driving factors in CO_2 emission changes, the Log-Mean Divisia Index (LMDI) method is applied to decompose changes in CO_2 emissions at both the national and provincial levels based on provincial panel data for the three sectors of the economy. Finally, the corresponding CO_2 emission reduction policies for the central and local governments are provided.

This paper contributes to the literature in three areas. First, this study tries to incorporate both direct CO_2 emissions (i.e., those discharged by fossil fuel consumption) and indirect CO_2 emissions (i.e., those discharged by thermal power and heating supply) into the provincial CO_2 emission estimation. The results of this estimation may more closely approximate actual CO_2 emissions. Second, on this basis, this paper examines the centre of gravity of CO_2 emissions in China and analyses provincial spatial and temporal variation in CO_2 emissions from 2000 to 2014. These analyses may help policymakers in China grasp the characteristics and evolution of CO_2 emissions across provinces. Third, this paper decomposes changes in CO_2 emissions at both the national and provincial levels based on provincial panel data for the three sectors of the economy. Further, this paper analyses the main factors driving provincial CO_2 emissions in detail. These detailed analyses might help China's central and local governments formulate realistic and scientific CO_2 emission reduction policies under the current development pattern.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 introduces the methodology and describes the panel data used in the empirical study. Section 4 presents the empirical results (the centre of gravity of CO_2