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Current status and future choices of regional sectors-energy-related CO_2 emissions: The third economic growth pole of China

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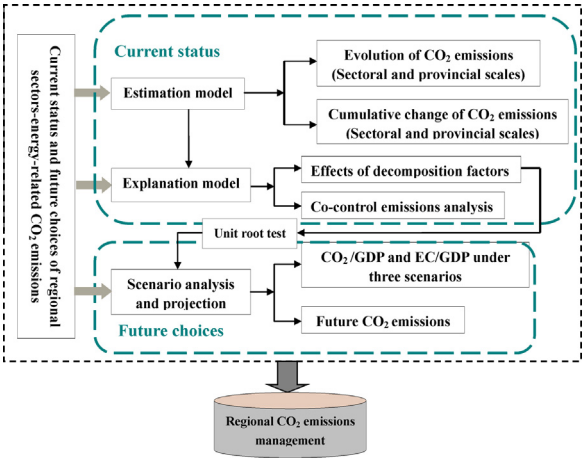
HIGHLIGHTS

- This paper proposes estimation model of sectors-energy-CO_2 emissions.
- The explanation model is originally contributed on basis of classified sectors.
- The application of the models in the third economical pole is first emphasized.
- The scenarios are originally designed and combined to forecast future emissions.

GRAPHICAL ABSTRACT



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ABSTRACT

Understanding the current evolution and drivers behind regional sectors' growing energy-related CO_2 emissions is critical for developing global climate policies and providing insights into how our emerging economies can target lower emissions in the future. We propose estimation and explanation models of sectors' energy-related CO_2 emissions and present a novel scenario design, all of which are originally applied in the CO_2 emissions of the third economic growth pole of China (i.e., the Bohai Rim region) during period 2002–2011. We can therefore track the evolution and cumulative change therein, identifying key drivers of CO_2 emissions change, and performing scenario analysis and projection. The estimation results show that CO_2 emissions on both regional and provincial scales are maintaining an upward trend. On the whole, Shandong has the largest emissions in absolute terms, followed by Hebei, Liaoning, Tianjin and Beijing during this period, while all sectors' CO_2 emissions changes show a fluctuating trend. With the exception of the residential life sector, all sectors' cumulative changes have increased over time. In addition, the explanation of the results prove that changes in per capita GDP and energy intensity are, respectively, the most significant stimulator and inhibitor for emissions' current status. Similarly, whether changes in sectoral structure play a positive or negative role depends on the increase or decrease in each sectors' share in total GDP. Moreover, all sectors' emissions in the Bohai Rim region will increase

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significantly regardless of the scenario. We can therefore achieve our 2020 CO_2 mitigation targets across all sectors only under a scenario whose annual average GDP growth rates and energy consumption are both set by the "12th Five-Year Plan."

1. Introduction

As the largest and fastest growing economy in the world, China has experienced wealth and prosperity in recent decades. This economic boom in turn has had a serious impact [1]; that being said, the environment [2] and development [3] are struggling to keep pace [4]. In essence, China faces not only the challenges of traditional environmental pollutants (e.g., SO_2 and NO_x) emissions [5,6] but also the emerging challenge of CO_2 emissions [7], primarily as increasing energy-related CO_2 emissions have raised international awareness [8]. In particular, there is a global consensus that an increase in CO_2 emissions—as the primary atmospheric greenhouse gas—is driving climate change due to anthropogenic activities' pronounced impact [9]. Rapid industrialization and urbanization that have led China to become one of the world's top energy consumers [10] and CO_2 emitters [11], overtaking the United States of America earlier than expected [12,13]. Long-term active energy consumption, in addition, can be expected to be one of the most substantial contributors of CO_2 emissions over the next 50 years [14]; especially in China and India, where both nations have recorded significantly increased energy consumption related to higher economic growth [15,16]. To balance the economic growth and slow down increasing CO_2 emissions, the Chinese central government has developed a ground-breaking target to control greenhouse gas emissions, deciding that the CO_2 emissions per unit of GDP (CO_2/GDP) should be cut by 40–45% in 2020 compared to emissions levels in 2005 [9]. Furthermore, the Chinese government's 12th Five-Year Plan (2011–2015) called for a 16% reduction in energy consumption per unit of GDP (EC/GDP) and a 17% reduction in CO_2/GDP [17]. Currently, emphasis is being placed on emissions reduction measures in China and on providing a renewed stimulus for specific explanations of energy-related CO_2 emissions for each region. Thus, it is necessary to understand the current status for more effective and practical policy-making towards a more appropriate emissions reduction path.

A reliable approach for dealing with the dilemma of balancing development and mitigation should be required in addition to understanding the significant contributors to CO_2 emissions change [18], especially concrete directions when framing effective energy management regulations for a specific region. Under such circumstances, multiple scientific researchers have endeavoured to influence the mechanisms and impact factors of CO_2 emissions change [8,9,19–21] to supply the base information for making more effective and practical policies. Furthermore, for various regions or provinces of China, there are large disparities in the pace and stage of population growth, economic development, industrialization, urbanization, energy efficiency and other indices [8]. These factors lead to different evolutionary trends and essential characteristics of CO_2 emissions. A supplement is therefore needed to improve upon existing processes and guarantee a more targeted implementation strategy where prior investigations have proven to be insufficient. On one hand, because local governments are responsible for domestic CO_2 emissions reduction targets at each location, understanding the factors behind emissions growth can greatly help to control greenhouse gases and make policy formulations for reduction. On the other hand, regions with experience in reducing CO_2 emissions—or regions that are knowledgeable in CO_2 emissions growth trends—can provide examples to other regions worldwide that have comparable economic and political architecture or are facing similar challenges [21].

Currently, a growing body of literature has catalogued valuable national and regional results related to CO_2 emissions growth, and various determinant analysis models have been used in previous studies. The first strand of research focuses on the notion that CO_2 emissions changes can be decomposed into economic and demographic veins, energy consumption structural changes, and technological-level changes using a decomposition model [21,22] or STIRPAT model [9,20]. More specifically, Zhu et al. [23], Tan et al. [18] and Minx et al. [13] adopted an LMDI model to decompose Chinese CO_2 emissions change into changes affected by population, per capita GDP, energy consumption intensity, energy consumption structure, and so forth. Li et al. [8], Fan et al. [24], and Lin et al. [25] used the STIRPAT model to perform an analysis of the impact factors of CO_2 emissions in China. The second strand of research concentrates on the relationship or interaction among CO_2 emissions, economic output, energy consumption or even urbanization [26,27]; the empirical evidence of which is often assessed by employing Granger causality and a cointegration model, from bivariate [28] to multivariate [26,27,15,29] models. Trans-boundary CO_2 emissions issues should also be emphasized [30]; to this effect, the input–output modelling approach has been applied widely [31]. Many studies have highlighted the great value of technology improvement in reducing CO_2 emissions and the significant economic scale on which CO_2 emissions have increased, thus providing some useful scientific supports for determining effective mitigation strategies. However, on the whole, attention to the features and drivers of energy-related CO_2 emissions from a number of more refined dimensions, such as several sectors under further subdivision or refinement, is scarce. Moreover, Yue et al. [32] used the IPAT model combined with scenario analysis to forecast CO_2 emissions and CO_2 emissions intensity in Jiangsu province through 2020, and Pao et al. [33] predict the carbon emissions, energy consumption, and real outputs of China between 2011 and 2020. Such researchers have devoted a significant amount of study to developing appropriate methods with which to forecast future CO_2 emissions. However, integrative studies of current and future status from sectoral perspectives are yet scarce, especially at the regional and provincial level. Additionally, a co-control emission analysis can also provide valuable information for making emissions reduction policy formulations.

The third economic growth pole of China, the Bohai Rim (BHR) region, covering Beijing, Tianjin, Hebei, Shandong and Liaoning provinces, is one of the leading economic zones in China as well as a political and cultural centre. The region shows relatively high levels of energy consumption and CO_2 emissions, accounting for approximately 1/3 of the energy consumption of China while only representing 1/4 of the nation's GDP (Fig. 1). Given these considerations, the BHR region is a good case with which to study CO_2 emissions, examining how different drivers influence the directions of emission changes across various sectors in all provinces. Moreover, most of the growth in CO_2 emissions, observed no regardless of GDP and energy consumption or per capita value (see Figs. S1 and S2 in supporting information), occurred after 2002. A similar consideration of China's CO_2 emissions growth can be found in Minx et al. [13]. Meanwhile, in 2011, "China's controlling greenhouse gas emissions scheme for the 12th Five-Year