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Determining factors and diverse scenarios of CO_2 emissions intensity reduction to achieve the 40–45% target by 2020 in China – a historical and prospective analysis for the period 2005–2020

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ABSTRACT

The Chinese government committed to reduce its national CO_2 emissions intensity by 40–45% until 2020 in response to climate change. This paper quantitatively evaluates the performance of CO_2 emissions reduction over the period 2005–2020 from the historical and prospective perspectives by using a combination of decomposition analysis and scenario analysis, aiming to provide suggestions about how to achieve the target in key emissions reduction fields. Unlike traditional index decomposition methods, this paper incorporates the total energy conversion efficiency effect into the model, and further decomposes it into a final energy mix effect and a final energy conversion efficiency effect by a multilevel decomposition procedure, allowing to measure the contributions of primary energy structure low-carbonization, the final energy mix electrification, and the energy conversion efficiency improvement. The results show that the carbon intensity could decline over the period 2005–2020 by 47.8%, 50.9%, 48.0%, 44.5% and 47.5% in the Business as Usual, S1, S2, S3 and S4 scenarios, respectively. This shows that the 40–45% target is very likely to be achieved. The final energy intensity effect is always the most important driving factor, causing carbon intensity to decrease by 24.0% and 22.1%, again respectively, from 2005–2012 to 2012–2020. Moreover, the energy conversion effect was another major driver during 2005–2012. The Chinese government needs to make more efforts to adjust the industrial structure, which could cause carbon intensity to decrease by 3.6% during 2012–2020, and to adjust the primary energy mix, which could cause carbon intensity to decrease by 7.1% during 2012–2020.

1. Introduction

Greenhouse gas (GHG) emissions reduction has received increasing attention worldwide. As the world's largest energy consumer and CO_2 emitter, China was responsible for nearly 20% and 25% of total global energy consumption and energy-related CO_2 emissions in 2010, respectively (IEA, 2011). China therefore faces the great pressure from the international community to reduce its carbon emissions. At the 2009 Copenhagen Summit, the Chinese government committed to reduce its CO_2 emissions per unit of gross domestic product (GDP) (i.e. carbon intensity) by 40–45% over the period 2005–2020. In addition, it stated its intention to achieve peak CO_2 emissions in about 2030 in the 2014 U.S.–China Joint Announcement on Climate Change (XNA, 2014). These commitments reflect not only China's attitude and determination about controlling GHG emissions, but also open a new era of economic growth, a transition from the traditional resource utilization mode to a low-carbon development mode.

Since the 11th Five-Year-Plan (FYP) (2005–2010), China has made great efforts to improve energy utilization and conversion efficiency, develop renewable energy, and adjust its economic structure (GOSC, 2013; Xu et al., 2014). It has gained remarkable achievements, including a 19.1% reduction of energy intensity during this period. In the 12th FYP (2010–2015), the Chinese government proposed that energy intensity and carbon intensity decline by 16% and 17%, respectively, and paid more attention to the energy mix and balance of industrial structure,[1] while it continued

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[1] The Chinese government intended to increase the share of non-fossil fuels in primary energy consumption to 11.4% and increase the share of service industry in national GDP to 47% in 2015.

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to promote the improvement of energy conversion and utilization efficiencies (GOSC, 2011, 2013). Energy intensity and carbon intensity were reduced by 8.95% and 10.6%, respectively, during the first three years of the 12th FYP (2010–2013), which accounted for 56% and 62%, again respectively, of the total five-year targets, but these reductions were not as profound as had been expected (NBS, 2014). Although there is no clear carbon emission reduction target for the 13th FYP (2015–2020), the Chinese government has intended to increase the share of non-fossil fuels in primary energy consumption to about 20% by 2030 (GOSC, 2014).

According to current emissions reduction programs, China might be still confronted with difficulty in achieving the target of 12th FYP and 40–45% target in 2020, or the way to reach them. It is meaningful therefore to investigate the historical contributions of various drivers of carbon emissions reduction, reveal the change trend of main drivers, and propose new corresponding solutions performed in the 12th FYP period to avoid economic harm resulting from some measures such as limiting production or electricity supply took by local governments for achieving energy intensity reduction target at the end of the 11th FYP (2005–2010) (XNA, 2010). Meanwhile, to suggest means for achieving the 40–45% target in 2020, it is more meaningful to explore potential emissions mitigation fields, evaluate the contributions of various drivers in the future, and set reasonable emissions reduction targets for the 13th FYP (2015–2020).

Many studies have analyzed whether and how China could achieve the 40–45% target in 2020 (Lu et al., 2013; Wang et al., 2011; Steckel et al., 2011; Jiao et al., 2013). Conclusions from these studies differ greatly, although their titles are similar. Some criticized that taking carbon intensity as a binding target would not necessarily lead to effective emissions reduction. For example, Cansino et al. (2015) indicated that the carbon intensity for 2020 was likely to be 50% lower than the carbon intensity of 2005 without implementing additional climate-change policies. Stern and Jotzo (2010) and Dai et al. (2011) believed, however, that the target was relatively challenging, and that the Chinese government would need additional mitigation policies to achieve it. Concerning the means to achieve the target, many studies provided correlative policy suggestions from various perspectives (Yi et al., 2011; He et al., 2010; Liu et al., 2015). Yuan et al. (2012) and Liu et al. (2014) suggested adjustments to the primary energy structure and thermal power development. Cui et al. (2014) analyzed the influence that emissions trading schemes could have on achieving the target.

Decomposition analysis is an effective tool for quantitatively identifying and analyzing the effects of various underlying factors that contribute to changes in some indicators over time (Ang et al., 1998). Compared with other index decomposition analysis (IDA) methods, the Logarithmic Mean Divisia Index (LMDI) method has been widely used in the field of energy (Ang and Zhang, 2000; Xu and Ang, 2013; Wu, 2012; Liu et al., 2007; Ma and Stern, 2008; Guo, 2010; Shao et al., 2014). Among these studies, the Kaya identity was developed to analyze the effects of various driving factors on CO_2 emissions (Kaya, 1989). The Kaya identity was subsequently extended to other research perspectives by other studies (O'Mahony, 2013; Zhang and Guo, 2013). For example, Xu et al. (2014) integrated the energy conversion effect into the decomposition model. In this effort, the energy intensity effect is further decomposed into a final energy intensity effect and an energy conversion efficiency effect to enable the assessment of energy utilization efficiency from both the energy supply and demand sides.

In general, the decomposition method is often used to analyze the effects of influencing factors of historical CO_2 emissions. This helps understanding which drivers are the main contributors to energy conservation and emissions reduction. Nevertheless, in recent years, some studies conducted prospective analyses to explore possible future changes in the main drivers of emissions reduction by combining scenario analysis with decomposition analysis (Agnolucci et al., 2009; O'Mahony et al., 2013; Hasanbeigi et al., 2013, 2014; Belakhdar et al., 2014; Lin and Ouyang, 2014). Projection and decomposition of future trends will provide a theoretical basis for policymakers to evaluate quantitatively how CO_2 emissions will change in the future, and how much of that change will be the result of each emissions reduction driver.

The conceptual analysis framework of this paper is shown in Fig. 1. First, this study evaluated the contributions of different drivers of emissions reduction from 2005 to 2012 from a historical perspective by a revised index decomposition method. The aim of this evaluation was to explore the rationale behind the changes of carbon intensity and find key drivers for the projection of future carbon intensity. Second, we estimated the future trends of various drivers of emissions reduction based on the literature, historical data, industrial plans, and national policy documents. Third, the future trends of carbon intensity and the contributions of various drivers of emissions reduction on those trends were explored in order to analyze the feasibility and main potential drivers of achieving the 40–45% target in 2020. Finally, the relevant policy suggestions are provided about which sectors and which emissions reduction fields require more effort to achieve these specified targets from a prospective perspective.

The contributions and innovations of this study are summarized as follows. (1) From both the historical and prospective perspectives, this study quantitatively evaluated the effects of emissions reduction from 11th FYP to 13th FYP, and developed a scientific assessment and policy suggestions about whether the 40–45% target could be achieved and how to achieve it. (2) The multilevel decomposition method combining with scenario analysis was built to explore the contributions of emissions reduction drivers in various possible scenarios, allowing for quantitatively investigating the contributions of low-carbonization of primary energy structure, electrification of final energy mix and the final energy conversion efficiency improvement and other drivers, which are original.

This paper is organized as follows. Section 2 provides a brief description of the decomposition method. Section 3 contains the collection, processing, and estimation of data and scenario design. Section 4 presents the results and discussion. Finally, some conclusions are presented in Section 5.

2. Methodology

2.1. Energy consumption and CO_2 emissions

According to the principle of energy balance, total energy consumption consists of final energy consumption and the loss of energy in conversion, as shown in Equation (1).

$$E^t = \sum_i \sum_j E^t_{ij} = \sum_i \sum_j FE^t_{ij} + CL^t_{ij} = \sum_i \sum_j FE^t_{ij} \Big/ e^t_j \quad (1)$$

where the subscript i represents the various sectors; the subscript j represents the various primary fuels the superscript t represents the years of the study period; E^t_{ij}, FE^t_{ij} and CL^t_{ij} represent the total energy consumption (TJ), final energy consumption (TJ), and the loss of energy in conversion (TJ) of the jth fuel type in the ith sector in year t, respectively and e^t_j represents the conversion efficiency of the jth fuel type in year t calculated by energy balance table of China Energy Statistical Yearbook.

According to the Intergovernmental Panel on Climate Change (2006), total CO_2 emissions in the ith sector can be estimated in

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