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Sector decomposition of China's national economic carbon emissions and its policy implication for national ETS development

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ABSTRACT

Uncovering the contributions of each sector's driving factors to the growth of national economic carbon emissions has great significance for China in developing its nationwide emission trading scheme (ETS). The paper applies the index decomposition analysis (IDA) and logarithmic mean divisia index (LMDI) model to discuss the underlying drivers behind China's national economic carbon emissions during the period 1996–2012 from both sector and factor decomposition perspectives and accordingly offers policy proposals for China's national ETS development. Major conclusions include: (1) Six heavy industry sectors, the transport & storage & post sector, and the construction sector are the largest contributors, and hence proposed for incorporation into the ETS's coverage. (2) The rapid expansion of economic output dominantly increases carbon emissions. The design of cap on emissions should allow for a proper increment and establish a new entrant reserve to coordinate economic development. (3) As the dynamics of carbon emissions vary markedly across sectors, allowance allocation needs to consider the changing sectoral structure of emissions. (4) The combined effects of sectoral energy intensity and structure changes largely offset carbon emissions. Benchmarking is suggested as an ideal allocation mechanism, and the setup of sectoral carbon intensity benchmark should synthetically evaluate the potential impacts of related factors. (5) Manufacturer-based manner and carbon offset mechanism are respectively recommended for the initial implementation of carbon trading in the transport & storage & post sector and the construction sector.

1. Introduction

The post-Kyoto greenhouse gases (GHGs) emission reduction agreement and its implementation mechanism are currently a core issue for the international community in addressing global climate change [1]. China became the largest carbon emitter in 2006 and contributed to 64.8% of the global carbon emission increments during the period 2007–2012 [2]. The amount of China's carbon emissions has reached 9977 Mt CO_2-e and accounted for 27.6% of total global emissions in 2013 [3]. Whether or not China can effectively curb its carbon emission growth, therefore, has quite important implications on mitigating global climate change. To be a responsible developing country, China promised a 40–45% reduction of carbon emissions per unit of gross domestic product (GDP) by 2020 compared to the 2005 level, and more urgently a 17% reduction during 2011–2015 [4]. In the 2014 US–China joint statement on climate change, China's government further announced its plan to reach the national peak of carbon emissions around 2030 and pursued efforts to reach it as early as possible.

Based on current conditions, China's government has been actively exploring economical and effective means to meet its commitment of carbon emission reduction [5–7]. In recent years, China has made the significant strategic move of promoting the application of market-based emission mitigation mechanism [8]. Carbon emission trading has advantages in emission reduction stability, political acceptability, flexibility, technology innovation and incentive, as well as coordination with other existing policies and internationalization [9–11]. It has been widely applied to mitigate carbon emissions around the world and achieved satisfactory effects in practice [12–14]. China launched its pilot carbon emission trading scheme (ETS) in 2011, and seven regional cap-and-trade ETSs were successively put into operation between 2013 and 2014. Afterwards, the "Interim Procedures for National Carbon Emission Trading Management" was issued by China's National Development and Reform Commission (NDRC) at the end of 2014. The pilots of regional ETSs are being expanded to develop cross-regional schemes, with the aim to ultimately establish a

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nationwide scheme during the period 2016–2020. In view of these advances, carbon emission trading scheme has become a vital instrument and is playing an increasingly important role in China's carbon emission mitigation.

The mechanism design of a carbon emission trading scheme largely determines its environmental and economic effectiveness, market efficiency and social welfare effect [15–17]. Moreover, there is no universal model for carbon emission trading. The ETS's mechanism design, in nature, is closely related to the stage of economic development, level of industrialization and urbanization, energy consumption, carbon emission characteristics and other related factors. Therefore, the experiences of the European Union, the United States, Japan and other developed economies may not be suitable for China. Exploring the proper mechanisms of the forthcoming national ETS is a major prerequisite for China to achieve cost-effective carbon emission reductions. Sector coverage, emission cap and allowance allocation are three key mechanisms and also the most challenging aspects of developing an ETS. The setup of sector coverage directly affects the cap on emission, allowance allocation and market structure, which makes it the first priority in developing China's national ETS. Against these, it is of great significance to explore the effects of related factors by sector on the dynamics of China's national economic carbon emissions (NECE, referring to carbon emissions from the national economic sectors, excluding the household sector). The article will apply index decomposition analysis (IDA) and logarithmic mean divisia index (LMDI) model to conduct both sector and factor decomposition analyses, with an aim to offer policy proposals on China's national ETS development. First, the contributions of 42 economic sectors to the overall growth of carbon emissions from China's national economy system are decomposed by a two-factor LMDI model during 1996–2012. Sectors that make the largest or ever-increasing contributions are identified to guide the setup of ETS coverage. Then, the identified sectors are further analyzed by the four-factor LMDI models to uncover the driving mechanisms of carbon emissions in individual sectors, and their implications are discussed to formulate cap and allocation mechanisms. Finally, several policy recommendations are proposed for China to design its nationwide emission trading scheme.

The remainder of this paper is organized as follows. Section 2 reviews the recent researches. Section 3 constructs the LMDI models and describes the data used in the study. Empirical results are presented and discussed in Section 4. Section 5 concludes the paper and puts forward policy proposals for China's nationwide ETS.

2. Literature review

To combat global climate change, China is confronted with severe challenges from both international climate negotiations and domestic trade-off between economic development and carbon emission abatement. Against this backdrop, increasing attention has been paid to explore the drivers behind the growth of China's carbon emissions as well as the effective policies/measures for mitigation.

Index decomposition analysis and structural decomposition analysis (SDA) are two commonly used methods to investigate the changes of carbon emissions over time. SDA uses input-output models to capture the interactions among various production sectors and the pulling actions from various final consumptions. It has advantages in incorporating all the direct, indirect and induced effects into a unified decomposition framework and in distinguishing a variety of technical, structural and final demand effects, and has thus been employed by some studies to detect the underlying driving forces of China's carbon emission or carbon intensity changes, especially from the consumption-based perspective [18–23]. However, it should be noted that the SDA's higher requirements of input-output table and related data to a considerable extent limit its application in practice and might lead to time lag in analysis result [24–26]. By comparison, IDA mainly focuses on the direct impacts of related factors on the aggregate indicator. Because of only requiring sector-level routine statistical data, the method exhibits a greater flexibility and may be applied in any region, time interval or problem formulation with better timeliness [25,27,28]. Among the various IDA technologies, LMDI decomposition has the capacity to process zero or negative values and incomplete data, together with the adaptability to variable variations and perfectness in decomposition. In view of this, LMDI is recognized as one of the most practical and accurate decomposition technologies [29,30] and has been increasingly applied to study current carbon emission issues in China.

The existing LMDI literature on China's carbon emissions can be generally classified into three categories: national, regional and sectoral. From the macroscopic perspective, Wu et al. noticed that the 1996–1999 "stagnancy" of carbon emissions in China was just a short-term fluctuation largely caused by the high rate of state-owned enterprise deterioration and the slowdown of industrial labor productivity growth [31]. Ma and Stern addressed the roles of technical and inter-fuel substitution changes, which clearly showed that the effect of technical progress was dominant in reducing energy intensity while inter-fuel substitution contributed little [32]. Furthermore, Wang et al. decomposed the change of CO_2 emissions into the effects of population, GDP per capita, energy intensity and structure, and fuel coefficient [33]; Zhang et al. broke down it into those of economic activity, industrial structure and emission efficiency [34]; both of them yielded similar conclusions, that economic growth had the largest effect on increasing emissions while energy intensity decline made the greatest inhibitory effect. Besides, by grouping carbon emissions into power-related and other emissions, Tan et al. noted that the improvements in the energy intensity of power generation, electricity intensity of GDP, and energy intensity of GDP from other activities contributed the most to carbon intensity decline [35]. Xu et al. as well as Zhang and Da provided a deeper understanding of the influences from energy-related factors, and clarified the key contributions from the cleaning of energy mix and improvement of energy conversion efficiency [36,37]. Chen and Yang performed both spatial and temporal decomposition analysis of China's carbon emissions, the results of which further disclosed that the influences of driving mechanisms varied significantly across phases and regions [38]. In addition, index decomposition was combined with scenario analysis, numerical simulation or prediction model to discuss the mitigation potential or peak of carbon emissions in the future. Brockway et al. exposed that the key driver of efficiency growth was not "technological leapfrogging" but structural change during 1971–2010, and China's 2030 energy demand might greatly exceed the mainstream projections [39]. Wu et al. detected an upward trend of the economic effect on increasing emissions between 2004 and 2010 and predicted that China might show the greatest growth rate of emissions by 2020 in the BRICS countries [40]. Niu et al. demonstrated that the rising share of clean energy played a vital role in abating carbon emissions between 1990 and 2013, and China might achieve its emission peak by 2035 [28].

From the regional perspective, the drivers of residential CO_2 emissions between urban and rural regions were compared by [41], which uncovered a rising tendency of positive population effects in urban regions while an opposite one in rural regions. Liu et al. and Zhao et al. placed more emphasis on the urban region. Their discussions indicated that CO_2 emissions from urban residents were largely raised by scale effects including urban population, output and income, while partially offset by energy price reform and carbon intensity reduction [42,43]. As for the rural region, Yao et al., Zhang and Guo declared that the improvement of farmer income dominantly drove up emissions, while the strong policy supporting rural development of renewable energy acted as a critical inhibition factor [44,45]. In addition, it was further demonstrated that the driving forces of CO_2 emissions varied distinctly across regions and provinces [46]. Zhang et al. and Li et al. divided China's thirty provinces into several categories according to geographical position or emission feature and

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