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Multi-sectoral decomposition in decoupling industrial growth from carbon emissions in the developed Jiangsu Province, China

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ABSTRACT

ICE (Industrial carbon emission) is one of most important sources of anthropogenic carbon emissions. To reduce the carbon emissions, many countries, particularly China, have adjusted their industrial structures and improved energy efficiency. The complete decomposition technique and decoupling method were used to investigate and quantitatively analyze the main factors influencing the energy-related ICE in Jiangsu, the Chinese province with the largest energy consumption and carbon emissions. The importance of the sectoral dimension was taken into account by dividing the industry into three main departments consisting of 38 sub-sectors. The results indicated that the industry of Jiangsu was in a weak decoupling state from 2005 to 2012. The industrial output growth was the biggest driver of the increase in ICE, while energy efficiency advancement was the main cause for the reduction, in a weakening trend. The year of 2008 was an important breaking point when the optimization of industry structure came into play and global financial crisis took place. The biggest dilemma in Jiangsu is heavy industry is still dominant, especially the five sectors of them made the biggest contribution (88.2%) to ICE. Thankfully, there were five manufacturing industries had achieved low carbon economy at various degrees.

1. Introduction

The continuous growth in energy consumption, particularly the fossil fuels, has threatened the environment by increasing the emissions of greenhouse gases [1] and exacerbating the scarcity of natural resources, such as water and land [2,3]. According to the IPCC (intergovernmental panel on climate change) reports, atmospheric CO_2 has increased by 2.0 ppm per year since 2001, climbing to 390.5 ppm in 2011 [4]. Atmospheric CO_2 has increased by 40% compared to the content in 1750, and the burning of fossil fuels constitutes approximately 95% of the increase in CO_2. Fossil fuels are mainly produced by industrial sectors, and therefore, knowledge of ICE (industrial carbon emissions) is one of the most important sources of anthropogenic CO_2 emissions.

Since 2008, China has become the world's largest carbon emitter [5], and the carbon emissions from industries accounted for approximately 65% of the total emissions [6]. China was not a signatory of the Kyoto Protocol, but it has faced increasing pressure to reduce carbon emissions and worsening urban hazes. China must pay more attention to balance emission reduction and economic growth, especially for industries. Chinese governments have worked on transforming from high-carbon to low-carbon energy by adjusting industrial structure and improving energy efficiency. To analyze the decoupling of industrial development and carbon emissions, it is important to research the various industrial sectors according to the different industrial developments and measurements in each region. However, few studies have been conducted on the smaller and detailed industrial groups, especially considering the huge regional differences in China's industry.

The decomposition technique is often combined with the Kaya identity [7] as an effective way to solve the aforementioned issues. It has been widely applied in energy fields to analyze the intensity and carbon emissions [1,8–10]. Among the popular decomposition techniques for time-series data, the LMDI (logarithmic mean Divisia index I) approach has time-reversal and factor reversal properties,

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Nomenclature

CE	total carbon emissions
I	energy intensity
i	industrial sector i
CE_{ij}	carbon emissions from fossil energy j of sector i
j	fossil energy j
ES	changes in industrial structure
CE_i	carbon emissions of sector i;
ε	elasticity
E_{ij}	consumption of sector i
ε_R	effect of corresponding emission factor
E_i	energy consumption of sector i;
ε_S	effect of energy structure
IO	industrial output
ε_I	effect of energy intensity
IO_i	industrial output of sector i
ε_{ES}	effect of industrial structure
R	corresponding emission factor
ε_{IO}	effect of industrial scale
S	coefficient of energy structure
D	decoupling effort index

leaves no residuals, and can address the zero values in the dataset [11,12]. Therefore, the LMDI method was adopted for use widely. There are some researches on the decomposition and driven forces analysis of ICE (Table 1). Some studies have used LMDI to investigate carbon emissions at regional and national scales [9,13–18]. They mainly focused on large-scale areas or sectors and achieved good results that embodied the macroscopic trends of carbon emissions. Shahiduzzaman and Alam [13] found a positive association between energy intensity and carbon intensity in Australia. Löfgren et al. [14] addressed the problem of double counting energy flows and pointed out potential problems related to output measured in monetary terms. Liu et al. [16] also analyzed the change of industrial carbon emissions from industrial sectors in China.

Recently, several studies were performed at regional levels or sub-sectors and provided more information from a more detailed perspective [19–21](Table 1). Alves et al. [8] used complete decomposition technique to examine CO_2 emissions intensity and its components, considering 36 economic sectors in Portugal. They found that energy intensity is the most important factor for the determination of CO_2 emissions intensity, and the using of advanced technologies can be more efficient and less polluting. The multi-sectoral decomposition analysis showed that energy efficiency improvements were primarily responsible for the decrease in carbon emissions in Tianjin, China [19]. Zhao et al. [6] found that the decline in energy intensity accounted for 90% of the reduction of ICE from 1996 to 2007 in Shanghai. Zhang et al. [20] also explored the contribution rates of various impact factors in Xinjiang Uygur autonomous region.

These studies produced results valuable for identifying the factors that influenced the changes of carbon emissions. However, these analyses rarely explored sub-sector dimensions on a smaller level, and some researches have highlighted the deficiencies of just analyzing carbon emissions at the national level, in terms of regional unevenness of economic development [22–24]. Moreover, most of them just focused on exploring the driving forces, not assessing the progress in decoupling industrial growth from ICE. Decoupling analysis is an effective way to measure the environmental pressure from economic growth based on the "Driving force-pressure-state-impact-reflect" framework [25]. It is a big challenge to maintain economic growth with a reduction of carbon emissions at national and international levels [26]. Therefore, relevant decomposition analyses have been combined with a decoupling framework to investigate the decoupling paths in both developed and developing countries [21,27,28]. In this paper, we combined the complete decomposition technique with decoupling index to carry out an attribution analysis, not only to assess the drivers of ICE, but also to measure the environmental pressure.

Table 1
Comparison of studies using decomposition technologies to dealing with energy and carbon emissions.

References	Reference ID	Method	Period	Area	Subject
Zhao et al. (2010)	[6]	LMDI	1996–2007	Shanghai, on a regional level	Carbon emissions of heavy and light industry, sub-sectors level
Alves et al. (2013)	[8]	LMDI	1996–2009	Portugal, on a national level	CO_2 emissions of sub economic sectors
Choi et al.(2001)	[10]	Divisia index approach	1961–1998	Korea, on a national level	CO_2 emissions of four sectors
Shahiduzzaman et al. (2013)	[13]	LMDI	1978–2009	Australia, on a national level	Energy intensity of 14 sectors
Löfgren et al. (2009)	[14]	LMDI	1993–2006	Swedish, on a national level	CO_2 emissions, on sub-sectors level
Lee et al. (2006)	[15]	LMDI	1980–1998	APEC countries, on a national level	CO_2 emissions, on a national level
Liu et al.(2007)	[16]	LMDI	1998–2005	China, on a national level	Industrial carbon emissions, on sub-sectors level
Brizga et al.(2013)	[17]	(IPAT) Index Decomposition	1990–2010	former Soviet Union, on a national level	CO_2 emissions on a national level
Zhang et al.(2013)	[18]	LMDI	1991–2009	China, on a national level	CO_2 emissions from electricity generation, on a national level
Kang et al., (2014)	[19]	LMDI	2001–2009	Tianjin, on a regional level	GHG emissions, on sub-sectors level
Zhang et al.(2014)	[20]	LMDI	1952–2008	Xinjiang Uygur autonomous region, on a regional level	CO_2 emissions of primary, secondary and tertiary industries
O'Mahony et al. (2012)	[21]	LMDI	1990–2007	Ireland, on a national level	Carbon emissions of eleven sectors
Jung et al.(2012)	[22]	LMDI	2002–2009	Five regions of South Korea; on a regional level	Carbon emissions of the whole industry
This study		Combining the methods of LMDI and decoupling index	2005–2012 (2008 was chosen as a breaking point)	Jiangsu, China, on a regional level	ICE, on a multi-sectoral level (38 industrial sectors)

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