Journal of Cleaner Production 127 (2016) 406–417

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Comparative analysis of the regional contributions to carbon emissions in China

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ARTICLE INFO

Article history:
Received 1 December 2015
Received in revised form
8 February 2016
Accepted 27 March 2016
Available online 13 April 2016

Keywords:
Energy consumption
Carbon emissions
LMDI method
Regional contribution

ABSTRACT

Using the logarithmic mean Divisia index (LMDI) method, we decomposed the factors that affect carbon emissions at a multi-regional level. Based on a comparative analysis of the regional contributions to carbon emissions in China from 1995 to 2012, we found that economic growth is a major factor that increases carbon emissions. Excluding Hainan, Guangxi, Ningxia, and Xinjiang, the energy intensity effects of other provinces and municipalities inhibited carbon emissions clearly. The energy structure effect in Beijing and Shanghai inhibited carbon emissions most obviously, whereas the energy structure effect in Xinjiang promoted carbon emissions to the greatest extent. The energy structure effect in most regions had little influence on carbon emissions. The output proportion effect enhances carbon emissions on the whole, which indicates China's regional economic development is not coordinated from the perspective of carbon emission reductions. Overall, Shandong, Inner Mongolia, and Hebei made the biggest contributions to national carbon emissions. Policy implications in terms of our study results are discussed.

1. Introduction

Climate change is a major focus of political and academic concern. As the largest carbon emitter, the pressure on China due to international negotiations related to reducing emissions is greater than ever. To solve this problem, China officially issued *The National Plan on Climate Change* (2014–2020) in September 2014, which clearly states that by 2020, carbon dioxide emissions per unit of GDP will decline by 40%–45% compared with that in 2005, where the proportion of non-fossil energy in the primary energy consumption will increase by around 15%. In addition, greenhouse gas emissions caused by non-energy activities such as industrial production processes will be effectively controlled, the growth of greenhouse gas emissions will continue to slow down, and a series of action targets related to the control of greenhouse gas emissions will be achieved. Thus, how to reduce China's carbon emissions is an urgent issue. Intuitively, whether the national carbon reduction target will be achieved or not depends on the implementation of regional carbon reductions. To achieve the reduction targets in China, the national emission reduction targets are often allocated to various provinces and municipalities. However, some problems have emerged under China's current institutional arrangements. For example, power cuts, factory closures, and other extreme measures have been taken in some regions to achieve the allocated reduction targets. However, decomposition theory shows that carbon emissions are influenced by the regional output proportion and GDP as well as by the regional energy structure and energy intensity. Thus, what are the relationships between these factors and the national and regional carbon emissions? Given these issues, it is necessary to study different effects on carbon emissions from the perspectives of different provinces and municipalities, as well as investigating the contributions of different provinces and municipalities to carbon emissions during the process of economic growth. It is also necessary to provide the government with mechanisms for reducing carbon emissions and to suggest some references for carbon emission reduction from the regional perspective.

Decomposition methods are useful for studying the factors that influence emissions, which are currently divided into structural decomposition analysis (SDA) and index decomposition analysis (IDA). Su and Ang (2012) performed a comparative analysis of SDA

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http://dx.doi.org/10.1016/j.jclepro.2016.03.149
0959-6526/

and IDA, and noted that IDA has been applied to study a wider range of problems within the broad area of energy and the environment. As a result, the number of publications arising from IDA applications has far exceeded that from SDA. Xu and Ang (2013) also considered recent developments in terms of IDA approaches. In IDA, the logarithmic mean Divisia index (LMDI) is a preferred method because it can be used for the decomposition of incomplete datasets and it benefits from the lack of an unexplainable residual in the results. The LMDI method can be used for either multiplicative or additive decomposition. Many studies have examined energy consumption and emissions using LMDI decomposition methods, such as Bhattacharyya and Ussanarassamee (2004), Paul and Bhattacharya (2004), Kaivo-oja and Luukkanen (2004), Ang (2005), Kwon (2005), Lee and Oh (2006), Liu et al. (2007), Ebohon and Ikeme (2006), Zhao et al. (2010), Elif et al. (2011), Jung et al. (2012), and Xu et al. (2014a).

Many previous studies have employed the decomposition method to analyze carbon emissions for various countries, such as the UK, Brazil, Greece, Turkey, and South Korea (Hammond and Norman, 2011; Hatzigeorgiou et al., 2008; Freitas and Kaneko, 2011; Akbostanci et al., 2011; Oh et al., 2010). However, most previous studies only examined carbon emissions at the national level due to the availability of reliable statistics, although some studies reported comparative analyses between nations. For example, Lee and Oh (2006) used a cross-sectional decomposition method to analyze the CO_2 emissions in APEC countries. Fernández González et al. (2014a) analyzed the factors that underlie changes in aggregate energy consumption in the EU-27, where they identified differences between member states by applying the LMDI to the multiplicative decomposition of the variation in aggregate energy consumption in the EU-27 member states for the period of 2001–2008 at the country level. Fernández González et al. (2014b) examined changes in CO_2 emissions in the EU at the country level and identified diverse patterns in large and small economies. To analyze China's carbon emissions, Zhang (2000) adopted the method of logarithmic difference to analyze the growth in China's carbon emissions from 1980 to 1997, and suggested that if China had failed to reduce its energy intensity through policy and technology, the gross carbon emissions would have been 50% higher than the actual value during this phase. Subsequently, Fan et al. (2007), Ma and Stern (2007), Wu et al. (2005), Wei et al. (2008), and Li et al. (2010) studied the factors that influence carbon emissions in China. They concluded that the economic output effect is a key factor that promotes carbon emissions, whereas the energy intensity has an inhibitory effect. Tan et al. (2011) examined the driving forces that improved China's CO_2 emissions intensity between 1998 and 2008, where the results showed that improvements in the energy intensity of power generation, the electricity intensity of GDP, and the energy intensity of GDP for other activities were mainly responsible for the success in reducing the carbon emissions intensity in China, where activities related to the electric power industry played a key role. Recently, Wang et al. (2014) generalized the LMDI method to analyze the driving factors that governed China's energy consumption during 1991–2011, where they noted that energy intensity effect played the dominant role in decreasing energy consumption, whereas investment and labor effects were the critical factors that influenced the growth in energy consumption and carbon emissions.

At the sectoral level, Liu et al. (2007) used the LMDI method to decompose the factors influencing carbon emissions from 36 Chinese sectors during 1998–2005. Wang et al. (2011) also investigated the factors that influence changes in transport sector carbon emissions in China. Lin and Moubarak (2013) analyzed the change in energy-related carbon emissions from the Chinese textile industry during 1986–2010. Ren et al. (2014) explored the impacts of industry structure, economic output, energy structure, energy intensity, and emission factors on the total carbon dioxide emissions from China's manufacturing industry during 1996–2010. Lin and Ouyang (2014) employed the LMDI method to evaluate the changes in CO_2 emissions related to energy consumption, where they presented a comprehensive picture of the underlying determinants of changes in emissions from the Chinese non-metallic mineral products industry during 1986–2010. Xu et al. (2014b) analyzed the changes in energy-related greenhouse gas emissions in China from a sectoral perspective. In addition, some studies have examined emissions from other countries. For example, Jeong and Kim (2013) decomposed the Korean industrial manufacturing greenhouse gas emissions using the LMDI method.

In a comparative analysis of regional carbon emissions, Zhao et al. (2010) employed the LMDI method to decompose the factors that influence industrial carbon emissions in Shanghai. Wang et al. (2013b) analyzed the contributions of the factors that influenced energy-related CO_2 emissions in Jiangsu province during 1995–2009. Kang et al. (2014) performed a decomposition analysis to disentangle the greenhouse gas emissions in Tianjin from 2001 to 2009. Dong et al. (2014) classified the carbon emissions inventories into territory, production, and consumption accounts in Beijing, and used an input–output method to calculate the production account and consumption account with a traditional competitive input–output table. Wang and Yang (2015) quantitatively analyzed the delinking indicators related to industrial growth and environmental pressures in the Beijing–Tianjin–Hebei economic band from 1996 to 2010. Moreover, Dhakal (2009) addressed the urban contribution of 35 Chinese cities to China's energy use and CO_2 emissions. The results showed that urban contributions comprise 84% of China's commercial energy usage, and the 35 largest cities in China contribute 40% of China's energy use and CO_2 emissions. However, this study only analyzed the urban contribution to energy use and CO_2 emissions, and it did not consider the differences in contributions among the 35 Chinese cities. Meng et al. (2011) analyzed the characteristics of China's regional CO_2 emissions and the effects of economic growth and energy intensity using panel data. Yu et al. (2012) estimated the regional characteristics of inter-provincial CO_2 emissions in China based on a particle swarm optimization approach. Zhang et al. (2011) and Xu et al. (2014a) used the LMDI method to investigate regional differences in the factors that influence China's carbon emissions due to energy consumption, but these studies did not address the differences in regional contributions to carbon emissions in China. Some previous studies have examined the factors that influence carbon emissions from other countries. For example, Jung et al. (2012) performed a decomposition analysis to identify the factors that drive energy-related CO_2 emissions in five regions of South Korea.

The previous studies mentioned above mainly used decomposition methods to analyze the factors related to carbon emissions at a national or sectoral level. Some previous studies have examined the factors related to carbon emissions at a regional level, but there are still some gaps in this research area. In general, the factors that influence China's carbon emissions have been examined in specific regions. Some studies have investigated carbon emissions from different regions in China, but there have been few comparative analyses of the different regional contributions to carbon emissions in China. The regional energy structure, energy intensity, and output proportion affect the regional and national carbon emissions, so it is necessary to investigate carbon emissions for different regions of China, thereby elucidating the differences in regional carbon emission characteristics in order to meet the overall national targets. Moreover, in the previous studies conducted at national, sectoral, or specific regional levels, the LMDI method was