Applied Energy xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

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

Uncovering driving factors of carbon emissions from China's mining sector

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HIGHLIGHTS

- We adopt a novel decomposition method – Generalized Divisia Index Method (GDIM).
- We use GDIM to uncover drivers of CO_2 emissions changes from China's mining sector.
- We carry out a scenario analysis of mitigation pathways for China's mining sector.
- Output scale and carbon intensity are two primary factors of CO_2 emissions changes.
- More efforts should be made for the whole mining sector to achieve the peak target.

ARTICLE INFO

Article history:
Received 28 June 2015
Received in revised form 25 November 2015
Accepted 20 January 2016
Available online xxxx

Keywords:
Carbon emissions
Mining sector
Factor decomposition
Scenario analysis
Generalized Divisia Index Method (GDIM)
China

ABSTRACT

China has proposed its ambitious cap targets of carbon emissions in both carbon intensity (CO_2 emissions per unit of GDP) and carbon scale (gross carbon emissions). Since mining sector is the foundation of the whole industrial production as well as a carbon intensive sector, it is critical to uncover the key driving factors on inducing corresponding carbon emissions so that appropriate mitigation policies can be raised. Under such a circumstance, this paper aims to fill such a research gap by employing a novel index decomposition method, namely, Generalized Divisia Index Method (GDIM), so that the driving factors of energy-related carbon emissions changes in China's mining sector and its five sub-sectors over the period of 1999–2013 can be identified. In addition, a scenario analysis approach is applied in order to seek the feasible mitigation pathways on China's mining sector and its five sub-sectors. The results indicate that output scale effect is the primary contributor of the increase in carbon emissions of both mining sector and its five sub-sectors and energy use effect also plays a positive role, while carbon intensity effect contributes most to the decrease in carbon emissions. All sub-sectors have achieved the target of 45% carbon intensity reduction except the extraction industry of petroleum and natural gas. Nevertheless, more efforts should be made for the whole mining sector in order to achieve the 2030 peak target of carbon scale.

1. Introduction

Climate change is a major global concern and has received increasing attentions worldwide. In order to respond such a challenge, different countries initiated different efforts by considering their own realities. However, these efforts do not achieve the expected targets due to imbalanced economic development, lack of budget and political eagerness, and reluctance of promoting innovative policies, technologies and energy efficient equipment. The global carbon emissions continued to rise by an annual growth rate of 3.4% from 2000 to 2008, much higher than the previous decade (with an increase rate of 1% from 1990 to 2000) [1]. Energy sector accounts for around two-thirds of the total greenhouse gas (GHG) emissions. Comparing with 2012, global energy-related carbon emissions reached 35.3 Gt (gigatonnes) in 2013, increased by 370 million tonnes [2]. While carbon emissions decreased in the United States and the European Union, other countries increased their carbon emissions. Among these countries, China's carbon emissions increased by 4.2%, and India's increased by 4.4%

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http://dx.doi.org/10.1016/j.apenergy.2016.01.047

Please cite this article in press as: Shao S et al. Uncovering driving factors of carbon emissions from China's mining sector. Appl Energy (2016), http://dx.doi.org/10.1016/j.apenergy.2016.01.047

in 2013 than in 2012 [2]. According to IEA [3], China became the world's largest carbon emitter in 2007, with an amount of 6.07 billion tonnes and 300 million tonnes higher than the US. Consequently, China should choose an appropriate mitigation pathway in order to contribute to the reduction of global carbon emissions [4]. In this regard, the Chinese government announced that China would lower its carbon emissions per unit of GDP by 40–45% in 2020 than the 2005 level in late 2009, i.e., 2020 target and promised to peak its carbon emissions in 2030 in the APEC CEO Summit 2014 in Beijing, i.e., 2030 target.

The COP-21 will soon be held in Paris in order to formulate a new global agreement on the GHG emissions, which will be implemented after 2020 to replace the Kyoto Protocol. Under such a circumstance, it is of significant importance to mitigate China's energy-related carbon emissions, which are mainly from fossil fuel combustion and industrial process. According to IEA, about 70% of China's carbon emissions caused by fossil fuel combustion came from industrial sector in 2013 [5], indicating that industrial sector is the largest carbon emitter in China. Therefore, it is necessary to uncover the key driving factors on carbon emissions from various industrial sectors in China.

This paper focuses on the carbon emissions issue of China's mining sector. As the foundation of the whole industrial production, mining sector deals with the extraction of ore or minerals from the earth and provides necessary "nutrients" to other industrial sectors. China is rich in mineral resources but limited in high-quality mineral resources. The main minerals in China include energy minerals, metallic minerals, and nonmetallic minerals. To date, China is the world's leading producer of many important minerals, such as aluminum, coal, gold, graphite, iron and steel, magnesium, mercury, rare earths, tin, zinc, and so on. China is now one of the top three countries in the world in the production of many mineral commodities. The total mineral amount that China produces and consumes is so large that China has been one of the few countries having significant impact on the international mineral market. On average, the gross output value and carbon emissions of China's mining sector accounted for approximately 4.09% and 8.61% of the total industrial sector over 1999–2013,[1] respectively, reflecting its relatively high carbon intensity.

Mining sector also has several sub-sectors. Among these sub-sectors, the mining and washing of coal and the extraction of petroleum and natural gas are the top two emitters and rank the fifth and tenth in the 36 industrial sectors with the average annual carbon emissions of 84.13 and 43.70 million tonnes[2] over 1999–2013, respectively. The above data reflects that the emission-reduction performance of mining sector is of great significance for the whole industrial sector to achieve the national carbon emission-reduction targets. Many previous studies focused on China's carbon emission-reduction issues at both regional and industrial levels [6–8], but there is still few on China's mining sector.

Several methods have been including decomposition analysis and scenario analysis. For example, Gambhir et al. [9] applied the Logarithmic Mean Divisia Index (LMDI) method to identify the key emission drivers for China's road transport sector and then estimated the related costs and potential carbon emission savings by setting up different scenarios. The results show that the carbon emissions of China's road transport sector would be reduced from 2.08 to 1.24 Gt per year and the total mitigation cost would be $64 billion (US2010) per year by 2050 [9]. Steenhof [10] also employed the scenario analysis and decomposition analysis methods to analyze the main factors that affect the carbon emissions of China's electricity sector and found that the gains in the efficiency of generation had been the most important factor affecting the change in the emission intensity of generated electricity.

As cement industry is an important source of CO_2 emissions in China and the production of cement releases a large number of CO_2 from both fuels combustion and its chemical process producing clinker [11], some studies specifically analyzed the drivers of carbon emissions and emission-reduction path in China's cement industry. For instance, Xu et al. [12] built a scenario that might reflect the different consequences of economic and technological conditions to evaluate whether it is feasible to achieve carbon emission-reduction target in China's cement sector based on the current technological conditions. In another literature, an inventory of primary air pollutants and carbon emissions in China's cement sector was provided and the results indicated that it is possible to reduce carbon emissions in this sector by approximately 12.8% if advanced energy-related technologies are implemented [11]. Xu et al. [13] analyzed the carbon emissions changes in China's cement sector and identified its driving factors over the period of 1990–2009 by using the LMDI method. Their results showed that applying the best available technologies would result in the carbon mitigation potential of 33% compared to 2009. In addition, the carbon emissions of lime industry, which is the second largest source of carbon emissions from industrial process, were estimated. The results showed that the direct carbon emissions from fossil fuel combustion were 56.55 million tonnes in 2012, while the indirect emissions were 4.42 million tonnes in China's lime industry [14].

Most existing literatures aiming to explore the drivers of carbon emissions employed the LMDI method as the primary decomposition method. In particular, such a method was adopted to decompose the changes of industrial carbon emissions in 36 industrial sub-sectors of China over the period of 1998–2005 into carbon emission coefficient, energy intensity, industrial structural shift, industrial activity, and final fuel shift [15]. However, except scenario and decomposition analyses, other studies also used other methods. For example, the vector autoregressive model was used to analyze the influential factors of the carbon emissions changes in China's iron and steel sector. The results show that energy efficiency plays a dominant role in reducing carbon emissions [16]. In addition, the LEAP model that contains three scenarios was employed to demonstrate that sector-based mitigation policies would be a proper option to reduce emissions and that identifying the most cost-effective mitigation measures would be the key information used to design these policies [17].

The above studies highlighted the importance of decomposing the drivers of carbon emissions from a single sector perspective [17,18]. Most of them use the LMDI method as their main decomposition approach, but such a method has some deficiencies. For instance, it cannot simultaneously incorporate the effects of multiplicate absolute and relative indicators on the resulting indicators, and the decomposition results strongly rely on the factor interdependence. Last but not the least, the previous studies did not focus on mitigation pathways for achieving the recently released 2030 emission peak targets of China. Therefore, it is difficult for policymakers to better understand the current carbon emissions and prepare appropriate sector-specific mitigation policies.

Under such a background, this study aims to investigate the driving factors and identify an appropriate mitigation pathway of energy-related carbon emissions of China's mining sector and its five sub-sectors for the period of 1999–2013. The following three questions are proposed to be answered: (i) What are the prime promotion and mitigation drivers that affect the changes

[1] The data are from our calculation.

[2] We calculate the carbon emissions of China's industrial sector and the detailed is described in Section 2.