Energy 127 (2017) 78–88

Contents lists available at ScienceDirect

Energy

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

Comparative decoupling analysis of energy-related carbon emission from electric output of electricity sector in Shandong Province, China

Qiang Wang [a, *], Xue-ting Jiang [b, c], Rongrong Li [a]

[a] School of Economic & Management, China University of Petroleum (Huadong), No. 66 West Changjiang Road, Qingdao 266580, PR China
[b] State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Urumqi 830011, PR China
[c] College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, PR China

ARTICLE INFO

Article history:
Received 12 October 2016
Received in revised form
19 March 2017
Accepted 24 March 2017
Available online 25 March 2017

Keywords:
CO_2 emissions
Electric power sector
Decoupling elasticity
Decoupling index
Comparative decoupling stability analysis
Shandong Province

ABSTRACT

As a major contributor to carbon dioxide emissions, the electric power sector has instigated significant changes in environmental issues. To show the effectiveness of the program, research on whether the changes of electricity production and CO_2 emissions are out of sync are conducted by applying a decoupling elasticity analysis method. Then the decoupling index from the electricity analysis on the basis of the extended multilevel LMDI method are applied to study Shandong Province, covering the period from 1995 to 2012. Finally, a comparative decoupling stability analysis is applied. Our results indicate electricity output and coal consumption play significant roles in determining levels of CO2 emissions. Also, “relative decoupling” and “no decoupling” were the main states during the study period. We also found that the decoupling index performed better (in terms of stability) than did the electricity output elasticity of CO_2 emission.

1. Introduction

Recently, almost 25% of the world’s annual coal consumption was used for China’s electricity generation. Electricity production in China reached 321.2 billion kW·h in 2012. Shandong’s coal-fired generation accounted for a larger proportion than any other region in China. As a consequence, Shandong is a classic example of an area where change is needed, for the benefit of both China and the whole world. More and more attention has been paid to decoupling issues in recent years [1–9]. China, the world’s largest carbon emitter, accounted for 80% of the overall global emissions increase in 2012 [10–12]. As reported by The National Energy Administration (NEA), China’s total installed power generation capacity reached 1.14 billion kilowatts (Kw) by the end of 2012 [13]. In other words, China, the world’s largest carbon dioxide emitter in recent years, is also the world’s largest power producer. Electricity is secondary energy source; one of vital importance to the country’s energy management. In turn, effective energy management is crucial to national economic growth. China relies to a large extent on the process of changing coal and transferring fossil fuels into electrical power and coal-fired power plants have contributed more carbon dioxide emissions than other types of power plants. Coal-fired power plants have caused massive amounts of emissions. However, coal-fired power is still the most important provider of electrical power. Most of the previous studies on CO_2 emissions focused more on the environmental impacts brought about by the changes in CO_2 emission levels and how they influence China’s system of economic activities [14–25]. Moreover, previous studies on the electric power sector focused more attention on the relationship between the development of the electric power sector and the resulting environmental impacts [10,26–29].

With regard to previous research methodologies, an Index decomposition analysis (IDA) method was applied in most of the earlier studies. The IDA method can be divided into two broad categories of decomposition technique: 1) the Laspeyres Index and 2) the Divisia Index [30,31]. The Laspeyres Index measures the percentage of change in a particular aspect of a group of items over time. The index uses weights based on values in a specified base year. The Divisia index, on the other hand, is a weighted sum of logarithmic growth rates. Here, the weights are the components’ shares in total value, which are given in the form of an integral line. However, regardless of whether the Laspeyres method or the Divisia index decomposition method is used, the residual value

* Corresponding author.
E-mail address: qiangwang7@outlook.com (Q. Wang).

http://dx.doi.org/10.1016/j.energy.2017.03.111
0360-5442/

cannot be eliminated, thus negatively impacting on the accuracy of the overall analysis.

In this paper, we try to figure out what the influencing factors are and how they work to change the CO_2 emission during electricity generation. Decoupling analysis of each effect is made, based on the results and analysis of decomposition. In our paper, on the basis of previous studies, we applied the preferred logarithmic mean Divisia index (LMDI) method. We used this method because of its advantages in terms of path independency, ability to handle zero values and consistency in aggregation [32–37]. Ang recommended the LMDI method due to its theoretical foundations, adaptability, ease of use, results interpretation, and other desirable properties [38]. Moreover, our study applies both the additive LMDI method and multiplicative LMDI method. Using the two methods is better at showing how the driving factors affect the levels of carbon dioxide emissions caused by electricity generation (compared to a single technology or process).

Previous studies tended to pay more attention to the decomposition of CO_2 emissions from regional or sector perspectives. Cansino studied the influencing effects of various sectors (including economic structures) by using a multisector analysis approach with data from the various sectors data [39]. Fernández and Landajo analyzed the aggregate energy consumption in the EU-27 countries by using the decomposition method [40]. Akbostanci studied the decomposition of CO_2 emissions in the Philippines from the perspective of fuel combustion and electricity generation [41]. Baldwin forecasted the CO_2 emissions of different states in the US by using the Vector Auto Regression (VAR) method [42]. However, the decoupling status and internal attribution analysis on the basis of decomposition is severely deficient. For this reason, our paper aims to report the status of decoupling between coal-fired CO_2 emissions and the growth in the electric sector. Our findings are based on the LMDI results in Shandong Province, rather than from just decomposition.

Based on the previous studies, our study decomposes the energy-related CO_2 emissions of the electric power sector in Shandong Province during the period from 1995 to 2012. We do this by applying the multilevel LMDI method. We chose these years, as this was a period of both rapid development in the electric power sector and a time of a rising trend in the level of CO_2 emissions caused by power generation. Moreover, on the basis of our decomposition results, we introduced a novel decoupling index, in order to demonstrate the relationship between the CO_2 from the electric power sector and the growth of electricity generation in Shandong Province. We also show the degree of the influence of each factor by analyzing the decoupling status and the decoupling index. After the analysis of the influencing mechanisms, feasible measures are given as suggestions for policy making.

2. Methodologies

We drew a flow chart of modeling concepts and methodologies to demonstrate the modeling concepts clearly, the process is shown in Fig. 1.

2.1. Energy-related CO_2 emission estimation approach

To estimate the level of CO_2 emissions caused by electricity generation, we applied the method proposed in the Intergovernmental Panel on Climate Change (IPCC) guidelines [43]. Using this method, the total energy-related CO_2 emissions caused by electricity generation in Shandong Province can be calculated using the equation below:

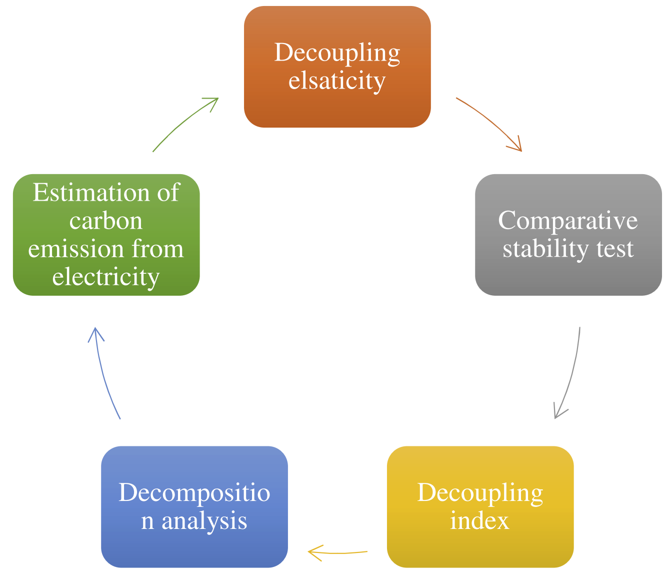

Fig. 1. Flow chart of modeling concepts and methodologies.

$$C^T = \sum_i C_i = \sum_i E_i * EF_i = \sum_i E_i * SC_i * O_i * k \quad (1)$$

In this equation, C^T refers to the total CO_2 emissions caused by electricity generation in year t; C_i(Mt) represents the CO_2 emissions caused by fuel i; E_i (Million ton of coal equivalent [Mtce]) and EF_i($kgCO_2/kg$ or $kgCO_2/m3$) indicate the total energy consumption and total CO_2 emission coefficient of fuel i; SC_i(tC/TJ) and O_i refer to the carbon content of unit calorific value and the fraction of carbon oxidized by fuel type i, and k indicates the constant coefficient (molecular weight of CO_2 divided by molecular weight of carbon). The potential carbon content, oxidation rate, and CO_2 emission factors are listed in Table 1.

2.2. Decoupling elasticity index

To test whether the development of the electric sector and the environmental protection are out of sync, we e applied the electric output elasticity of CO_2 emissions, in order to show the decoupling status. The method is exhibited in Eq. (2):

$$\beta = \%\Delta C / \%\Delta T = \left(\frac{\Delta C}{C^0}\right) \Big/ \left(\frac{\Delta T}{T^0}\right) = \frac{C^t/C^0 - 1}{T^t/T^0 - 1} \quad (2)$$

Here, β is the electricity output elasticity of CO_2 emissions; $\%\Delta C$ and $\%\Delta T$ refer to the percentage of change in carbon dioxide emissions and the percentage of change in the output of electricity; C^t and T^t represent the CO_2 emissions and the electric output in year t. According to the former studies [44–49], we show the eight possibilities, respectively, in Table 2.

2.3. Multilevel index decomposition for decoupling

In order to demonstrate the decoupling status more clearly, we employ a novel decoupling index method on the basis of the decomposition results. Firstly, based on an expanded Kaya identity [50–55] and the research of Ang [56–58], we applied both additive LMDI and multiplicative LMDI to probe the driving factors of the CO_2 emissions caused by electricity generation. Among the various index decomposition methods, Ang recommended that LMDI is a better method than others in many aspects, including LMDI's