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Investigation of carbon dioxide emission in China by primary component analysis

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HIGHLIGHTS

- Before OLS regress analysis is used, principle component analysis is used to eliminate the variables' correlation.
- The CO_2 emission is decomposed according to the variables.
- The variables contained not only population, but also economic structure and economic scale.

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ABSTRACT

Principal component analysis (PCA) is employed to investigate the relationship between CO_2 emissions (COEs) stemming from fossil fuel burning and cement manufacturing and their affecting factors. Eight affecting factors, namely, Population (*P*), Urban Population (*UP*); the Output Values of Primary Industry (*PIOV*), Secondary Industry (*SIOV*), and Tertiary Industry (*TIOV*); and the Proportions of Primary Industry's Output Value (*PPIOV*), Secondary Industry's Output Value (*PSIOV*), and Tertiary Industry's Output Value (*PTIOV*), are chosen. PCA is employed to eliminate the multicollinearity of the affecting factors. Two principal components, which can explain 92.86% of the variance of the eight affecting factors, are chosen as variables in the regression analysis. Ordinary least square regression is used to estimate multiple linear regression models, in which COEs and the principal components serve as dependent and independent variables, respectively. The results are given in the following. (1) Theoretically, the carbon intensities of *PIOV*, *SIOV*, and *TIOV* are 2573.4693, 552.7036, and 606.0791 kt per one billion $, respectively. The incomplete statistical data, the different statistical standards, and the ideology of self sufficiency and peasantry appear to show that the carbon intensity of *PIOV* is higher than those of *SIOV* and *TIOV* in China. (2) *PPIOV*, *PSIOV*, and *PTIOV* influence the fluctuations of COE. The parameters of *PPIOV*, *PSIOV*, and *PTIOV* are −2706946.7564, 2557300.5450, and 3924767.9807 kt, respectively. As the economic structure of China is strongly tied to technology level, the period when *PIOV* plays the leading position is characterized by lagging technology and economic developing. Thus, the influence of *PPIOV* has a negative value. As the increase of *PSIOV* and *PTIOV* is always followed by technological innovation and economic development, *PSIOV* and *PTIOV* have the opposite influence. (3) The carbon intensities of *P* and *UP* are 1.1029 and 1.7862 kt per thousand people, respectively. The carbon intensity of the rural population can be inferred to be lower than 1.1029 kt per thousand people. The characteristics of poverty and the use of bio-energy in rural areas result in a carbon intensity of the rural population that is lower than that of *P*.

Abbreviations: BTS, the Bartlett's test of sphericity; $C_{i,j}$, the loading coefficient which indicates how much the *i*th variable participates in defining the PC_j; CO_2, the CO_2 emissions defined in this study are those stemming from fossil fuel burning and cement manufacturing. They include the CO_2 produced by gas flaring and that produced during the consumption of solid, liquid, and gas fuels. Its unit is kiloton; GHG, Green House Gas; *GDP*, the Gross Domestic Production in China, its unit is one billion $; KMO, the Kaiser–Meyer–Olkin; *P*, the Population, its unit is one million people; *PIOV*, the Output Value of Primary Industry, its unit is one billion $; *PPIOV*, the Proportion of Primary Industry's Output Value, its unit is %; *PTIOV*, the Proportion of Tertiary Industry's Output Value, its unit is %; *PSIOV*, the Proportion of Secondary Industry's Output Value, its unit is %; *SIOV*, the Output Value of Secondary Industry, its unit is one billion $; *TIOV*, the Output Value of Tertiary Industry, its unit is one billion $; *UP*, the Urban Population, its unit is one million people.

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1. Introduction

Since the 1990s, climate change that features global warming has generated increasing attention in the international community. The accumulation of greenhouse gas (GHG) emission plays an important role in global warming (Ford, 2008). CO_2 emission (COE) which accounts for over 80% of the GHG emissions is one of the main causes of global warming. COEs are always attributed to the combustion of fossil fuels, such as gasoline in vehicles, coal in power plants, and gas in households (IPCC, 2007). The Forth Assessment Report released by Intergovernmental Panel on Climate Change in 2007 cited COEs as one of the driving forces that lead to the high concentration of GHGs in the atmosphere. According to this report, Annex 1 countries have begun to mitigate their COE under the Kyoto Protocol. Meanwhile, the major developing countries, such as China and India, are faced with an increasing international pressure to reduce GHG emissions (Zhang, 2004).

The Chinese economy has been growing rapidly since the 1970s when China initiated an economic reform program. In 2003, China emitted 3.17 billion tons of CO_2, which accounted for 14.9% of the global total emissions during that period (IEA, 2005). In 2005, China consumed 1554 million tons of standard coal and consequently became the second largest energy consumer and emitter of GHG in the world (BP, 2006; IEA, 2005). Some researchers contend that China has replaced the USA as the largest emitter of CO_2 (Zhao and Ji, 2008). High total of total energy consumption and the primary energy consumption structure dominated by coal define the status of COE (Ramanathan, 2006).

The relationship among energy consumption, economic growth, and COEs has been extensively discussed in literature. The causality between energy consumption and economic growth is generally argumentative or uncertain. Unidirectional, bidirectional, and no-directional causalities exist in different study areas or are based on different research methods. An auto-regressive distributed lag (ARDL) bounds test approach has been used to test the causality between energy consumption and economic growth in Portugal, Italy, Greece, Spain, and Turkey; the empirical results suggest that a bidirectional causality exists in the long-run and short run, thus supporting the feedback hypothesis (Fuinhas and Marques, 2012). Panel cointegration techniques, including panel unit root test, panel cointegration, and Granger causality test, have also been used to study the causality between energy consumption and economic development in 15 African countries; the causality ranges from energy consumption to gross domestic product (*GDP*) in the long-run and from *GDP* to energy consumption in the short run (Al-mulali and Sab, 2012). As applied methods differ among countries, different causalities may be found between energy consumption and economic growth.

COE is directly caused by energy consumption, and energy consumption is mainly caused by economic growth and daily living (Zhang et al., 2011a). Economic indicators, such as *GDP*, the Output Value of Primary Industry (*PIOV*), the Output Value of Secondary Industry (*SIOV*), the Output Value of Tertiary Industry (*TIOV*), the Proportion of Primary Industry's Output Value (*PPIOV*), the Proportion of Secondary Industry's Output Value (*PSIOV*), the Proportion of Tertiary Industry's Output Value (*PTIOV*), and the Person Income (*PI*), and the Social factors such as the Population (*P*) and the Household Numbers (HN), are usually employed (Deng et al., 2014) to investigate energy consumption.

The former Chinese leader promised that China will deliver a 45% reduction in carbon intensity by 2020. This target is viewed as a difficult goal to reach. The 12th Five Year Plan for our national economic and social development highlights the following plans: firstly, the share of non-fossil fuel in the primary energy consumption will increase to 11.4%, and the share of installed non-fossil fuel capacity will increase to 30% by 2015; secondly, the energy consumption of the unit production value and COE of the unit production value will be cut by 16% and 17%, respectively, by 2015 compared with the 2010 values. To achieve these goals, the following questions must be answered. How is energy consumed? How is CO_2 emitted? How can energy consumption be enhanced? How can energy consumption and COE be reduced? Many studies have investigated energy-saving methods or CO_2 reducing methods for a specific type of industry, including agricultural industry (Li et al., 2010), steel industry (Cheng et al., 2010), building industry (Zhang et al., 2006), transportation (Hofer et al., 2010), retail industry (Li and Sha, 2014) and so on.

The present investigation aims to use principle component analysis (PCA) to decompose the COE of China. The rest of this paper is structured as follows. Section 2 presents a brief literature review on COE. Section 3 develops PCA and ordinary least square (OLS) regression, both of which are used to decompose the COE of China. Section 4 discusses the results of PCA and OLS regression, and then discusses the reasons that cause the result.

2. Literature review

The panel cointegration techniques, including panel unit root, panel cointegration, and Granger causality test, are the widely used methods for panel contest. These methods consist of four steps in investigating the causality between independent and dependent variables (Mahamat, 2012). Firstly, the panel unit root test for the series is conducted. Second, cointegration test is carried out if the series is integrated at order one. Third, the long-run cointegration vector is estimated by the panel fully modified OLS and the panel dynamic OLS methods, if the series is cointegrated. The results of the panel cointegration techniques answer whether COE is the cause of the economic indicators, or whether the economic indicators are the cause of COE. If a random error exists in the trend in variables, the traditional regression analysis, such as OLS, will lose its ability to show the relationship among variables correctly. The panel cointegration techniques can test the random errors of variables and solve the problem according to error-correcting models. However, these techniques have two imperfections. First, different results are obtained when different error-correcting models are applied. Second, the economic sense of the error-correcting models or practical sense of variables may become fuzzy as the correcting models transform variables.

Most studies on COE performance are based on a cross-sectional data framework. By contrast, the Malmquist performance index is based on the time-series data. This index can measure the changes of COE performance over time. Compared with partial indicators, the Malmquist performance index measures the relative COE performance according to production efficiency. This index ranks countries based on their dynamic behavior toward the empirical production frontiers. The index was initially developed as a ratio of two distance functions for the measurement of productivity (Caves et al., 1982). The Malmquist productively index has been widely applied in different areas, such as environmental performance (Zhou et al., 2008). The Malmquist performance index can measure the change in the COE performance of a certain country or area from one period to another and decompose COE performance into two components, namely, efficiency and technological change (Zhou et al., 2010).

Input–output models are generally divided into physical and value input–output tables. When the relationship between COE and economic growth is discussed, the physical input–output tables are often applied. The physical input–output tables can reflect the technical effects of each production department. For example, the COEs of each production department could be divided into direct and indirect emissions based on the physical input–output tables (Acquaye and Duffy, 2010). The direct COE is released as a result of the activities directly related to construction on site, such as excavation, fit-out, and plant operation. Indirect COE is associated with the use of energy in necessary construction-related activities, which are the upstream of site work in the construction procurement supply chain. The majority of the content of the physical input–output tables is calculated by the nominal parameters; thus,