Applied Energy 106 (2013) 65–71

Contents lists available at SciVerse ScienceDirect

Applied Energy

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

Examining the impact factors of energy-related CO_2 emissions using the STIRPAT model in Guangdong Province, China

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HIGHLIGHTS

- We employ the STIRPAT model to examine the impact factors of CO_2 emissions in Guangdong Province.
- We employed the ridge regression to fit the extended STIRPAT model.
- Population size, urbanization and GDP per capita, industrialization increase emissions.
- Carbon intensity, energy structure and export dependence decrease emissions.
- Population scale is the most important impact factors of CO_2 emissions.

ARTICLE INFO

Article history:
Received 28 July 2012
Received in revised form 3 January 2013
Accepted 15 January 2013
Available online 13 February 2013

Keywords:
CO_2 emissions
STIRPAT model
Ridge regression
Elastic coefficients
Guangdong Province

ABSTRACT

To find the key impact factors of CO_2 emissions to realize the carbon intensity target, this paper examined the impact factors of population, economic level, technology level, urbanization level, industrialization level, service level, energy consumption structure and foreign trade degree on the energy-related CO_2 emissions in Guangdong Province, China from 1980 to 2010 using an extended STIRPAT model. We employed ridge regression to fit the extended STIRPAT model. Empirical results indicate that factors such as population, urbanization level, GDP per capita, industrialization level and service level, can cause an increase in CO_2 emissions. However, technology level, energy consumption structure and foreign trade degree can lead to a decrease in CO_2 emissions. The estimated elastic coefficients suggest that population is the most important impact factor of CO_2 emissions. Industrialization level, urbanization level, energy consumption structure, service level and GDP per capita are also significant impact factors, but the other factors such as technology level and foreign trade degree are less important impact factors. Some policy recommendations are also given on how to mitigate the growth of CO_2 emissions.

1. Introduction

There is a global consensus that climate change is being driven by an increase in atmospheric greenhouse gases, most notably CO_2 emissions. To deal with this issue, Chinese government proposed targets in December 2009 aimed at controlling greenhouse gas emissions. More specifically, it was decided that CO_2 emissions per unit gross domestic product (GDP) (carbon intensity) should be cut by 40–45% in 2020 compared to that in 2005. This is a binding target in the mid-long term plans for the national economic and social development. In addition, "the Outline of National Economic and Social Development Plan in the Twelfth Five-year (2011–2015)" clearly pointed out that energy consumption must be reduced by 16% and carbon intensity must be decreased by 17% during the period its validity. Moreover, in January 2012, "China's controlling greenhouse gas emissions scheme for the Twelfth Five-Year Plan" required Guangdong Province to reduce its carbon intensity by 19.5%. To realize the carbon intensity reduction targets, we need to examine the influence factors of CO_2 emissions, and then find the appropriate CO_2 emissions reduction paths for Guangdong Province.

As the most affluent and populous province in China, Guangdong Province intends to take the lead in relieving and adapting to the challenges posed by climate change. In the past 30 years, the GDP of Guangdong Province has steadily increased with an average annual increase in excess of 18%, reaching 4600 billion Yuan in 2010. Moreover, as the economic development is

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http://dx.doi.org/10.1016/j.apenergy.2013.01.036

dependent on energy consumption, the latter has also increased in Guangdong Province. In fact, the province consumed up to 21.9 million tons of standard coal in 2010, with an annual growth rate in energy consumption approaching 11% from 2000 to date. Accordingly, CO_2 emissions have also increased greatly, which poses a significant problem as far as energy saving and emission reduction are concerned. However, because Guangdong is extremely deficient in energy resources, energy restrictions present a choke effect on her economic and social development, which makes the cost of economic growth largely increase. Therefore, energy saving and emission reductions are imperative for Guangdong Province, but in such a manner as to augment, rather than impede, socio-economic growth.

Currently, many different methods are used to examine the impact factors of CO_2 emissions. Among them, the logarithmic mean Divisia index (LMDI) and stochastic impact by regression on population, affluence, and technology (STIRPAT) models are the two most well-known methods used for examining such factors. Wang et al. [1], Zhu et al. [2], Elif et al. [3] and Tan et al. [4] used the LMDI model to decompose Chinese CO_2 emissions into population, GDP per capita, energy consumption intensity and energy consumption structure. Guo et al. [5], Zhao and Long [6] and Liu et al. [7] applied the LMDI model to examine the impact factors of CO_2 emissions in Shanghai, Jiangsu Province and Beijing, respectively. These workers decomposed CO_2 emissions into the impact factors of GDP, industrial structure, energy consumption intensity, energy consumption structure and carbon emission coefficient. More recently, Song [8] used the LMDI model to discuss CO_2 emissions in Shandong Province in terms of population, GDP per capita, industrial structure, energy consumption intensity, energy consumption structure and carbon emission coefficient. These studies provide some useful scientific supports for making out effective CO_2 reduction strategies. However, within the LMDI model, the impact factors considered only are population, GDP per capita, industrial structure, energy consumption intensity, energy consumption structure and carbon emission coefficient. As a result, the LMDI model is a rather poor method of examining more detailed influence factors, so it can only provide limited supportive information for shaping CO_2 emissions reduction strategies. Moreover, the STIRPAT model can examine much more impact factors than the LMDI model, which makes its conclusions much more reliable. Consequently, the STIRPAT model has become an increasingly dominant method in examining the impact factors of CO_2 emissions.

In recent years, the STIRPAT model has been widely applied by more and more researchers. York et al. [9] and Shi [10] studied the relationship between CO_2 emissions and population using the STIRPAT model. Fan et al. [11] used the STIRPAT model to examine the impact factors of CO_2 emissions in countries with different income levels. Lin et al. [12], Zhu et al. [13], Li et al. [14], Song et al. [15], Li et al. [16], Zhu and Peng [17] and Wei [18], used the STIRPAT model to make an analysis of the impact factors of CO_2 emissions in China. Shao et al. [19] and Wang et al. [20] also applied the STIRPAT model to make an analysis of the impact factors of CO_2 emissions in Shanghai. More recently, Wang et al. [21] empirically studied the influences of urbanization level, economic level, industry proportion, tertiary industry proportion, energy intensity and R&D output on CO_2 emissions in Beijing using an improved STIRPAT model incorporating partial least square regression.

All of the studies outlined above prove that STIRPAT is an efficient model for examining the impact factors of CO_2 emissions. However, existing studies have inevitable shortcomings. Firstly, the theory for impact factors of CO_2 emissions is relatively weak, focused mainly on population, economic level and technology level, and seldom on energy structure, industrial structure, urbanization level, industrialized level and foreign trade degree. These additional factors should be explored for their influences on CO_2 emissions. Secondly, existing studies often adopt the input–output method and the structure decomposition method, but seldom use the econometric analysis method, which may lead to their results remaining less than convincing. Nevertheless, as the number of impact factors of CO_2 emissions is considerable, there may be multicollinearities among them. Currently, the STIRPAT model most widely used in studies involves ordinary least squares (OLS) regression, which may lead to unreliable regression coefficients. Thirdly, most existing studies focus on the national, and seldom on the provincial, level: due this benign neglect, the inter-provincial differences result in different conclusions, thereby necessitating further research. Fourthly, to the best of our knowledge, there are no reports in the literature that use the STIRPAT model to examine the impact factors of CO_2 emissions in Guangdong Province. Moreover, to avoid multicollinearity, we employed ridge regression to fit the extended STIRPAT model.

The innovation in, and contribution of, this paper lies in its examination of the following impact factors: population, economic level, technology level, urbanization level, industrialization level, service level, energy consumption structure, and foreign trade degree on the energy-related CO_2 emissions in Guangdong Province, China using an extended STIRPAT model incorporating ridge regression, to help policy makers design appropriate energy saving and emission reduction measures for Guangdong Province. Moreover, this paper can also be viewed as a prime example of how to examine the impact factors of CO_2 emissions of a province region as a whole.

The remainder of this paper is organized as follows: Section 2 describes the study area; Section 3 describes the extended STIRPAT model incorporating ridge regression, data are presented in Section 4; results and discussion are given in Section 5, and the conclusions and policy implications are summarized in Section 6.

2. Study area

Guangdong Province is located in southern China, adjacent to the special administrative regions of Hong Kong and Macao. The whole area lies between 20°09′ and 25°31′N and 109°4′ and 117°20′E, as shown in Fig. 1. It accounts for 1.85% of the land area of the whole country (~179,800 km^2).

In 2010, the province's GDP reached 4600 billion Yuan, accounting for 11.4% of that of the whole country. At that time, it had ranked first in terms of economic performance for 22 successive years. GDP per capita was up to 44,103 Yuan (~6700 USD based on mean annual exchange rate) close to the income levels of middle developed countries or regions.

The province's permanent population in 2010 was 104,300,000, ranking first in China. The number of people aged 65 and above reached 7,040,000, accounting for 6.8% of the population. This is lower than average level for the country as a whole, which was 8.87% at the time. The main reason for this is the large number of workers from other provinces that work in Guangdong Province, which enlarges the proportion of working-age population. In addition, the urban population was 69,030,000 (66.2% of the total population) which was much larger than the average of the whole country, which was only 49.7%. This is due to an increase in the quantity and scale of urban areas, on the one hand, and large numbers of migrants from other provinces collecting in these urban areas, on the other.

In the last 30 years, energy consumption in Guangdong Province has maintained a rapid growth. From 1980 to 2010, the coal consumption increased from 23.15 to 219 million tons, implying a mean annual increase of 8%. From 2000, in particular, the amplitude of the annual increase in energy consumption reached 11%, and it is predicted that this rapid growth rate will be maintained.