Research on Relationship between Energy Saving and Emission Reduction Efficiency and Economic Development of Guangdong

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Abstract. First, energy consumption and industrial waste gas emission factors are selected to analyze the energy conservation and emission reduction efficiency of Guangdong. Based on which, panel data model is established selecting the three indicator variables of per capita GDP, unit energy consumption, and unit industrial waste gas emission. In addition a series of empirical analysis is carried out through software to explore and research the relationship between energy saving and emission reduction efficiency and economic development.

1. Introduction
As the world’s economy develops rapidly since the 20th century, problems such as environmental pollution, energy crisis, and climate changes become increasingly highlighted. Therefore, a large number of scholars attach their attention on how to coordinate the relationship between economic development of human society and ecological environment. It is known from the environmental Kuznets curve (EKC) model that economic development and energy saving and emission reduction play the same positive effect on the improvement of environment. Because benefits generated from energy conservation and emission reduction promote economic development, while economic development advances energy conservation and emission reduction, indicating that improving the efficiency and effectiveness of energy conservation and emission reduction is conductive to further promote the economic growth. In this paper, Guangdong Province is taken as an example to analyze the relationship between its current energy saving and emission reduction efficiency and economic development, so as to explore effective ways for achieving their coordinated developments.

2. Evaluation on Energy Saving and Emission Reduction of Guangdong Province
Over the decade, Guangdong Province has been insisting on implementing strategic measures such as energy saving and emission reduction, optimal and intensive land-use, and environment-driving transformation to speed up building the resource-saving and environment-friendly production methods and consumption models, so as to vigorously develop the green economy and constantly improve the ability to sustain economic development. During the "Twelfth Five-Year Plan" period, the entire province's energy consumption per GDP has dropped by 20.98%, overfulfilling the national goal of reducing energy consumption per GDP by 18% set during the "Twelfth Five-Year Plan" period. This paper will evaluate the energy saving and emission reduction efficiency of Guangdong Province from two indicators of energy consumption and industrial waste gas emissions.
2.1 Energy consumption.

Energy consumption constitutes one of the main costs of economic development and wealth creation, which reflects the economic development level to a certain extent. Generally, extensive economy develops at the cost of high energy consumption. However, in intensive economy, energy is generally consumed slower than slower the creation of social wealth. That’s why this indicator can both measure the energy saving and emission reduction efficiency, and reflect the economic development level [1]. Unit energy consumption is the specific indicator adopted, which is also known as energy intensity[2]. Calculation formula: Energy consumption per GDP (one ton of standard coal/10,000 yuan) = total energy consumption (one ton of standard coal)/gross domestic product (10,000 yuan). First, the unit energy consumption is calculated based on the conversion of relevant data accumulated by Guangdong Province over the past 10 years. Figure 1 is the change trend chart:

![Unit energy consumption](image)

Data source: Statistical Yearbook of Guangdong Province

It can be seen from the trend chart that the overall unit energy consumption shows a decreasing trend, that is, the energy consumed every unit of GDP increased gradually decreases. Such a situation indicates that Guangdong has steadily implemented the overall energy saving and emission reduction works. Meanwhile, its green economic benefits gradually stand out. However, the decline speed is slowing down considering from the decline speed in the past four years, indicating that energy efficiency still needs to be further improved.

2.2 Industrial Waste Gas Emissions.

Industrial waste gas emission serves as an important indicator reflecting the basic situation of environmental protection. In this paper, the industrial waste gas emissions per GDP is taken as another reference variable for measuring the energy saving and emission reduction efficiency, which is referred to as unit industrial waste gas emissions for short, and marked as UIWG [3]. Calculation formula: unit industrial waste gas emissions = the total amount of industrial waste gas emissions / gross domestic product. It can be seen from Figure 2 that over the past ten years, the unit industrial waste gas emission in Guangdong Province generally shows a declining trend, which has been dropped from 0.56 in 2009 to 0.45 in 2018. Such a result shows that the environmental pollution level decreases. However, the overall decrease is not that ideal, and significant increasing trend even appeared in 2010 and 2016 respectively.
Figure 2: Trend of the industrial waste gas emissions in Guangdong
Data source: Statistical Yearbook of Guangdong Province

3. Empirical Analysis of Relationship between Energy Saving and Emission Reduction Efficiency and Economic Development of Guangdong Province.

3.1. Model Design and Data Description
To deeply analyze the relationship between energy saving and emission reduction efficiency and economic development quality of Guangdong Province, so as to explore and research on the effective path for the low-carbon economic development in Guangdong Province, panel data analysis will be carried out in this paper to analyze the unit energy consumption, unit industrial waste gas emission and GDP per capita of 21 prefecture-level cities in Guangdong Province. Among which, unit energy consumption and unit industrial waste gas emissions are taken as explanatory variables, that is, the independent variables, while GDP per capita is taken as the explanatory variable, that is, the dependent variables. Moreover, logarithmic processing is performed to the above-mentioned three variables to stabilize the variable series, and they are respectively marked as: LNUEC, LNUIWG, LNPGDP; in addition, relevant cross-sectional data of prefecture-level in Guangdong Province from 2009 to 2018 is selected for empirical analysis. Based on which, the following panel data model is built [4]:

$$\text{LNPGDP} = c + a \text{LNUEC} + b \text{LNUIWG} + \xi$$

3.2. Unit Root Test
Although panel data is conducive to stabilize data and reduce the correlation between variables, problems such as change trend or intercept exists, as well as unit roots. Therefore, unit root test is also required for panel data to enhance the stability of data. Such a requirement is more needed by economic variables mentioned in this paper. Since they are characterized in time trend, the unit root test needs to be carried out between modeling to avoid data instability, so as to ensure the effectiveness of model analysis. Generally, 6 methods are involved for the unit root test of panel data. However, only 2 commonly used methods are adopted in this paper to increase the reliability of data, that is, LLC (Levin-Lin-Chu) test and IPS (Im-Pesaran-Shin) test. Here are the test results:

| Method         | Statistic | Prob.  |
|----------------|-----------|--------|
| LLC            | 0.6823    | 0.9564 |
| -17.4417       | 0.0000    |
| IPS            | 13.2869   | 1.0000 |
| -4.7883        | 0.0000    |
It can be seen from the test data in Table 1 that both the tests show that the original sequence of all three variables are unstable. However, the first-order difference sequence is stable, which indicates that the three index variables are of the same order and suitable for co-integration.

3.3 Co-integration Test
Co-integration test is carried out for the variables to verify whether a long-term stable equilibrium relationship exists between them. The panel data co-integration test methods generally involve 3 kinds of Kao test, Pedroni test, and Westerlund test. The more flexible Pedroni test is adopted in this paper. It can be seen from the test results in Table 2 that a long-term and stable equilibrium relationship indeed exists between the GDP per capita and unit energy consumption, and unit industrial waste gas emissions.

| Table 2 Pedroni Test Results |
|-----------------------------|
| Pedroni Test                 | cointegration |
| Panel v                      | 2.7855        |
| ( 0.0894)                    |               |
| Panel PP                     | -9.3341       |
| ( 0.0000)                    |               |
| Panel ADF                    | -9.6617       |
| ( 0.0000)                    |               |
| Group PP                     | -8.5663       |
| ( 0.0000)                    |               |
| Group ADF                    | -8.7146       |
| ( 0.0000)                    |               |

3.4 OLS Estimation
Next, F test is carried out for panel data, and a fixed effects model is determined to be built at last. And the following model is obtained through adopting the non-weighted OLS estimation method:

\[
\text{LNPGDP}=3.5498+0.4469\text{LNUEC}+1.5731\text{LNUIWG}
\]

\[
\begin{align*}
(137.6593) & \quad (7.1711) & \quad (59.3881) \\
R^2=0.9916 & \quad DW=2.36 
\end{align*}
\]

Regression results show that each variable is characterized in high degree of fitting proved by the test, and no important variables are missing. Therefore, the model is reasonably built and is able to fully explain the relationship between variables.

4. suggestions

4.1 Optimize industrial structure and increase the proportion of green industries. In recent years, changes constantly occurred to the proportion of three industries in Guangdong Province. During which, the tertiary industry occupies an increasingly big proportion, while the secondary industry losses its proportion. However, industrial enterprises with certain size still emit a large amount of waste gas. Under such circumstances, it is required to relocate the "three high" industries of high pollution, high energy consumption and high water consumption in accordance with the energy saving and emission reduction efficiency differences. Otherwise, it needs to carry out industrial transformation and upgrading, so as to increase energy consumption, reduce environmental pollution, and create more green wealth.

4.2 Optimize energy consumption structure and increase the consumption proportion of new energies. At present, Guangdong province is characterized in single energy consumption structure. Meanwhile, it relies more on fossil energy consumption and possesses a low proportion of new energies. As a result, huge difficulties are encountered in environmental pollution control and governance. Therefore, the government is required to vigorously advocate enterprises to use various clean energies and
renewable energies, and improve social activity participants’ awareness and consciousness on new energy consumption through specific measures such as financial subsidies or technical supports [5].

4.3 Accelerate research and development of energy saving and emission reduction technologies and promote results transformation, and improve environmental protection efficiency. The energy saving and emission reduction technology innovation level plays a decisive effect for reducing unit energy consumption and unit industrial waste gas emissions. So that more efforts shall be made by government in increasing investment in the research and development of energy saving and emission reduction related technologies, providing certain financing facilities and policy favors to some newly emerging environmental technology development enterprises, and perfecting corresponding results transformation and intellectual property protection mechanisms, so as to enhance and activate enterprises’ enthusiasm in independent research and development [6]. Moreover, government shall establish the “industry-university-research” platform for the energy saving and emission reduction technology innovation, so as to improve the communication efficiency between enterprises, universities and relevant research institutions.

5. Conclusion
This paper analyzes the impact of energy conservation and emission reduction efficiency on economic development in Guangdong Province. Considering from the coefficient of each variable, all unit energy consumption and unit industrial waste gas emissions are positively correlated to the GDP per capita, indicating that the increase of GDP per capita of Guangdong Province still takes the energy consumption and industrial waste gas emissions as its cost. Meanwhile, although energy saving and emission reduction efficiency is improved to a certain extent, more efforts shall be made to energy saving and emission reduction if achieving green economic growth is set as the goal. Moreover, the coefficient of unit energy consumption is 0.4469, which is significantly smaller than that of unit industrial waste gas emissions, indicating a great improvement in energy use efficiency and significant energy saving effect. Generally speaking, the smaller the unit energy consumption is, the higher the regional technical level is. Therefore, it can be concluded that Guangdong province has constantly improved its technological innovation level and steadily improved the economic development quality; however, Guangdong province fails to control and govern the industrial waste gas emission. And for every increase of 1 unit of GDP per capita, 1.5731 units industrial waste gas emissions increase accordingly, indicating that the environment pollution pressure is still huge in economic development. Therefore, we should further improve the efficiency of energy conservation and emission reduction by optimizing the industrial structure, optimizing the energy consumption structure, accelerating the research and development of energy conservation and emission reduction technology and achievement transformation, so as to promote the rapid and healthy development of green economy.

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