Influences Energy Consumption has on Green GDP Growth in China

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Abstract: This paper examines the relationship between China’s total energy consumption growth and GGDP growth based on the data of 1997-2016. With path analysis employed, the direct and indirect influence on GGDP growth rate exerted by several energy consumption ratios as well as the relationship among them is explored. Furtherly, the author determines how much each of these ratios contributes to GGDP. This research suggests that proportion of natural gas consumption and that of other energy consumption are the two major drivers of GGDP growth, while coal and oil consumption proportion inhibits GGDP Growth. Specifically, increasing the proportion of natural gas consumption contributes the most to GGDP growth.

1. Introduction
With the acceleration of industrialization in the world, the contradiction between economic development and energy and environment is becoming more and more prominent. As the world’s second largest economy, the rapid growth of China's economy for many years has caused serious ecological and environmental problems, and the further development of economy is confronted with severe constraints of resource environment limitation. Therefore, the relationship between energy consumption and economy has been a hot topic for scholars. Zhaolixia (1998) introduced energy as a new variable into Cobb-douglas production function, and obtained the result that China's energy consumption has positive correlation with economic growth [1]. Han Zhiyong (2004) used the E-g two-step method to analyze the GDP sequence and total energy consumption data between 1978-2000, and concluded that there is a two-way causality between energy consumption and GDP [2]. Based on 1990-2014 series data, Wu Mingran (2016) established a vector autoregressive model (VAR) to reveal the dynamic relationship between energy consumption and economic growth. The result shows that there is a long-term stable relationship between energy and economic system [3].

With China's carbon intensity targets being put forward in 2009, many scholars have been studying the relationship between carbon emissions and energy consumption in recent years. Based on divisia index decomposition method, Xu Guangyue (2010) concluded that there is a long-term cointegration relationship between energy consumption, carbon emission and economic growth and this causality varies with region [4]. Wang Shaohua (2013) studied the optimization of energy structure based on Low-carbon economy by using rough set theory and AHP method [5].

Characterized by safeguarding the living environment of mankind, protecting resources and energy and benefiting human health, the green economy is highly valued at present. The above literature mainly studied the relationship between energy consumption, low-carbon development and economic growth respectively but not directly linked. Besides, the contribution of energy consumption as a driving factor
to the low-carbon economy is mainly studied, but deep study on the impact of internal changes of energy structure on the development of Low-carbon economy can hardly be seen. This paper makes use of path analysis to clarify the relationship between energy consumption ratio and its direct and indirect relationship with GGDP, and analyzes the contribution of different kinds of energy to GGDP directly, thus providing reference for the optimization of energy structure to promote green economic growth.

2. Comparison of total energy consumption growth and GGDP growth in China

2.1. Data and its source
According to China Statistics Yearbook, China Energy Statistics Yearbook, World Energy Statistics Yearbook, Provincial and municipal Statistics Yearbook and annual water price adjustment plan of capital cities, the author collected 1997-2016 national GDP data, as well as coal, oil, natural gas and other energy’s (hydro, nuclear, wind power, etc.) annual consumption data, their proportion of total energy consumption and the data of prices needed in the calculation of GGDP.

2.2. GGDP Accounting
The accounting formula and calculation method of GGDP:
\[ \text{GGDP} = \text{GDP} - C - E \]
In the formula, \( C \) represents the cumulative depletion of natural resources. \( E \) represents the cumulative cost of environmental degradation [6]. To simplify the calculation, this paper let the value of water and energy consumption as \( C \) (Depletion value = Price \* Total consumption), and let handling costs of waste water, waste gas, general industrial solid waste and waste as \( E \) (Degradation cost = Unit handling price \* Waste discharge) [7].

2.3. Comparison of energy consumption growth and GGDP growth

According to Figure 1, green Gross Domestic Product growth rate in China is greater than the rate of energy consumption growth most of the time, for the reason that energy consumption is merely one of the factors that affect GGDP. What is more, in addition to 2001-2005 and recent years, these two growth rates are basically reversed. This is mainly because China used to rely heavily on conventional energy like coal and oil to promote economic development. The increase of total energy consumption would lead to the increase of environmental governance costs, thus inhibiting the growth of GGDP. However, in recent years, with the transformation of economic growth mode and development of new technologies and energy, this obstruction is slightly diminished.

3. The influence mechanism of energy consumption structure on GGDP growth
Path analysis is often used to describe the directed dependencies among a set of variables in statistics. This method is a development of simple correlation analysis for decomposing total effects into their constituent direct and indirect effects [8]. Path analysis was developed around 1918 by geneticist Sewall
Wright, who wrote about it more extensively in the 1920s [9]. It has since been applied to a vast array of complex modeling areas, including biology, psychology, sociology, and econometrics [10].

![Path analysis model](image)

**Fig.2. Path analysis model**

Path model is composed of a set of linear equations, which reflects the relationship between independent variables, intermediate variables, latent variables and dependent variables. For example, we may write as

\[
\begin{align*}
P_{1y} + r_{12}P_{2y} + \cdots + r_{1n}P_{n} &= r_{1y} \\
r_{21}P_{1y} + P_{2y} + \cdots + r_{2n}P_{n} &= r_{2y} \\
&\vdots \\
r_{ni}P_{1y} + r_{n2}P_{2y} + \cdots + P_{ny} &= r_{ny}
\end{align*}
\]  

(1)

Here, \( r_{ij} \) is the total association between \( x_i \) and \( y \), \( p_{ij} \) is both the total and direct effect of \( x_i \) on \( y \), and \( r_{ij}P_{ij} \) is the indirect effect of \( x_i \) on \( y \) [11]. Equation that the simple correlation coefficients of independent variable \( x_i \) and dependent variable \( y \) is equal to the sum of total direct path( \( p_{ij} \) ) and total indirect path (\( \sum_{i \neq j} r_{ij}P_{ij} \)) can be seen from the path model.

To analyze the influence mechanism of energy consumption structure on GGDP growth, we let \( y \) be GGDP growth rate, and \( x_i \) (i=1,2,3,4) be corresponding proportion of total energy consumption. Based on 1997-2016 statistical data and spss22.0, we get direct path coefficients of independent variables as

\[
\begin{align*}
p_{2y} &= -0.010, \quad p_{3y} = 0.681, \quad p_{4y} = 0.681 \\
r_{2y} &= -0.814, \quad r_{3y} = 0.981, \quad r_{4y} = 0.954
\end{align*}
\]

Results are in high correlation after t test. Through table 1 the total association of each variable on GGDP can be seen as

**Table 1. Path coefficients**

| Ind. var. | Tot. ass. | Ind. effect | By \( x2 \) | By \( x3 \) | By \( x4 \) | Total ind. |
|-----------|-----------|-------------|-------------|-------------|-------------|------------|
| x1        | -0.89     | -           | -           | -           | -           | -          |
| x2        | -0.82     | -0.01       | -           | -0.56       | -0.24       | -0.81      |
| x3        | 0.98      | 0.68        | 0.0087      | -           | 0.29        | 0.98       |
| x4        | 0.95      | 0.31        | 0.0078      | 0.63        | -           | 0.95       |
From the table above we can find proportion of coal and oil consumption are the main factors inhibiting the growth of GGDP in China, while Proportion of natural gas consumption and other energy consumption are the main drivers of GGDP growth. Therefore, reducing the proportion of coal and oil consumption and increasing the proportion of other energy and natural gas consumption [12] can effectively promote GGDP growth. According to table 1, the effect of energy consumption ratio on GGDP can be obtained, as shown in Figure 3(take proportion of natural gas consumption as an example).

![Fig.3. The mechanism analysis of the influence of natural gas consumption ratio on GGDP](image)

### 4. Contribution of energy consumption intensity to GGDP

#### 4.1. Data processing

To further analyse the relationship between data of energy consumption and GGDP, the author used standardized processing method to get energy consumption per capita and GGDP per capita. Besides, logarithm of coal consumption per capita $\ln E_1$, logarithm of oil consumption per capita $\ln E_2$, logarithm of natural gas consumption per capita $\ln E_3$, logarithm of other energy consumption per capita $\ln E_4$ and logarithm of GGDP are obtained through Logarithmic processing.

#### 4.2. Establishment and test of the model

**4.2.1. Linear regression of LNGGDP and logarithm of total energy consumption per capita LNE.**

With Eviews we can get the regression results as follows:

\[
\text{LNGGDP}=5.5382+1.7\ln \text{LNE}
\]

T-Statistic: 11.2238 27.2288

\[R^2=0.9763\]

This model illustrates that when energy consumption per capita increases by 1%, on average, it can lead to a 1.7881% increase in GGDP per capita [13]. This regression model’s coefficient of determination is 0.9763, which shows a high goodness of fit.

T-test for regression coefficients: Assume $h_0: \beta_1=0$ and $h_0: \beta_2=0$, degree of freedom=N-2=18, when at a confidence level of 0.05, $T(18)=1.734$. As $T(\beta_1)=11.2238> T(18)=1.734$, and $T(\beta_2)=27.2288> T(18)=1.734$, $h_0: \beta_1=0$ and $h_0: \beta_2=0$ should be declined. Therefore, it could be concluded that energy consumption per capita has a significant impact on GGDP per capita.

**4.2.2. Linear regression of LNGGDP and logarithm of four energies consumption per capita.**

With Eviews we can get the regression results as follows:

\[
\text{LNGGDP}=0.2348\ln E_1+0.1631\ln E_2+
0.5837\ln E_3+0.1226\ln E_4+13.3961
\]
This model illustrates that when coal consumption per capita increases by 1%, on average, it can lead to a 0.2348% increase in GGDP per capita. When oil consumption per capita increases by 1%, on average, it can lead to a 0.1631% increase in GGDP per capita. When natural gas consumption per capita increases by 1%, on average, it can lead to a 0.5837% increase in GGDP per capita. When other energy consumption per capita increases by 1%, on average, it can lead to a 0.3226% increase in GGDP per capita. T-test for regression coefficients’ rejection of original hypothesis that four parameter statistics are not significant shows the four factors above do have a significant impact on GGDP per capita.

Moreover, by comparing the two regression equations we can find that when it comes to Green Gross Domestic Product, contribution of natural gas rather than coal ranks first. This is because coal causes great damage to the environment while promoting economic growth, which brings about a large amount of green cost. Oil, as China's second largest traditional energy, has the same problem with coal. Although natural gas is relatively new in China, it performs well in promoting GGDP growth, contributing the most to GGDP development. Other sources energy has the lowest contribution to GGDP growth, but actually very close to that of oil. With the further development of new energy sources, there is a great probability that it will be a greater contribution to GGDP growth.

5. Conclusion

According to the study we can find proportion of natural gas consumption and other energy consumption are the main drivers of GGDP growth, while coal and oil consumption proportion inhibits GGDP Growth in China. More importantly, natural gas ranks first in the contribution of green gross domestic product.

Therefore, properly reducing coal and oil consumption and increasing the proportion of natural gas consumption can effectively promote GGDP growth. In addition to optimizing the energy structure, we should also vigorously improve new energy technical level, reducing the environmental damage during energy consumption, and truly realize the green development of economy.

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