An Analysis of energy consumption and economic growth of Cobb-Douglas production function based on ECM

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Abstract. Energy is one of the important factors affecting economic growth, the motive force of the economic development of countries in the world, essential for the world economic development and people's living material resources, an important resource of the relationship between the national economies. The paper sums up the evaluation and literatures on energy consumption and economic growth at home and abroad, thinks "southern talk" as the energy consumption and economic growth in the time division, makes a series of empirical tests on the relationship between total energy consumption and economic growth in China from 1978 to 1991 and from 1992 to 2016. The results show that total energy consumption is a one-way causal relationship between economic growths in china, Economic growth has a strong dependence on energy, there is a co-integration relationship between energy consumption and economic growth. However, economic growth depends on the energy consumption decreased by year by year in China, The way of economic growth is changing from the extensive economic growth mode to intensive mode of economic growth.

1. Introduction
Two "oil crisis" appeared in 1970s make people aware that energy has a strong constraint on economic growth, energy is an important factor affecting economic growth in addition to capital, labor, technological progress, is the motive force of social economic development in the world, is essential material resources for the world economic development and people's life, is an important resource influencing the national economy. A large number of facts show that the contradiction between the limited energy reserves and unlimited consumption desire is a worldwide problem, energy problem has become the world focus of the humankind, and it has very important strategic meaning to the economic development of various countries.

2. Literature reviews
Representatives of the earliest studies on the causal relationship between energy consumption and economic growth can be traced back to the Kraft.J and Kraft. A, they studied the datas for the period 1947-1974, found that only GDP to energy consumption in the one-way causal relationship, the results meant that the implementation of energy conservation policy will not affect economic growth. However, other American scholars studies are not the same, Akarca and Long using the time series data also did not come to the same conclusion, Yu and Hwang based on the expensed sample data got the conclusion that there is no causal relationship between energy consumption and economic growth, Hannesson showed that the relationship between energy consumption and economic growth is also different due to different time intervals.

Foreign scholars also studied the causal relationship between energy consumption and economic
growth in China. Hwang and Gum's studies found that there is a two-way causal relationship between energy consumption and economic growth in Taiwan; however, Cheng and Lai indicated that there is a one-way causality between economic growth and energy consumption. Yang showed there is a two-way causal relationship between economic growth and total energy consumption, and the direction of causality is not consistent with coal, oil, natural gas and electricity. Thoms's studies found that it is impossible for China to achieve economic growth under the condition of declining energy consumption.

The domestic scholars also carried on the empirical analysis of the causal relationship between energy consumption and economic growth by time series analysis and panel data analysis in China, Zhao Lixia by VAR model found that energy is not be replaced completely, and is the limiting factor of Chinese economic growth. Zhang Minghui et al used Grainger causality to test the close relationship between energy consumption and economic growth in China, but it was not a strict two-way causality. Wang Huogen's research finds that the sustained growth of Chinese economy has a long-term dependence on energy consumption, and energy for a necessary factor of production has a significant impact on economic development in China. Zhou Jiang by Grainger Granger causality test, co-integration analysis, VAR analysis found that the short-term impact of economic aggregate on energy consumption is greater than the long-term impact, while the increase or decrease of energy consumption has no obvious impact. Xu Xiaobin's study showed that there is bidirectional Granger causality of energy consumption and economic growth in China, and one-way causal relationship from energy consumption to economic growth in eastern, and one-way causal relationship from economic growth to energy consumption in western and central region from the long term, there is no causal relationship between energy consumption and economic growth in the overall China and the Eastern and western, and is a two-way causal relationship in the central region from the short term.

The literature studied the relationship between energy consumption and economic growth is extremely rich. The existing results can be close to reality, pay more attention to the relationship between energy consumption and economic growth, and lay stress on research methods, new perspective, and thorough analysis. But there is also lack of system analysis, no clear time span, region gaps, policy gaps and other issues.

3. An empirical analysis of energy consumption and economic growth in China

3.1 A general situation of energy consumption and economic growth in China.
Since the reform and opening, energy consumption and economic growth showed a rapid increase trend. Energy consumption rose from 571.44 million tons of standard coal in 1978 to 43.6 hundred million tons of standard coal in 2016, GDP raised from ¥364.5 million in 1978 to ¥74.4 trillion in 2016. As the world's largest population, and the fastest economic growth in developing countries, Chinese energy consumption is second in the world, is driving the rapid and sustainable development of strategic resources, and has become the focus of attention Chinese government and all sectors of society.

3.2 The relationship between energy consumption and economic growth in China.
Combined with the existing literature, the causal relationship between energy consumption and economic growth can be arbitrary direction uncertain, be unidirectional causality from energy consumption to economic growth, and be one-way causal relationship from economic growth to energy consumption, and be two-way causality and causal relationship, and be the causal relationship, different types corresponded to different policy recommendations. If there exist the causality from energy consumption to economic growth, it means this is the energy dependent mode of economic growth, energy is the booster of economic growth, lack of energy will have a negative effect on economic growth. If the causality between the two is that economic growth leads to increased consumption of energy, that is to say, economic growth is not based on energy consumption, energy saving protection policies will produce less effect on economic growth or not. If the influence between
the two shows two-way causality, that is to say, energy consumption promote economic growth, economic growth causes energy consumption. If the study finds that there is no causal relationship between energy consumption and economic growth, the conservation policy of energy conservation will not have any impact on economic growth. Therefore, the causal relationship between energy consumption and economic growth will affect our country within a period of time to domestic macroeconomic policies, we should take seriously.

3.3 Dates and treatments of energy consumption and economic growth in China.

The paper uses the annual dates since the reform and opening up in 1978, uses “China energy statistical yearbook”, “new data Chinese fifty-five years statistical data collection” to analyze. Among them. The actual GDP is based on 1978, and converted the dates of other years; The stock of capital uses the perpetual inventory method, namely, the capital stock of a year is equal to the depreciation amount of the capital stock in the previous year, plus part of the investment amount of the year, the depreciation rate of the international 5%; the other dates directly uses the original dates of the statistical yearbook. When analyzing the dates, to accurately study the relationship between economic growth and resource consumption, but also to avoid the deviation, the paper will be Deng Xiaoping's "southern talk" in 1992 as the time division, which explores the relationship between energy consumption and economic growth in 1978 - 1991 and 1992 - 2016. At the same time, based on the Cobb Douglas production function, the parameters of the total energy consumption, using the logarithm function, explain the important value of energy consumption on economic growth.

3.4 The empirical analysis of the relationship between energy consumption and economic growth from 1978 to 1991.

3.4.1 Granger causality test. Granger causality test method was used to determine the causal relationship between capital, energy consumption, labor and economic growth. Because the lag of the causality test selection is very sensitive, lag differences may lead to completely different results. According to the AIC information criterion to determine the optimal lag order of 2, the test results are shown in table 1.

| Null hypothesis | F-Statistic | significant level | conclusion |
|-----------------|-------------|-------------------|------------|
| $\triangle \text{LNGDP}$ isn’t the Granger reason of $\triangle \text{LNK}$ | 0.5992 | 0.5791 | accept |
| $\triangle \text{LNK}$ isn’t the Granger reason of $\triangle \text{LNGDP}$ | 0.3038 | 0.7487 | accept |
| $\triangle \text{LNGDP}$ isn’t the Granger reason of $\triangle \text{LNL}$ | 2.4002 | 0.1714 | accept |
| $\triangle \text{LNL}$ isn’t the Granger reason of $\triangle \text{LNGDP}$ | 0.1359 | 0.8756 | accept |
| $\triangle \text{LNGDP}$ isn’t the Granger reason of $\triangle \text{LNE}$ | 0.7980 | 0.4928 | accept |
| $\triangle \text{LNE}$ isn’t the Granger reason of $\triangle \text{LNGDP}$ | 6.9679 | 0.0273 | refuse |

The results show that, at the significant level of 5%, the total energy consumption is the one-way Granger cause of economic growth in China from 1978 to 1991, and the increase of total energy consumption promotes the economic growth in China.

3.4.2 Unit root test. In order to prevent spurious regression, the stationary of the sequence must be tested before the co-integration test. Unit root test is a commonly used method to test the stationary of time series. The test results of ADF are shown in Table 2.

| variables | ADF | critical value (5%) | Test form | conclusion |
|-----------|-----|---------------------|-----------|------------|
| \text{LNGDP} | -2.4935 | -3.8753 | (C,T,2) | instability |
| \text{LNK} | -2.3420 | -3.9334 | (C,T,2) | instability |
| \text{LNL} | -1.5171 | -3.8753 | (C,T,2) | instability |
| \text{LNE} | -2.7028 | -3.8753 | (C,T,2) | instability |
3.4.3 Co-integration test. Unit root test provides the necessary premise for establishing the regression model between LNGDP/LNK/LNL/LNE, and the regression model estimated by OLS regression method is as follows:

$$\begin{align*}
\text{LNGDP} &= 0.11\text{LNK} + 0.86\text{LNL} + 1.84\text{LNE} - 21.68 \\
T &= 2.2189, 3.5264, 4.8672, -7.8962 \\
R^2 &= 0.9973, \text{ADR}^2 = 0.9965, F = 1228.461, P = 0.0000
\end{align*}$$

Look at the results from the model estimation, the regression equation and the fitting is very good, the goodness of fit was 99.73%, T-statistics and F-statistics are significant. If the residual regression model could passes through unit root test, there is a stable equilibrium relation. The residual LNGDP/LNK/LNL/LNE stationary test results are shown in Table 3.

| T-Statistic | Prob. |
|-------------|-------|
| -3.19983    | 0.0437|

The results show that the residual sequence of the regression model satisfies the stationary requirement, and there is a co-integration relationship between LNGDP/LNK/LNL/LNE in 1978—1991.

3.4.4 Establish error correction model. The regression equation was established the static relationship of total energy consumption, capital, labor force and economic growth in 1978—1991 in China, in order to investigate the dynamic relationship between total energy consumption, capital, labor and economic growth, we must establish the error correction model to analyze the hypothesis. The error correction term is denoted by ECM, error correction model is established as follows:

$$\begin{align*}
\text{⊿LNGDP}_t &= 0.0574 + 0.0742\text{⊿LNK}_t + 0.3318\text{⊿LNL}_t + 1.2221\text{⊿LNE}_t - 0.7026\text{ECM}_{t-1} \\
T &= 3.2535, 3.8901, 2.5230, 3.4133, -2.9443 \\
R^2 &= 0.8472, \text{D.W.} = 1.8546
\end{align*}$$

The error correction model determination co-efficient of R2 is relatively high; LNK/ LNL/ LNE/ECM can explain 84.72% of $\text{⊿LNGDP}$. Durbin Watson value is 1.8546, which indicates that the residual error correction model has no first-order auto-correlation. Combining T-statistics, we can determine the error correction model is a better fitting degree. The model shows that there is a positive relationship between China's total energy consumption, capital, labor and economic growth in the short term; total energy consumption increased by 1%, GDP increased 1.2221%. Co-efficient of the error correction term reflects the adjustment efforts to deviate from the long-term equilibrium. When short-term fluctuations deviate from the long-term equilibrium, it will be with the adjustment of -0.7026 from Non-equilibrium state back to equilibrium state.

3.5 The empirical analysis of the relationship between energy consumption and economic growth in China from 1992 to 2016

Referencing 1978-1991, the relationship between energy consumption and economic growth also
needs to carry on Granger causality test / ADF test / co-integration test / error correction model in 1992 - 2016. The results of each step are listed in table 4/ table 5/ table 6.

Table 4. the results of Granger causality test of variables in 1992—2016

| Null hypothesis | F-Statistic | Significant level | conclusion |
|-----------------|-------------|--------------------|------------|
| δLNGDP isn’t the Granger reason of δLNK | 0.2639 | 0.7732 | accept |
| δLNK isn’t the Granger reason of δLNGDP | 0.9691 | 0.424 | accept |
| δLNGDP isn’t the Granger reason of δLNL | 0.3907 | 0.6865 | accept |
| δLNK isn’t the Granger reason of δLNGDP | 0.8811 | 0.4442 | accept |
| δLNE isn’t the Granger reason of δLNGDP | 3.3990 | 0.0748 | refuse |

Table 5. Unit root test results of variables in 1992—2016

| variables | ADF | critical value (5%) | Test form | conclusion |
|-----------|-----|---------------------|-----------|------------|
| LNGDP | 0.2453 | -3.0810 | (C,T,2) | instability |
| LNK | -1.8032 | -3.7597 | (C,T,3) | instability |
| LNL | 1.3989 | -3.7105 | (C,T,3) | instability |
| LNE | -2.6966 | -3.7332 | (C,T,3) | instability |
| δLNGDP | -4.2157 | -3.8290 | (C,T,3) | instability |
| δLNK | -5.8264 | -3.7332 | (C,T,3) | instability |
| δLNL | -3.8287 | -3.8753 | (C,T,3) | instability |
| δLNE | -5.2154 | -4.0082 | (C,T,6) | instability |

It will be known by unit root test, LNGDP/LNK/LNL/LNE are first order single integral sequence, so we can set up a regression model, and then apply the test to determine the stationary of the residuals, and then determine whether there is a co-integration relationship between the four variables. The regression model is estimated using the regression method of OLS.

LNGDP=0.95LNK+5.24LNL+0.29LNE-35.52

\[ T = 8.0631 \quad 4.1442 \quad 1.9547 \quad -4.6658 \]
\[ R^2=0.9948, \quad ADR^2=0.9937, \quad F=890.254, \quad P=0.0000 \]

The model estimation results of coefficient of determination R2/F statistics /T statistics and other indicators are supported that the regression equation and the fitting is good. The residual stability test of the model shows that there is a co-integration relationship between LNGDP/LNK/LNL/LNE.

Table 6. Residual stationary test results of LNGDP/LNK/LNL/LNE

| Significant level | T-Statistic | Prob. |
|-------------------|-------------|-------|
| 1% | -4.329800 | 0.0003 |
| 5% | -2.717511 | |
| 10% | -1.605603 | |

After establishing the static relationship between capital, total energy consumption, labor and economic growth in 1992 –2016, we should set up ECM to explain the dynamic relationship between the four variables. The error correction model as follows.

\[ \Delta \text{LNGDP}_t=1.0792+0.4393 \Delta \text{LNK}_t+0.9774 \Delta \text{LNL}_t+0.1963 \Delta \text{LNE}_t-0.8030\text{ECM}_{t-1} \]

\[ T=1.9690 \quad 3.2320 \quad 2.3067 \quad 3.3760 \quad -2.9443 \]
\[ R^2=0.6805, \quad D.W. =1.9933 \]

Error correction model of the coefficient of determination R2 was 0.6805, LNK/ LNL/ LNE/ECM can explain 68.05% of \( \Delta \text{LNGDP} \). Durbin Watson value is 1.9933, which indicates that the residual error correction model has no first-order auto-correlation. Combining T-statistics, we can determine the error correction model is a better fitting degree. The relationship between total energy consumption, capital, labor and economic growth is positive. The error correction co-efficient reflects the adjustment when short-term fluctuations deviate from the long-term equilibrium.
4. Conclusion
In this paper, "southern talk" is thought as the time division of energy consumption and economic growth, empirical analyses respectively the relationship between energy consumption and economic growth in 1978—1992 and in 1991—2016. Grainger causality test shows that the total energy consumption of economic growth is a one-way causal relationship between economic growths; China has strong dependence on energy. It is found that the co-integration test and error correction model, there is a co-integration relationship between China total energy consumption and economic growth. However, comparing the two sets of data, we found that Chinese economic growth of dependence on the energy consumption decreased year by year, China has gradually realized that the mode of economic growth relying on the amount of energy input is not sustainable, and economic growth mode is changing from extensive economic growth mode to intensive economic growth mode.

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