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# An Empirical Study of the Relationship Between Clean Energy Consumption and Economic Growth

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***Abstract:*** To achieve the dual carbon objectives, the Chinese government adopted and implemented a policy of restructuring energy consumption. This paper empirically analyses the relationship between clean energy and economic growth in China by modifying the Cobb-Douglas model. Data on GDP, labour, capital, non-clean energy consumption, and clean energy consumption over the period 1990-2021 are selected to be examined using time series measures. The results show that there is no long-term equilibrium relationship between clean energy and economic growth. Based on the result, this paper suggests that the Chinese government should continuously transform its energy structure to boost its reliance on clean energy so that clean energy can advance the dual carbon goals while fostering economic growth. Finally, the paper gives recommendations on restructuring the energy structure, achieving the dual carbon goal, and promoting sustainable economic growth.

***Keywords:*** clean energy, dual carbon target, economic growth, energy structure

## 1. Introduction

To combat global climate change and promote sustainable development, China explicitly proposed the “3060” goals at the 75th United Nations General Assembly, which are to achieve peak carbon emissions by 2030 and strive to accomplish carbon neutrality by 2060. Accomplishing the objectives requires China to come up with approaches in two directions. One is to increase carbon sequestration. For instance, raising the amount of forest cover would harness the capacity of forest carbon sinks to absorb carbon effectively and efficiently. A study shows that a regular hardwood tree can take in approximately 48 pounds of carbon dioxide annually [1]. The other direction is to minimise carbon emissions. Specifically, changing the energy structure is one of the key measures to mitigate emissions. According to the World Nuclear Association 2022, annually, 34 billion tonnes of carbon dioxide are released into the atmosphere due to the combustion of fossil fuels [2]. NRDC also presented that burning coal, oil, and gas accounts for more than 80% of the main energy consumption nowadays [3]. These data indicate that it is vital and urgent to reduce the consumption of non-clean energy and encourage the consumption of clean energy. The Chinese government has taken a series of measures and enacted a series of laws to promote clean energy usage. For example, at the International High-Level Forum "Greening Low Carbon - Transforming Energy" on August 19, 2022, scientists, scholars, and industry representatives analysed relevant issues and proposed recommended policies on challenges associated with the energy transition [4]. Whether clean energy, which has

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been strongly promoted in recent years, became a driving force of China's economic growth provoked this paper to ponder. This paper aims to explore this issue via empirical analysis and propose some policy recommendations on how the government takes measures to assist China in transforming energy structures to attain the "dual carbon" target. This paper also serves as an example and provides insights for other emerging economies around the world.

## 2. Literature Review

In the context of tackling global warming, the relationship between non-clean energy, clean energy, and economic growth has piqued the interest of economic researchers. Some research has discovered there is a relationship between non-clean energy, clean energy, and economic growth. For instance, Jiang et al. used a time series to verify that both fossil fuels and renewable energy sources had a significant influence on economic growth in a short time in the East Asia-Pacific region from 1985 to 2020 [5]. Besides, Pao, Li, and Fu found that the use of fossil fuels and nuclear energy had a bidirectional long-run causal relationship with economic growth, whereas the use of renewable energy had a unidirectional long-run causal relationship with economic growth in emerging economies, such as Mexico, Indonesia, South Korea, and Turkey [6]. Additionally, Apergis, Payne, Menyah, & Wolde-Rufael confirmed the causal association between carbon dioxide emissions, consumption of nuclear energy, consumption of renewable energy, and economic growth for a set of 19 nations from 1984 to 2007 via a panel error correction model [7].

However, some studies did not find a causal relationship between clean energy consumption and economic growth. Via a panel causality test, Ummalla and Goyari reveal that there is no causal relationship between clean energy consumption and economic growth in the BRICS nations between 1992 and 2014 [8].

Some researchers also investigated the Chinese situation . For instance, Xi and Yao discovered that clean energy development has a positive impact on economic growth generally by using provincial panel data from 2003 to 2019 in China [9]. Moreover, Lin and Moubarak discovered that consumption of renewable energy and economic growth are causally related in the long run in both directions in China from 1977 to 2011 by utilising autoregressive distributed lag [10].

## 3. Model, Data and Methodology

### 3.1. Theoretical Model

The Cobb–Douglas production function, which belongs to the neoclassical growth theory, was examined by Cobb and Douglas [11] in 1928 after being first introduced by Knut Wicksell [12]. We use this function to explore the relationship between non-clean, clean energy, and economic growth in China from 1990 to 2021. The function is:

$$Q = AK^{\alpha}L^{\beta} \tag{1}$$

where Q represents total production, K represents the input of capital, L represents the input of labour, α represents the capital's output elasticities, and β represents labor's output elasticities.

Solow improved the production function by making technological progress independent and argued that capital, labour, and technological advancements are all key factors influencing production [13]. After that, other researchers made the point that energy, playing an essential role in production and living, has emerged as one of the primary sources of economic growth in many nations in recent decades. For instance, Rahman and Velayutham emphasized that, with growing infrastructure, energy is considered as a vital component in the growth process, along with capital and labour force [14].

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Stern also claimed a modification of the typical neoclassical model that takes energy into account is one of the basic analytical models in ecological economics [15]. The Cobb-Douglas production function serves as the theoretical basis for this model [14][16][17][18]. The model is as follows:

$$Y = AK^{\alpha}L^{\beta}NE^{\gamma}CE^{\delta} \tag{2}$$

For the same units and to facilitate regression analysis, we take the natural logarithm of both sides and get the following:

$$lnY = lnA + \alpha lnK + \beta lnL + \gamma lnNE + \delta lnCE \tag{3}$$

## 3.2. Sources of Indicator

This paper takes GDP as an indicator to measure economic growth, whose data comes from the World Bank [19]. Moreover, the total social fixed capital stock K is used as an indicator to measure the physical capital stock, and the required data comes from China Statistical Yearbook – 2021 [20]. We take the number of employees L as an indicator to measure the workforce, which was selected from employment data from China Economic Data. The indicator of non-clean energy consumption is the total consumption of non-clean energy (coal, oil) NE, and the data comes from China Statistical Yearbook - 2021 [20]. The primary electricity and other energy net energy values are used as clean energy consumption indicators, and the data are from China Statistical Yearbook - 2021 [20].

# 4. Results

## 4.1. Stationary Test

To investigate whether data existed united roots, we do the Stationary test using the Augmented Dickey-Fuller test. The null hypothesis is the variable has a unit root, and the alternative hypothesis is the variable does not have a unit root. The tests show that we reject the null hypothesis for lnk and lnl at 1% significance, while we cannot reject the null hypothesis for lngdp, lnne, and lnce. It means that the variables lnk and lnl are stationary, while the variables lngdp, lnne, and lnce are not stationary. We then used the same method to find lngdp and lnce as satisfying first-order stationary. Table 1 below summarises the unit root tests.

Table 1: Results of the Stationary test.

| | Test statistic | Critical value | | |
|---|---|---|---|---|
| | | 1% | 5% | 10% |
| | | -3.709. | -2.983 | -2.623. |
| lnGDP Z(t) | -0.086 | Cannot reject hull hypothesis at 10% significance | | |
| lnK Z(t) | -4.278 | Reject hull hypothesis at 1% significance | | |
| lnL Z(t) | -7.591 | Reject hull hypothesis at 1% significance | | |
| lnNE Z(t) | -1.595 | Cannot reject hull hypothesis at 10% significance | | |
| lnCE Z(t) | 0.751 | Cannot reject hull hypothesis at 10% significance | | |

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Table 1: (continued).

| | | |
|---|---|---|
| lnd.GDP Z(t) | -4.922 | Reject hull hypothesis at 1% significance |
| lnd.NE Z(t) | -1.823 | Cannot reject hull hypothesis at 10% significance |
| lnd.CE Z(t) | -5.348 | Reject hull hypothesis at 1% significance |

## 4.2. Cointegration Test

To examine whether the no stationary data is cointegrated, we use the Johansen test. Table 2 below summarises the Johansen test.

Johansen tests for cointegration
Trend: Constant Number of obs = 28
Sample: 1994 thru 2021 Number of lags = 4

Table 2: Results of the Cointegration test.

| Maximum rank | Params | LL | Eigenvalue | Trace statistic | Critical value 5% |
|---|---|---|---|---|---|
| 0 | 14 | 58.279577 | . | 6.3015* | 15.41 |
| 1 | 17 | 61.270422 | 0.19235 | 0.3198 | 3.76 |
| 2 | 18 | 61.430324 | 0.01136 | | |

The result shows that we cannot reject the null hypothesis that there is no cointegrated equation. Based on the above analysis, this paper concludes that we don't find there to be a long-term equilibrium relationship between clean energy and economic growth between 1990 and 2021 in China. Therefore, this paper argues that China should keep up its efforts to promote sustainable energy usage. Not only will it assist in the reduction of carbon emissions to fulfill the nation's dual carbon target, but it also facilitates clean energy as a source of economic growth, which can promote economic development. The following are suggestions on modifying the energy structure, achieving a dual carbon strategy, and attaining sustainable development.

# 5. Recommendation

## 5.1. Form a New Energy Structure by Changing the Consumption of Different Energy and Raising Civic Awareness

### 5.1.1. From the Perspective of Energy Consumption

On the one hand, it's advisable to settle the problem by cutting back on non-clean energy usage. The government needs to restrict the establishment of industrial firms that use conventional energy sources and limit the carbon cap on emissions from energy-intensive enterprises through the execution of legislation. Besides, the government needs to create the appropriate incentives to encourage relevant industries to enhance their efficiency in using non-clean energy. It can also make enterprises reduce the amount of non-clean energy consumption. On the other hand, raising clean energy consumption deserves immediate consideration. The government is supposed to give policy preference to enterprises using clean energy concerning talent and financial investment. Specifically, the government should train human resources and input capital to promote breakthroughs in the

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research and development of core clean energy technologies. Moreover, the government should have a sound fiscal policy to macro-regulate clean energy prices. For instance, the government can lower the market price of clean energy by applying government spending to purchase relevant clean energy. As a result, it stimulates more businesses to utilise energy at a relatively low cost and increases their motivation to consume clean energy.

#### 5.1.2. From a Perspective of Society

The government should expand publicity and information dissemination to build up the awareness about the climate environment and non-clean energy emission reduction in a short period. In addition, the government should call on community to organise public service activities (e.g., a one-hour power outage), or release entertaining advertisements (e.g., Green Excursion). These activities can increase people's participation and responsibility in utilising clean energy.

### 5.2. Facilitate a New Energy Structure to Assist in Achieving the Dual Carbon Goal

One of the priorities of the peak carbon phase is to establish a carbon emissions trading market. It can facilitate carbon emissions management by improving the statistical and accounting capacity of carbon emissions in various industries. Besides, the government can also reduce market-based emissions by strengthening professional carbon verification agencies and carbon emission technical services. In the carbon neutrality phase, the government should play a crucial role in providing financial and fiscal support to coordinate the formulation of a carbon-neutral financial support policy and planning framework. Besides, it is recommended that the government use carbon trading to promote carbon monetisation and use financial support to leverage social capital.

### 5.3. Energy Restructuring, Dual Carbon Targets Contribute to Sustainable Economic Growth

To realize sustainable development, the government should encourage society to create new economic growth engines, such as green energy investment. In addition, the government is suggested to expand the volume of new energy sources and further tap into the carbon reduction potential of each region, which is beneficial to promote the mutual benefits of technology, capital, and resources in the various areas of China. It creates new pathways for carbon reduction and supports sustainable economic growth.

## 6. Conclusion

Using an enhanced neoclassical growth model, this paper concludes that there is no long-term equilibrium relationship between clean energy and economic growth in China during the period 1990 to 2021. Based on the results, this paper recommends that China keep up its efforts to restructure its energy and further promote clean energy. However, this paper has some limitations that need to be improved. Due to limited information collection, the amount of data taken in this paper is only 32 years, which may affect the results of the empirical evidence. In addition, the final data in this paper were treated to retain two or three decimal points, which may make the data less precise. The accuracy of the empirical results would be enhanced if the amount and precision of the data were increased.

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