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## **Transition Towards a Green Economy in China do Consumption of Renewable Energy Effects on it**

### **Abstract**

This paper examines the impact of renewable energy consumption on China's transition toward a green economy and evaluates whether it has contributed to reducing CO<sub>2</sub> emissions between 1990 and 2018 using a random error correction model (VECM). As the world faces growing environmental challenges, understanding the relationship between renewable energy use and carbon emissions is crucial, particularly for China, the largest global emitter. The study's findings indicate that all chains are stable at the second level, ensuring the reliability of the data used. Additionally, the analysis of the causal relationship using the Granger causality test reveals a strong and significant connection between renewable energy consumption and CO<sub>2</sub> emissions in China during the study period, highlighting the role of renewable energy in shaping emission trends. The research further identifies a co-complementarity between CO<sub>2</sub> emissions and renewable energy consumption, attributed to the presence of a significant linear relationship between the dependent and explanatory variables, suggesting that increased renewable energy use correlates with changes in emission levels. This result underscores the importance of renewable energy as a critical component of China's efforts to mitigate climate change. Moreover, diagnostic tests confirm that the model is both economically and statistically robust, reinforcing its credibility for policy evaluation. These findings contribute to the broader discussion on sustainable energy transitions by providing empirical evidence on the effectiveness of renewable energy in reducing emissions, offering valuable insights for policymakers aiming to enhance energy sustainability and environmental protection in high-energy-consuming economies like China.

**Keywords:** *renewable energies, greener economy, Gas CO<sub>2</sub> emission, VECM*

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## Çində yaşıl iqtisadiyyata keçid etmək istehlak bərpa olunan enerjinin ona təsiri?

### Xülasə

Bu sənəd bərpa olunan enerji istehlakının Çinin yaşıl iqtisadiyyata keçidinə təsirini araşdırır və təsadüfi səhvlərin düzəldilməsi modelindən (VECM) istifadə edərək 1990-2018-ci illər arasında CO<sub>2</sub> emissiyalarının azaldılmasına töhfə verib-vermədiyini qiymətləndirir. Dünya artan ekoloji problemlərlə üzləşdiyi üçün bərpa olunan enerjiden istifadə və karbon emissiyaları arasındakı əlaqəni başa düşmək, xüsusən də ən böyük global emissiya edən Çin üçün çox vacibdir. Tədqiqatın nəticələri göstərir ki, bütün zəncirlər ikinci səviyyədə sabitdir və istifadə olunan məlumatların etibarlılığını təmin edir. Əlavə olaraq, Qrancer səbəbiyyət testindən istifadə edərək səbəb əlaqəsinin təhlili tədqiqat dövründə Çində bərpa olunan enerji istehlakı ilə CO<sub>2</sub> emissiyaları arasında güclü və əhəmiyyətli əlaqəni aşkar edərək, emissiya meyllərinin formalaşmasında bərpa olunan enerjinin rolunu vurğulayır. Tədqiqat daha sonra CO<sub>2</sub> emissiyaları və bərpa olunan enerji istehlakı arasında bir-birini tamamlayanı müəyyən edir ki, bu da asılı və izahedici dəyişənlər arasında əhəmiyyətli xətti əlaqənin olması ilə əlaqələndirilir və bu, bərpa olunan enerjiden istifadənin artmasının emissiya səviyyələrindəki dəyişikliklərlə əlaqəli olduğunu göstərir. Bu nəticə Çinin iqlim dəyişikliyi azaltmaq səylərinin mühüm komponenti kimi bərpa olunan enerjinin əhəmiyyətini vurğulayır. Bundan əlavə, diaqnostik testlər modelin həm iqtisadi, həm də statistik cəhətdən möhkəm olduğunu təsdiqləyir və siyasətin qiymətləndirilməsi üçün etibarlılığını gücləndirir. Bu tapıntılar emissiyaların azaldılmasında bərpa olunan enerjinin effektivliyinə dair empirik sübutlar təqdim etməklə, Çin kimi yüksək enerji istehlak edən iqtisadiyyatlarda enerji davamlılığını və ətraf mühitin mühafizəsini gücləndirməyi hədəfləyən siyasətçilər üçün dəyərli fikirlər təqdim etməklə davamlı enerji keçidləri ilə bağlı daha geniş müzakirələrə töhfə verir.

*Açar sözlər: bərpa olunan enerji, daha yaşıl iqtisadiyyat, Qaz CO<sub>2</sub> emissiyası, VECM*

### Introduction

As global economic growth continues alongside rising concerns about climate change and pollution, there has been a growing focus on environmental issues and the transition toward a green economy to achieve the Millennium Development Goals and, ultimately, sustainable development. China, as one of the world's largest emerging industrial nations, has experienced rapid industrial expansion in recent decades, leading to significant environmental challenges. In response, the country has implemented various measures aimed at fostering a green economy, with a key focus on promoting the production and consumption of renewable energy. This raises an important question: Does the consumption of renewable energy contribute to advancing China's transition toward a green economy? To explore this issue, we will examine three key aspects: China's energy structure, the concept of a green economy, and the impact of renewable energy consumption on carbon dioxide emissions in the country.

### Research

#### I. Energy structure in China

China has witnessed during the last decade rapid economic developments. This growth has required a significant increase in energy consumption, which causes China to face increasing challenges in energy supply and demand.

For example, the total energy production jumped from 627.7 million tons to 3.6 billion tons of coal equivalent during the period from 1978 to 2014; signifying a 4.83% annual increase in production during this period. A corresponding increase in energy consumption evaluated at 5.58% ensued during the same period (Zhanga, Wang, 2017, p. 866).

By the end of 2014, China has reached nearly 23% of the global energy consumption; China is now the largest energy consumer and CO<sub>2</sub> emitter in the world. These alarming numbers urged China to set a primary goal of reducing CO<sub>2</sub> emissions per unit of GDP by 40-45% by 2020.

This increasing pressure and contradicting objectives caused China to turn to renewable energies, which is available in large reserves that are currently untapped. It represents a reliable alternative environment friendly as it reduces CO2 emissions (Zhanga, Wang, 2017, p. 866).

### **1. An overview of different renewable energies usage in China**

There is a long history of renewable energies usage in China, including biomass, solar, ocean, wind and other renewable energy. Renewable energy technologies produce marketable energy by converting natural phenomena/resources into useful energy form. These resources represent a massive energy potential, which greatly exceeds that of fossil fuel resources. However, the proportion of renewable energy used is still much smaller than that of the conventional energy resources (Chang, 2003, p. 458).

The following is an introduction of various renewable energies used in China in recent years.

#### **1.1 Hydro power**

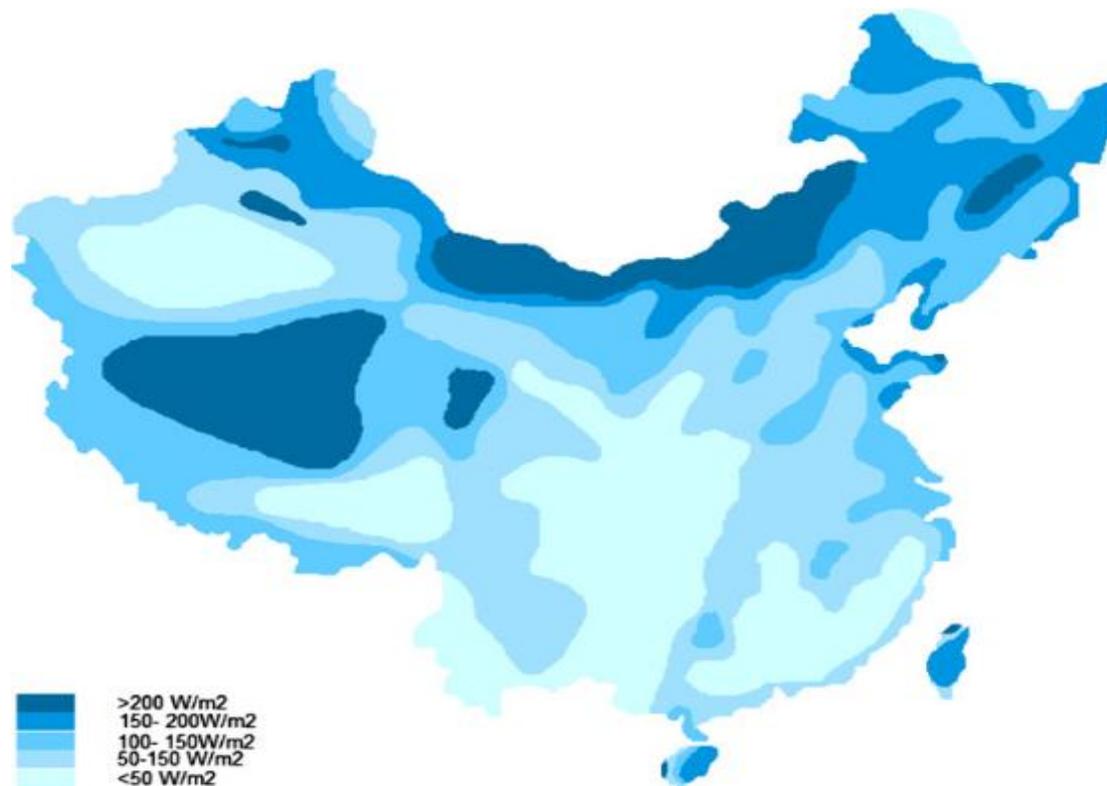
China is the richest country in the world in terms of water resources on the planet. China has a large number of rivers, of which 3886 contain a theoretical hydroelectric reserve of more than 10 megawatts. According to the outputs of the Fourth National Survey of Hydropower Resources in November 2005, the total theoretical hydropower reserves It is estimated at 694 gigawatts, and the average annual power generation in China is 6,083 TWh. The economically exploitable capacity is 402 gigawatts, and the power generation is 1753 terawatt hours, which is why it ranks first in the world. It also includes many small-sized hydropower resources with a installed capacity of less than 50 megawatts, where the technological potential of these small absorbent energy resources is 128. Gigawatts, which can generate 450 terawatt hours of energy (Liu, Li, 2010, p. 519-520).

#### **1.2 Wind power**

China has a coastal strip with a length of more than 14,500 km and a vast area of more than 9 million square kilometers (Wikimedia Foundation, 2020), which made it a rich source of wind energy, with great development potential. Figure 01 shows the distribution of effective wind energy intensity in 2008. After the National Climate Center for Wind Energy Resources in China was evaluated from Through the data modeling method it was concluded that at an altitude of 10 meters above ground level, without taking into account the Qinghai-Tibet Plateau, the technically exploitable wind energy resource is about 2548 gigawatts which equates to about 7644 TWH of power generation assuming an average The annual number of wind hours is 3000 hours. According to a study conducted by a joint team of Chinese and American experts, which concluded an estimate of the electricity that could be generated through a distribution group of 1.5MW GE turbines on the ground. The evaluation of potential wind resources on the land, excluding the study of forested areas, areas occupied by permanent snow or ice, areas covered by water, areas that have been identified as either developed or urban, as well as the area of land whose slopes exceed 20%. The data presented here indicates that a set of 1.5 MW turbines deployed in onshore areas with adequate wind resources could provide up to 24.7 kWh of electricity annually, more than seven times the current national consumption (Liu, Li, 2010, pp. 520-521).

It should be noted that the cumulative capacity of wind energy for the year 2015 amounted to 180.4 gigawatts, while the capacity newly installed in the same year is 30.5 gigawatts, an increase of 16.90%, and this cumulative installed capacity of wind energy represents about 48.4% of the new windmills worldwide (Zhanga, Wang, 2017, p. 867).

**Figure 01:** shows the distribution of effective wind energy intensity in 2008



**Source:** (Liu, Li, 2010, p. 520)

### 1.3 Solar power

China is located in the northeastern part of East Asia between latitudes 4°-53° degrees north and longitudes 135°-173° degrees east. It sits on an area of 9.6 million square kilometers, where the largest share of solar radiation is concentrated in the western part of China with an area estimated at 67% of The total area, and the radiation of more than 5000 MJ / m<sup>2</sup> per year and more than 2200 hours of sunshine annually (Wen Liu, 2010, p. 521). Thinking about the exploitation of solar energy in China goes back to the fifties of the last century through the process of research and development in the field of photovoltaic energy, but the phase of application began in the seventies and the actual marketing was in the mid-eighties, when a crystalline production line for silicon solar cells was introduced (J. Chang, 2003, p. 458). With the abundance of solar radiation and the early start to exploit it, the rapid growth in converting it into photovoltaic energy has been since 2004, with an increase of 100% annually, as China ranked first in the world in the production of photovoltaics in 2007, and the Chinese government has worked to provide direct subsidies For solar PV installations, as part of implementing a series of incentives to encourage its use during the period from 2009 to 2015, and in response to these incentives, the domestic photovoltaic energy market in China witnessed an increasing growth, as its cumulative installed capacity increased from 140 megawatts in 2008 to 300 megawatts in 2009, reaching 43,180 Megawatts by the end of 2015 (Zhanga, Wang, 2017, p. 867).

### 1.4 Biomass Energy

Biomass energy has been used since humans began to use fire and burn wood to cook food or for heating, and wood remains to this day the largest source of biomass energy (J. Chang, 2003, p. 460), and yet many other sources of biomass are used such as crop stems, unpleasant waste, and household garbage. In China, the total potential biomass energy is estimated at about 70-100 million tons of equivalent coal, 50% of which comes from crop stalks (Oxley, Gibson, Ma, 2009, p. 1784-1785), and given that China is an agricultural country, it is rich in biomass resources. Agricultural waste throughout the country provides an annual amount equivalent to 440 million tons of coal equivalent, while forest residues annually provide the equivalent of 350 million tons of coal equivalent, and the

annual amount available of manure throughout the country is equivalent to 28 million tons of coal equivalent. The annual available municipal solid waste in China is equal to 12 million tons of coal equivalent (Zhanga Wang, 2017, p. 868), and it can also be noted that the total exploitable biomass capacity in China will be 0.7 billion tons of coal equivalent by 2020 (Liu, Li, 2010, p. 521).

### **1.5 Other renewable energy sources**

There are other sources of renewable energy that can be exploited in China other than that we have mentioned, and they are ocean energy, which includes tidal energy, wave energy, marine current energy, ocean thermal energy, and salinity gradient energy. It is estimated that the total reserve of ocean energy resources available in China can be in the range of 1000 gigawatts, which has great potential for exploitation (Zhanga, Wang, 2017, p. 868).

Geothermal energy is one of the other renewable energies widely available in China and is mainly concentrated in the tropical region surrounding the Pacific Ocean and the tropical Mediterranean Himalayas, and the largest geothermal power plant is located in Yanbajin, Tibet, with a capacity of 25.18 MW (Liu, Li, 2010, p. 521-522).

### **2. Challenges facing the renewable energy sector in China**

Although China possesses great potential and has made great progress in developing renewable energy, its integration into the current energy sector still faces many of the following technical, economic and political challenges (Jin Yanga, He, 2016, p. 5-6):

- Renewable energy has not been placed in a strategic and essential position in the current energy sector. The Chinese government has recognized the strategic importance of renewable energy in law. China's price and tax policy and cost allocation for renewable energy have also provided enough momentum to start renewable energy projects. However, those policies and measures are insufficient to integrate renewable energy into the current national energy system because the government has focused its future development strategies for national and local infrastructure and energy supply systems largely on traditional fossil fuels, and this is an indication that China lacks confidence and patience with renewable energy, which negatively affected its development.

- The current energy sector has not made the necessary adjustments to adopt renewable energy. The current energy sector in China for traditional fossil fuels is set up to be operated and managed on a large power and grid control and transmission system as needed.

- The marketing mechanism for sustainable development of renewable energy has not yet been established. China's energy pricing and tax system does not fully reflect the environmental cost of resources. China subsidizes fossil fuels, but subsidies and subsidies for renewable energy remain limited.

- The technological innovation of renewable energy in China is not competitive. The research and development of renewable energy in China depends mainly on importing and modifying foreign technologies. There is also a big gap between China and developed countries in terms of key technologies required for the renewable energy industry. Renewable energy technologies in China are considered weak in terms of competitiveness, in addition to insufficient Chinese investment in basic and applied research on renewable energy technologies.

## **II. Concept of Green Economy**

### **1. Historical overview**

Thinking about the green economy goes back to 1962 through the book "Carson Rachel's Silent Spring", as it is called the introduction to the green revolution, and Dr. Dennis L. Meadows' publication in the 1970s entitled "The Limits to Growth" was an attempt to look at the problem of global environmental resources. by the end of the twentieth century and the beginning of the twenty-first century, through the expansion of manufacturing activities at an unprecedented scale and speed, which made the British economist "David Pearce" publish his book in 1989 under the title "A blueprint for a green economy", a call to move towards the direction of an environmentally friendly economy.

As for China, research on the issue of the green economy began in 1972, to participate in the same year in the Stockholm Conference on the Human Environment, for Beijing in 1973 to hold a national

meeting for environmental protection, and in 1989 China passed the Environmental Protection Law, and in 1997 the demand for the establishment of the Chinese Green Economic Corporation, At the 15th Asia Pacific Economic Cooperation leaders meeting in 2007, Chinese President Hu Jintao openly called for the imperative to develop a low carbon economy (Qi, Yanfeng, Xiaowei, 2011, p. 1365-1366).

In 2008, the world faced multiple crises (fuel, food, and financial). In response to the negative effects of economic development on the environment, as well as the financial crisis, the international community sought to find solutions to reach a sustainable economy and society. In this context, the concept of "green economy" has become more present at the international level and in developed countries (Ciocoiu, 2011, p. 36-37).

## **2. Definition of green economy**

The United Nations Environment Program defines the green economy as an economy that results in improvement in human well-being and social equality and significantly reduces environmental risks and scarcity of ecological resources. We can view the green economy as an economy in which carbon emissions are reduced and resource use more efficient, as it accommodates all social groups and the green economy.

Growth in income and employment opportunities must be driven by public and private investments that reduce carbon emissions and pollution, increase resource and energy efficiency and prevent the loss of biodiversity and ecosystem services (Brink, 2014, p. 3).

Through this definition, we can extract some future goals and ambitions that can be summarized in the following points (Ivlev, 2018, p. 866)

- The "green economy" aims to establish a more harmonious coexistence between nature and society.
- coexistence between nature and society.
- Improving human well-being and social justice.
- Significantly reduce environmental risks and environmental scarcity.
- Optimal use of resources within the planet's renewable capabilities and avoiding critical environmental thresholds.
- Sustainability for Future Generations and Business: Available Natural Capital and a Clean Environment.
- Ensuring health and decent livelihoods for citizens and societies.
- An economy separate from environmental influences and resource use.

## **3. Crises and challenges facing the green economy in China**

The Chinese economy has experienced significant growth in recent decades, which has made energy consumption witness a rapid growth, as it moved from 570 million tons of coal equivalent in 1978 to 3.05 billion in 2009 and it is expected that 6 billion tons of coal equivalent will reach by the end of 2020. Carbon dioxide, China released 6 billion tons of carbon dioxide into the air in 2007, and this number is expected to reach 11.3 billion tons in 2020, which is nearly a one third of the global total.

Coal represents the largest part of energy consumption in China, accounting for 70%, followed by petroleum and natural gas at 20%, and non-fossil fuels only 9%.

This massive exploitation and massive depletion of natural resources and the deterioration of environmental pollution have made China already facing multiple crises and challenges in the way of adopting a green economy (Siwei, 2011, p. 4).

### **4. The Various crises**

There are many crises make the Chinese economy face Difficulty, we try to enumerate it in the following (Qi, Yanfeng, Xiaowei, 2011, p. 1365-1370):

#### **4.1 Environmental crisis**

Energy consumption in China has increased sharply, and this is as a result of the increase in the urbanization process and the rapid and unprecedented increase in the various manufacturing sectors, which made it a great pressure on the environment in China. This rapid economic development has

led to more and more serious environmental pollution and deformation, melting of glaciers and river floods, severe forest degradation, grassland desertification, wildlife close to extinction etc.

#### **4.2 Currency crisis**

The large global influx of currency leads to a false boom in the economy, and this false boom leads to an increase in energy consumption, and this rise leads to a climate crisis.

#### **4.5 Food and water resource crisis**

China is also facing a crisis in foodstuffs, and this is due to the shortage of arable land and water pollution on the one hand and the continuous growth of the population on the other hand. China also faces the clean water crisis, and although China has the sixth water reserve in the world, the per capita share is only 2,500. Cubic meters, which is 1/4 of the world's water per capita, and it ranks 110th in the world. Due to the climate crisis and currency inflation, the food crisis and the water crisis have become more severe.

#### **4.6 The Challenges that may face the development of the green economy**

The path of reaching environmental civilization in China, specifically abandoning the traditional growth model of the twentieth century based on high carbon energy consumption, taking advantage of modern technology and the new era based on low-carbon energy consumption and achieving sustainable social development still faces a set of challenges, represented in the following (Qi, Yanfeng, Xiaowei, 2011, p. 1365-1370).

#### **4.7 Contrasted energy requirements and rapid growth in consumption**

Due to the rapid growth of energy requirements in China resulting from industrial development and urbanization, which led to a continuous increase in energy consumption, which in turn helped to increase high carbon emissions, making it an obstacle to sustainable development in China.

#### **4.8 The gap in energy use**

Many Chinese companies' products are characterized by their high energy consumption compared to their counterparts in developed countries, as their consumption exceeds 47% of the level of the rest of these countries' products, and this is what creates a gap between energy use in China and developed countries.

#### **4.9 The State of Energy Architecture Resources in China**

Energy structure resources in China depend on a large abundance of coal, while low-carbon resource options are limited. Hydropower, for example, represents less than 20%, and high-carbon energy exceeds 77%. Burning one ton of coal produces 4.12 tons of carbon dioxide, which is 30% and 70% higher than gasoline and gas, respectively, per ton. This situation cannot be changed in the short term.

#### **4.10 The growth of Chinese industrial sectors**

The Chinese industrial sectors are the first in terms of energy consumption, as their energy consumption represents 70% of the total consumption, and this is an annual increase of 5.8% for the period 1993/2005. Note that the industrial production technology in China is characterized by high carbon, which put China in a great challenge between reducing carbon emissions (green economy) on the one hand and maintaining industrial growth on the other hand.

### **III. The impact of renewable energies consumption on carbon dioxide emissions in China**

In order to examine the previous relationships, we will use toolkit of econometric and associated tests for time-series variables such as the unit root test, Johansson co-integration test and the error vector correction model that will be discussed during the analysis process.

#### **1. Data sources:**

Data on the study variables were collected in order to study the measurement of the relationship between renewable energy (RE) and the green economy, expressed in CO<sub>2</sub> emissions, from the concerned sources.

**Table 1: The definition of model variables is given**

variabe symbol	Full name	The definition	ID Source	Source
CO2	Carbon Dioxide	Carbon dioxide emissions come mainly from burning fossil fuels and making cement. It includes the carbon dioxide emissions that are emitted during the consumption of solid, liquid and gaseous fuels and the burning of gas	data.albankaldawli.org	<a href="https://ourworldidata.org/">https://ourworldidata.org/</a>
RE	Renewable energy consumption	It comes from an energy resource that is replaced by a natural process at a rate equal to or faster than the rate at which that resource is being consumed, thus renewable energy will not run out “as long as the sun rises”, unlike so-called traditional sources of energy that refer to fossil fuels (oil, coal or gas) and nuclear power	Thomas Indexer, A Hypothetical Enhanced Renewable Energy Utilization (EREU) Model for Electricity Generation in Thailand, GRIN Verlag, Auflage 1, Germany, 2008, P 15.	<a href="https://www.iea.org/countries/china">https://www.iea.org/countries/china</a>

Source: Prepared by researchers based on sources in the table

**Data processing (descriptive analysis of variables)**

The data analysis was based on descriptive analysis of the data as it was processed using the (EViews9) program in order to estimate the study model during the period 1990-2018.

Table 2: Descriptive data analysis

Date: 12/15/20 Time: 13:41  
 Sample: 1990 2018

	CO2	RE
Mean	5730.931	167449.0
Median	5334.888	176381.0
Maximum	9507.110	205335.0
Minimum	2323.831	113860.0
Std. Dev.	2728.780	36060.67
Skewness	0.163360	-0.322512
Kurtosis	1.325475	1.416054
Jarque-Bera Probability	3.517194	3.534303
	0.172286	0.170819
Sum	166197.0	4856020.
Sum Sq. Dev.	2.08E+08	3.64E+10
Observations	29	29

Source: Prepared by researchers based on EViews9 outputs

It is clear from Table02 that the arithmetic mean of CO2 and RE, is 5730.931 and 167449.0, respectively, while the standard deviation of both is 2728.780 and 36060.67, respectively.

**2. Model Description**

The error correction ray model estimation was used in order to examine and analyze the behavior of variables in the short and long term; thus, we will study the stability of time series, then the co-integration test. as follows:

**Equation:**

$$D(D2CO2) = C(1)*( D2CO2(-1) + 0.0801025720008*D2RE(-1) + 9.73701247857) + C(2)*D(D2CO2(-1)) + C(3)*D(D2CO2(-2)) + C(4) *D(D2RE(-1)) + C(5)*D(D2RE(-2)) + C(6)$$

$$\text{Equation: } D(D2RE) = C(7)*( D2CO2(-1) + 0.0801025720008*D2RE(-1) +9.73701247857) + C(8)*D(D2CO2(-1)) + C(9)*D(D2CO2(-2)) + C(10) *D(D2RE(-1)) + C(11)*D(D2RE(-2)) + C(12)$$

**5. Normal distribution test**

One of the most important conditions for estimating the model is the necessity to use a normal distribution of variables, using the. test (C.Jarque, 1987), Through our reading of the EVIEWS10 outputs, it became clear that the outputs show the normal distribution of the model through the Jarque-Bera probability (Table No. 04).

**Table 3:** Normal distribution of variables

Variable Test		CO2	RE
Normal distribution (Jarque-Bera)	Jarque-Bera	<b>3.517194</b>	3.534303
	Probability	0.172286	0.170819

Source: Prepared by researchers based on EVIEWS9 output

Through Table 3: we notice that the morale of each variable is greater than 5%, which indicates that all the variables follow a normal distribution, including the acceptance of the null hypothesis or the null hypothesis which states that there is a normal distribution of the variables.

**6. Stability test (unit root test):**

The econometric literature emphasizes the necessity of using the unit root that most time series suffer from (Nelson, 1982)

At this level of research, the stability of the time series will be tested to determine the extent of the stability of the variables, in the sense of ensuring the stability of the time series at the level or when calculating the first differences. One of the most widely used tests for time series stability or unit root presence is the Augmented Dickey Fuller (ADF) test. This is in order to avoid false regression, and to determine the appropriate estimation method (Granger, 1974).

It is known that when making the first difference of the time series, the general trend and the fixed boundary are deleted, and from it the results were extracted in Table No. 04.

**Table4:** Using the ADF test for study variables (unit root test)

variabl e	The level			The first difference	The second difference	degree of integratin
	Time vector and transversl	Categorica l	without direction and categoricl	without direction and categoricl	without direction and categoricl	
<b>CO2</b>	<b>2.5781-0.2920</b>	<b>0.6871-0.8337</b>	/	<b>1.3198-0.1683</b>	<b>5.4944-0.0000</b>	<b>I(2)</b>
<b>RE</b>	<b>2.6900-0.2484</b>	/	/	<b>1.8365-0.0638</b>	<b>6.3948-0.0000</b>	<b>I(2)</b>

Source: Prepared by researchers based on EVIEWS9 output

After studying the stability at the level and it was found that it is unstable, we used this test again on these variables by making first-degree differences, and this is what the above table shows. and integrated first class I(1). Then we made the differences of the second degree and it was found that the study variables are stable, that is, the absence of a unitary root, and the absence of the general trend component, and therefore the series are stable and integrated of the second degree I(2).

- For the first series related to CO2: we say that the series is unstable in the level and at the first difference, that is, the Dickey-Fuller value in absolute value is less than the tabular value in absolute value, and from it the second-degree differences were relied upon and found that they are stable, that is, they are integrated of the second degree I(2).

- For the second series related to RE: the series is unstable at I(0) and at I(1), which means that the Dickey-Fuller value in absolute value is less than the tabular value in absolute value, and from it the second-order differences were relied upon and found to be stable, that is, they are integral Class II(2).

## 7. Estimation of the VAR or VECM model

### 7.1 Determining the optimum deceleration rate:

It is evident in the results presented in the table below that the majority of the differentiation tests show that the degrees of delay that give the lowest value for the differentiation criteria are the second degree. Which means that the number of degrees of lag in the model is 2. As shown in the following Table:

**Table 5: Determine the optimum deceleration**

VAR Lag Order Selection Criteria  
 Endogenous variables: CO2 RE  
 Exogenous variables: C  
 Date: 12/14/20 Time: 21:34  
 Sample: 1990 2018  
 Included observations: 26

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-496.9698	NA	1.60e+14	38.38229	38.47907	38.41016
1	-420.8773	134.6252	6.26e+11	32.83671	33.12704	32.92032
2	-405.0653	25.54236*	2.54e+11	31.92810	32.41199*	32.06744*
3	-400.6829	6.405100	2.51e+11*	31.89869*	32.57612	32.09376

\* indicates lag order selected by the criterion  
 LR: sequential modified LR test statistic (each test at 5% level)  
 FPE: Final prediction error  
 AIC: Akaike information criterion  
 SC: Schwarz information criterion  
 HQ: Hannan-Quinn information criterion

Source: Prepared by researchers based on EVIEWS9 output

### 7.2. Johansen's Cointegration Test:

The Johansson Cointegration Test outperforms (Juselius and Johansen; 1991, 1988: Johansen 1990) on other tests, such as the Engel and Granger test, and the Darbin-Watson test, especially when there are small samples and if there are more than two variables. One of the most important advantages of Johansson's test is its ability to detect if there is a unique co-integration, i.e. now the co-integration is the result of the regression of the dependent variables on the independent variable.

In line with recent trends in the analysis of time series, which have played a prominent role in making economic relations based on measurable time series and quantitative analysis, we will use unconventional analysis methods away from the least squares test, which depends mainly on the Johansson integration test. Subscriber Johansen co-integration test and error correction factor vector error correction model, we will also use the Granger test of causality to analyze the trend of the relationship between CO2 emissions as a variable of green economy and renewable energy consumption.

**Table 6: Johansson's Cointegration Test**

Date: 12/14/20 Time: 21:55  
 Sample (adjusted): 1995-2018  
 Included observations: 24 after adjustments  
 Trend assumption: Linear deterministic trend  
 Series: D2CO2 D2RE  
 Lags interval (in first differences): 1 to 2

**Unrestricted Cointegration Rank Test (Trace)**

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.522878	25.42865	15.49471	0.0012
At most 1 *	0.273520	7.669071	3.841466	0.0056

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level  
 \* denotes rejection of the hypothesis at the 0.05 level  
 \*\*MacKinnon-Haug-Michelis (1999) p-values

**Unrestricted Cointegration Rank Test (Maximum Eigenvalue)**

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.522878	17.75957	14.26460	0.0135
At most 1 *	0.273520	7.669071	3.841466	0.0056

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level  
 \* denotes rejection of the hypothesis at the 0.05 level  
 \*\*MacKinnon-Haug-Michelis (1999) p-values

**Unrestricted Cointegrating Coefficients (normalized by b\*S11\*b=I):**

D2CO2	D2RE
-0.007266	-0.000582
0.005630	-0.000653

**Unrestricted Adjustment Coefficients (alpha):**

	D(D2CO2)	D(D2RE)
	151.4668	-34.08085
	1257.918	1551.734

**1 Cointegrating Equation(s):** Log likelihood -383.4077

**Normalized cointegrating coefficients (standard error in parentheses)**

D2CO2	D2RE
1.000000	0.080103
	(0.02705)

**Adjustment coefficients (standard error in parentheses)**

D(D2CO2)	D(D2RE)
-1.100558	-9.140033
(0.27177)	(5.48228)

Source: Prepared by researchers based on EViews9 output we can say that there is a co-integration between the variables whose results appear in Table 06 and that the trace statistic probability is smaller than the critical values at a significant level of 5% and therefore we accept the null hypothesis, that is, there is a relationship of simultaneous integration between the study variables, i.e. between CO2 and RE.

**7.3 VECM Error Direction Correction Model:**

The presence of co-integration between the variables means the possibility of designing an autoregressive vector model (VAR) in the form of differences for the variable with the addition of a decelerated time gap. Therefore, this study will use the error vector correction model as one of the modern statistical techniques in analyzing the speed of adaptation and adequacy of variables over time. The error correction vector model is used to verify the equilibrium relationship (short and long-term) between economic variables, and one of the most important conditions of this model is the existence of co-integration according to the Johannes method. The stability of the two variables is that they are complementary to the same degree, and what appeared through the Johannes test for co-integration proved the existence of a long-term equilibrium relationship between them. Therefore, this result calls for the application of VECM error correction technique to monitor the various interactions between the model variables:

**Table 7: VECM model estimation.**

Vector Error Correction Estimates		
Date: 12/14/20 Time: 22:00		
Sample (adjusted): 1995 2020		
Included observations: 24 after adjustments		
Standard errors in ( ) & t-statistics in [ ]		
Cointegrating Eq	CointEq 1	CointEq 1
D2CO2(-1)	1.000000	
D2R(-1)	0.080103	
	[2.906099]	
C	9.737012	
Error Correction	D(D2CO2)	D(D2RE)
CointEq1	-1.100558	-9.140033
	(0.27177)	(5.15410)
	[-4.04964]	[-1.66719]
D(D2CO2(-1))	0.132441	4.575853
	(0.25550)	(0.15410)
	[0.51836]	[0.88781]
D(D2CO2(-2))	0.317556	2.644720
	(0.18749)	(3.78211)
	[1.69376]	[0.69927]
D(D2RE(-1))	0.068965	-0.412822
	(0.01687)	(0.33978)
	[4.09441]	[-1.21496]
D(D2RE(-2))	0.039429	-0.454581
	(0.01052)	(0.21230)
	[3.74550]	[-2.14155]
C	-0.103353	12.38851
	(37.4725)	(755.922)
	[-0.00276]	[0.01639]
R-squared	0.702082	0.687663
Adj. R-squared	0.619327	0.600902
Sum sq. resids	604346.2	2.46E+08
S.E. equation	183.2342	3696.336
F-statistic	8.483867	7.926002
Log likelihood	-155.6607	-227.7647
Akaike AIC	13.47173	19.48039
Schwarz SC	13.76624	19.77490
Mean dependent	4.331791	32.66667
S.D. dependent	295.9924	5851.024
Determinant resid covariance (dof adj.)		4.58E+11
Determinant resid covariance		2.58E+11
Log likelihood		-383.4077
Akaike information criterion		33.11731
Schwarz criterion		33.80451

Source: Prepared by researchers based on EVIEWS9 output

Through the table, it appears that there is a long-term equilibrium relationship between CO2 and RE, as it turns out that there is a long-term equilibrium causal relationship that tends from carbon dioxide emissions towards the consumption of renewable energy, according to the error correction parameter that takes the negative sign as it is significant according to the T-level test Morale 5%.

**7.4 Diagnostic tests**

To judge the suitability of the model used in measuring the estimated elasticities in the long term, a set of statistical and standard tests were performed as shown in Table 8.

**Table 8: Diagnostic test results**

Test	Statistic	Value	Probability
Autocorrelation Breusch-Godfrey	F-statistic	<b>34.4798</b>	<b>0.4325</b>
normal distribution (arque-Bera)	Jarque-Bera	<b>2.8954</b>	<b>0.5755</b>
Contrast instability Breusch-Pagan-Godfrey	F-statistic	<b>9.7684</b>	<b>0.04</b>
	Chi-Square	<b>70.2546</b>	<b>0.1717</b>
Error correction coefficient significant test	C(1)	<b>1.100558-</b>	<b>0.0003</b>

Source: Prepared by researchers based on EVIEWS9 output

Through the table 08, we note that the residuals of the model do not suffer from the problem of autocorrelation of degrees higher than the first degree, as they are distributed normally, and their variance is constant, as well as the absence of errors in setting the model at the level of significance.

- The problem of autocorrelation, which we reveal through the Lagrangian multiplier test, from the table we notice that the probability of Fisher = Prob.F = 0.7325 is bigger than 0.05 (the level of significance), which means rejecting the alternative hypothesis that there is a self-correlation, and accepting the null hypothesis.

- One of the most important conditions for estimating the model is the necessity to use a normal distribution of variables, using the test (C.Jarque, 1987), through our reading of the outputs of EVIEWS9, it became clear that the outputs show the normal distribution of the model through the probability of Jarque-Bera, which amounted to (propability = 0.57), which is greater than the level of significance 5%, and this confirms the acceptance of the null hypothesis, which confirms the normal distribution of the residuals.

- Data instability: From the table, we note that the test probability value is not significant at the level of significance of 5%, that is, the acceptance of the alternative hypothesis that states that there is homogeneity between the data, and the rejection of the null hypothesis.

- Based on the results of the diagnostic tests for the estimated model, a decision can be made about the validity of using these models in estimating the long-term relationship.

- Granger causality test to test the causal relationship between the study variables, CO2 emissions and renewable energy consumption, we will use the La causalité de Granger test, which allows us to know the nature of the relationship between the following variables: CO2 and RE during the time period between 1990-2018.

**Table 9: Granger causality**

Pairwise Granger Causality Tests  
 Date: 12/15/20 Time: 14:03  
 Sample: 1990 2018  
 Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
RE does not Granger Cause CO2	27	3.29353	0.0561
CO2 does not Granger Cause RE		4.31726	0.0262

Source: Prepared by researchers based on EViews9 output

The results are shown in Figure No. showing that:

- The consumption of renewable energy affects carbon dioxide emissions at a significant level of 10%.
- That carbon dioxide emissions affect the consumption of renewable energy at a significant level of 5%.
- Therefore, we can conclude that there is a two-way causal relationship between the variables CO2 and RE.

#### **IV. Results:**

The analysis reveals that all variables are stable at the second level, ensuring the reliability of the dataset for further econometric modeling. By examining the causal relationship through the Granger causality test, the study finds strong evidence of a significant influence between renewable energy consumption and CO2 emissions in China over the period from 1990 to 2018. This suggests that changes in renewable energy consumption have a direct impact on emission levels, highlighting the critical role of sustainable energy in environmental management. Furthermore, the results indicate the existence of a long-term co-integration between CO2 emissions and renewable energy consumption, as demonstrated by a significant linear relationship between the dependent and explanatory variables. This finding underscores the interconnected nature of economic and environmental factors in China's transition toward a greener economy. Additionally, diagnostic tests confirm that the model is both statistically and economically robust, reinforcing its validity for analyzing the relationship between renewable energy usage and carbon emissions. These results provide a solid foundation for policy recommendations aimed at enhancing the effectiveness of renewable energy strategies in reducing environmental degradation.

#### **V. Discussion**

The findings clearly indicate that as China increases its consumption of renewable energy, there is a corresponding decline in carbon dioxide emissions. This strong inverse relationship suggests that renewable energy plays a pivotal role in driving China's transition toward a greener and more sustainable economy. By reducing reliance on fossil fuels and expanding the use of cleaner energy sources, China can effectively mitigate the environmental damage caused by industrialization and urbanization. Moreover, this trend highlights the significance of government policies and strategic investments in renewable energy infrastructure, which not only contribute to reducing greenhouse gas emissions but also support economic growth through the development of green industries and job creation in the renewable energy sector. The shift toward renewable energy aligns with global sustainability goals and strengthens China's commitment to international climate agreements, further positioning the country as a leader in the global movement toward environmental responsibility. As renewable energy technologies continue to advance and become more cost-effective, their role in shaping a low-carbon economy will become even more critical. Therefore, expanding renewable energy consumption should remain a priority in China's long-term energy planning, as it not only helps in reducing emissions but also enhances energy security, fosters innovation, and supports the overall transition to a more resilient and sustainable economic model.

#### **Conclusion**

In conclusion, this study confirms that China's growing dependence on renewable energy sources plays a significant role in reducing carbon dioxide emissions. The findings highlight that expanding the use of renewable energy is not only an effective strategy for mitigating environmental degradation but also a crucial step toward achieving a more sustainable and greener economy. By shifting away from fossil fuels and embracing cleaner energy alternatives, China can significantly lower its carbon footprint while enhancing energy security and economic resilience. Furthermore, investing in renewable energy infrastructure and technologies can drive innovation, create green jobs, and position China as a global leader in sustainable development. As the country continues to implement policies that promote renewable energy adoption, it will further strengthen its commitment to international

climate agreements and contribute to global efforts in combating climate change. Ultimately, the transition toward a green economy will not only benefit the environment but also support long-term economic growth and energy stability, making renewable energy a fundamental pillar of China's future development strategy.

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