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RESEARCH ON THE ROLE OF GREEN INNOVATION, TRADE AND ENERGY IN PROMOTING GREEN ECONOMIC GROWTH

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Abstract

Green economic growth (GG) has assisted the transition of many nations from just seeking economic development to a green economy growth mode for resource and environmental preservation. The energy business is becoming more innovation-driven, trade-driven, and energy-driven as China's economy transitions into a new normal stage, as shown by renewable energy. The goal of this research is to add to the current discussion about green economic development (GED) by experimentally analyzing the role of green energy (GE), green innovation (GI), and green trade (GT) on green economic growth. The purpose of this article is to examine how green patenting affects a company's future performance. Initially, data is gathered, and a hypothesis is formed based on the aforementioned elements. We employ the Panel Co-integration Test (PCT) and the Cross-sectional dependence (CSD)) for empirical analysis. For verifying the suggested hypothesis, we presented a new Non-linear Fourier Panel Unit Root Test (NFPURT). We establish a positive and substantial association between green patenting and company performance in China's publicly traded industrial enterprises. The study's findings reveal that green energy, innovation, and trade all contribute to green economic development.

Keywords: green economic growth (GG), green energy (GE) production, green innovation (GI), green trade (GT), Panel Co-integration Test (PCT), Cross-sectional dependence (CSD), Non-linear Fourier Panel Unit Root Test (NFPURT).

1. INTRODUCTION

As a consequence of "climate change", "air pollution", "polluted water", and "the loss of biodiversity", several studies have concluded that the current level of economic development is not sustainable. With these environmental issues, governments have begun to explore for a sustainable economic growth strategy [1]. In addition, the failure of international policies necessitated the development of a new growth paradigm. As a result, the global debate on economic growth has begun. "UN Economic and Social Commission for Asia and the Pacific (UNESCAP)" said that natural conservation is critical to a long-term economic trajectory [2]. Thus, a new framework of development, termed as "green economic growth" has been created. "Green Development" is a term used to describe the utilisation of natural resources sustainably as a means of promoting national economy. The concept of green growth has grown more significant in recent years as policymakers seek to simultaneously advance economic growth and environmental preservation. [3]. Figure 1 depicts the elements for greener economic growth.

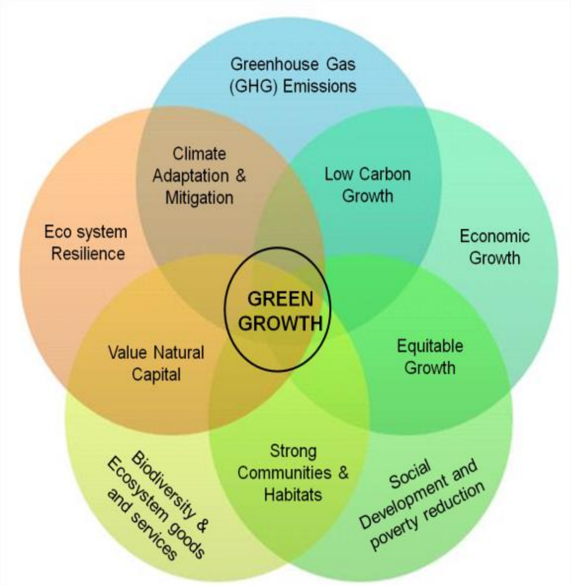

Figure 1: *Elements for Greener Economy*

As a consequence of environmental contamination, the world's ecology is deteriorating at an alarming rate [4]. Deforestation, global warming, and pollution are only a few of the factors cited as contributing to the state of the environment today. New research suggests that using green energy might lead to a rise in the overall economy [5]. Green innovation decreases pollution by making modern equipment available to the general public, and this, in turn, encourages economic prosperity. Greenhouse gas (GHG) emissions may be reduced and energy efficiency can be improved while protecting the environment. Green trade is another major predictor of GED, since it facilitates the transition to a green economy by providing access to affordable services. The rest of this part is devoted to Section II, which explains the literature work and problem statement, Section III, which illustrates the approach utilized, and Section IV, which examines and assesses the methodology's performance. Finally, in section V, the paper's conclusion is presented.

II. RELATED WORKS

In [6] the author looks at how environmental rules affect GED and renewable energy development in China. First, the “Metafrontier-Global-SBM super-efficient data envelopment analysis (DEA)” methodology analyses the amount of green economic development in Chinese cities. It was also evaluated utilising a new fuzzy comprehensive assessment approach. A longitudinal spatial econometric system was constructed to investigate the non-linear impact of environmental limitations on GED, regional spill, and feedback mechanisms..Environment regulation and renewable energy development was also studied.

In [7] the author mentions that environmental stewardship and economic development are often associated, although the causal relationship between fiscal expenditure and GED has not been well explored. Green economic development is measured using the non-radial distance function in a panel of two hundred and eighty one percent prefecture-level cities. The government investment impact on education and research on GED is next examined using the “System-generalized method of moments (SYS-GMM)” approach.

Entropy-weighted "TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)" is used in [8] by the author to analyse the GED.

An analysis of 286 Chinese cities' GED levels and their geographical evolution patterns and internal impacting factors is described in [9] by the author. The findings of this study have policy implications for further harmonising the relationship between resource conservation, environmental preservation, and economic growth in China's urban areas.

In [10] the author explores the influence of “Information and Communication Technologies (ICT)”, financial growth, open trade and energy on Pakistan's growing degree of ecological footprint. The impact of technological and financial advancement on environmental footprint is also explored in this research. Over all, the report concludes that investment in clean and renewable energy sources, as well as creative environmental policies for the industrial sector, is needed to help the nation emerge.

In [11] the author mentions that the threshold regressive model investigates the complicated nonlinear connection between the two major study objects using the factor substitution, energy path dependency, and scale effects. The model's moderating factors include renewable energy usage, energy intensity, and regional economic growth. We further separate threshold intervals to differentiate impacts driven by geographical variability.

In [12] the author illustrated that an urban green total factor productivity index based on “Directional Distance Function” and “Global Malmquist–Luenberger productivity index” measures GED.

In [13] the author explains that improving the institutional environment has a significant impact on GED. It was separated into 3subenvironments: “governmental”, “legal”, and “cultural”. They used the generalised technique of moments to analyse Chinese province panel data from 2000 to 2016 to examine the impact of each dimension on green growth.

In [14] the author mentions that green economic development means lowering pollution while improving productivity. Although renewable energy consumption is “green,” technological limits may prevent it from promoting GED. In order to connect renewable energy consumption with GED, a technical progress method is required. That is, considering whether to create new technologies or enhance current ones should be prioritised in light of the rising need for renewable energy.

In [15] the author mentions that in order to better understand the link between “green logistics and energy consumption”, “economic development”, and “environmental sustainability” in a global panel of 43 nations, this study aims to identify the elements that influence this connection. GMM estimations were used in the research to make valid conclusions about the relationship between the two variables.

In [16] the author explains that using data from forty seven China nations pilot smart cities, this research aims to investigate how policies and measurements of China's innovation strategy affect the country's green economy.

Problem statement

Existing “Sustainable development goals (SDG)” demonstrate that “environmental sustainability”, “job creation and economic growth”, “safe drinking water and sanitation”, “health and well-being”, and “responsible production and consumption” are the most pressing issues facing developing countries, that can be addressed through the implementation of GED policies. Additionally, it is a legitimate strategy for increasing energy efficiency and mitigating climate change.

III. PROPOSED METHODOLOGY

The importance of “Green innovation”, “trade”, and “energy” to the establishment of a green economy is explored in depth in this section. The proposed procedure's flowchart is shown in Figure 2. First, data have been collected and an initial hypothesis is established. The PCT and CURT tests are used to do empirical analysis. The NFPURT test is used in this research to see whether the hypotheses put forward can be verified.

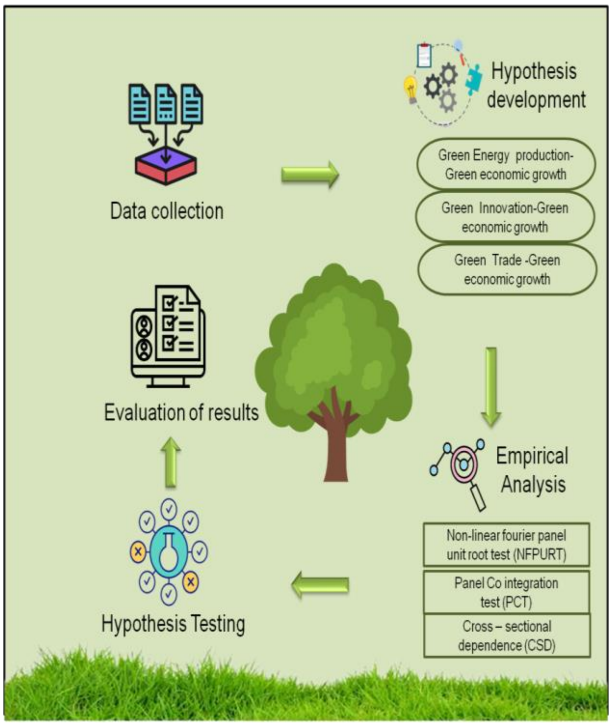

Figure 2: *Flow of the suggested methodology*

A. Data collection

There are 288 prefecture-level cities in China, excluding four "provincial-level" cities from the list. Among them, 283 cities can be found. "Haikou", "Heze", "Loudi", "Ningde", "Shijiazhuang", and "Sanya" are all dropped because linear programming methods used to solve NDDFs infeasibility for 6 cities. The data for "Lhasa" and "Puer" are not available. Thus, there are 275 cities that are part of a prefecture [17]. Six were chosen for our research:" Beijing", "Shanghai", "Hong Kong", "Canton", "Taipei" and "Macao" were the six cities that we chose.

B. Hypothesis development

This study found that various academics have concentrated on the connection between “green innovation”, “trade” and “energy” after reviewing the existing works. However, green economic development in relation to renewables is still under dispute, particularly in the case of developing countries. With that in mind, researchers are now looking at how China's economy might benefit from GED strategies. The hypotheses produced for this study are denoted by the letters H1, H2, and H3. Specifically, H1 is a hypothesis established for GE and GG, while H2 is a hypothesis produced for GI and GG. H3 is a hypothesis that has been established for GT and GG.

H1: “There is a significant relationship between clean energy production and green economic growth”

H2: “There is a significant relationship between green innovation and green economic growth”

H3: “There is a significant relationship between Green trade and green economic growth”

C. Empirical analysis

1. Cross-sectional dependence (CSD)

Cross-sectional dependence is a common issue with panel data, as many researchers have shown. This is due to cross-sectional shocks and other undiscovered causes. Assimilation of financial and economic resources is another cause of cross-sectional reliance. Small N and big T panels may benefit from the test's use of pair-wise correlation coefficients. A "cross-sectional independence" null hypothesis is used to assess the issue of CSC in Equation 1.

$$AB = \sqrt{\frac{2P}{M(M-1)}} \sum_{x=1}^{M-1} \sum_{y=x+1}^{M} \hat{\delta}_{xy} \qquad (1)$$

where δˆ is the calculated correlation coefficient, M is the cross-section numbers, and P denotes the period.

2. Non linear Fourier Panel Unit Root Test (NFPURT)

In panel data, CSD is a prevalent concern. First-generation unit-root tests have been employed in a number of previous research to test for data stationarity. Influential properties are a concern with first-generation unit root tests. They reject the null hypothesis of "cross-sectional dependency" and test the data's stability under a fundamental assumption of "cross-section independence". Because of this, "Non linear Fourier Panel Unit Root Test" were created in order to prevent these false findings. It takes into consideration the issue of cross-sectional dependence to ensure that the data is stationary. By using cross-sectional augmented dickey fuller (CADF) regression, it is possible to track the influence of common causes on the cross-sectional lagged average of all individuals. CADF regression is specified in Equation (2).

$$\Delta y_{xp} = \alpha_x + \delta_x y_{x,p-1} + \gamma_x \bar{y}_{p-1} + \sum_{i=0}^{L} \gamma_{xy} \Delta \bar{y}_{j,p-i} + \sum_{i=0}^{L} \gamma_{xy} \Delta y_{j,p-i} + \mu_{jp} \qquad (2)$$

Where $\bar{y}_{p-1} = \left(\frac{1}{M}\right) \sum_{j,p-i}^{M} y_{x,p-1}$, $\Delta \bar{y}_p = \left(\frac{1}{M}\right) \sum_{j,p-i}^{M} y_{Jp}$, and $p_j\ (M, J)$ is the j-statistic for the estimation of δ_J in Equation (2), which is used to compute the CADF statistics individually. CIPS test statistics are calculated using the mean of each CADF, as stated in Equation (3).

$$CIPS = \left(\frac{1}{M}\right) \sum_{x=1}^{M} p_x\ (M, P) \qquad (3)$$

3. Panel cointegration tests

Cointegration methods are used to determine if variables have a long-term connection. As is the case with “Panel Unit Root Tests (PURT) “, not all cointegration tests are acceptable for determining the long-term relationship between variables under the CD crucial assumption. As a result, we use a newly constructed bootstrap test of cointegration to examine the long-run relationship between green economic development, green innovation, green trade, and clean energy output. This strategy is superior since it addresses structural discontinuities. Additionally, the bootstrapping characteristic is used to cope with the issue of CSD. A common factor constraint issue is avoided, and the hypothesis of "no-error correction" is used to verify whether the suggested variables are cointegrated. An error-correction test is carried out on the series that are integrated in order 1.

$$\Delta HH_{jp} = \beta_{0j} + \sum_{j=1}^{w} \beta_j \, \Delta HH_{j,p-j} + \sum_{j=1}^{w} \varphi_j \, \Delta y_{j,p-j} + \gamma_j ECM_{j,p-j} + f_{jp} \quad (4)$$

A measure of the rate at which the error-term may be adjusted is given by the symbol γ_j, and the vector of independent variables Y includes variables. According to the theory, when a variable's γ_j= 0, it signifies that the variables are not cointegrated, which means there is no error correction.

Long-run coefficients may be estimated if all variables are cointegrated. For predicting the coefficients of cointegrating vectors, this work uses "Fully modified least square (FMOLS)" and "dynamic least square (DOLS)" systems. For example, FMOLS takes into account “CSD”, “endogeneity” and “heterogeneity” in the estimation of parameters. However, the DOLS estimator also addresses the issue of serial correlation, endogeneity, and heterogeneity. The residuals are parametrically modified, and existing and future values of the predictors are integrated to order 1, which allows DOLS to give estimators that are both fair and consistent.

IV. RESULTS AND DISCUSSION

The descriptive statistics of variables employed in the sample of chosen Chinese Economies are provided in Table 1. The null hypothesis of the test is that "residuals are regularly distributed." A substantial value of Jarque-Bera probability indicates that residuals are not normally distributed. Here GG stands for Green Economic Growth, GI stands for Green Innovation, GT is for Green Trade, GE stands for Cleaner Energy Production.

Table 1 *Descriptive statistics*

	GE	**GG**	**GT**	**GI**
Median	3.4342	−1.8094	−0.1448	2.1928
Mean	3.0099	−1.7853	3.17E-07	2.2304
Minimum	−2.6758	−2.0303	−2.3747	0.0393
Maximum	4.6068	−1.3006	2.0933	3.8746
Skewness	−1.3261	0.9245	0.5815	−0.0702
Std. Dev.	1.4688	0.1917	1.0000	0.7644
Jarque-Bera	40.274	13.534	5.4235	3.8267
Kurtosis	4.7722	3.0163	3.1296	2.8060
P-value	0.0000	0.0012	0.0365	0.0729

1. Cross-sectional dependence

It is used to determine cross-sectional dependence in the data by using Pesaran CD test. Cross-sectional dependency's null hypothesis is rejected at the 1% level in Table 2's results.

Table 2 *Cross-sectional dependence results*

Variables	**p-value**	**CD statistics**	**Decision**
GE	0.000	6.8491	“Cross-Sectional dependence”
GG	0.000	7.1816	“Cross-Sectional dependence”
GT	0.000	4.7829	“Cross-Sectional dependence”
GI	0.000	9.3571	“Cross-Sectional dependence”

2. Non linear Fourier Panel unit root

Using the NFPURT, which measures data stationarity, the findings of Table 3 are shown. The test has a "nonstationary series" null hypothesis. Regardless of whether the trend is there or not, the results show that none of the series are stationary. When the null hypothesis of "non-stationary series" is rejected at the level of 1%, however, the series become stationary.

Table 3 *NFPURT analysis*

Variables	First-Difference		Level		Order of integration
	Without trend	With trend	Without trend	With trend	
GE	−3.7370***	−3.6820***	−1.3510	−1.2110	I(1)
GG	−3.7960***	−3.7760***	−1.1930	−1.9950	I(1)
GT	−4.9940***	−5.1140***	−1.4920	−1.6840	I(1)
GI	−4.4360***	−4.4510***	−1.6580	−1.3660	I(1)

3. Panel Cointegration

Using the cointegration test, we may determine whether two variables have a long-term relationship. Table 4 shows that there is a long-term association between green economic growth, GE, GI, and GT, which means that rejecting the null hypothesis of "nocointegration" at the level of 1 percent requires a probability value of Gt, Ga, Pt, and Pa to be less than 0.01.

Table 4 *Panel cointegration results*

	Statistics test	p value (robust)	Decisions
Ga	−18.0660***	0.000	Cointegration exists
Gt	−4.0490***	0.020	Cointegration exists
Pa	−16.4230***	0.000	Cointegration exists
Pt	−9.2900***	0.002	Cointegration exists

4. Hypothesis testing

The postulated hypotheses of the research are tested using “FMOLS (Fully Modified Ordinary Least Squares)” and “DOLS (Dynamic least Square)”, which are used in this study. Table 5 summarises the findings of the FMOLS and DOLS studies. As a result of FMOLS, it was discovered that the coefficient of GE (0.0282) is positive and statistically significant at the 5 percent level since the p-value is less than 0.05 i.e., (0.0342<0.05). This suggests that a one percent increase in GE has the potential to enhance green economic development by 2.81 percent if implemented.

Green innovation (GI) is likewise positively and statistically significant at the ten percent level, with a p-value less than 0.10, or (0.0740<0.10), indicating that it is statistically significant at the ten percent level. According to the findings, a one-percent rise in GI has the potential to improve green economic development by 1.32 percentage.. In addition, the coefficient of GT (0.0505) is positive and statistically significant at the level of one percent since the p-value is less than 0.01 (0.0003<0.01), which indicates that a one percent rise in GT tends to boost green economic growth by 0.504 percent. The value of Adjusted 〖 R〗^2 indicates that GE, GI, and GT Table 6 jointly explain 93.8 percent of the variability in green economic growth.

Table 5 *Hypothesis testing*

Variables	**DOLS**		**FMOLS**		**Decisions**
	p-value	**Coefficient**	**p-value**	**Coefficient**	
GE	0.0313	0.0606**	0.0342	0.0282**	Support H1
GI	0.0820	0.0082*	0.0740	0.0131*	Support H2
GT	0.0003	0.0111***	0.0004	0.0505***	Support H3
R^2		0.988		0.943	
R^2 **Adjusted**		0.961		0.938	

Figure 3(A) depicts the longer-term prospects for the green economy: if the present trend is maintained, the green economy will account for 7 percent of total market capitalization by 2050. With increased green investment, the market capitalization might reach 10% by 2030, which would be around the same size as the health industry and slightly below the banking sector at the time of the forecast. Interestingly, according to the FTSE Russell statistics, the green economy encompasses a wide range of economic sectors, as seen in Figure 3(B), and is not limited to sectors whose principal purpose is to contribute to environmental protection, such as the waste management sector, as previously thought.

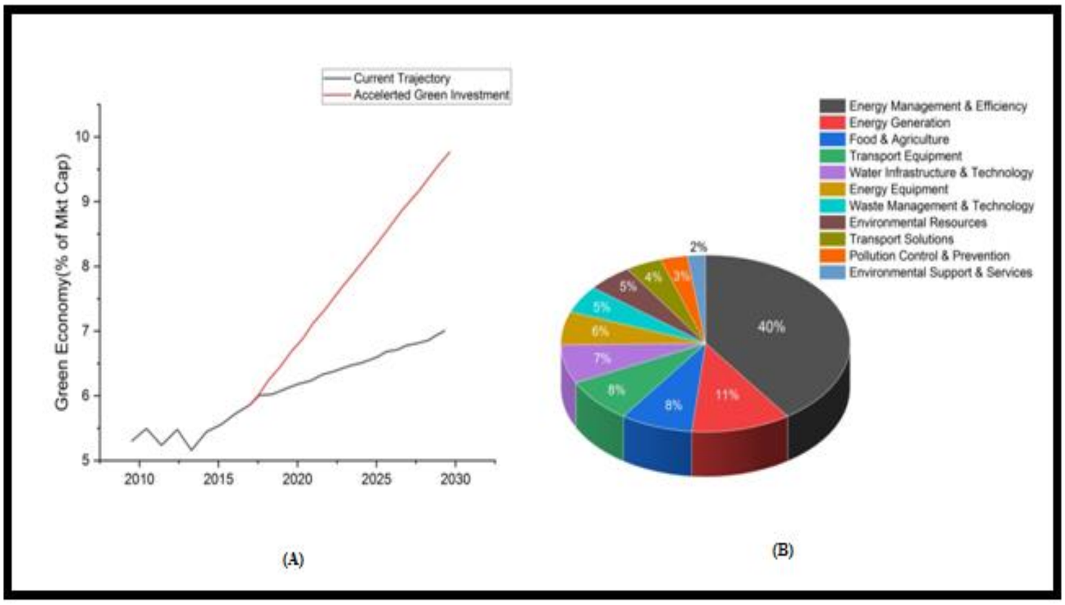

Figure 3 *(A) Potential future growth of the green economy (B) Green economy by green sector. Source: FTSE Russell (2018[21])*

A comparison of current approaches such Augmented Dickey Full [18], Phillips perron [19] and KPSS [20] with the proposed NFPURT is shown in Figure 4. It is obvious from the figure 4a that the suggested approach is more accurate than the current method. Also, the comparison of error prediction is shown in Figure 4(b). This clearly illustrates that the suggested strategy predicts a lower percentage of error than current methods.

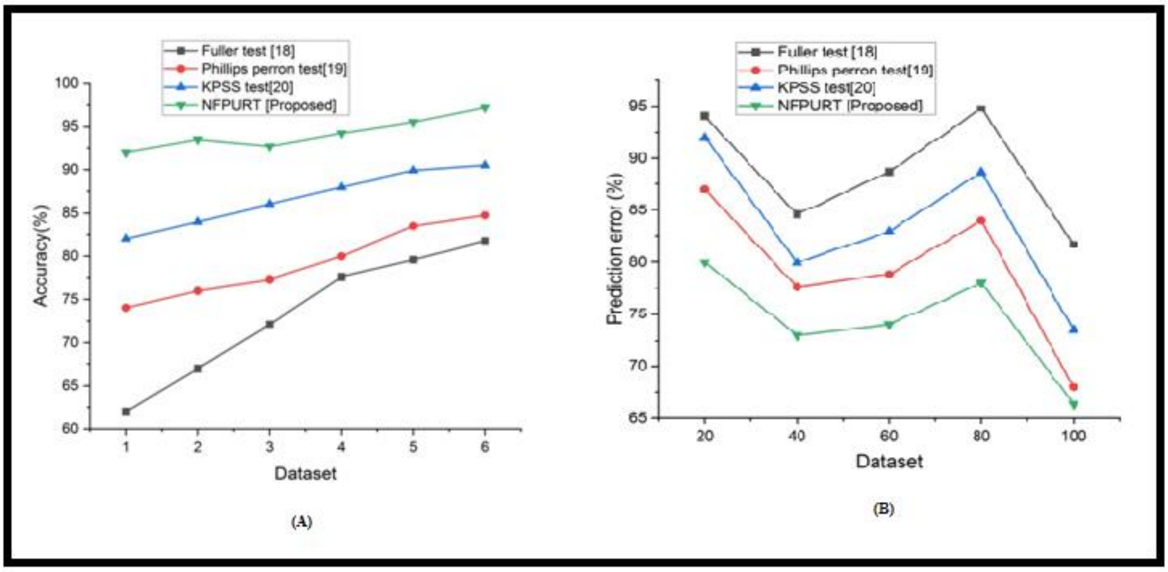

Figure 4 *Dataset Vs. (A) Accuracy and (B) Prediction Error*

V. CONCLUSION

Due to China's serious resource depletion and environmental deterioration, a deeper knowledge of its green economy and green productivity development is required. In this study, we use the PCT, CURT, and NFPURT tests to evaluate China's green economic performance. It is possible that future studies will be able to overcome the study's shortcomings. Although this research is focused on China, the development of the green economy differs greatly from country to country. In this way, future researchers may replicate this work on a panel of underdeveloped countries. In order to acquire more accurate and genuine findings, they may also conduct a cross-national comparison. The current study only looked at three aspects that lead to green economic development; however, in the future, academics may look at even more antecedents to green economic growth.

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