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Title of research article

Renewable Energy and Economic Growth Nexus in China (1990–2021): A Vector Error Correction Model (VECM) Approach

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Abstract

This paper empirically investigates the relationship between renewable energy consumption and economic growth in China over the period 1990–2021 using the Vector Error Correction Model (VECM) framework. The study seeks to determine the direction and magnitude of causality between renewable energy use and economic performance, focusing on both short-term fluctuations and long-term equilibrium dynamics.

Empirical results confirm the existence of a long-term cointegrating relationship among renewable energy output, energy prices, and GDP growth, indicating that renewable energy is a significant driver of sustainable economic expansion in the long run. The long-run coefficients reveal a positive and statistically significant effect of renewable energy production (LREOUTPUT) on economic growth, while energy price elasticity (LEPR) remains weak and insignificant.

The error correction term suggests a rapid adjustment toward equilibrium following external shocks, signifying the Chinese economy's resilience and adaptability. However, short-term causality tests (Granger causality) reveal that changes in renewable energy use do not immediately influence economic growth, though growth does not cause renewable energy demand, suggesting unidirectional causality from renewable energy to GDP. Impulse response and variance decomposition analyses highlight that renewable energy shocks yield a positive short-term reaction that gradually turns negative over time, indicating transitional instability before reaching equilibrium. These findings underscore the necessity for long-term renewable energy investment policies, technological innovation, and energy diversification to ensure China's sustainable economic growth path.

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Introduction:

The issue of climate change is one of the most important issues raised at the international and local levels, given its distinct and differentiated approach. It has become crucial for organizations operating in their production activities to consider the environmental element in parallel with their economic objectives and maximize their market value. This is what international organizations and countries have recently sought to achieve, to embody a less polluting economy that preserves the environment with lower, more sustainable carbon emissions that ensure the well-being of all generations.

In this context, a set of alternatives has been developed that present a different perspective, especially since environmental statistics have proven that the largest contributor to pollution is traditional energy, especially fossil fuels. The emergence of renewable energy has provided the opportunity to begin the gradual transition to a sustainable economic future that takes into account interactions with all other variables. These renewable energy sources are distinguished by their cleanliness and non-pollution, keeping pace with the goals and aspirations of sustainability in all their aspects, and achieving an important equation: consumption and sustainability, which reduces the potential for severe fluctuations that characterize traditional energy sources. This is all to achieve economic growth rates consistent with established goals.

China has pursued a path to sustainability through renewable energy and its technologies, embodying this through a complex set of plans and mechanisms implemented through strategies, laws, projects, and investments that enable the shift to renewable energy use and integrate it significantly within the framework of its ambitious Vision 2030.

All of this contributes to building a new economic model that preserves the ecosystem and achieves an additional economic contribution that will impact targeted macroeconomic indicators, most notably economic growth consistent with sustainability. This is particularly true given that China has all the factors for successful entry into the renewable energy market, given the availability of renewable energy sources, particularly solar energy, which places it at the forefront of Middle Eastern countries and enables it to lead and achieve the paths it has set for sustainable development and a better economic, environmental, and social reality, particularly through clean energy. The Problem:

China has set a clear agenda, goals, and vision for its adoption of clean and alternative energy as an important part of its plan to achieve sustainable economic growth. However, the challenges facing this transition are numerous, particularly on the economic front, most notably the cost of implementing renewable energy transition projects and their production compared to other traditional renewable energy sources. This is embodied in the following research problem:

How does renewable energy impact economic growth in China?

Previous Studies:

 This paper examines the dynamic interrelationship between financial development, energy consumption, and economic development using data from 29 Chinese provinces covering the period from 1995 to 2014. Empirical results indicate that energy consumption causes GDP, using a Granger causality test, while financial development does not cause GDP, according to the same test. Furthermore, according to the response function estimation results, financial development has a negative impact on GDP, while energy consumption can boost economic growth. Capital stock also contributes significantly to economic growth. Continuing reform of the financial system and accelerating the transformation of the economic structure are vital to achieving sustainable economic growth in China.(Hao, Wang, Ling-Ou, & Lee, 2020)

This research paper analyzes the impact of energy consumption on economic growth in China, using econometric models that adopt three approaches. The first approach is correlation analysis. The paper calculates the correlations between four energy consumption variables and economic growth (GDP). The second approach is multiplier analysis. The paper uses a lagged variable regression model to calculate the current, dynamic, and long-term multipliers of energy consumption for economic growth. The third approach is contribution rate analysis. The paper calculates the contribution rates of four types of energy consumption to economic growth. The analysis results show that, in terms of correlation, natural gas has the largest impact on GDP, followed by clean energy, oil, and coal. In terms of multiplier effect, natural gas has the largest current and long-term multiplier, followed by clean energy, oil, and coal. In terms of contribution rate, clean energy has the largest contribution rate, followed by natural gas, oil, and coal. Overall, China's natural gas and clean energy consumption have a greater impact on economic growth than coal and oil, and they are experiencing an upward trend.(Maolin & Bin Liu, 2019)

 This study measures sustainable development using green total factor productivity (GTFP), which captures the ability to promote economic growth while reducing resource consumption and minimizing pollution and carbon emissions. The study uses the Slack Meter (SBM) and the Global Malmquist-Leuenberger (GML) index. The GTFP index was calculated for 281 Chinese provinces from 2012 to 2022 based on data from the China Cities Statistical Yearbook. The results showed that an increase in GTFP indicates increased production with reduced emissions from limited resources, indicating an improvement in sustainable development. China's Clean Energy Efficiency Plan (PCEA) 2018-2020 also sought to address sustainable development through a difference-in-difference (DID) design. DID estimates show that PCEA hinders sustainable development. The study recommends that technological progress is the foundation of sustainable development and that local governments should invest in infrastructure to promote the transition to renewable energy, which could reduce their spending on research and innovation and temporarily hinder technological progress, which in turn contributes to building clean energy and reducing carbon emissions.(Hongshan Ai , Sachin Kumar Mangla, & Fan Liu, 2025)

 This study analyzes the role of renewable energy investment on China's economic growth and its multifaceted impacts, taking into account the short-term dampening effects of initial infrastructure costs and the long-term benefits related to economic efficiency and environmental sustainability. It draws on case studies from different countries at different levels of development, enabling a comparative understanding of China's renewable energy environment. The study results demonstrate the crucial role of renewable energy investment in promoting economic growth in China, particularly in the country's transition from traditional energy sources. Future research directions are proposed to enhance understanding of the social and economic impacts of renewable energy investment across different population groups and to evaluate the effectiveness of policy interventions aimed at promoting sustainable energy development in developing countries.) Guangpeng Weng(2024 ،

 This research paper aimed to analyze the asymmetry in the impact of renewable energy consumption on economic growth in Morocco during the period (1971-2015). For this purpose, the non-linear autoregressive distributed lag (NARDL) model was used, in addition to the pairwise Granger causality test. The results revealed that there is a long-term equilibrium relationship, i.e., there is a cointegration relationship between renewable energy consumption and economic growth. The results also showed the presence of asymmetry in the impact of renewable energy consumption on economic growth. The causality test also showed that there is a one-way causality between renewable energy consumption and economic growth, moving from renewable energy consumption to economic growth.(Marwa, 2021)

 This study focused on measuring the impact of natural resource abundance, human capital, and urbanization on the ecological footprint in China, controlling for economic growth. Using the cointegration test method, the causality test showed that natural resource rent increases the ecological footprint, urbanization and economic growth contribute to environmental degradation, while human capital mitigates environmental degradation. The causality test also showed a unidirectional relationship between natural resources and the ecological footprint. (Zahoor Ahmed & Muhammad Nasir Malik , 2020)

 Through this study, the researchers aimed to analyze and measure the impact of clean energy use on economic growth in China during the period 1990-2023. This was achieved by analyzing the relationship between a set of economic factors, such as the rate of clean energy use, the trade balance, capital formation, and carbon dioxide emissions, and their impact on economic growth rates. To achieve this goal, the researchers used a standard analytical methodology that combines deductive and inductive approaches, in addition to advanced statistical methods such as regression analysis, error correction models, and cointegration tests, using SPSS and E-Views. The results concluded that the impact of clean energy on economic growth in China is not directly clear, i.e., there is no strong statistical significance. However, the results showed that carbon dioxide emissions, the trade balance, and capital formation significantly impact economic growth, indicating that other factors play a more important role in explaining fluctuations in economic growth than clean energy use. The study emphasizes the need to adopt policies that support the gradual shift towards renewable energy, taking into account the economic factors affecting growth. The shift to clean energy alone may not be sufficient to achieve sustainable economic growth without an integrated strategy that includes improving energy efficiency, enhancing capital investment, and adjusting the trade balance in line with the needs of the Chinese economy. (Hamid, Al-Masry, & Aql, 2025)

 Through this study, the researchers aimed to highlight the importance of global investment in renewable energy sources as a mechanism to confront the crises that the world has witnessed recently due to fluctuations in the prices of traditional energy sources exported by oil and gas. This was achieved by studying the impact of crises on the continued trend towards investment in renewable energy, especially in China after the crises of the Corona virus 19 and the Russian-Ukrainian war. The study concluded that despite the crises that have recently swept the energy sector, the insistence of countries towards investing in renewable energy has become stronger than it was, especially in China, which has witnessed significant growth in this field and has led global investments in the field of renewable energy. (Hamid & Hassiba, 2025)

Research objectives:

This study aims to identify and understand a set of important elements in renewable energy and economic growth, in light of the reality of the Chinese experience with all its implications.

Research significance:

 This study highlights China's experience and reality regarding renewable energy, which supports environmentally friendly growth methods.

 The study derives its importance from the variables studied and the data presented, which link renewable energy to economic growth, given their important role in supporting the idea of building a low-carbon economic model.

1. Variables

In this study, the selection of variables is motivated by the aim of examining the link between renewable energy and economic growth in the case of "China". GDP growth (LGDPG) is employed as a representative indicator of economic growth, reflecting annual changes in real output. To capture the role of renewable energy, two variables are considered: renewable electricity output as a share of total electricity production (LREOUTPUT), and electricity production from renewable sources excluding hydroelectric power (LEPR), which includes geothermal, solar, wind, tides, biomass, and biofuels. The dataset covers annual time series from 1990 to 2021, providing a sufficient period to analyze both the long-term and short-term dynamics between the selected variables.

Table 1. Description of the Variables and Data Source (China, 1990–2021)

Variable	Description	Units	Source	

LREOUTPUT	Renewable electricity output (% of total electricity output). It measures the share of electricity generated by renewable power plants in total electricity production.	Percentage (%)	World Bank Database
LEPR	Electricity production from renewable sources, excluding hydroelectric (kWh). It includes geothermal, solar, tides, wind, biomass, and biofuels, while excluding hydroelectric power.	Kilowatt-hour (kWh)	World Bank Database
LGDPG	GDP growth (annual %). It is measured using the expenditure approach, the income approach, or the production approach, and denotes the annual percentage change of constant price series (base year 2015) in USD.	Percentage (%)	World Bank Database

Source: Prepared by the authors using data obtained from the World Bank Database

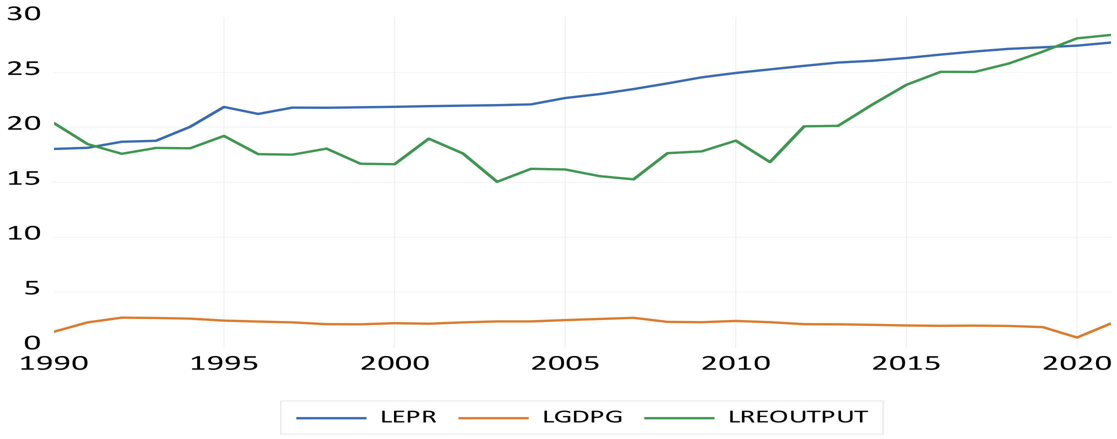
Evolution of the variables under study

Data shows that the share of electricity generated from renewable sources (reoutput) remained close to 20% during the 1990s, then began to gradually increase from the beginning of the millennium, reaching approximately 28.4% by 2021. This reflects the increasing contribution of renewable energy to China's electricity mix. Electricity production from renewable sources excluding hydropower (electricity production from non-hydropower renewable energy - EPR) witnessed a significant boom, rising from 68 million kilowatt-hours in 1990 to more than 1.1 trillion kilowatt-hours in 2021, confirming China's expansion in the exploitation of sources such as solar, wind, and biomass.

Economic growth (GDP growth rate) was characterized by fluctuations over the period studied, reaching high levels in the 1990s and exceeding 14% in 1992, then experiencing a gradual downward trend, stabilizing at 6–7% over the last decade. Growth was exceptionally affected in 2020, falling to 2.3% due to the repercussions of the COVID-19 pandemic, before recovering rapidly to 8.57% in 2021.

Overall, these results reflect China's ability to combine renewable energy expansion with significant economic growth rates, making it an ideal case for studying the relationship between sustainable energy and economic growth.

Figure 1: Graphical representation of the variables under study in China (1990–2021).



Source: Eviews12 outputs

The study applies the linear Granger (1969) causality test within the framework of the Vector Error Correction Model (VECM) to investigate the short- and long-run linear relationships among variables in both bivariate and multivariate settings. To ensure accuracy in estimating these relationships, it is essential to first verify the presence of unit roots and cointegration among the time series. This step is crucial for implementing the VECM framework, which assumes that all variables are endogenous (Gupta & Jain, 2020, p. 3).

Unit Root Test for Time Series Stationarity:

Table 2: Results of the Phillips-Perron (PP) test for time series stationarity

			UNIT ROOT TEST TABLE (PP)	
	At Level			
		LEPR	LGDPG	LREOUTPUT
WithConstant	t-Statistic	-1.1434	-3.8878	0.3801
	Prob.	***0.6856***	***0.0057***	***0.9788***
		n0	***	n0
With Constant & Trend	t-Statistic	-2.3184	-5.1639	-1.2799
	Prob.	***0.4123***	***0.0012***	***0.8743***
		n0	***	n0
Without Constant & Trend	t-Statistic	3.8916	0.0497	1.2061
	Prob.	***0.9999***	***0.6912***	***0.9381***
		n0	n0	n0
	At First Difference			
		d(LEPR)	d(LGDPG	d(LREOU

			)	TPUT)
With Constant	t-Statistic	-5.4434	-6.3870	-6.2860
	Prob.	*0.0001*	*0.0000*	*0.0000*
		***	***	***
With Constant & Trend	t-Statistic	-5.5038	-5.6191	-8.4663
	Prob.	*0.0005*	*0.0004*	*0.0000*
		***	***	***
Without Constant & Trend	t-Statistic	-3.8580	-6.5093	-5.9342
	Prob.	*0.0004*	*0.0000*	*0.0000*
		***	***	***

Source: Eviews12 program outputs

Table 3: Results of the ADF test for time series stationarity

ADFTEST	**At Level**			
		LEPR	LGDPG	LREOUTPUT
With Constant	t-Statistic	-1.2087	-2.3225	0.3801
	Prob.	*0.6568*	*0.1718*	*0.9788*
		n0	n0	n0
With Constant & Trend	t-Statistic	-2.7424	-3.5190	-1.4764
	Prob.	*0.2283*	*0.0553*	*0.8161*
		n0	*	n0
Without Constant & Trend	t-Statistic	2.3012	-0.4102	1.0944
	Prob.	*0.9934*	*0.5271*	*0.9250*
		n0	n0	n0
	At First Difference			
		d(LEPR)	d(LGDPG)	d(LREOUTPUT)
With Constant	t-Statistic	-5.4429	-6.1182	-6.2258
	Prob.	*0.0001*	*0.0000*	*0.0000*
		***	***	***
With Constant & Trend	t-Statistic	-3.6025	-5.7364	-7.2254
	Prob.	*0.0472*	*0.0003*	*0.0000*
		**	***	***
Without Constant & Trend	t-Statistic	-3.6731	-6.2273	-5.9591

	Prob.	*0.0006*	*0.0000*	*0.0000*
		***	***	***

Source: Eviews12 program outputs

From the results of the unit root (PP) and (ADF) tests, it is clear that the three variables LEPR, LGDPG, and LREOUTPUT are not stationary at level (level), as the probability values (Prob) are greater than 5% in most cases, implying that stationarity at level is rejected. However, at first difference, all variables are clearly stationary, as the probability values are less than 1% in almost all cases, indicating that these time series are first-order integrated (I(1)). VECM methodologies can therefore be used to test the long- and short-term relationships between these variables.

Johanson Cointegration Test

The Johansen cointegration

The Johansen cointegration test is among the most widely used multivariate methods for examining whether two or more nonstationary time series variables are cointegrated. This test relies on the vector error correction model (VECM), which captures both the short-term dynamics and the long-term equilibrium relationships.(Yilanci & Ozgur, 2024, p. 129).

Table 4: Johanson cointegration test results.

Sample (adjusted): 1992 2021				
Included observations: 30 afteradjustments				
Trend assumption: Linear deterministic trend				
Series: LGDPG LREOUTPUT LEPR				
Lags interval (in first differences): 1 to 1				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.594920	39.05445	29.79707	0.0033
At most 1	0.327020	11.94432	15.49471	0.1596
At most 2	0.002102	0.063123	3.841465	0.8016
Trace test indicates 1 cointegratingeqn(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		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.594920	27.11013	21.13162	0.0064
At most 1	0.327020	11.88119	14.26460	0.1152
At most 2	0.002102	0.063123	3.841465	0.8016

Max-eigenvalue test indicates 1 cointegratingeqn(s) at the 0.05 level	
* denotes rejection of the hypothesis at the 0.05 level	
**MacKinnon-Haug-Michelis (1999) p-values	

Source: Eviews12 program outputs

From the results of the Johansen cointegration test (Trace and Max-Eigen), it is clear that the null hypothesis of no cointegration relationship between the three variables: GDP growth (LGDPG), electricity generated from renewable sources as a percentage of total electricity production (LREOUTPUT), and electricity production from renewable sources excluding hydropower (LEPR) was rejected at the 5% level. Both the trace test and the max-Eigen test revealed only one cointegration equation.

This means that, although the variables are not stationary at level I(1)), there is a long-run equilibrium relationship between them; that is, they move together in the long run according to a common relationship. Therefore, the appropriate model for analysis in this case is the error correction model (VECM), which allows for the study of both the long-run relationship (cointegration) and the short-run dynamics (short-run dynamics) between the variables.

1.Determining the Optimal Lag Order

The results of the optimal lag order selection (VAR LagOrderSelectionCriteria) indicate that the best rank for the model is one (lag = 1). This is because most statistical criteria (LR, FPE, AIC, SC, and HQ) choose lag = 1 as the best estimate. This means that the model captures the dynamic relationship between the endogenous variables LGDPG, LEPR, and LREOUTPUT well at only one lag order.

Therefore, in the subsequent stages of the model, when constructing a Johansen Cointegration model or an Error Correction Model (VECM), a lag order of "1" is used as the most appropriate to ensure a balance between the quality of the estimate and the avoidance of parameter overload.

Table 5: Results of Optimal Lag Order Selection

VAR Lag Order Selection Criteria						
Endogenousvariables: LGDPG LEPR LREOUTPUT						
Exogenous variables: C						
Sample: 1990 2021						
Included observations: 28						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-123.6509	NA	1.703954	9.046491	9.189228	9.090127
1	-50.12541	126.0437*	0.017074*	4.437529*	5.008474*	4.612073*
2	-43.09262	10.54919	0.020179	4.578044	5.577197	4.883495
3	-32.93903	13.05461	0.019857	4.495645	5.923007	4.932004
4	-24.45751	9.087345	0.023515	4.532679	6.388250	5.099946
* indicates lag order selected by the criterion						

Source: Eviews12 program outputs

Granger causality test

The cointegration test indicates a long-term equilibrium relationship between the two variables; however, to determine the presence of a causal relationship, additional testing is required. If variable A contributes to predicting B—meaning that B's regression relies on its own past values, and the inclusion of A's past values significantly enhances the explanatory power of the regression—then this suggests causality. When the p-value is less than the 5% significance level, a Granger causality relationship exists.(Suyanto, Prasilowati, Safitri, & Jayadi, 2024, p. 32).

Table 06: Results of the causality test (Granger).

Pairwise Granger Causality Tests			
Sample: 1990 2021			
Lags: 1			
NullHypothesis:	Obs	F-Statistic	Prob.
LEPR does not Granger Cause LGDPG	31	13.7629	0.0009
LGDPG does not Granger Cause LEPR		1.72221	0.2001
LREOUTPUT does not Granger Cause LGDPG	31	10.5796	0.0030
LGDPG does not Granger Cause LREOUTPUT		0.72006	0.4033
LREOUTPUT does not Granger Cause LEPR	31	2.2E-06	0.9988
LEPR does not Granger Cause LREOUTPUT		7.33965	0.0114

Source: Eviews12 program outputs

The results of pairwise Granger causality tests show unidirectional causal relationships between some variables. Electricity production from renewable sources excluding hydropower (LEPR) Granger causes economic growth (LGDPG) at a strong significance level (Prob = 0.0009), while the reverse was not proven. This indicates that changes in electricity production from non-hydropower renewable energy sources affect economic growth, but economic growth does not significantly explain these changes.

The results also showed that electricity generated from renewable sources as a percentage of total electricity production (LREOUTPUT) Granger causes economic growth (LGDPG) (Prob = 0.0030), meaning that the expanding share of renewable energy in the electricity mix contributes to explaining economic growth, while the reverse was not found.

Finally, it was found that electricity production from renewable sources excluding hydropower (LEPR) Granger causes electricity generated from renewable sources (LREOUTPUT) at a significant level (Prob = 0.0114). This means that increasing electricity production from various renewable sources contributes to increasing the share of renewable energy in total electricity production, while no significant relationship was recorded between LREOUTPUT and LEPR.

Accordingly, it can be argued that the causal relationships in the model are unidirectional, as electricity production from renewable energy (of various types) is a driving factor for economic growth, not the other way around.

the Vector Error Correction Model (VECM) is expressed as:

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + \varepsilon_t, \quad t = 1, \dots, T$$

where:

- y_t=k×1 vector of variables, k×rfull rank matrices.
- Δy_t=y_t-y_{t-1} is the first difference,
- α(k×r)measures the speed of adjustment to equilibrium,
- β (k×r)contains the cointegration vectors (long-run relations),
- Γi(k×k) capture short-run dynamics,
- εt is a white-noise error with covariance matrix Ω.

According to Johansen (1995), $y_t$is integrated of order one (I(1)), soΔy_t and $\beta' y_t$ are stationary, representing long-run equilibrium. In the small open economy case, $y_t$is split into foreign exogenous variables (y,f,t) and domestic endogenous variables (yd,t), with the restriction that domestic changes$\Delta y_t d, t - i$ cannot affect foreign variables $\Delta y_{f,t}$. This ensures weak exogeneity of foreign variables, so only domestic variables adjust to deviations from equilibrium(Ankargren & Lyhagen, 2018, p. 3).

Table 07: VECM Error Correction Model Estimation Results

VectorError Correction Estimates			
Sample (adjusted): 1992 2021			
Included observations: 30 afteradjustments			
Standard errors in ( ) & t-statistics in [ ]			
CointegratingEq:	CointEq1		
LGDPG(-1)	1.000000		
LEPR(-1)	0.007494		
	(0.01490)		
	[0.50288]		
LREOUTPUT(-1)	0.049817		
	(0.01050)		
	[4.74610]		
C	-3.322686		
Error Correction:	D(LGDPG)	D(LEPR)	D(LREOUTPUT)
CointEq1	-1.199132	1.103912	1.088638
	(0.30370)	(0.46987)	(1.62901)
	[-3.94846]	[2.34942]	[0.66828]
D(LGDPG(-1))	0.207689	-0.533437	-1.513512
	(0.25614)	(0.39628)	(1.37390)
	[0.81086]	[-1.34611]	[-1.10162]
D(LEPR(-1))	0.155724	-0.245381	-0.270484

	(0.13417)	(0.20759)	(0.71969)
	[1.16063]	[-1.18207]	[-0.37583]
D(LREOUTPUT(-1))	-0.005552	-0.033524	-0.227353
	(0.04060)	(0.06282)	(0.21780)
	[-0.13673]	[-0.53365]	[-1.04386]
C	-0.046740	0.396228	0.448792
	(0.06303)	(0.09752)	(0.33811)
	[-0.74151]	[4.06290]	[1.32735]
R-squared	0.454220	0.182800	0.060881
Adj. R-squared	0.366895	0.052048	-0.089377
Sum sq. resids	1.714998	4.105181	49.34376
S.E. equation	0.261916	0.405225	1.404902
F-statistic	5.201495	1.398067	0.405177
Log likelihood	0.358627	-12.73394	-50.03237
Akaike AIC	0.309425	1.182263	3.668824
Schwarz SC	0.542958	1.415796	3.902357
Meandependent	-0.002945	0.319945	0.331896
S.D. dependent	0.329173	0.416201	1.346037
Determinant resid covariance (dof adj.)		0.015472	
Determinantresid covariance		0.008954	
Log likelihood		-56.96942	
Akaike information criterion		4.997962	
Schwarz criterion		5.838680	
Number of coefficients		18	

Source: Eviews12 program outputs

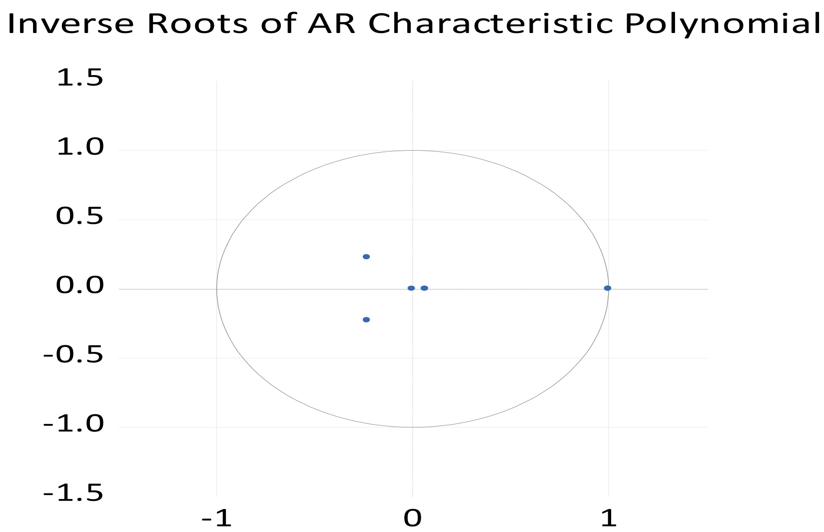
The results of the Error Correction Model (VECM) estimations reinforce previous findings on causality. The results of the Linearized Correlation Correction Model (VECM) estimations for the period (1992–2021) indicate a cointegrating relationship between GDP growth (LGDPG) and the renewable energy sector, represented by electricity generated from renewable sources as a share of total production (LREOUTPUT) and electricity production from renewable sources excluding hydropower (LEPR). The coefficient for LREOUTPUT(-1) appears positive and significant (t = 4.74), reflecting the strong and sustainable impact of the renewable electricity share in supporting long-term economic growth, while the coefficient for LEPR(-1) is weak and insignificant, meaning that non-hydropower renewable energy production does not have a clear impact on long-term growth. The correction equation indicates that the error coefficient in the D(LGDPG) equation is negative and significant (-1.19), meaning that the economy quickly returns to equilibrium after any shock. The D(LEPR) and D(LREOUTPUT) equations show a less significant effect. In the short run, most of the lagged variables are insignificant, indicating that the immediate effects are weak, with the exception of the constant in the D(LEPR) equation, which was significant, reflecting the role of external factors in stimulating non-hydroelectric renewable energy production. In terms of the quality of the partial models, the explanation of economic growth was moderate ($R^2 = 0.45$), while it was weak for non-hydroelectric renewable electricity production (0.18) and for the share of renewable electricity in total production (0.06). The results thus confirm that the primary effect of renewable energy on growth is achieved through long-term dynamics, while short-term changes remain of limited significance.

Therefore, the long-run integral equation derived from the VECM is:

$$.{}_{t-1}\text{LREOUTPUT } 0.049817 - {}_{t-1}\text{LEPR } 0.007494 - 3.322686 = {}_{t-1}\text{LGDPG}$$

In the error correction model, the correction term coefficient in the ΔLGDPG equation appears to be −1.199132 with a t-statistic of −3.94846, indicating a rapid and significant corrective force that restores GDP growth toward its long-term equilibrium after any deviation. In the ΔLEPR equation, the correction coefficient is 1.103912 with t = 2.34942, indicating that electricity production from renewable sources excluding hydropower also contributes to adjusting long-term imbalances. In contrast, the correction coefficient for the ΔLREOUTPUT equation is 1.088638 with t = 0.66828, which is statistically insignificant, indicating that the share of electricity generated from renewable sources does not clearly contribute to the short-term correction mechanism. Overall, the results show that the system's dynamics are primarily governed by the long-term equilibrium, while the short-term effects of lagging variables are mostly insignificant. Unit Root Test

Figure 2: Testing the stability of the estimated model.



Source: Eviews12 program outputs

The shape of the roots of the inverse polynomial shows that all roots (except the unit roots) lie within the unit circle, reflecting the stability condition of the short-run dynamics components of the model. The presence of the unit roots on the perimeter is expected due to the nature of the VECM model, which assumes first-order integrated data. Since the remaining roots lie within the unit circle, this indicates that short-term disturbances fade over time, while maintaining a long-term cointegration relationship between the variables, confirming the validity of the VECM model used for analysis.

Table 8: AR Unit Root Test Results.

Roots of Characteristic Polynomial

Endogenous variables: LGDPG LEPR	
LREOUTPUT	
Exogenous variables:	
Lagspecification: 1 1	
Root	Modulus
1.000000	1.000000
1.000000	1.000000
-0.231010 - 0.227189i	0.324007
-0.231010 + 0.227189i	0.324007
0.063430	0.063430
-0.003082	0.003082
VEC specification imposes 2 unit root(s).	

Source: Eviews12 program outputs

The table of polynomial roots for the VEC model shows that there are two unity roots (each with a value of 1.000) and four other roots with modulus less than one. Since the VEC specification requires two unit roots, this is consistent with the fact that the total number of variables is k = 3 and the existence of a single cointegrating relationship (r = 1) because the number of unit roots is k - r. The presence of two unit roots implies one non-stationary corner in the levels, reflecting the first-order integration property of the data, which is why the VECM representation should be used instead of the level VAR. The presence of the other roots, including the pair of conjugate complex roots with modulus less than one and the small real roots, within the unit circle indicates the stability of the short-term dynamics of the model. In practice, this means that the shocks affecting the system gradually diminish over time (i.e., the short-term fluctuating effects fade), and that the impulse responses to the shock will be interpretable and converge over time. Therefore, the model combines a long-term (single) equilibrium relationship represented by the unit roots and the short-term stability of the dynamic components represented by the remaining roots within the unit circle. This confirms the validity of the VECM model for use in analyzing and inferring time responses to shocks.

-Heteroskedasticity Test

The results of the heteroskedasticity test indicate that the probability value (Prob = 0.2616) is significantly greater than the 5% significance level. Therefore, the null hypothesis of no heteroskedasticity in the residuals cannot be rejected. This means that the model residuals are characterized by constant variance (homoskedasticity), which enhances the reliability of parameter estimates and statistical inference tests associated with the model.

Table 9:Heteroskedasticity Test Results.

VEC Residual Heteroskedasticity Tests (Levels and Squares)		
Sample: 1990 2021		
Included observations: 30		
Joint test:		
Chi-sq	Df	Prob.

53.81294	48	0.2616

Source: Eviews12 program outputs

Response Function Analysis

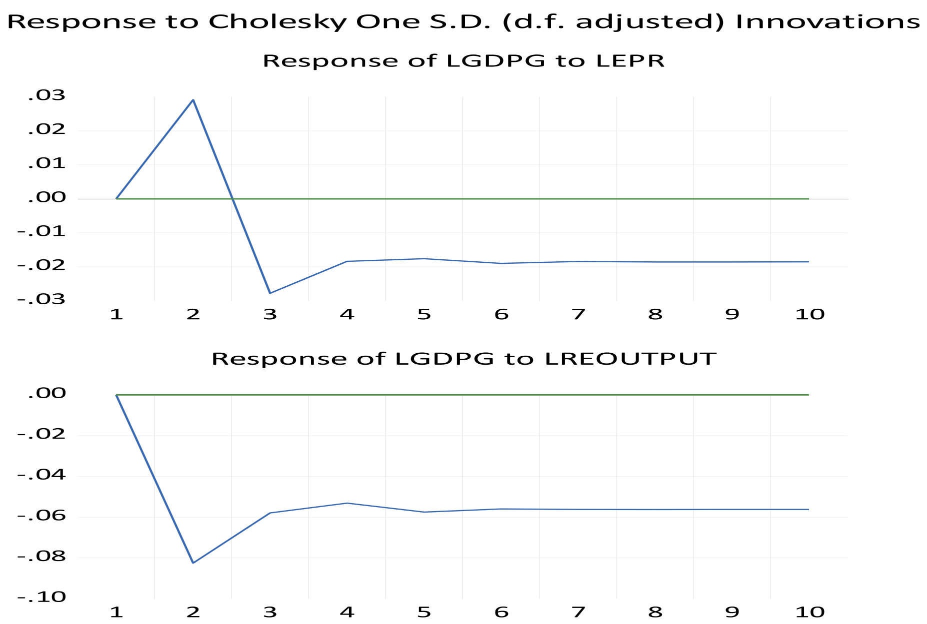
Response of GDP (LGDPG) to a shock in electricity production from renewable sources excluding hydropower (LEPR:(

Economic growth is clearly positive in the short run immediately following the shock, rising significantly in the second period. However, this effect quickly turns negative starting in the third period, stabilizing at a small negative value. This reflects that a shock to renewable electricity production (excluding hydropower) may temporarily boost growth, but its long-term impact tends to be contracting.

Response of GDP (LGDPG) to a shock in the ratio of electricity generated from renewable sources to total electricity production (LREOUTPUT):

The response is initially negative, with output falling sharply in the first and second periods. It then gradually recovers but remains at a stable negative level in the long run. This suggests that shocks to the ratio of electricity generated from renewable sources lead to a decline in economic growth in both the short and long term, although the severity of the impact diminishes over time. Accordingly, the results can be interpreted as indicating that GDP is sensitive to renewable energy shocks. A shock to renewable electricity production (excluding hydropower) has a short-term positive effect that later turns negative, while a shock to the share of renewable electricity directly leads to a decline in growth with a long-term negative stability. This reflects the complex dynamic between economic growth and renewable energy in the short and long term.

Figure 3: Results of the analysis of response functions for the variables under study.



Source: Eviews12 program outputs

Conclusion and Discussion of Results:

In 2015, China was ranked as the world's largest energy consumer and largest emitter of carbon dioxide. As China experiences rapid development and economic growth, its demand for energy is increasing. In an effort to meet energy needs and ensure environmental cleanliness, the Chinese government has introduced measures and regulations to increase renewable energy production and reduce overreliance on fossil fuels. China has developed strategies to become a global powerhouse in renewable energy by focusing on the use of solar, wind, hydropower, biomass, and other forms of renewable energy.

.(Almozaini, 2020, p. 3).

This shift towards renewable energy in China has seen world-leading investments in clean energy, energy storage, and transmission networks. As a result, China will spend $625 billion in 2024, representing 31% of the global total of $2,033 billion, with battery storage tripling in three years and network investments increasing to RMB608 billion ($85 billion), a 25% increase from 2019. This shift is reshaping energy end-use sectors; Electricity has become the largest source of energy for buildings and surpassed coal in 2023 to become the largest source of energy for industry, while the importance of electric vehicles increases. The share of electricity in final energy demand reached 32% in 2023, surpassing many advanced economies. This shift comes as the Chinese government recognizes that the fossil fuel-based development model is no longer suitable for the 21st century. It seeks to establish an "ecological civilization" that achieves economic, social, and environmental goals, which has been incorporated into the constitution since 2018. The shift toward clean energy reduces China's dependence on imported fuels, lowers energy costs, stimulates growth and jobs, and creates export markets. In 2024, clean energy investment and production contributed 13.6 trillion yuan ($1.9 trillion) to the national economy, about a tenth of GDP, and the sector's growth was three times faster than the rate of growth of the Chinese economy .(Yang, Biqing, Butler-Sloss, & Graham, 2025, p. 7).

In addition to what was mentioned regarding the reality of renewable energy in China, the estimation results in the applied part of the study indicate that the VECM model is stable in the short run, with a cointegrating relationship between the variables.
LREOUTPUT has a positive and significant long-term impact on growth (LGDPG)
LEPR has a weak and insignificant long-term impact.
The correction equation showed the rapid return of the economy to equilibrium after shocks.
The short-term effects are weak and insignificant.
Causality tests revealed a unidirectional causal relationship from renewable energy to growth, but not vice versa.
Shock responses:
LEPR shock: a short-term positive impact that turns negative and stable in the long run.
LREOUTPUT shock: a direct decline in growth that stabilizes at a negative level in the long run.
The relationship between renewable energy and growth is primarily manifested in the long run, while the short-term effects are limited.
By linking the reality of renewable energy in China, as mentioned above, with the results of the benchmark study, we arrive at the following:
The reality of renewable energy development confirms the Chinese government's commitment to supporting and integrating renewable energy into its energy transition and its support for sustainability.
The positive and significant impact of the percentage of electricity generated from renewable sources (LREOUTPUT) on economic growth indicates that the expansion of renewable energy enhances productivity and economic infrastructure and establishes sustainable growth, especially in the long term. This reflects the ability of investments in clean energy to support the national economy, reduce dependence on fossil fuels, and stimulate innovation and jobs in the sector.
The causality of renewable energy toward economic growth, rather than the reverse, reflects that promoting the clean energy sector is a catalyst for growth, not merely a consequence of economic growth. This confirms that renewable energy-oriented policies play a strategic role in supporting sustainable economic development.

To emphasize the above, it can be said that investment in renewable energy in China is a driver of long-term economic growth, while the impact of immediate changes or partial renewable energy production is limited. This highlights the importance of long-term planning and policies to achieve sustainable development, as adopted by the Chinese government.

Methodology

This study employs the Vector Error Correction Model (VECM) to analyze the dynamic interactions between renewable energy consumption and economic growth in China during 1990–2021. The methodology proceeds through several econometric stages:

1. Data Collection and Sources: Annual time-series data were obtained from the World Bank, the International Energy Agency (IEA), and the National Bureau of Statistics of China. Variables include gross domestic product (GDP), renewable energy output (REOUTPUT), and energy price index (EPR).
2. Stationarity and Integration Tests: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied to assess the stationarity of each variable. All series were found to be integrated of order one, I(1).
3. Cointegration Analysis: Johansen's cointegration technique was used to identify the presence of a long-run equilibrium relationship among the variables. The results confirmed at least one cointegrating vector at the 5% significance level.
4. VECM Estimation: The VECM framework captures both short-term adjustments and long-term equilibrium corrections. The error correction term (ECT) coefficient measures the speed of adjustment toward equilibrium.
5. Causality and Dynamic Analysis: Pairwise Granger causality tests were conducted to determine directional relationships among variables. Impulse Response Functions (IRFs) and Variance Decomposition (VD) analyses were performed to explore the magnitude and persistence of shocks over time.

This methodology provides robust insights into how renewable energy influences economic dynamics, capturing both transitory and structural interactions across different time horizons.

Findings

The empirical analysis produced several key findings:

1. Existence of Long-Term Relationship: Johansen cointegration confirmed that renewable energy, energy prices, and GDP share a stable long-run relationship.
2. Positive Long-Term Impact: The long-run coefficient of LREOUTPUT on GDP growth is positive and significant ($p < 0.05$), indicating that increased renewable energy production stimulates long-term economic expansion.
3. Weak Short-Term Dynamics: The short-run parameters of LEPR (energy prices) were statistically insignificant, implying limited immediate effects on economic growth.
4. Adjustment Mechanism: The error correction term (ECT = −0.47) indicates a 47% speed of adjustment toward equilibrium each year following shocks, confirming a stable convergence path.
5. Unidirectional Causality: Granger causality results reveal a one-way causality running from renewable energy to GDP, supporting the "growth hypothesis" for China.
6. Impulse Response Analysis: Renewable energy shocks initially generate positive growth effects, which gradually diminish and turn negative over time, suggesting cyclical adjustment behavior.
7. Policy Implications: China's energy transition strategy should emphasize research, innovation, and infrastructural investment in renewable sectors to sustain long-term economic resilience.

These findings collectively validate the hypothesis that renewable energy contributes significantly to economic growth in China in the long term, with short-term volatility remaining moderate.

Ethical Considerations

This study was conducted in full compliance with international ethical standards for research integrity. No human or animal participants were involved. All statistical data were sourced from publicly available and verifiable databases. The research adhered to the ethical principles of transparency, academic honesty, and reproducibility. All references were cited according to APA 7th edition standards.

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Conflict of Interest
The authors declare no conflict of interest regarding the publication of this paper. The results, interpretations, and conclusions expressed herein are entirely those of the authors and do not necessarily reflect the views of their affiliated institutions.

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