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Dynamic Relationship between Green Economy and Energy Utilization Level: Evidence from China

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Abstract: Based on the panel data from 30 provinces in China from 2010 to 2020, this paper employs the panel vector autoregression (PVAR) model to investigate the dynamic relationship between a green economy and energy utilization level. The results show that: (1) the green economic development level and energy utilization level of 30 provinces in China have been continuously enhancing in recent years, the increase in green economic development level is higher than energy utilization level, and the geographical characteristics of both levels are significant, decreasing from East to West; (2) the causal relationship between the green economy and the energy utilization level has passed the Granger test; the two have formed a relatively high-level balanced relationship over a long period, showing a benign and orderly development trend; (3) the green economy generates a positive pulse response on energy utilization level in the initial period, but the impulse response weakens in the period of lag 1, entailing the relationship needs to be further strengthened in the long term; (4) in the process of continuous enhancement of energy utilization level, it is difficult to drive economic benefits due to high input costs in the initial stage, but it can form a two-way interaction relationship with a green economy as time goes by.

Keywords: green economy; energy utilization level; dynamic relationship; impulse response

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1. Introduction

Modern industrialization and urbanization have greatly encouraged the development of the economy, technology, and society. Still, the huge energy consumption and environmental pollution have become common problems worldwide, which need to be solved urgently [1]. To achieve sustainable development in a green and efficient way, China has formulated an action program for sustainable development in the early 21st century. According to the "Sino-USA Joint Statement on Climate Change (2014)" [2], China committed to increasing the proportion of non-fossil fuels to 20% in 2030. According to the document issued by the State Council of China titled "Implementing the New Development Concepts, Achieving Carbon Peak and Carbon Neutrality" [3], China has pledged to decrease carbon emissions after 2030 and strive to achieve carbon neutrality before 2060. Controlling total energy consumption is an important part of the transition to a sustainable economy. The enhancement of energy utilization level is the key to attaining energy conservation and enhancing the quality of economic growth [4]. The increasingly severe energy situation has put forward higher requirements for the green economy. As such, high-level energy utilization can provide more efficient power for economic development [5]. Therefore, we asked if there is a mutual promotion relationship between a green economy and energy utilization and focused on this topic.

In the past, China's energy consumption was dominated by fossil fuels such as coal, petroleum, and natural gas. The energy consumption remained at a level of high consumption and low efficiency. The development of clean energy has been valued by various countries in recent years [6]. It is generally regarded as one of the most important steps to solve the problem of pollutant emission and climate change and an important process in developing a green economy. However, the transition to a green economic mode is a long-term process as it takes a long time for resource investment and government governance to achieve results. Capital-intensive industries account for a high proportion of green economy-related industries, which are influenced by the marketization level, price level, industrial structure, and technological level, bearing in mind that the initial development costs are relatively high [7]. At present, certain challenges persist in China. Some of them include imperfect urbanization, unbalanced regional development, and a low level of social welfare that needs urgently to be solved [8]. These issues entail cities must consider the efficiency of economic growth while considering environmental impacts. The change of energy utilization level in the process of green economy development is an important experience for predicting the future development trend. The above-mentioned points lead us to the following question: can green economic growth drive the improvement of regional energy utilization levels, and ultimately feed back into the economy?

Most existing literature focuses on the relationship between clean energy, carbon emissions, and economic growth. They rarely explore the dynamic relationship between the green economy and energy utilization level [9]. The basic regression analyses are mainly used in relevant research, and only a few articles used the PVAR model with panel data. The PVAR model can be used to investigate the long-term causal relationship, which reflects the influence between variables and maintain independence [10], thereby ensuring real and valid results. The contributions of the paper are as follows: (1) based on the existing research, this paper constructs an evaluation index system for green economy and energy utilization level by entropy method; (2) based on the PVAR model, the study uses a scientific and objective method to accurately evaluate the dynamic coordination relationship of a green economy and energy utilization level. And provides empirical evidence of great significance to understand the relationship and guide regional development planning; (3) explore a growth pattern that considers economic growth, environmental protection, and resource conservation. The main purpose of the paper is to explore new evidence for the interaction relationship between the green economy and energy utilization level, and to provide experience for guiding the policy.

The rest of this article is structured as follows. Section 2 provides a literature review on a green economy and energy utilization levels. Section 3 introduces the methods used and data sources. The results are discussed in Section 4. Finally, this paper presents its conclusions and policy suggestions in Section 5.

2. Literature Review

The concept of "green economy" comes from the "Blueprint for a Green Economy" authored by the British environmental economist Pearce in 1989 [11]. His work equates a green economy with a sustainable development economy and deeply explores ways to achieve sustainable development from the perspective of the environment [12]. Unlike the traditional efficiency-oriented economic mode, the green economy advocates economic growth while controlling the cost of natural resources within a certain range. However, ecological environment capacity and limited resources are not regarded by scholars as constraints on energy utilization and economic growth. A green economy takes sustainable development with high energy efficiency and environmental protection as the goal, which aims to achieve maximum benefits from both economic and environmental systems through coordination and control [13]. To improve the marginal benefit of the eco-environmental system, the energy utilization level is a crucial element to consider. Modern companies also undertake activities in the field of corporate social responsibility to enhance a green economy. Green economy driving diversity is a long-term process, which more attention to attached in all industries [14].

Referring to the existing research results, the connotation of energy utilization level mainly includes three aspects: First, the quantitative relationship between energy consumption and economic development [15]; second, the capacity of natural resource management [16]; and third, the capacity to control pollution [17]. Energy utilization is an important indicator reflecting the relationship between energy, economics, and the environment. The relevant literature is predominantly divided into two categories. The first category mainly focuses on the relationship between socio-economic variables and energy utilization efficiency. Relevant variables include technological advances, economic structural changes, foreign direct investment [18], etc. In recent years, considering environmental resource constraints, there has been emerging literature focusing on the relationship between energy utilization efficiency and environmental policies [19]. The second strand of literature focuses on the improvement of consumer capacity in the process of energy consumption [20], including optimizing resource allocation, reducing transaction costs, stimulating technological advances, and improving pollution control.

There is a certain coordination mechanism that exists between a green economy and energy utilization level [21]. The impact of the green economy on energy utilization levels is mainly reflected in the following aspects: First, the green economy affects energy utilization levels through technological innovation. The improvement of energy utilization levels benefits from technological advances. The advances within the industry can also encourage energy conservation, which is the final goal when implementing clean energy technology. Second, the transition to a green economy can enhance energy utilization by optimizing the industrial structure [22]. Some studies show that the optimization of industrial structures can promote the improvement of energy utilization levels. The impact of energy utilization level on the green economy is shown as follows: First, it stimulates green economic growth through innovation of production mode [23]. As such, energy can replace labor, capital, and other production factors, changing the original way of using it and providing assistance for developing a green economy. Second, it drives the green economy by stimulating economic transformation. The improvement of regional energy utilization level can promote the transformation of the economy to a high level of efficiency and environmentally friendly, thereby improving the vitality of the regional economy.

Empirical research on the dynamic relationship between green economic and energy utilization levels is conducive to improving the understanding of a green economy, clean energy investment, environmental pollution, and energy utilization. Such academic studies further guide formulating industrial policies, achieving energy conservation targets, and improving green economic efficiency.

3. Methods

3.1. Evaluation Model

The model to investigate the comprehensive development level of green economy and energy utilization is as follows:

$$U = \sum_{j=1}^{m} \omega_{ij} v_{ij}; \sum_{j=1}^{m} \omega_{ij} = 1 \tag{1}$$

U refers to the comprehensive development level of Green Economy (U_G) and Energy Utilization Level (U_E); v_{ij} is the standardized value of each indicator within the system; ω_{ij} is the weight of each indicator.

Before calculating the comprehensive development level, the Entropy Method should be used to standardize the original data. The calculation steps are as follows:

Data standardization:

$$x_{ij} = \begin{cases} \left(F_{ij} - F_{j\min}\right) / \left(F_{j\max} - F_{j\min}\right) \\ \left(F_{j\max} - F_{ij}\right) / \left(F_{j\max} - F_{j\min}\right) \end{cases} \tag{2}$$

Calculate the proportion of the j index of the i evaluation object:

$$X_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij} \tag{3}$$

Calculate the entropy value of the indicator:

$$e_j - \frac{1}{\ln m}\sum_{i=1}^{m}(X_{ij} \times \ln X_{ij}), 0 \leq e_j \leq 1 \quad (4)$$

Calculate the discrepancy coefficient of the indicator:

$$d_j = 1 - e_j \quad (5)$$

Calculate the weight:

$$W_j = d_j / \sum_{j=1}^{n} d_j \quad (6)$$

3.2. PVAR Model

There is a complicated dynamic relationship between a green economy and energy utilization level, with the possibility of a lag effect. Using models such as the POOL model for regression analysis will cause problems associated with endogeneity and sequence. However, the PVAR model allows all variables to be endogenous and reflects the dynamic relationship between multiple variables [24], taking into account the differences between each individual. Introducing variable lags into the model can also effectively solve the endogeneity problem related to some of the variables. The PVAR model has advantages for both panel data regression and vector autoregression, as it can minimize the limitation of vector autoregression on time series length and capture the influence of each sample on model parameters. In view of this, this study selects the PVAR model to explore the dynamic relationship between the green economy and the energy utilization level, as follows:

$$Y_{it} = \alpha_0 + \sum_{j=1}^{n} \alpha_j Y_{i,t-j} + \beta_i + \gamma_i + \varepsilon_{it} \quad (7)$$

Y_{it} is a column vector of order 1×2, contains two endogenous variables of green economy (U_G) and energy utilization level (U_E), α_0 is the intercept term, j is the lag order, α_j is the parameter matrix of lag j, β_i is the individual fixed effects, γ_i is the individual time point effects, ε_{it} is the random disturbance term.

3.3. Index Construction

The construction of the evaluation index system for a green economy and energy utilization level follows the principles of systematicness, comparability, representativeness, and availability. In the research, the green economy evaluation index system is constructed based on the indicators proposed by the United Nations Environment Program. The economic situation in China has also been taken into consideration [25], the index system including the scale, structure, and benefit to the economy [26–28]. The scale of the economy constitutes a requirement for achieving economic power. The structure of the economy represents the inclination of each economic field to the green economy transition and the measures taken by the various departments in the process of transition. The benefits of the economy are predominantly emphasized in environmental economics. A total of 11 indicators are selected to assess the green economy. This paper constructs an index system of energy utilization levels based on recent research publications [29–31], including three layers: energy utilization intensity, resource allocation capacity, and environmental pollution control capacity. A total of 10 indicators are selected to measure the level of the energy industry and the governance capacity of institutions. The index system is shown in Table 1.

Table 1. The index system of green economy and energy utilization level.

Target Layer A	Criteria Layer B	Indicator Layer C
Green economy	The scale of economy	GDP (billion yuan) Investment in fixed assets (billion yuan) Level of financialization (%) insurance penetration (%)
	The structure of economy	Proportion of the value of tertiary industry (%) Proportion of the value of secondary industry (%) Per capita retail spending (thousand yuan)
	The benefit to economy	Green finance index (%) Wage gap (yuan) Internet penetration (%)
Energy utilization level	Energy utilization intensity	Energy consumption per unit of GDP (thousand tons coal/billion yuan) Energy consumption per unit of industrial output (thousand tons coal/billion yuan) Energy consumption per unit of investment in fixed assets (thousand tons coal/billion yuan)
	Resource allocation ability	Proportion of the value of tertiary industry (%) The ratio of local government expenditure to GDP (%) Number of employees of state-owned enterprises (thousand people)
	Environmental pollution control capacity	Investment in environmental governance control (billion yuan) Industrial dust emission (thousand tons) Comprehensive utilization of industrial waste (thousand tons) Per capita SO_2 emissions (thousand tons) Per capita dust emissions (thousand tons)

3.4. Data Sources

Referring to the existing research results and combining the development trend of China's green economy, this study selected the period according to three criteria: (1) Data availability; (2) The principle of timeliness, where we study the contemporary period to ensure the timeliness value of the research output; (3) The principle of continuity, which comprehensively considers the goal of data continuity and annual differences. Based on the above principles, this study selects 2010–2020 as the study period. Data are made available from the following sources: China Statistical Yearbook (2010–2020), China Industrial Statistical Yearbook (2010–2020), China Science and Technology Statistical Yearbook (2010–2020), China Environmental Statistical Yearbook (2010–2020), and regional statistical publications. Missing data are estimated by the average annual growth rate using the interpolation method, and results are presented using three decimal places. The research area covers 30 provinces, municipalities, or districts, and the data on Tibet were not included in the study.

4. Results

4.1. Comprehensive Evaluation of Green Economy and Energy Utilization Level

The value of the green economy and energy utilization level of 30 provinces in China from 2010 to 2020 is estimated through the evaluation index system, as shown in Tables 2 and 3. It can be found that during the study period, the green economy and energy utilization level in China have reached different degrees of improvement. The national average level of the green economy increased from 0.160 to 0.359, constituting an increase of 124.3%. The national average energy utilization level increased from 0.304 to 0.416, an increase of 36.8%. By examining the differences among provinces, we found that the regional distribution characteristics of the green economy and energy utilization level in China are significant.

Table 2. Comprehensive evaluation results of a green economy.

Province	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.343	0.346	0.371	0.393	0.425	0.404	0.447	0.445	0.458	0.473	0.479
Tianjin	0.225	0.243	0.245	0.255	0.275	0.259	0.261	0.257	0.256	0.296	0.293
Hebei	0.414	0.455	0.428	0.431	0.431	0.453	0.446	0.487	0.489	0.534	0.562
Shanxi	0.313	0.349	0.394	0.393	0.393	0.396	0.442	0.367	0.403	0.436	0.464
Neimenggu	0.268	0.346	0.318	0.339	0.373	0.373	0.361	0.367	0.376	0.394	0.410
Liaoning	0.318	0.382	0.440	0.393	0.372	0.362	0.339	0.351	0.347	0.363	0.378
Jilin	0.253	0.253	0.255	0.268	0.267	0.276	0.286	0.294	0.300	0.335	0.335
Heilongjiang	0.314	0.312	0.331	0.336	0.321	0.336	0.352	0.348	0.365	0.364	0.375
Shanghai	0.275	0.290	0.292	0.296	0.31	0.323	0.325	0.318	0.329	0.333	0.337
Jiangsu	0.382	0.416	0.422	0.468	0.473	0.488	0.472	0.469	0.478	0.516	0.550
Zhejiang	0.308	0.300	0.324	0.328	0.348	0.357	0.395	0.373	0.402	0.433	0.453
Anhui	0.322	0.351	0.369	0.392	0.383	0.405	0.418	0.429	0.445	0.475	0.496
Fujian	0.265	0.259	0.293	0.309	0.273	0.284	0.295	0.304	0.309	0.316	0.331
Shanxi	0.290	0.324	0.341	0.331	0.333	0.347	0.352	0.360	0.371	0.392	0.407
Shandong	0.461	0.504	0.522	0.537	0.540	0.525	0.574	0.610	0.615	0.670	0.716
Henan	0.337	0.372	0.388	0.403	0.412	0.417	0.429	0.474	0.479	0.501	0.531
Hubei	0.303	0.333	0.334	0.337	0.355	0.355	0.404	0.401	0.415	0.437	0.459
Hunan	0.295	0.312	0.322	0.334	0.327	0.382	0.333	0.345	0.356	0.374	0.384
Guangdong	0.539	0.391	0.387	0.398	0.390	0.408	0.434	0.436	0.445	0.471	0.498
Guangxi	0.293	0.299	0.315	0.320	0.317	0.33	0.329	0.343	0.351	0.377	0.387
Hainan	0.240	0.249	0.245	0.244	0.247	0.256	0.261	0.265	0.275	0.285	0.293
Chongqing	0.237	0.281	0.281	0.282	0.288	0.289	0.284	0.298	0.304	0.307	0.312
Sichuan	0.340	0.343	0.355	0.374	0.391	0.386	0.404	0.412	0.429	0.430	0.450
Guizhou	0.268	0.314	0.305	0.314	0.324	0.327	0.333	0.349	0.363	0.387	0.392
Yunnan	0.315	0.352	0.341	0.363	0.352	0.356	0.369	0.367	0.378	0.389	0.397
Shaanxi	0.309	0.315	0.316	0.315	0.337	0.346	0.364	0.349	0.348	0.365	0.381
Gansu	0.265	0.287	0.285	0.296	0.301	0.325	0.332	0.329	0.335	0.342	0.352
Qinghai	0.211	0.301	0.285	0.284	0.301	0.328	0.353	0.353	0.346	0.383	0.399
Ningxia	0.183	0.206	0.212	0.219	0.229	0.23	0.243	0.241	0.243	0.253	0.257
Xinjiang	0.240	0.275	0.297	0.315	0.330	0.329	0.353	0.375	0.360	0.389	0.406
Average	0.304	0.325	0.334	0.342	0.347	0.355	0.366	0.371	0.379	0.401	0.416

Table 3. Comprehensive evaluation results of energy utilization level.

Province	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.418	0.425	0.439	0.453	0.481	0.518	0.556	0.572	0.564	0.597	0.619
Tianjin	0.168	0.181	0.197	0.217	0.233	0.258	0.290	0.296	0.313	0.353	0.369
Hebei	0.163	0.173	0.186	0.207	0.231	0.265	0.296	0.317	0.341	0.383	0.395
Shanxi	0.138	0.148	0.153	0.174	0.200	0.256	0.280	0.250	0.258	0.259	0.266
Neimenggu	0.095	0.108	0.123	0.147	0.156	0.176	0.204	0.238	0.256	0.261	0.265
Liaoning	0.169	0.176	0.195	0.218	0.239	0.254	0.266	0.273	0.276	0.281	0.293
Jilin	0.119	0.119	0.125	0.138	0.155	0.186	0.220	0.238	0.257	0.300	0.304
Heilongjiang	0.129	0.137	0.160	0.181	0.209	0.243	0.271	0.308	0.316	0.323	0.333
Shanghai	0.281	0.295	0.301	0.311	0.335	0.365	0.400	0.402	0.409	0.443	0.461
Jiangsu	0.245	0.297	0.310	0.339	0.373	0.410	0.447	0.481	0.509	0.554	0.573
Zhejiang	0.208	0.246	0.260	0.284	0.308	0.339	0.367	0.392	0.419	0.446	0.466
Anhui	0.131	0.153	0.143	0.160	0.183	0.215	0.247	0.272	0.294	0.335	0.345
Fujian	0.145	0.168	0.308	0.203	0.222	0.249	0.270	0.289	0.305	0.330	0.345

Table 3. *Cont.*

Province	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Shanxi	0.094	0.114	0.116	0.131	0.152	0.181	0.212	0.232	0.248	0.275	0.290
Shandong	0.203	0.236	0.261	0.296	0.331	0.366	0.406	0.429	0.463	0.503	0.519
Henan	0.144	0.170	0.170	0.198	0.236	0.270	0.308	0.341	0.372	0.411	0.424
Hubei	0.154	0.177	0.176	0.202	0.235	0.258	0.291	0.320	0.338	0.377	0.389
Hunan	0.145	0.155	0.164	0.185	0.209	0.237	0.266	0.297	0.325	0.354	0.362
Guangdong	0.261	0.293	0.310	0.339	0.369	0.411	0.454	0.491	0.516	0.562	0.577
Guangxi	0.112	0.131	0.141	0.151	0.169	0.189	0.207	0.242	0.261	0.293	0.307
Hainan	0.170	0.181	0.178	0.190	0.207	0.23	0.244	0.255	0.263	0.274	0.284
Chongqing	0.139	0.154	0.157	0.177	0.208	0.228	0.248	0.266	0.288	0.310	0.319
Sichuan	0.169	0.187	0.187	0.210	0.239	0.276	0.324	0.348	0.364	0.392	0.404
Guizhou	0.121	0.139	0.144	0.153	0.158	0.177	0.195	0.210	0.225	0.251	0.261
Yunnan	0.127	0.138	0.146	0.163	0.179	0.200	0.223	0.241	0.248	0.279	0.283
Shaanxi	0.136	0.149	0.150	0.169	0.189	0.217	0.245	0.259	0.275	0.303	0.320
Gansu	0.116	0.134	0.131	0.147	0.168	0.208	0.234	0.245	0.250	0.260	0.273
Qinghai	0.076	0.079	0.079	0.091	0.115	0.141	0.155	0.176	0.187	0.208	0.218
Ningxia	0.101	0.101	0.115	0.126	0.139	0.154	0.175	0.186	0.200	0.220	0.228
Xinjiang	0.120	0.135	0.140	0.158	0.179	0.209	0.223	0.230	0.237	0.264	0.271
Average	0.160	0.177	0.189	0.204	0.227	0.256	0.284	0.303	0.319	0.347	0.359

The evaluation results of a green economy and energy utilization levels in 2010 and 2020 are selected to form the spatiotemporal differentiation diagram, as shown in Figures 1 and 2.

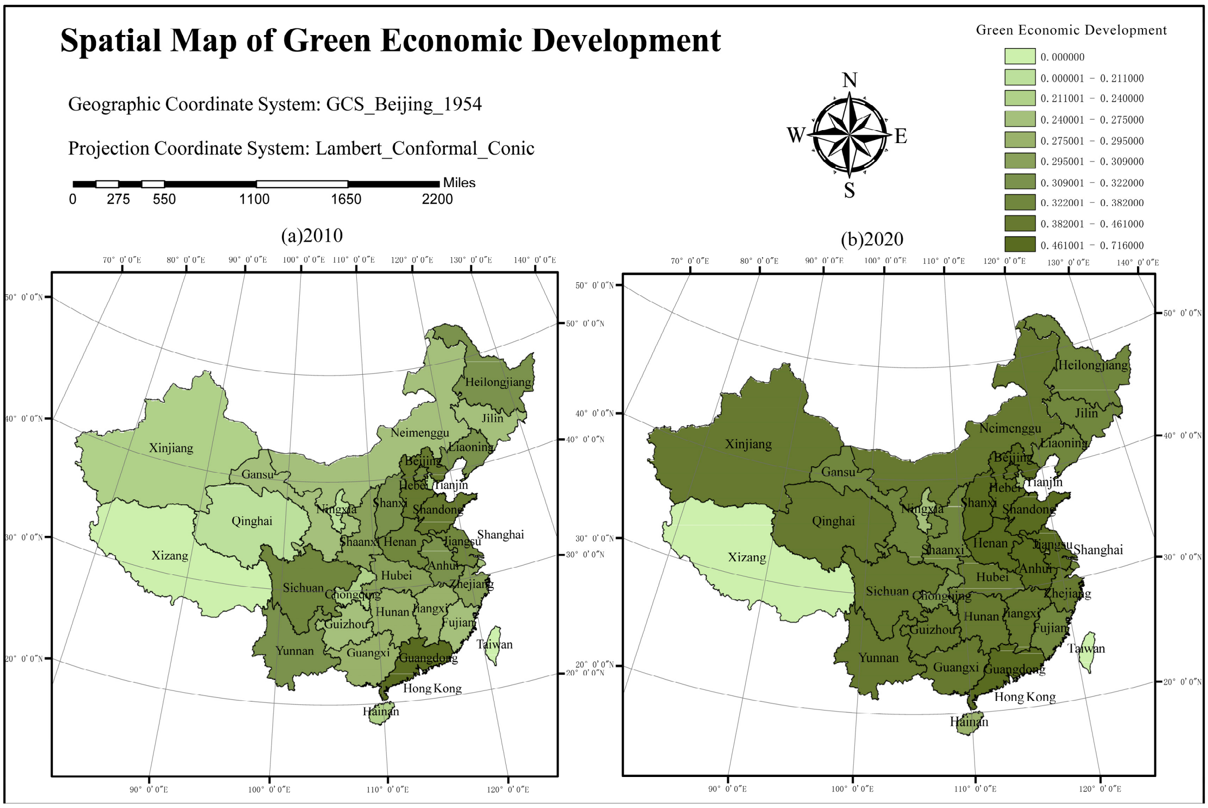

Figure 1. Spatiotemporal differentiation diagram of a green economy. Note: The islands in the South China Sea are not shown in the figure.

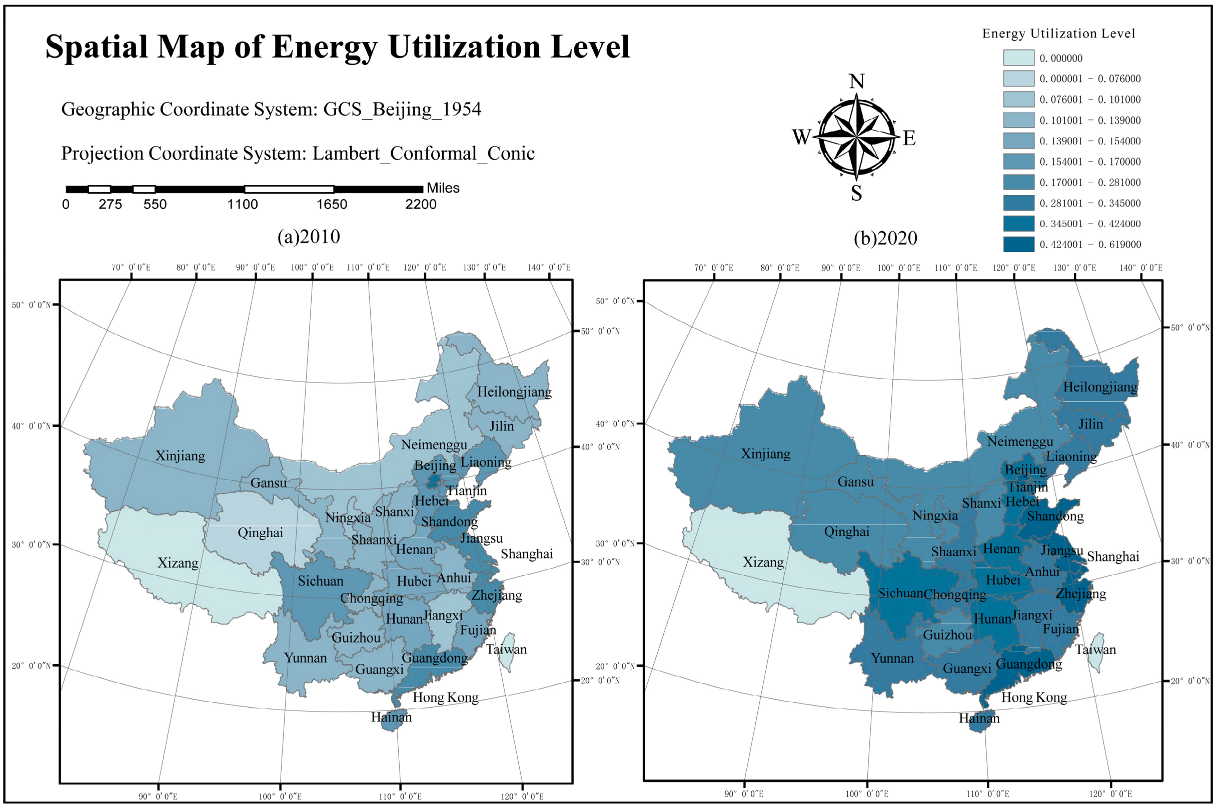

Figure 2. Spatiotemporal differentiation diagram of energy utilization level. Note: The islands in the South China Sea are not shown in the figure.

4.2. PVAR Model Dynamic Relationship Analyze

To clarify the dynamic relationship between a green economy and energy utilization level, we employed the PVAR model to conduct our analysis. After calculating the value of a green economy and energy utilization levels, the variables were examined in the order of "Unit Root Test → Cointegration Test → Model Optimal Lag Order Test → Granger Causality Test" to assure the reliability of empirical results. Finally, the impulse response model was used to test the short-term interaction relationship, and 500 times Monte Carlo simulations were used to define the standard deviation of the impulse response model.

4.2.1. Unit Root Test

First, the Unit Root Test was conducted to test its stationarity and to avoid deviation of results caused by "spurious regression". The results are shown in Table 4. It can be seen from the table that the original data of a green economy (U_G) and energy utilization level (U_E) is unstable. To achieve the integration in the same order, this study conducted a first-order difference analysis. The results show that the data are stable after the order processing, which can be used for the Cointegration Test.

Table 4. Results of Unit Root Test.

Variables	LLC Test	IPS Test	ADF Test	PP Test	Conclusion
U_G	0.3507	2.6587	4.0858 ***	−1.4748	Unstable
ΔU_G	−10.0155 ***	−6.2073 **	9.0219 **	24.0738 ***	Stable
U_E	4.6339	−0.5439	4.6857 ***	13.5129 ***	Unstable
ΔU_E	−5.6854 ***	−8.0232 ***	8.1237 ***	60.5206 ***	Stable

Note: *** represents $p < 0.001$; ** represents $p < 0.01$.

4.2.2. Cointegration Test

The Unit Root Test shows integration in the same order between a green economy and the energy utilization level, so the cointegration test can be performed to test whether there is a long-term equilibrium relationship. Based on regression residuals, this study constructed 8 statistical sub-tests of the Kao Cointegration Test and the Pedroni Panel Cointegration Test. The results are listed in Table 5. According to the results of the Kao Cointegration test, there is a cointegration relationship between variables. According to the results of the Pedroni Panel Cointegration Test, there is a cointegration relationship between the variables, and it is statistically significant at a 1% level. In conclusion, there is a long-term equilibrium relationship between a green economy and energy utilization levels.

Table 5. Results of Cointegration Test.

Test	Statistical Test	Result	Conclusion
Kao	Modified Dickey–Fullert	−0.5180	Cointegration relationship exists
	Dickey–Fullert	−1.7783 ***	
	Augmented Dickey–Fullert	−0.1296	
	Unadjusted modified Dickey–Fullert	−3.0528 ***	
	Unadjusted Dickey–Fullert	−3.3138 ***	
Pedroni	Modified Phillips–Perron	2.5015 ***	Cointegration relationship exists
	Phillips–Perron t	−9.8172 ***	
	Augmented Dickey–Fullert	−6.7124 ***	

Note: *** represents $p < 0.001$.

4.2.3. Model Optimal Lag Order Test

The results of the Cointegration Test show that there is a long-term equilibrium relationship between China's green economy and energy utilization level. However, it is necessary to test whether there is a causal relationship between the two phenomena using the Granger Causality Test. Before conducting the Granger Causality Test, we need to calculate the optimal order of the model, and the order with the largest number of test passes as the optimal order. The results of the optimal lag order test of the PVAR model are shown in Table 6. Among them, AIC, BIC, and HQIC all support the PVAR model with lag order 1.

Table 6. Results of PVAR model optimal lag order test.

Lag	AIC	BIC	HQIC
1	−10.2615 *	−9.33328 *	−9.88747 *
2	−10.0329	−8.95524	−9.6011

Note: * represents $p < 0.05$.

4.2.4. Granger Causality Test

After passing the cointegration test, our results suggest a long-term equilibrium relationship between a green economy and energy utilization levels. Therefore, the Granger Causality Test can be conducted to further examine the causal relationship between variables. The test results are shown in Table 7. According to the results, the hypothesis that "green economy is not the cause of energy utilization level" is rejected at the statistical significance of 5% level. The hypothesis stating that "the energy utilization level is not caused by the green economy" is supported. A green economy is a one-way Granger cause of energy utilization levels. The results show that the development of the green economy in China has improved the regional energy utilization levels, and both present a benign and orderly trend.

Table 7. Results of Granger causality test.

Hypothesis	df	chi2	p	Conclusion
U_G is not the cause of L_U_E	1	5.2866 *	0.021	reject
U_E is not the cause of L_U_G	1	9.2753	0.070	accept

Note: * represents $p < 0.05$.

4.2.5. Impulse Response Analyze

The Impulse Response Model and the Monte Carlo Simulation Method are used to analyze further the interaction between a green economy and energy utilization level. In the simulation process, we define 5 model periods, where the number of repetitions of the data simulation is 500 times. The impulse response results are shown in Figure 3. The abscissa represents the lag periods; the ordinate represents the response degree. The uppermost and lowermost curves represent the upper and lower bounds of the 95% and 5% confidence intervals, respectively, and the middle curve represents the estimated impulse response.

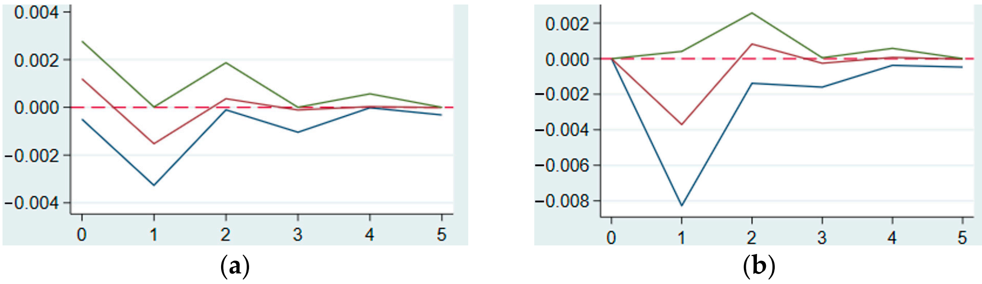

Figure 3. Results of impulse response. (**a**) impulse response from UG to UE. (**b**) impulse response from UE to UG.

As shown in Figure 3, the green economy has a positive impulse response to energy utilization level in the current period, also producing the maximum value. It, however, shows a negative impulse response within lag period 1, which reaches the minimum value. Then it presents a positive response but gradually weakens and approaches 0 towards the end of lag period 5.

The initial impulse response of the energy utilization level is 0. Still, when a negative response appears, it reaches the negative peak value in lag period 1, and after that, the value increases to a positive value. The maximum value of the positive impulse response is reached in lag period 2, and the subsequent impulse response gradually weakens.

5. Discussion

In the analysis of the comprehensive evaluation, we found that the green economy and energy utilization level in China have reached different degrees of improvement. This is in line with the trend in developed countries [32]. By examining the differences among provinces, we found that the regional distribution characteristics of the green economy and energy utilization level in China are significant. In terms of the level of the green economy, the value in Eastern China is higher than that of the underdeveloped areas in Central and Western China, and it is much higher than the national average. The main reason is that the economic, scientific, and technological levels of Eastern China are much higher than the areas elsewhere, thus gaining stronger action power in the process of green economy transformation [33]. The concept of open innovations significantly improves the flow of information and technology and allows for obtaining more prosperous green economies related to various aspects of business [34]. There is also an unbalanced phenomenon of energy utilization level in China as the level in Western China is much lower than the national average.

To clarify the dynamic relationship between a green economy and energy utilization levels, we employ the PVAR model to conduct our analysis. We found a long-term equilibrium relationship between a green economy and energy utilization levels, and a green economy is a one-way Granger cause of energy utilization levels. The reason might be that China has gradually increased its emphasis on sustainable development in recent years [35], the regional industry structure has become more scientific, and the development of a green economy has generated a favorable external environment for enterprises, which is beneficial for improving the efficiency of an enterprise [36]. The rapidly developing economy also puts forward higher requirements for the management capacity of government departments, which has a positive impact on energy utilization levels. There is also a study that investigates the positive effects of elements on a green economy when considering green open innovation activities as the mediator. A major finding is that if a company introduces one, the longer the duration of a green project is, the stronger the green open innovation activities and green economy are [37]. Green open innovation might bridge the green economy and the energy utilization levels.

There are also some experiences brought from the impulse response analysis. (1) green economy. The U-shaped change trend in the early stage shows that the green economy has effectively promoted energy utilization by improving the efficiency of resource allocation and spawning high-tech enterprises [38]. However, because there are few enterprises with the goal of a green economy in the early stage, the investment in technology, manpower, and capital is insufficient after the government subsidies stage [39]. After lag period 1, the industrial foundation of the green economy has been constantly improved, with the short-term constraints being gradually solved. The green economy actively encourages improving energy utilization levels as time goes by. It is consistent with the research result of Cai. Only by using green resources reasonably can we effectively solve the energy shortage problem and environmental protection and lay a good foundation for economic development [40]. Ma's research shows that, in addition to the green economy, the green credit policy has a significantly positive effect on the energy utilization level, while subregional regression results reveal that improvement caused by the implementation of the green credit policy varies across regions in China [41]. (2) energy utilization level. The result indicates that improving energy utilization levels cannot drive the green economy in the short term. The impulse response reaches the minimum value of -0.008 in lag period 1 since the efficiency of energy utilization is overemphasized and the benefit is ignored [42]. With the improvement of clean energy utilization capacity and initial results of new energy input, the energy utilization level reached a positive response in lag period 2. Chen shows that economic development is mainly established on the utilization of nonrenewable resources. Government should regulate the industrial structure, promote the utilization rate of resources, and enhance the sustainable development of an ecological economic system, which is consistent with the study [43]. In the process, explained by Midilli, all negative effects on the industrial, technological, sectoral, and social developments partially and/or decrease throughout the transition to and utilization of green energy and technologies, and when possible, preferred sustainable energy strategies are applied [44].

6. Conclusions

Based on the panel data of 30 provinces in China from 2010 to 2020, this paper employs the PVAR model to investigate the dynamic relationship between a green economy and energy utilization levels. The conclusions are as follows: (1) The levels of green economy and energy utilization for 30 provinces in China have been continuously enhancing in recent years, and the increase in the green economy is higher than the energy utilization level. The geographical characteristics of both levels are significant, decreasing from East to West. (2) There is an equilibrium relationship between the green economy and energy utilization levels, which exists at a relatively high level over a long period, from the perspective of causality, t. The development of the green economy has improved regional energy utilization levels, showing a benign and orderly trend. (3) A green economy can improve energy utilization levels through resource allocation efficiency and technological innovation in the early stage, but it also faces the risk of insufficient momentum. With the increase in the proportion of clean energy, while that of fossil energy decreases, it puts forward higher requirements for energy utilization technology, and therefore, the coordination needs to be further strengthened. Due to the high cost of improving energy utilization in the initial stage, the economic benefit cannot be attained in the short term. However, as time goes by, the continuous improvement of the industrial foundation will eventually form a two-way interaction.

Based on the conclusions above, the policy suggestions are proposed as follows: (1) Build a high-tech capital investment system including government, financial institutions, and enterprises as participants, increase investment in innovative projects, speed up the upgrading of industrial structure, develop low-carbon industry and high-tech industry, and enhance industrial production efficiency. At the same time, optimize the energy consumption structure and actively introduce advanced technologies to improve carbon emission efficiency. (2) In the process of energy utilization, follow the trend of protecting the environment, and coordinate with energy mining enterprises, energy processing enterprises, and energy consumption enterprises to further optimize the energy consumption and supply structure. (3) The economically underdeveloped western regions should take advantage of resource functions, increase investment in clean energy, utilize the economic benefits of terrain and solar energy, develop distinctive industries corresponding to local conditions, and make sure a green economy continues to play a positive role. They should also improve the market and financial support system, sweeten the business environment, undertake the industrial transfer from Eastern China, and encourage enterprises to transfer to a green mode with low pollution, low energy consumption, and high efficiency through tax policies, laws, and market construction.

The article has some limitations: (1) the difficulty of data availability and the presence of incomplete data; (2) the limitation of the research result, which may be different than in other geographical areas. In the future, the author plans to expand the research to other countries, including both developed and underdeveloped countries. Moreover, we would like to design a green economy and energy policy proposal for the government and try to help the government officer identify the current stage, opportunities, and strengths.

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