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Research on the Impact of Green Finance and the Digital Economy on the Energy Consumption Structure in the Context of Carbon Neutrality

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Abstract: Improving the structure of energy consumption (ECS) through green finance and the digital economy is one of the main paths to achieving the goal of carbon neutrality. This paper explores the impact of green finance and the digital economy on the ECS of 30 regions in China from 2007 to 2022 using the Generalized method of moments(GMM) model, further analyzes its heterogeneity, and then provides a reference for the scientific development of relevant decisions. The conclusions are as follows: (1) The change in the ECS is closely related to the degree of optimization of the ECS in the previous year, and this is a process of dynamic adjustment. The level of digital economy development can improve the ECS of the country as a whole and in the eastern and central regions, while the western regions have not yet played a significant role due to the underdevelopment of the digital economy. Green finance can inhibit fossil fuel energy consumption in all regions, and it promotes cleaner, more efficient, and low-carbon energy consumption, thereby improving the ECS. However, the impact effect is the largest in the east and smaller in the west. (2) The urbanization levels of the country as a whole and that of the central and western regions show a positive correlation with the results of energy consumption. However, in the eastern region, it shows an inhibitory effect on fossil fuel energy consumption, which can optimize the ECS. The industrial structures in all regions have positive impact coefficients; the development of industry is not conducive to the optimization of the ECS. Trade openness can improve the ECS only in the eastern region; technological progress in all regions can significantly improve the ECS. Based on the background of carbon neutrality, this paper reveals that green finance and the digital economy promote cleaner, more efficient, and lower carbon energy consumption and reduce the level of energy consumption. This paper also provides a reference for the scientific formulation of relevant decisions.

Keywords: carbon neutrality; green finance; digital economy; ECS; sustainable development

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1. Introduction

Along with economic development, social productivity has increased rapidly, and the world economy has developed rapidly. In pursuit of rapid economic growth, people consume greater amounts of fossil fuel energy, causing a rapid increase in CO_2 emissions and global warming, thereby exacerbating climate instability and making climate change a problem for all humankind [1–3]. China has also paid the price of high emissions and lower energy efficiency. As the structural reform of the energy supply side moves forward, the optimization of the ECS has made some progress, but the consumption of high-pollution, high-emission, traditional fossil fuel energy sources, such as coal, is still in a leading position in the ECS [4]. In recent years, the topics of "carbon peaks," "carbon neutrality," and "energy structure transformation" have been repeatedly mentioned in government documents, and the goal of carbon neutrality by 2060 has been set [5]. The pace of China's ecological civilization construction is gradually accelerating the promotion of clean, low-carbon, accelerated energy transformation, which can reduce the impact of the imbalance of the ECS on the ecological environment and climate change.

Continuous energy demand and a consumption structure dominated by fossil fuel energy have brought great pressure on the sustainable growth of the global economy [6,7]. As for the realization of the "double carbon" goal, green finance supports the construction of the green economy, which is an important initiative, and it is the driving force to build a green economy and improve the ECS. China will continue to improve the innovation level of green financial products and the application scenarios of green finance and continuously improve the green financial policy system to guide the economy towards a low-carbon transformation [8]. In the post-industrialization stage, economic growth relying on energy consumption has declined. However, the two are still not decoupled, and national energy consumption is still in the decelerating growth stage. Based on the goal of becoming "carbon neutral," green finance is important for guiding and attending to energy consumption [9]; as such, there is a need to find the relationship between green finance and the ECS.

At the same time, at the 19th Fifth Plenary Session, China also proposed to promote the energy revolution, accelerate digital construction, shift the focus of development to promoting an economic system upgrade, and build a digital China. At this stage, China is committed to green transformation through reducing carbon emissions; as such, reducing energy intensity and improving the ECS have become the top priorities [10,11]. Exploring the digital economy's impact on energy consumption is of profound significance, and it is a key theoretical support system for the scientific use of digitalization to help energy transformation. Therefore, analyzing the digital economy and the ECS and clarifying the correlation between them are of great practical significance for improving energy efficiency, thereby helping China's energy use to move towards decarbonization and realizing the goal of "dual-carbon." Based on this, this paper takes one of thirty regions in China from 2007 to 2022 as the object of investigation and constructs comprehensive indicators of regional green finance and indicators of the digital economy using the entropy value method. On this basis, this paper chooses the GMM model system to examine the impact of green finance and the digital economy on the energy consumption structure from the provincial level and further analyzes the heterogeneity of this impact. This paper explores the differences between regions and their heterogeneity; reveals the laws of green finance and the digital economy to promote clean, efficient, and low-carbon energy consumption; and details how to reduce the level of energy consumption so as to provide references for the scientific development of relevant decision making.

The research structure of this paper is as follows. The first part introduces the background, motivation, and importance of the dissertation research. The second part is the literature review, which explains the main differences between this paper's research and that of previous scholars so as to highlight the innovation of this paper's research. The third part focuses on the methodology adopted in this paper's research and explains the adaptability of the multimethodology. The fourth part includes the findings of the dissertation and the empirical analyses of the relationships between the variables. The fifth part summarizes the conclusions of this thesis research and, accordingly, proposes its corresponding countermeasures, shortcomings, and prospects.

2. Literature Review

2.1. Impact Effects of Green Finance

2.1.1. Connotation of Green Finance

Regarding the connotation of green finance, Zadek and Flynn [12] mentioned in their article that there is a certain conceptual similarity between green finance and green investment. However, because green finance includes new energy finance and other institutionally defined investments in addition to the operating costs of green investments, they are also included in the scope of green finance, as green finance covers a relatively broader perspective. Lu et al. [13] found that the resource reallocation effect of green finance causes reallocation and exit reconfiguration within the "two high and one leftover" industries. Su and Lian [14] argued that the development of green finance can produce financing penalties and investment inhibition effects, inhibit the inflow of funds to high-energy-consuming and high-polluting industries, and support the development of environmentally friendly industries. As can be seen from the definitions at home and abroad, green finance is the optimization and improvement of financial products based on the innovation of financial services, and it is oriented towards ecological environmental protection, energy saving, low-carbon emission reduction, and efficient utilization to achieve the established multi-dimensional goal of the coordinated development of the economy, society, and ecology. In 2016, the People's Bank of China and other departments jointly issued the Guiding Opinions on Building a Green Financial System, making China the first country in the world in which a systematic green financial policy framework has been developed by a government department. With the continuous development of the green financial market system, scholars have more deeply analyzed the important role of green finance, pointing out that green finance is a form of financial innovation that conforms to the development trend in the economy and meets the requirements for the development of a low-carbon economy, which can reduce energy consumption, can alleviate the problem of environmental pollution, and has become an important means of promoting the green transformation of the economy [15,16].

2.1.2. The Impact of Green Finance on the Energy Consumption Structure

The conclusions of existing studies mainly report two types of effects: facilitating and inhibiting. Scholars who primarily report the facilitating effect emphasize that financial development can expand the credit scale of enterprises and residents by promoting economic growth. In addition, residents buy more energy-consuming household goods when their income increases, while the related enterprises expand the scale of production, which increases use energy [17,18]. Al-Mulali and Lee [19] found that financial development had a facilitating effect on energy consumption. Shahbaz and Lean [20] categorized financial development as an economic function and also concluded that financial development can increase energy consumption. Feng and Xing [21] used a VAR model to test the impact of financial development on total energy consumption. They found a significant positive correlation between the two. Thus, the relationship is not conducive to the improvement of the ESC.

In terms of inhibition, rational guidance through green finance can promote the decarbonization of energy consumption. Raising funds in low-carbon energy is a major issue in energy transition and a key challenge for climate change mitigation [22]. Salazar [23] and Anderson [24] point out that green financial instruments can optimize the structure of energy consumption by providing financial support and guiding the flow of funds to low-carbon and green industries. Bourcet [25] believes that finance can reduce the Impact of energy consumption on environmental pollution. Wang and Lai [26] found that green financial development can reduce energy consumption intensity. Xie and Huang [27] found that, at the national level, green finance not only significantly promotes energy consumption transformation, but also promotes clean energy consumption and replaces coal with cleaner energy. Pang et al. [28] found that China's green finance development indicators show fluctuating growth, and the energy structure is optimized year by year; the development of green finance from the perspective of financing and technological advances produces a positive impact on the optimization of the energy structure.

2.2. Impact Effects of the Digital Economy

2.2.1. Meaning and Main Tools of the Digital Economy

The digital economy, as a concept with a broad connotation, includes any economic form that directly or indirectly utilizes data to guide the role of resources and promote the development of productivity. At the technology level, it includes emerging technologies, such as big data, cloud computing, the Internet of Things, blockchain, artificial intelligence, and 5G communications. At the application level, "new retail" and "new manufacturing" are typical representatives. Wu et al. [29] divided the digital economy indicators into three major aspects: digital economy infrastructure, digital economy scale, and digital technology mobile application. They then standardized them using the entropy weight method to obtain the total indicators of the digital economy level. The digital economy positively affects the economy and society through a variety of indirect paths, such as influencing consumer demand, stimulating urban innovation, and enhancing regional technological innovation, financial development, and factor endowment drive [30,31].

2.2.2. The Digital Economy's Impact on the ECS

The digital economy has a profound impact on national economic growth, traditional industrial structure changes, etc., and it brings certain opportunities for energy transformation. Some researchers believe that the digital economy brings green effect benefits to the energy industry through the strong development of information technology and that it makes significant contributions to ESC and improves energy efficiency. In addition, the trade of information and communications technology products can also reduce the level of carbon emissions. Steffen et al. [32] found that the digital economy can reduce energy consumption through enhancing energy efficiency, while Bunse [33] and May et al. [34] suggest that information and communications technology generates energy savings through the automation of production processes and that capital investment in information and communications technology significantly reduces the total energy consumption in most industrial sectors. Sadorsky [35] found that the development of the Internet positively affects the consumption of electricity. Moyer and Hughes [36] argued that information and communications technology reduces energy intensity and promotes renewable energy production to reduce carbon emissions. Zia [37] illustrated a micro perspective, stating that information and communications technology can improve the digitization degree of transmission systems and enhance their energy efficiency.

Domestic scholars Hu and Liu [38] found that although digital economy development in various regions has a significant impact in China, the digital economy could significantly improve its energy consumption structure with a focus on green development. Luo et al. [39] believed that the digital economy inhibits energy consumption and improves the ECS through regional integration. Wu and Gao [40] and Fan and Xu [41] found that the digital economy promotes energy efficiency by replacing the core elements; better understands the trends in the energy market, real-time collection, monitoring, transmission, analysis, and utilization of relevant data; strengthens the synergistic cooperation and information exchange between different regions and subjects; and promotes energy efficiency. It can also strengthen the cooperation and information exchange between different regions and subjects, which also promotes energy efficiency.

2.3. Impact of Green Finance and the Digital Economy on the ECS

Regarding the existing research, the literature on the impact of green finance and the digital economy on the energy consumption structure is not comprehensive; it mainly focuses on the impact of green finance on the energy consumption structure and the impact of the digital economy on the energy consumption structure, separately. Some scholars have also carried out research from the perspective of the environment, such as Wang et al. [42], who investigated the impact of green finance and the digital economy on environmental pollution. They concluded that in the case of introducing the intermediate regulating variable of the digital economy, green finance plays a useful complementary role in reducing environmental pollution. Liu et al. [43] found that the digital economy has a significant role in promoting regional green technological innovation in China and that there is a spatial spillover effect; green finance is an important conduction path for the digital economy to enhance the level of regional green technological innovation.

In summary, a large number of existing studies have explored the impact of financial development and information and communications technology on the ECS, providing theoretical references for this paper. The main contributions of this paper are described here. First, it provides a new perspective for studying the improvement of China's energy consumption structure and enriches the theoretical foundation of the improvement of the energy consumption structure through the digital economy. The existing literature on the improvement of the energy consumption structure of the digital economy is mostly focused on theoretical analysis, and a small number of empirical analyses also study the impact of the digital economy on energy efficiency. This paper explores the impact of the digital economy on the improvement of the energy consumption structure from the perspective of the overall digital economy and utilizes empirical analysis methods to test, to a certain extent, the expanding research field of China's energy consumption structure at this stage. Second, international scholars have explored the role of green finance in the energy structure and the reasons it works. Domestic scholars have empirically proven it from the perspectives of environmental, influence, and abatement effects. Both domestic and international scholars actively promote research related to green finance and energy consumption, and the number of papers published in recent years has seen significant growth. Methods such as panel regression are widely used. Comparing domestic and international perspectives, it is found that the connotation of green finance is constantly deepening and reflects the characteristics of the current context. Regarding the current context of China's efforts to promote carbon peaks, reduce carbon emissions, and promote high-quality economic development, it is necessary to study the connotation of green finance in greater depth to obtain a scientific evaluation method of the level of green finance development and to explore the impact of green finance on energy consumption and its heterogeneity, which is more lacking in research, so as to promote green finance and energy consumption. Third, the digital economy and green finance should be combined. The inclusion of the digital economy and green finance in the same framework to analyze their impact on the energy consumption structure is useful and improves the existing research on the subject.

3. Methodology

3.1. Model Setting and Variable Selection

3.1.1. Model Selection

In real economic phenomena, economic relationships change dynamically over time. The dynamic panel model is a further development of the panel data model, which contains one-period or several-period lagged terms of the dependent variable in the explanatory variables, and it is able to reveal this dynamic relationship of the economic variables. Therefore, the dynamic panel model has an extremely wide range of applications in the study of the long-run relationship (equilibrium relationship) and the short-run dynamic behavior of economic phenomena [44].

In general, the dynamic panel model with first-order autoregression has the following form:

$$y_{it} = \alpha y_{it-1} + \beta x'_{it} + \mu_i + \varepsilon_{it}, \quad i = 1, \cdots, N; t = 1, \cdots, T \tag{1}$$

where μ_i denotes an individual effect that is unobservable and does not vary over time, ε_{it} denotes a heterogeneous error term, and x'_{it} is a vector (which can also be a scalar) containing the explanatory variables in the regression equation except for the lag term and its several-period lagged terms. In a general theoretical or empirical study, y_{i0} and x'_{i0} are assumed to be known or to obey a certain data generating process and to fulfill a set of assumptions.

Normally, general estimation methods in dynamic panels are plagued by two problems. One is the endogeneity problem and the resulting weak instrumental variables problem, and the other is the poor nature of the estimators under finite samples. In order to resolve the abovementioned shortcomings arising from endogeneity, this article utilizes the one-step-system generalized moment estimation (one-step-system GMM) method to carry out the estimation of the model. GMM models include differential GMM and system GMM models. Arellano and Bond [45] found that differential GMM can be used to take first-order difference measures to offset individual differences and later overcome the correlation problem using lagged variables as auxiliary variables. The system GMM method is an optimization upgrade of the differential GMM. When the sample data are limited and the instrumental variables can represent limited information, there is a small correlation with the endogenous variables, and then the application of the differential GMM estimation method leads to an inaccurate inference. Arellano [46] proposed a system GMM for model estimation with the new moment conditions that associates the original equations with the differential transformation equations to compensate for this shortcoming. Based on the regression analysis, the autocorrelation test of the disturbance term and the over-identification test were adopted to check the reliability of the results [47].

3.1.2. Model Setting

First, a static panel regression model without lagged dependent variables is established based on the following formula to verify the impact of green finance and the digital economy on the ECS:

$$ECS_{it} = \beta_0 + \beta_1 DE_{it} + \beta_2 GF_{it} + \alpha_i Z_{it} + \varepsilon_{it} + \mu_{it} \quad (2)$$

In the above equation, t denotes the year; i denotes the region; DE stands for digital economy; GF stands for green finance; Z_{it} denotes a column of control variables, consisting of industrial structure (IC), trade openness (OP), technological advancement (TE), and urbanization (UR); β_i and α_i are variable coefficients; ε_{it} is the random error term; and μ_{it} is the individual effect. Logarithmic changes are made to the corresponding variables to prevent the existence of correlations and heteroskedasticity. Since the change in the ECS is a dynamic process, a lag term of the ECS must be used in the model to describe the dynamic process of ECS change more accurately. Referring to the research of previous scholars, this paper constructs the lagged-variable model as follows:

$$\mathrm{ECS}_{it} = \beta_0 + \beta_1 ECS_{i,t-1} + \beta_2 DE_{it} + \beta_3 GF_{it} + \alpha_i Z_{it} + \varepsilon_{it} + \mu_{it} \quad (3)$$

In the above equation, $ECS_{i,t-1}$ is the lag term of the ECS.

3.1.3. Variable Selection

(1) Explained variables

The explained variable of this study is the ECS, and it is measured through the proportion of fossil fuel energy (coal, oil, and natural gas) consumption in the studied regions. The units of each type of energy are converted uniformly according to the discounted standard coal coefficient, and then the fossil fuel energy consumption/total energy consumption are determined to obtain the explained variable of this paper—ECS (%).

(2) Core Explanatory Variables

Green finance (GR): The development of green finance provides financial support for China's new energy industry and environmental protection industry by playing a role in the supply side of energy, thus affecting energy consumption and realizing the optimization and upgrading of the structure of energy consumption. It can also play a role in the demand side of energy, thus impacting energy consumption. We refer to the research of Li [48] and Zhang et al. [49]; based on green finance connotation and service types, green finance was defined with five dimensions of indicators, namely, green credit, green securities, green investment, green insurance, and government expenditures. We then synthesized these five dimensions into green financial development comprehensive indicators (Table 1).

Digital economy (DE): On the one hand, the technological innovation and industrial structure improvements brought about by the development of the digital economy is the main engine for promoting green development. On the other hand, the development of the digital economy and the transformation of data from auxiliary elements to core elements are conducive to energy conservation, emission reduction, and improvements in the efficiency of energy use, thereby improving the structure of energy consumption.

Combining this foundation with the existing research, we have constructed an indicator evaluation system for the digital economy, dividing it into the digital economic foundation (digital-related infrastructure, which can function better with the guarantee of the relevant infrastructure), digital industrialization (representing the latest application results and the most cutting-edge direction of the development of digital technologies which embodies the digital economy and provides products, services, technologies, solutions, etc.), and industrial digitization (industrial digitization refers to the application of digital technology to carry out industrial digital transformation to improve production efficiency), three first-level indicators. Specifically, a total of 14 third-level indicators were selected in Table 2.

Table 1. Green finance indicator system.

Primary Indicators	Secondary Indicators	Weights
Green Credit	Total green credit of top five banks/Total loans of top five banks	0.112
	Interest expenditure of six major energy-consuming industries/ Total interest expenditure of industrial industries	0.123
Green Securities	Total market capitalization of environmental protection enterprises/ A-share total market capitalization	0.145
	Total market capitalization of six high-energy-consuming industries/ Total market capitalization of A-shares	0.133
Green Insurance	Agricultural insurance expenditure/Total insurance expenditure	0.056
	Agricultural insurance expenditure/Agricultural insurance income	0.093
Green Investment	Fiscal expenditure of environmental protection industry/Total fiscal expenditure	0.118
	Investment in environmental pollution control/GDP	0.077
Carbon Finance	Carbon emissions/GDP	0.143

Table 2. Digital economy indicator system.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Unit	Weight
Digital Economy	Digital Infrastructure Index	Cell phone exchange capacity	Million households	0.075
		Internet broadband access ports	Million	0.066
		Number of web pages	Units	0.121
		Length of fiber optic cable	Kilometers	0.067
		Number of Internet domain names	Million	0.088
	Digital Industry Index	Number of employees in information industry	Units	0.032
		Patents granted per 10,000 people	Units	0.048
		E-commerce sales	Billion dollars	0.173
		Number of websites owned by enterprises	Units	0.063
		Output of basic circuits	Million units	0.051
	Industry Digitization	Value added of tertiary industry	Billion dollars	0.057
		Number of computers used by enterprises	Million units	0.045
		Total telecommunications business	CNY/person	0.055
		E-commerce purchases/total GDP	%	0.059

Openness to trade (OP) is expressed through the ratio of the total import and export to the GDP of the region. The trade openness level can introduce advanced production technology and its manufacturing production products to optimize the ECS and reduce the number of fossil fuel energy inputs; additionally, the export of energy products increases their consumption [50].

Technological progress (TE): Improvements in energy technology can have a significant impact on the existing structure of energy consumption. On the one hand, new types of energy have been applied on a large scale and have gradually replaced traditional fossil fuel energy. For example, clean energy sources, such as wind and solar energy, are constantly being developed and utilized. On the other hand, technological advances have also opened up brand new opportunities for traditional coal and petroleum energy sources, allowing them to constantly provide China's power to human society. At the same time, through the support of technology, crude oil processing technology continues to progress, with the application of clean combustion technology, so the utilization efficiency of petroleum energy has been greatly improved. At the same time, it can greatly reduce the environmental pollution caused by energy consumption to optimize the structure of energy consumption. In this study, the number of patent applications per capita was selected to represent the technological progress [51].

Urbanization (UR): First, urbanization leads to scaled economies and a shift in production from low energy-consuming agriculture to high energy-consuming industries, which has a significant impact on energy consumption. Second, urbanization affects the transport sector by increasing the number of cars in towns. This increases energy consumption. Third, urbanization places increasing demands on infrastructure, the construction of which requires many energy-intensive products as raw materials. The most commonly used indicator is the population urbanization rate [52], which is expressed as the proportion of the resident population of a region's towns and cities to the total resident population of the region. This calculation is also used in this paper to represent the level of urbanization.

Industrial structure (IC): China's energy consumption in various industries shows an obvious unbalanced pattern. Energy consumption is heavily concentrated in the industrial sector; energy consumption in the industrial production process accounts for about 70% of the total energy consumption, especially in some high energy-consuming industries with high energy demand [53,54], while the primary industry accounts for only about 2% of the energy consumption. In this paper, the proportion of regional industrial added value to GDP is used to represent the industrial structure.

3.2. Data Processing Methods

(1) Standardized treatment of raw data

There are positive and negative indicators in the above index system; therefore, to avoid the differences in the indicators, the data are standardized first. Then, the weights and the comprehensive score are calculated. The standardized processing of the positive indicators is as follows:

$$V_{ij} = \frac{X_{ij} - min(X_{ij})}{max(X_{ij}) - min(X_{ij})} \tag{4}$$

The negative indicators are processed as follows:

$$V_{ij} = \frac{max(X_{ij}) - X_{ij}}{max(X_{ij}) - min(X_{ij})} \tag{5}$$

where X_{ij} represents the calculated value of the *j*th indicator of the ith region and V_{ij} is the jth indicator of the standardized ith region.

(2) Entropy weight method to determine the weight of indicators

The weight of the *j*th indicator of province *i* in the indicator is calculated as follows:

$$p_j = \frac{V_{ij}}{\sum_{i=1}^{n} V_{ij}} \tag{6}$$

The information entropy of the *j*th indicator is calculated as follows:

$$E_j = -(lnn)^{-1}\sum_{i=1}^{n} p_j \times lnp_j \tag{7}$$

The utility value of the *j*th indicator is calculated as follows:

$$D_j = 1 - E_j \tag{8}$$

The weight of the jth indicator is calculated as follows:

$$w_j = \frac{D_j}{\sum_{j=1}^{k} D_j} \quad (9)$$

where n is the number of evaluation units and k is the number of indicators. The indicator weights of green finance and the digital economy can be calculated using standardized processed data.

4. Results

4.1. Cross-Sectional Dependence Test

In recent years, the cross-section correlation problem has received increasing attention in the panel data modeling process. Existing research results show that the cross-section correlation of panel data leads to cross-section heterogeneity (heterogeneity here refers to the heterogeneity of the variance and covariance of the perturbation terms) or correlation among the perturbation terms. This, in turn, affects the first- and second-order properties (including unbiasedness, consistency, and validity) of the standardized panel data estimators [55], hence it is necessary to test for the cross-sectional dependence of the variables. The method used in this paper is the Pesaran CD test. The results of the test are shown in Table 3 below. It can be seen that no autocorrelation should be accepted; thus, there is no autocorrelation.

Table 3. Cross-sectional dependence test results.

Test	Statistics	Prob.
ECS	1.231	0.121
DE	2.102	0.176
GF	1.221	0.233
IC	4.321	0.312
OP	1.458	0.197
TE	2.189	0.149
UR	1.110	0.212

4.2. Multicollinearity Test

There are relatively more empirical research variables in this paper to ensure that our empirical results are not affected by multicollinearity. First of all, the variables are subjected to the variance inflation factor test, which is an important method to test multicollinearity. The test standard is to determine whether the variance inflation factor of each variable is less than 10. If it is less than 10, then the variables do not exhibit multicollinearity [56]. The variance inflation factor test results of this paper are shown in Table 4 below. The results show that the test values are all less than 10, indicating that there is no multicollinearity between the variables.

Table 4. Multicollinearity test results.

Variable	GR	DE	OP	TE	UR	IV	Mean
VIF	2.44	2.77	4.18	3.44	2.12	3.31	3.04
1/VIF	0.41	0.36	0.48	0.29	0.47	0.32	-

4.3. Smoothness Test and Cointegration Test

In order to explore the relationship between the variables, we need to carry out the unit root test to avoid false regression and ensure the validity of the results before the model analysis. For the relevant data in this paper, we first pass the unit root test to determine the smoothness of the variable series. When the variable is smooth, we can directly perform regression model construction of the variable; when the variable is not smooth, we need to carry out the differentiation process. If the series becomes smooth in the *i*th differentiation, then the relevant series is subject to the *i*th order of monointegration. Under the condition that the series obeys the same order of monotonicity, the cointegration test can be carried out to determine whether there is a cointegration relationship between the tested variables. To overcome the errors that may exist in a single method, we carry out the test of each variable using four methods, such as the LLC test and the Fisher-ADF test [57]. The results are as shown in Table 5.

Table 5. Results of the stability test.

Variable	LLC Test		ADF-Fisher Test	
	Statistic	*p*-Value	Statistic	*p*-Value
lnECS	−8.876	0.0000	55.221	0.0000
lnDE	−9.221	0.0000	122.324	0.0000
lnGR	−11.114	0.0000	109.212	0.0000
lnUR	−27.091	0.0000	122.334	0.0000
lnTE	−18.669	0.0000	144.689	0.0000
lnOP	−33. 789	0.0000	123.445	0.0000
lnIC	−9.118	0.0000	117.228	0.0000

The results above show that the variables accept the alternative hypothesis of the test at the 1% level, and each variable is a single integrated variable of the same order and passes the smoothness test. We used the Kao cointegration test to verify whether a long-term dynamic equilibrium relationship exists between the variables. The results in Table 6 show that each variable passes the significance test with a 95% confidence interval, rejecting the original hypothesis of the absence of cointegration.

Table 6. Cointegration test results.

Methodology	Null Hypothesis: H0	*t*-Statistic	*p*-Value
KAO cointegration test	There is no cointegration relationship	−3.2291	0.0001

4.4. Model Selection Test

There are three main types of regression models: mixed OLS estimation, fixed effects model, and random effects model. The specific form of the model used needs to be determined through testing, and the main tests are the F test and Hausman's test. Table 7 shows the test results of this paper. It can be seen that the results of the F test dictate we should choose the fixed effects model, and the results of Hausman's test also dictate that we should choose the fixed effects model. Therefore, based on the synthesis of the test results of the two methods, for this paper, we chose the fixed effects model for the regression analysis.

Table 7. Model selection test results.

Test Methods	*t*-Statistic	*p*-Value
F Test	33.14	0.0000
Hausman Test	77.98	0.0000

4.5. Regression Results

Before the estimation of the "system GMM", first of all, it is necessary to judge the reasonableness of the over-identification test [58,59]. We can see that the over-identification test *p*-values are greater than 0.05, which means no over-identification. Thus, the validity of the tools chosen in this paper is affirmed. Meanwhile, the autocorrelation test of the perturbation term of the systematic generalized moments estimation is carried out. The first-order autocorrelation test *p*-value is less than 0.05, but the second-order autocorrelation test is greater than 0.05. Therefore, the model's original hypothesis is accepted. Specifically, the stochastic perturbation term is without significant autocorrelation, and the validity of the selected first-order lag is affirmed. In other words, the model selected in this paper is justified. After validation, the sample is estimated using the "system GMM", and the results are presented in Table 8.

Table 8. Regression results.

Variable	National	Eastern	Central	Western
$\ln ECS_{i,t-1}$	0.033 *** (4.22)	0.018 *** (3.87)	0.022 *** (2.99)	−0.149 *** (4.78)
lnDE	−0.239 *** (−3.77)	−0.217 ** (−5.66)	−0.1411 *** (−4.22)	−0.0211 (−1.22)
lnGR	−0.118 *** (−4.11)	−0.145 ** (−3.56)	−0.116 *** (−4.77)	−0.067 *** (−2.995)
lnOP	−0.059 (0.88)	−0.097 *** (−4.18)	−0.044 (0.99)	−0.089 (−0.45)
lnTE	−0.223 *** (−3.77)	−0.315 *** (−2.89)	−0.211 *** (−4.87)	−0.134 *** (−5.13)
lnUR	0.112 *** (4.27)	−0.078 *** (−4.55)	0.0988 ** (2.26)	0.123 * (1.87)
lnIC	0.132 *** (5.66)	0.012 * (1.81)	0.145 *** (2.88)	0.281 *** (4.89)
AR(1)	0.003	0.001	0.000	0.000
AR(2)	0.121	0.123	0.224	0.216
Sargan test	0.133	0.156	0.178	0.266

Note: ***, **, and * mean $p < 0.01$, $p < 0.05$, and $p < 0.1$.

The results show that for every 1 percent increase in the logarithmic result of ECS in the previous year, there is a corresponding increase in the logarithmic result of ECS, and this has also been verified to be significant in different regions. The degree of change in the ECS is closely related to the degree of optimization of the ECS in the previous year, which is a dynamic adjustment process.

The digital economy can improve the ECS on a national level. When the coefficient of the digital economy increases by 1%, the proportion of fossil fuel energy consumption decreases by 0.239%. This indicates that the technological progress and technical efficiency brought about by the digital economy effectively improve the energy efficiency of industrial enterprises, which can reduce the total amount of fossil fuel energy consumption and optimize the ECS. Comparing different regions, the digital economy significantly improves the ECS in the eastern and central regions, probably because of the developed digital economy in eastern regions. The digital economy has an effective guiding role in improving the ECS. First, the technology diffusion and effective allocation of market factors brought about by the digital economy in the central region have promoted the progress of energy technology, optimized the allocation of energy factors on the basis of its abundant energy resources, and improved the ECS. Second, the developed digital economy in the eastern region can overflow to the neighboring regions; thus, the central region benefits from this, which reduces fossil fuel energy consumption and optimizes the ECS. The western region has a lower digital economy level and weak competitiveness. First, the center of gravity of research and development as well as innovation is tilted to the east, and famous universities and research institutes are numerous in the coastal eastern region, which creates the problem of large regional differences and unbalanced development. Second, the digital economy is usually the first to introduce high-tech industries with high market access thresholds. Enterprises in the western region are unable to quickly stand out from the crowd, so there are fewer channels to obtain advanced digital technologies to improve energy efficiency. Therefore, although the digital economy in the west appears to be able to optimize the ECS, it cannot do so to a significant degree.

The green financial coefficient is −0.118 on a national level, indicating that the level of optimization of the ECS is positively correlated with green financial development. This finding also indicates that the increase in the green financial coefficient will reduce fossil fuel energy consumption and improve the ECS, and the impact is significant. In different regions, green finance can improve the ECS to different degrees; from east to west, this impact shows a downward trend.

The test results in the eastern region show that green financial coefficient is −0.145. This result indicates that under the 5% significance level, for every 1% increase, the degree of optimization of ECS increases by 0.145%, demonstrating that green finance in the eastern region can directly promote the optimization of the ECS. The western coefficient has the smallest impact effect at 0.067. The reason for this is that, first, the financial resources between regions are not balanced; the green financial market is not the same in each region. The western region lacks a good economic and policy environment, which causes the efficiency of its green finance to lag behind that of the eastern regions. Additionally, the supply of green finance is unable to satisfy the growing demand for green consumption and the capital demand for green and low-carbon industries, so the optimization of the ECS in the west cannot be effectively improved. Second, there is a gap in technological innovation among enterprises. In the eastern region, research and development investments, institutional environment, and other aspects present prominent advantages. The central region also has technological innovation as a basis for promoting the transformation of the mode of economic development. Its vitality in technological innovation is constantly stimulated, and the improvement of the level of energy technology in an orderly manner promotes the use of clean energy and new energy. The western region lacks the corresponding conditions and environment. In addition, the technological innovation momentum is insufficient, and the optimization of ECS cannot be effectively improved. The lack of corresponding conditions and environment and technological innovations in the west means that the use of clean energy is more difficult, which leads to the relatively poor effect of green finance in the ECS in the central and western regions.

Urbanization cannot improve the ECS on a national level. Although the acceleration of urbanization reduces energy consumption, China's large rural population base still shows a positive correlation at the urbanization-level stage of development. Energy consumption is positively correlated with the industrial structure, and the rapid development of the secondary industries has led to an increase in fossil fuel energy consumption, which is detrimental to improvements in the ECS. Comparing the different regions, urbanization in the eastern region shows an inhibitory effect on total fossil fuel energy consumption, while urbanization in the central and western regions promotes total fossil fuel energy consumption. From the perspective of transmission channels, the increase in urbanization level in the three regions brings about technological innovation and optimization of the industrial structure, but the intensity of the role of urbanization in three regions is different. In the eastern region, the driving strength of the industrial structure on the total energy consumption is larger. However, the improvement in the energy utilization rate caused by technological innovation leads to greater inhibition of the total energy consumption, so urbanization inhibits energy consumption in general. In the other two regions, which mainly rely on the development of the energy industry, the inhibition of total energy consumption caused by technological innovation brought about by urbanization is lower than the inhibition of total energy consumption caused by the industrial structure. Thus, urbanization is still the best way to promote energy industry development. In the central and western regions, which rely mainly on the development of energy industries, urbanization has a lower inhibitory effect on the total energy consumption than the industrial structure does on the total energy consumption, so urbanization eventually increases total fossil fuel energy consumption.

The industrial structure coefficients are significantly positive in all regions. Generally speaking, fossil fuel energy consumption has a relatively strong relationship with the secondary industry and has a smaller effect on the tertiary industry. The primary and secondary industries are more dependent on energy, and the tertiary industry is a high-yield and low-consumption industry. The share of the tertiary industry in the GDP inhibits energy consumption, so the eastern region is more able to inhibit energy consumption than the central region. The tertiary industry dominated by low-energy consumption and emerging high-tech service industries in the eastern region amplifies this inhibition, so the coefficient of elasticity of the industrial structure in the east is lower than that in other regions. In the central and western regions, the energy industry is the dominant industry. Its effect of suppressing energy consumption is limited, so the industrial structure's impact on energy consumption is positive.

Overall, trade openness is not significant for the optimization of the ECS mainly because foreign capital brings technological innovation conducive to the ECS. However, foreign trade also brings high energy-consuming industries, leading to an increase in the consumption of fossil fuel energy, which is not conducive to the optimization of the ECS. Comparing different regions, trade openness in the eastern region significantly inhibits energy consumption because the advanced technology introduced by trade openness can improve the efficiency of energy use and thus improve the structure of energy consumption. Technological progress can significantly reduce energy consumption, which may be related to the preference of production technology. However, trade openness in the western and central regions cannot improve the ECS significantly because trade openness in these regions has yet to be improved.

The level of technological progress has significantly improved energy consumption results in all regions. This is because while technological improvement promotes energy utilization efficiency, it also increases industrial enterprises' demands for and investment in energy factors. This finding indicates that improving scientific and technological innovation capacity is conducive to reducing energy consumption, thereby improving the regional ECS. However, the effect in the central and western regions is significantly smaller than that in the eastern region mainly because the higher technological level of the eastern region and the effect in the central region are higher than the effect in the western region due to the technological spillover effect from the eastern region.

4.6. Robustness Test

This work adopts the replacement model method for testing, replacing the system GMM model with the Tobit model to verify the regression results. The results presented in Table 9 show that the direction of the coefficients of the impact of the core variables is the same, indicating that the core variables' impact on the ECS does not change much when using either the Tobit or system GMM models. The signs of the coefficients of the four control variables also remain largely consistent with the previous results, with only a slight difference in significance. In summary, it can be concluded that the model setting of this paper is more reasonable, which also indicates that the results of the previous GMM estimates are relatively robust.

4.7. Discussion

This paper examines the impact of green finance and the digital economy on the energy consumption structure at the provincial level and further analyzes the heterogeneity of that impact, with the aim of providing theoretical implications for the improvement of the energy consumption structure. The relationship between the variables is derived through empirical analysis, which first verifies the important role of the digital economy in improving the energy consumption structure, consistent with the conclusions of most scholars' studies. For example, Hu and Liu [38] found that although there is a large gap in the level of development of the digital economy in various regions of China, the development of the digital economy can significantly promote the energy consumption structure towards the direction of green development, and the result still holds under the robustness and endogeneity tests. Luo et al. [39] used regional integration to mediate the relationship between the digital economy and the energy consumption structure. These researchers found that under the mediating effect, the digital economy and energy consumption structure show a negative correlation. From a general view, the conclusion of this paper is consistent. However, a large number of scholars have not analyzed the regional heterogeneity in previous works, although the country as a whole aims to improve the structure of energy consumption. However, due to the imbalance in the level of development of the digital economy in various regions, this paper concludes that the role of the digital economy in the western region has not yet been determined, meaning that the western region should pay attention to the areas in which the digital economy should be improved. Additionally, the region should increase the investment in the digital economy and take full advantage of the spillover effect of the eastern and central regions of China to improve the structure of energy consumption and, thus, regional heterogeneity. Providing tools to improve the energy consumption structure and, thus, the study of regional heterogeneity is one of the main innovations of this paper.

Table 9. Robustness test results.

Variable	National	Eastern	Central	Western
$\ln ECS_{i,t-1}$	0.076 *** (3.13)	0.045 *** (2.99)	0.076 *** (3.45)	−0.198 *** (6.21)
lnDE	−0.211 *** (−2.89)	−0.200 ** (−4.72)	−0.158 *** (−3.99)	−0.054 (−1.45)
lnGR	−0.133 *** (−4.55)	−0.245 *** (−2.99)	−0.123 *** (−4.45)	0.087 *** (−5.44)
lnOP	−0.055 (0.77)	−0.045 *** (−6.33)	−0.078 (−1.22)	−0.098 (−1.21)
lnTE	−0.212 *** (−5.33)	−0.256 *** (−3.77)	−0.201 *** (−3.32)	−0.114 *** (−4.57)
lnUR	0.134 *** (3.89)	−0.099 *** (−4.68)	0.121 *** (2.90)	0.135 * (1.78)
lnIC	0.119 *** (4.78)	0.023 ** (2.19)	0.155 *** (3.72)	0.231 *** (3.18)

Note: ***, **, and * mean $p < 0.01$, $p < 0.05$, and $p < 0.1$.

Second, this paper derives the important role of green finance in the energy consumption structure. The paper concludes that green finance shows a significant inhibitory effect on all regions and can be used to improve the energy consumption structure. Most scholars focus on green finance to promote the innovation and application of green technology, increase the production and use of new and renewable energy, and implement green and low-carbon energy consumption. Currently, there are fewer research results on the relationship between green finance and the optimization of the energy consumption structure. For example, some scholars propose that green financial development can play a driving role in energy saving and energy efficiency [60,61], which can be achieved by supporting the green transformation of industries and promoting the innovation of green technology in enterprises, as well as other methods. This paper examines the regional heterogeneity of the optimization of the energy consumption structure affected by the development of green finance from general and regional perspectives in China in order to enrich the relevant research and provide a basis for strategic planning and policy formulation regarding the development of green finance in China.

5. Conclusions and Implications

5.1. Conclusions

This research takes data from 30 regions from 2007 to 2022 as the objects of examination to explore the impact of green finance and the digital economy on the ECS and then further analyzes the regional heterogeneity of this impact. The conclusions are as follows:

(1) The change in the ECS is closely linked to the degree of optimization of the ECS in the previous year, which portrays a dynamic adjustment process. The development of the digital economy has a negative impact on the ECS in the whole country, primarily the eastern and central regions, which can inhibit the consumption of fossil fuel energy and thus improve the ECS. However, the western region of China has not yet played a significant role due to its low level of digitization. In addition, green finance has inhibited fossil fuel energy consumption in all regions and improved the ECS. However, its impact effect is the largest in the eastern region and smaller in the western region mainly because there is a large gap in green finance within the various regions, which, in turn, affects the role of green finance.

(2) Urbanization on a national level, particularly in the central and western regions, shows a positive correlation with the ECS results. Urbanization has led to an increase in total fossil fuel energy consumption, which cannot improve the ECS. However, in the eastern region, it shows an inhibitory effect on fossil fuel energy consumption mainly because the industrial structure and technological innovation in the eastern region are better than those in the other two regions. This can inhibit fossil fuel energy consumption and optimize the ECS. The influence coefficients of the industrial structure in the whole country, including the eastern, central, and western regions, are all positive. Industry is not conducive to the optimization of the ECS, but the tertiary industry in the east, which is dominated by the low energy-consuming and emerging high-tech service industries, can inhibit fossil fuel energy consumption. Therefore, the effect in the east is the smallest. The level of trade openness is not significant in optimizing the ECS because the positive and negative effects of trade openness lead to uncertainty, and they only have an inhibitory effect on fossil fuel energy consumption in the eastern region. Technological advancement significantly improves the ECS in all regions.

5.2. Recommendations

According to the results of the above analysis, there is significant regional heterogeneity in the optimization of the ECS through green finance and the digital economy, and the following recommendations for improving the energy structure are put forward based on the results of research and the actual situation of the development of each region:

(1) Policies should strengthen the improvement of infrastructure for the digital economy. The local government should actively increase the construction of infrastructure for the digital economy. Increasing this investment can maximize the advantages of the digital economy for improving ECS, creating a platform to accelerate the flow of energy factors and promoting the creation of energy technology and innovation. The digital economy has a role to play in promoting the development of energy efficiency, and the completeness of the digital infrastructure will further promote the development of the digital economy in various regions and provide a new engine for ECS improvement.

(2) The digital economy should focus on the regional coordination layout and the integration of regional resources, pay attention to the differences in the digital economy between different regions, give policy support to the less developed areas of digital economy, and help the “households in difficulty” regarding elements, such as capital, technology, data, and talent. Local governments should introduce distinctive, regionalized, and highly compatible digital economy development policies; promote the construction of autonomous technology platforms; facilitate inter-regional factor

flows; and build a digital economy system with synergistic development of financial capital, infrastructure, human resources, and research and development levels in the region to obtain higher economic benefits in the era of rapid development of the digital economy and to empower the ECS.

(3) The continuous development and gradual improvement of green finance should be promoted. First, it is important to strengthen the construction of basic systems related to green finance, improve all types of green assessment mechanisms, establish a more standardized and perfect green information disclosure system, and form a stronger green atmosphere and green concepts. Second, China's green financial market should be further improved to guide the banking system funds to green, low-carbon industrial project investments, reduce the capital investment of high energy-consumption industries, and continuously improve the efficiency of energy use, thereby reducing the proportion of fossil fuel energy use to achieve the goal of optimizing the energy consumption structure.

(4) The comprehensive performance of green finance in different regions is different. For the development of green finance to promote reducing energy consumption and reduce the level of consumption, different regions need to make decisions according to the interaction between the two, and the country needs to design relevant policies for different regions. They should encourage the development of technology exchange so that different regions may learn and exchange advanced technology experience, promote green technological innovation, and promote green product upgrading and replacement to alleviate the problem of uneven development of technological innovation in different regions of China. Through green financial support, governments should promote the development of high-quality energy development and utilization on various scales, make full use of green financial policy tools to develop renewable energy, and boost the high-end development of energy and chemical industry to optimize the structure of energy consumption.

5.3. Shortcomings and Prospects

(1) Due to the immaturity of China's green financial product system, its market construction is not perfect. The disclosure of information is not comprehensive, especially based on the lack of regional-level relevant statistical data. A shorter statistical time dimension problem exists, and research on the construction of China's green financial indicator system is not yet comprehensive. Thus, this paper selects the indicator system. To a certain extent, this system can reflect the development level of China's green finance. However, compared with the actual development of green finance in China, there may be a certain bias. In future research, we need to continuously improve the relevant data to measure the development of green finance more accurately.

(2) In the actual operation of the economy, there are many factors affecting the structure of energy consumption, which is a complex influence system. This paper refers to the research results of other scholars at home and abroad and can only select the factors that have an impact on the structure of energy consumption as significant as the core and control variables of the model. These factors need to be gradually determined in future research and added to the other influencing factors.

(3) This paper uses the panel data of provinces or municipalities directly under the central government. The provincial panel data related to the structure of energy consumption have certain deficiencies; for example, the incomplete data of the Tibet region cannot be included in the empirical analysis, which may lead to incomplete sample data. Thus, we cannot accurately reflect the actual situation in all the regions, and our research needs to be further supplemented with the relevant data to analyze and improve the comprehensiveness and accuracy of the research and analysis.

(4) Due to the relatively short development time of the digital economy, which has only begun developing rapidly in recent years, the research in this paper is limited by the difficulty of obtaining relevant data and the lack of relevant studies, which limit the

analysis of energy saving and consumption reduction in the digital industry itself. In the context of the "dual-carbon" goal, data centers are facing severe challenges of energy conservation and greenhouse gas emissions, and the development of the digital economy needs to be focused on how to find a balance among driving economic growth, energy conservation, and carbon reduction.

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