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Some global implications of China's new energy policy initiative: Lessons and conclusions

Chen Rurong

The "East Data West Computing" project was launched in February 2022 to alleviate the current imbalance of energy distribution in China and to promote the development of a green digital economy. It is designed to improve the ideal energy layout in China, using the abundant renewable energy available in the West to supply electricity for existing and planned data processing and analyzing centers and other high-tech businesses in the East. The nature of the paper is impact analysis based on qualitative and quantitative research methods. The paper's first objective is to quantify the probable impact of the initiative on China's energy balance in general, the electricity market in particular, its expected effects on Chinese energy imports, and its global implications. The second objective is to analyze the expected impact of the new initiative on the international competitiveness of China's high-tech industries and the structural optimization in the eastern digital industry using a two-way fixed effects model as well as its global implications. Based on the analysis, generalized and instructive conclusions are drawn, first, on the role of renewables in the regional distribution of electricity and the green transition, and, second, on the significance of the supply and price of electricity in the competitiveness of high-tech industries. It is assumed that the project would promote the development of green digital industries across the East and west regions.

At first glance, the paper is a Chinese case study focusing on global effects and implications, exploring the relationship between electricity production and consumption and how the high-tech industries give a chance to arrive at scientifically novel or new conclusions.

Keywords: China, "East Data West Computing", two-way fixed effects model, electricity, high-tech industries, Green Digital Economy Transformation.

1. Introduction

With the escalation of Russia's war against and Ukraine, oil and gas prices have spiked rapidly. In addition, the destruction of gas pipelines has made the energy supply more challenging. China has pursued the principle of energy diversification to mitigate the adverse effects of energy crises on domestic production and life. China has always been a significant energy consumer, with coal accounting for most energy consumption, mainly in the form of power generation. However, with the pollution effects, coal burning has been causing an increasingly severe damage to the environment. Therefore, China has made it a priority task in the 14th Five-Year Plan to realign the energy structure and promote the transition to a green digital economy.

The East Data and West Computing Project includes sending data generated by various industries in Eastern China to data centers in Western China for processing, computing, and storing. In February 2022, the state agreed to construct ten national data center clusters and start the construction of national computing hub nodes. The East Data and West Computing Project has officially started with this announcement. It is necessary to provide a large amount of power support for extensive data processing. This project is based on the abundance of power resources in the western region, including wind and hydropower. Unlike the original project, 'Western Electricity to the East,' this project provides direct access to electricity in the western regions, and it saves transportation costs from west to east. Ultimately, this will ease tensions between power consumption and generation in the eastern region, drive the economic development of the western region, and facilitate the coordination of regional development efforts (Ismail et al., 2023).

The present paper has two goals: first, it aims to discuss the current energy production and consumption structures in China to determine how the changing energy structure affects the development of the digital economy. Second, it examines the relationship between China's energy structure and its high-tech industries to help the global transition to a cleaner energy supply and consumption pattern. In this paper, I want to answer the following research questions by studying the current energy structure:

(1) What does the structure of energy production and consumption in China look like under the influence of the Russia-Ukraine conflict? Has China's energy structure changed and adjusted?
(2) What are the Chinese government's policies in the current electricity market?
(3) How does the change in energy structure affect the transition to a green digital economy?

Several scholars are also exploring the relationship between the energy structure and the economy. Yu and Weidong (2008), for example, use panel data to investigate whether the energy structure and economic growth are cointegrated and argue that the relationship between energy increase and GDP growth is more robust in the eastern region than in the western region. A study by Hou and Hou (2021) asserts that the high-tech industry hurt energy consumption. Most scholars have examined how economic growth factors affect the structure of energy consumption. However, they ignored considering the reverse effects of the energy structure, which is a research gap. This paper discusses the impact of changes in the energy structure on the digital economy, high-tech industries, and industrial upgrading.

The nature of this study is interdisciplinary, combining the energy industry development with economic development issues. The main innovation of this paper is the examination of the relationship between the energy structure and the digital economy in the context of the current technological transformation. Based on an updated strategic planning context, this paper examines how the energy consumption structure influences the Chinese economy's shift to a knowledge-intensive and technology-oriented growth model (Wilczynski, 1972). The experience of China's energy restructuring in this context may be instructive for EU countries in elaborating and implementing their strategy of the energy transition.

China is undergoing a rapid switch to new energy sources for which limited data are available. The current energy data were updated to 2021 but not to 2022, which is the time when Russia’s war against Ukraine began. As a result, this paper is only a starting point for collecting the relevant normative data in the future and using the existing model for future research to compare and observe how the results of the two studies differ.

The logic of this paper is as follows. Section 2 contains an overview of the previous studies on the relationship between the energy structure and economic development and compare the issues of interest to scholars in different regions. In order to gain a more comprehensive understanding of the significance and innovation of the present study, it is necessary to identify the limitations. Section 3 briefly justifies the reasons for data collection and highlights the meaning and interpretation of the data. Section 4 describes the methodological design. This paper adopts a mixed (qualitative and quantitative) approach. In Section 5, data are visualized to illustrate the distribution of energy portfolios in China and the relationship between the digital economy and energy consumption. A discussion of the differences between this paper and previous studies is provided in Section 6 to answer the research questions of the paper. Section 7 summarizes the man findings and conclusions and indicates directions for further research.

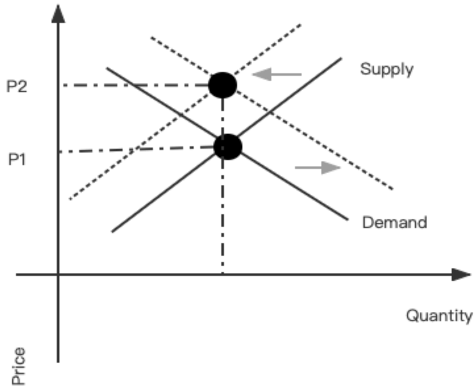
2. Literature Review

2.1. Theoretical background

According to the supply-demand principle, a commodity's price is determined by its supply and demand (Worchel et al., 1975). The individual products of the energy sector are ignored and treated as a tradeable aggregate. Its equilibrium price is dynamically adjusted according to what happens in the market that triggers it. (Figure 1 displays the relationship between supply and demand in a general form.) China is currently in an economic transition, moving from former heavy industries to high-tech industries and gradually transforming into a digital economy. Powerful computers with increasing electricity demand constitute a significant component of the digital economy. Furthermore, Russia’s war against Ukraine resulted in a global energy shortage. Therefore, the supply shortage and the rise in demand have led to a rapid rise of energy prices. The increase in electricity and natural gas costs spilled over to the goods and services resulting in the acceleration of global inflation.

The energy supply and demand structure determine a balance between supply and demand (Guo et al., 2023). The structure of the regional distribution of energy and the structure of energy types can be described by visual graphs, and numerous scholars have undertaken in-depth energy supply and demand balance analyses. Analyzing the structure of energy types is necessary for understanding the relationship between raw materials for power generation and electricity consumption. The energy structure can be analyzed according to regional distribution, energy types, and supply and demand. Achieving a low-carbon energy future will require widespread changes in consumer behavior. Therefore, social media will have an impact on consumer perceptions, which will be transmitted to consumer behavior. Ultimately, consumer behavior will change the energy mix (Axsen–Kurani, 2012). The three structures are discussed in this paper. It is essential to study how to achieve coordinated regional energy balances based on the regional distribution structure of energy. It is also critical to pay attention to green digital transformation (Xue et al., 2022).

Figure 1. Supply and demand in the energy industry



Source: own construction

2.2. The relationship between energy structure and economic development

Economic development and energy structure are closely related with each other. Based on the above, the energy structure in this paper can be viewed from the following three perspectives. (1) Economic development increases energy demand, while energy supply also contributes to economic growth. (2) The regional distribution of energy is closely correlated with the local economic growth level. (3) The energy type will influence green economic development. Many researchers mainly focused on three of these parts to discuss the relationship.

Supply-demand is one of the most popular research fields in energy structure. Regarding the relationship between economic transition and development on the one hand, and energy demand structure on the other hand, energy demand increases as the economy develops and the population grows. However, the growth rate of energy demand can be reduced by promoting energy conservation and using renewable energy sources, among other things, which will result in sustainable economic growth. In order to test the endogeneity of the vector's three variables, Hondroyiannis et al. (2002) use vector error correction modeling (VECM) techniques to empirically evaluate the dynamic interactions between energy consumption, real output, and price level. Energy demand can be reduced while economic growth is stimulated by policies that increase economic efficiency through structural reforms (implementation of adjustment policies, implementation of endogenous growth mechanisms) (Hondroyiannis et al., 2002). From an economic perspective, (Rui–Di, 2010) qualitatively analyze the main factors influencing China's energy demand. Employing the grey correlation theory, they empirically examine the relationship between energy demand and the main factors influencing it: energy prices, economic growth, population, industrial structure, energy consumption structure, and consumers' income levels. Judson et al. (1999) estimate the relationship between GDP per capita and energy consumption per capita for the significant economic sectors based on panel data for 123 countries. The paper assumes time and country fixed effects, uses a flexible form of income effects, and finds that the energy demand structure in different sectors is affected differently (Judson et al., 1999). According to Stern (2019), energy use and economic development are positively correlated. It is important to note that the degree of socioeconomic development will determine energy use efficiency (Stern, 2019). Ozturk and Acaravci (2010) use the autoregressive distributed lag bounds test for cointegration to investigate the issue of long-run causality between economic growth, carbon emissions, energy consumption, and employment rate in Turkey. In the short run, neither carbon emissions per capita nor energy consumption per capita affect real GDP per capita, but the employment rate affects real GDP per capita (Ozturk–Acaravci, 2010). Using panel data for 27 provinces from 1978 to 2008, Sheng et al. (2014) employ an instrumental variable regression technique to examine the relationship between economic growth, energy demand and production, and relevant policies in China. In their study, the authors conclude that strengthening infrastructure development facilitates the establishment of cross-provincial energy markets and energy transfer between regions (Sheng et al., 2014). An adequate energy supply can help economic development. Therefore, optimizing the energy structure and upgrading energy efficiency are necessary to accelerate economic development. According to the Chinese economist Yifu, the energy structure is an essential enabler for economic development (Yifu, 2010). According to Sheng (2011), the C-D production function extension model also revealed an intrinsic proportional relationship between GDP growth and energy consumption growth. He argues that energy structure utilization needs to be improved to achieve sustainable development (Sheng, 2011). According to Xu et al. (2023), the marketization of the supply of energy sources can reduce carbon emissions and pollution by rationalizing energy prices. Ruoxiang and Yi (2003) showed that several factors are essential to promote the optimal allocation of power resources in China, including optimizing the power supply structure, expanding the development of hydropower resources in southwest China, and actively establishing the financing channels for hydropower construction. In addition, the interconnection of power grids plays a vital role in enhancing the ecological environment of China (Ruoxiang–Yi, 2003).

Coordinated regional development is the main economic development task at present. Wang et al. (2020) pointed out that the mismatch of resources phenomenon exists in the eastern and western regions. The findings from Dong et al. (2016) revealed that four local renewable energy industry clusters were formed, including the Bohai Sea region, the Yangtze River Delta, the central region, and the western region. Supply chains were distributed differently based on regional resource allocation as well as economic development level (Dong et al., 2016). All these researchers noticed the regional disparity of energy resources and tried to coordinate the regional development by offering solutions. Siala et al. (2021) think that the deployment of decentralized renewable energy technologies and strategic dam planning are two aspects of the same problem, but they are typically dealt with separately. The distribution of renewable energy can be seen in the form of regional cooperation, centralized planning, and cross-border power trading using solar photovoltaics (Siala et al., 2021).

New Energy can promote green digital transformation. Xue et al. (2022) believed that digital transformation could substantially encourage innovation in green technologies. Its internal mechanism is that digital transformation may boost the level of creativity in green technologies by reducing financing constraints and attracting government subsidies (Xue et al., 2022). Qi with Li (2017) gave their own opinions on renewable energy consumption, whose results proved the negative relationship between energy consumption and economic growth. The government is not the only contributor to promoting the green energy transformation as there are no significant effects from the innovation subsidy policies (Qi–Li, 2017). While local development of digital technologies tends to result in higher greenhouse gas emissions, local development of environmental technologies tends to result in lower emissions, with big data and computing infrastructures having the worst effects, according to Bianchini et al. (Bianchini et al., 2023).

Based on the above literature, the production and consumption of energy and their relationship with economic development were discussed. Nonetheless, this paper innovatively examines the relationship between energy production and the digital economy by considering the latest national support for digital centers based on a fixed-effect model. It also provides constructive recommendations for measures to be taken in response to the energy crisis in Europe and other countries through analyzing the structure of energy distribution in China's different provinces.

3. Data collection

3.1. The reasons of selection

This paper uses electricity data from 2010 to analyze panel data for 30 provinces. Between 2010 and 2020, there were more complete records and reliable data sources for electricity data. Furthermore, this period also encompassed the era of key energy policies and technological innovations, such as investments and developments in renewable energy and the diffusion and application of smart grids. It is, therefore, possible to gain important insights into the power sector trends, policy effects, and technological developments from electricity data collected during this period.

For selecting 30 provinces for the study of power structures, there are two primary reasons: on the one hand, the data are complete and comprehensive. Each of the 30 provinces represents an economic, energy, and development level in China's eastern, central, and western regions. However, a significant bias can be mitigated due to the reliability of the data, which is based on data collected over ten years from 30 provinces. On the other hand, the Tibetan region may need more comprehensive and accurate data due to its geographic location and other factors. Since incomplete or biased data can negatively affect analysis and decision-making, this paper excludes data from this region to ensure quality stability.

3.2. Description of the data

Data for this paper were collected from the CSMAR[1]. Database for the energy sector and the digital economy, as described below.

[1] CSMAR, i.e. China Stock Market & Accounting Research Database, is a comprehensive research-oriented database focusing on China's Finance and Economy.

Table 1. The data collection and description

Name	Unit	Description
Electricity Generation	100 million kwh	The total power generation.
Hydropower Generation	100 million kwh	Generate the power by using the energy in moving water.
Thermal Power Generation	100 million kwh	Heat energy is converted to electrical energy, and the heat usually can be produced by the coal, natural gas and so on.
Electricity Consumption	100 million kwh	The consumption of electricity
Gross Output Value Of Construction Industry	10,000 yuan	Total of construction products and services, expressed in money terms, produced or rendered by construction and installation enterprises during a given period of time.
Total Population (Year-End)	10,000 persons	A legal population measure, referenced in many legislative and regulatory texts.
Revenue from Software Business	100 million yuan	The revenue from the commercial activity of the software industry.

Source: own construction

4. Research design

4.1. Descriptive and comparative analysis

Comparison is the process of identifying similarities and differences between two or more objects, things, concepts, or phenomena. This paper examines the consumption, the production, the supply structure of energy, and other aspects of energy supply in various Chinese provinces or regions. The energy structure of China is compared horizontally from region to region, and the changes in energy consumption and supply structure are compared vertically over time. By examining China's energy structure distribution and energy policies, we can better understand the energy policies and development directions of different countries and regions.

4.2. Two-way fixed effects model

Fixed effects models (FEMs) or fixed effects regression models are methods of analyzing panel data. Generally, two-way fixed effects refer to both time and individual fixed effects. Wallace, Hussain consider these two-way error components disturbances first (Wallace–Hussain, 1969). The differences between each province are fixed to compare the effects of different regions on the digital economy. This is due to the significant differences between China's eastern and western regions. Regarding the fixed time effect, since China is developing rapidly, the changes can be enormously quick, so adjusting time helps reduce the impact of macrocycles.
The basic two-way error model is as follows:

$$u_{it} = \mu_i + \lambda_t + \nu_{it} \; (i = 1, \ldots, N; t = 1, \ldots, T)$$

μ_i *denotes the unobservable individual effect*;

λ_t *denotes the unobservable time effect*;

ν_{it} *is the remainder stochastic disturbance term*.

Usually, the calculation process is by simple regression:

$$y_{it} = \alpha + \beta x_{it} + \mu_i + \nu it$$

$$\bar{y}_{i.} = \alpha + \beta\bar{x}_{i.} + \mu i + \bar{v}_{i.}$$
$$\bar{y}_{.t} = \alpha + \beta\bar{x}_{.t} + \lambda t + \bar{\nu}_{.t}$$
$$\left(y_{it} - \bar{y}_{i.} - \bar{y}_{.t} + \bar{y}_{..}\right) = \beta(x_{it} - \bar{x}_{i.} - \bar{x}_{.t} + \bar{x}_{..}) + (\nu_{it} - \bar{v}_{i.} - \bar{v}_{.t} + \bar{v}_{..})$$

Usually, The calculation of μ and λ is by OSL simple regression:

$$\tilde{\mu}_i = (\bar{y}_{i.} - \bar{y}_{..}) - \beta(\bar{x}_{i.} - \bar{x}_{..})$$
$$\tilde{\lambda}_i = (\bar{y}_{.t} - \bar{y}_{..}) - \beta(\bar{x}_{.t} - \bar{x}_{..})$$

In fixed-effects models, individual heterogeneity is considered in a time-invariant manner. Nevertheless, fixed-effect models have the disadvantage of wasting too much freedom when identifying fixed effects. The specific model is as follows.

$$Revenue\ from\ Software\ Business_{it} = \beta_0 + \beta_1 Power\ Consumption_{it} + \eta \sum_j X + \lambda_i + v_t + \varepsilon_{it}$$

i denotes that the variables will change from the individual side;
j denotes the number of control variables;
t denotes that the variables will change over time;
β_0 *is the constance;*
β_1 *and* η *are the coefficiences of the regression;*
X is the data set of controlable variables;
λ *is the individual fixed effect;*
v is the time fixed effect.

Under the strategic plan of 'East data, West computing', this paper explores the impact of energy transformation on the digital economy. Consequently, the income of the digital economy is used as the dependent variable, the energy production structure as the core explanatory variable, and the remaining infrastructure output and total population as control variables. The extent of the impact of energy on the digital economy is observed for a fixed region and fixed time.

5. Results

5.1. The energy distribution in China

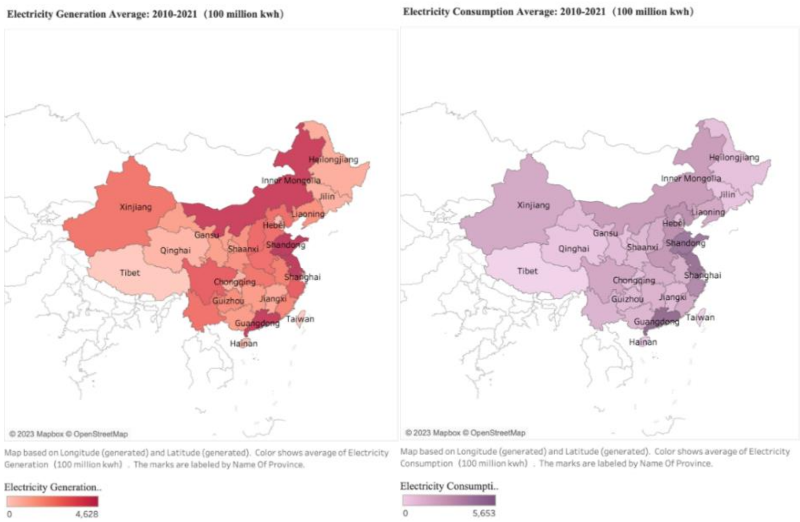
Over the past decade, China has witnessed a significant increase in its electricity production. The National Bureau of Statistics estimated that China would produce 8.88 trillion kilowatt hours of electricity by 2021, up from 4.98 trillion kilowatt hours in 2012 (Fisher-Vanden et al., 2004). Total electricity production varies from province to province: Jiangsu, Guangdong, Shandong, Zhejiang, and Fujian provinces have been at the forefront of electricity production in the eastern region. There is a relatively low level of electricity production in the central region, but it is also increasing. Electricity production has steadily risen in Henan, Hunan, and Hubei provinces although it is relatively low in the central region but also growing. The total electricity production in Henan, Hunan, and Hubei provinces has risen yearly.

Regarding consumption, China's electricity consumption has been increasing over the last decade. Electricity demand has gone up significantly due to dynamic economic growth and accelerated urbanization. The eastern region includes Guangdong, Zhejiang, Jiangsu, and Shandong. These provinces have been ranked among the top in the country in terms of electric power consumption and production capacity. Among them, Guangdong Province's electricity consumption is the highest in the country. The electric power demand and production capacity in the central region, including Hunan, Hubei, Henan, Jiangxi, etc., are relatively low. The imbalance between supply and demand is the most critical problem of China's present electric power resources. The distribution of China's electricity production and consumption is shown in Figure 2.

A significant source of electricity in China is thermal power, primarily coal, and natural gas. China enhanced thermal and hydroelectric power generation over the past decade at different rates. By 2021, it generated 58,058.87 billion kilowatt-hours (kWh) of thermal power, an increase from 3,416.6 billion kWh in 2010 (Dinani et al., 2023). The growth of hydropower has been significantly faster in the last decade, having increased from 686.7 billion kWh in 2010 to 134.01 billion kWh in 2021. Many hydropower plants have been constructed in the Yangtze River basin, the Yellow River basin, and the Pearl River basin, resulting in China's vigorous development of hydropower energy.

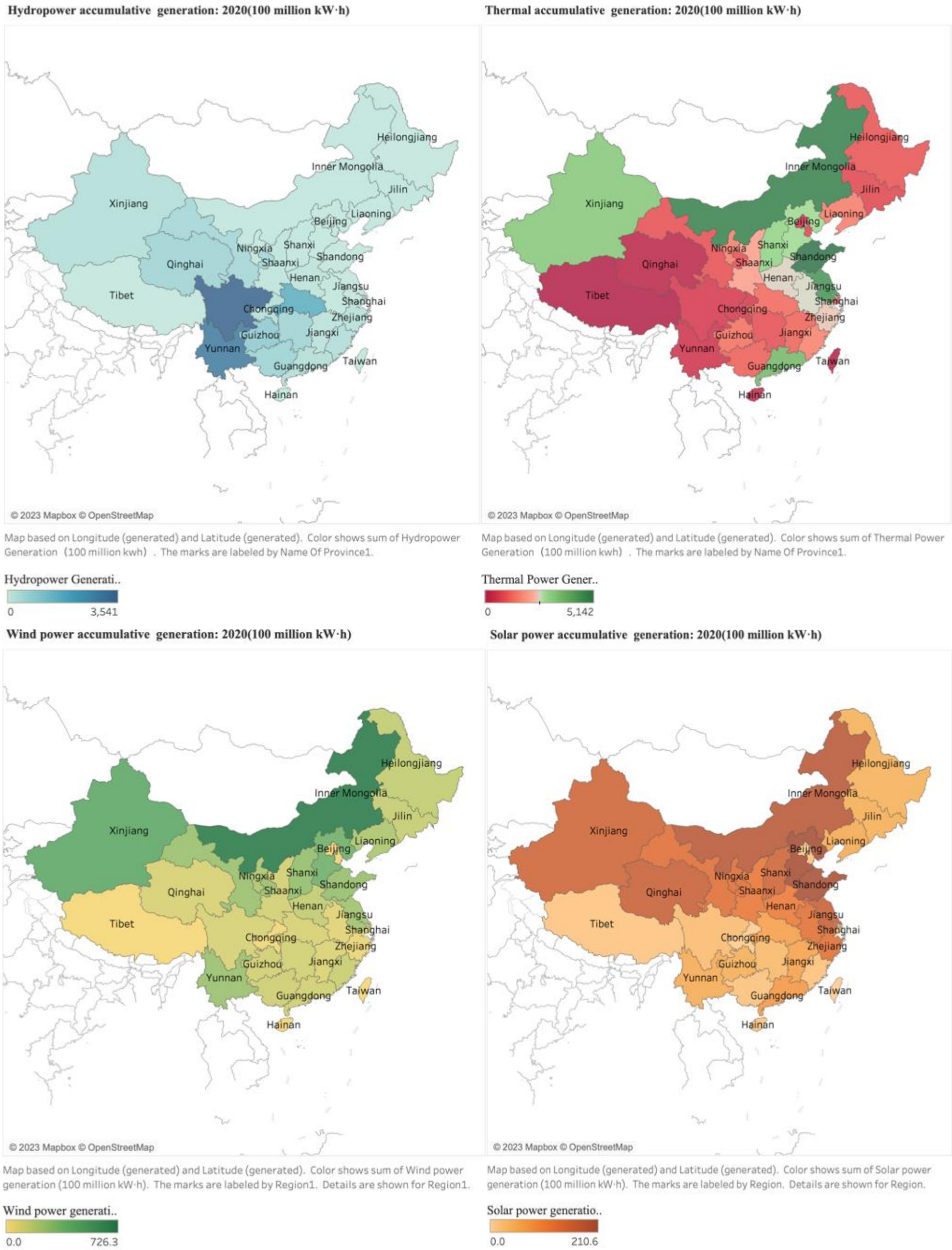
The share of thermal power in China's electric energy structure is decreasing year by year as it transforms into a clean energy and low-carbon structure (Su et al., 2023). Hydropower is taking its place as a clean energy source. In Sichuan, hydroelectric power makes up 85 percent of the province's electricity generation, which varies from province to province. Most of the average power came from Hubei hydropower. Inner Mongolia, Xinjiang, Shandong and Jiangsu are at the top of thermal power production, but the reasons for their high production volumes vary. The first two regions concern the provinces that produce Western Electricity East, while the latter two ones the need for economic development. Figure 3 demonstrates the distribution of electricity by type of energy carriers.

Figure 2. The distribution of China's electricity production and consumption



Source: own construction based on CSMAR database

Figure 3. The distribution of China's electricity by type of power resources



Source: own construction based on CSMAR database

Wind and solar power is mainly generated in the country's northwestern part, with Inner Mongolia, Shaanxi, Xinjiang, and Qinghai provinces having abundant wind and solar resources. As of 2020, Inner Mongolia generated the highest amount of wind power at 726.29 kWh, while Beijing had the least at 3.74 kWh. This large gap indicates that the power resources in the eastern region are significantly less abundant than those in the western part.

Table 2. The structure of energy import and export

Year Sign	Name Of Product	Imports	Exports	Balance	Unit
2020	Coal	30361	319	-30042	10,000 tons
2020	Coke and Semi-coke	298	349	51	10,000 tons
2020	Crude Oil	54201	164	-54037	10,000 tons
2020	Gasoline	48	1600	1552	10,000 tons
2020	Kerosene	266	997	731	10,000 tons
2020	Diesel Oil	119	1976	1857	10,000 tons
2020	Fuel oil	1253	1583	330	10,000 tons
2020	Liquefied petroleum gas	2005	95	-1910	10,000 tons
2020	Other Petroleum Products	2606	323	-2283	10,000 tons
2020	Natural Gas	1397	52	-1345	100 million m3
2020	Electricity	48	218	170	100 million KWH

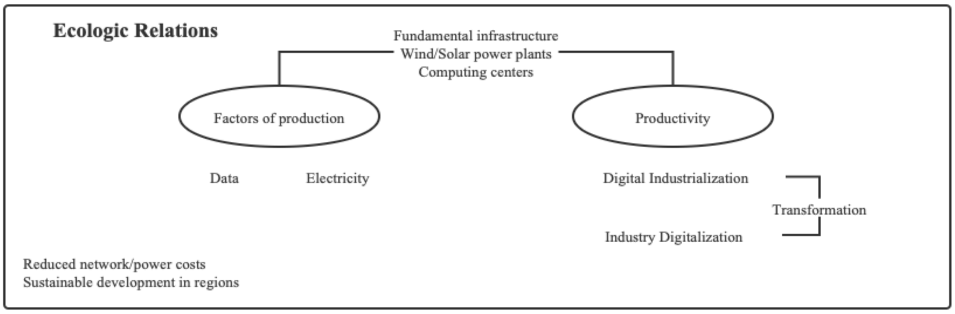
Source: own construction based on CSMAR database

China imports more energy than it exports, with crude oil, coal, and natural gas constituting its main energy import items. In contrast, its exports are mainly gasoline, diesel, and other petroleum products. There is a large trade deficit in crude oil, with imports of 542.01 million tons and exports of just 1.64 million tons. In 2020, coal, with imports of 303.61 million tons and exports of 3.19 million tons, ranked second in the energy trade balance. Diesel, gasoline, and other petroleum products constituted the majority of energy products with a trade balance surplus.

5.2. Digital business activity

Figure 4 below displays the relationship between the new energy development plan and the establishment of the big data center in terms of production factors, productivity, and production relations. The policies of digital transformation constitute the beginning of these production relations. The most critical issue in the 14th Five-Year Plan is to achieve technological transformation, i.e. the use of science and technology as a carrier to promote the overall economy. Digital economies cannot function without the infrastructure and computing power of data centers. Therefore, the government initiated the 'Eastern Digital and Western Computing' program, applying the logic of distributional energy to the computing system. This means relying on power production sites and establishing computing centers, where the data from the East will be arithmetical in the West. Increasing data centers' layouts in the West will significantly increase green energy use. The green energy in the West will be consumed nearby, while data centers' energy use efficiency will be continuously optimized through technological innovation, large-scale data centers, and low-carbon development measures. Digital tools will be used in the industry (in a process called digital industrialization) and manufacturing will achieve digital transformation (in a process called industry digitalization). Thus, energy production and consumption patterns will be optimized, and the computing efficiency of arithmetic centers will be improved.

Figure 4. The distribution of China’s electricity types

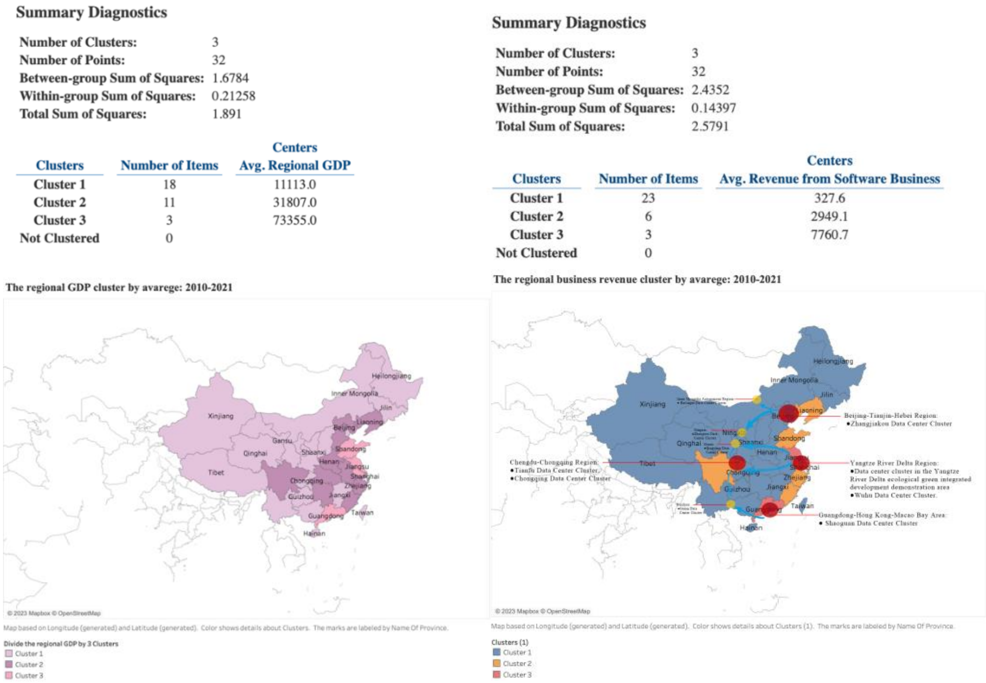


Source: own construction

This paper innovatively divides the GDP average into three categories. From figure 5, we can depict that the western region, except Sichuan Province, is in the range of 111.3 billion yuan, while the central and Sichuan Provinces are in the second echelon of economic development, and the eastern coastal region, especially Shanghai, Jiangsu, and Guangdong, are among the most economically developed regions.

There is a connection between economic development and digital services. These services are also divided into three categories in this paper. On the right of Figure 5, we can see that the more developed the economy in the East, the higher the revenue of its digital services. Only Sichuan has a high level of digital revenue in the Midwest, indicating a more mature digital economy. The pace of digitized industrialization in Sichuan increased in 2021, with the value added of the core industries contributing to the digital economy reaching 432.41 billion yuan, a 6.5 percent year-on-year increase, that is 1.6 percentage points higher than the regional GDP growth rate and contributing 10 percent to the province’s economic growth. There has been a significant increase in digital economy revenues in the eastern region, indicating that the degree of digital economy development is consistent with the level of overall economic development in the region. Furthermore, the eastern region is characterized by a digital policy environment and industry clusters, making regions such as Guangdong and Shanghai leaders in digital services. As opposed to the level of economic development reflected in GDP, the level of digital economy development in the central region is not in line with its comprehensive economic development level, and its digital economy development level remains at a unified level with other Western regions, which needs to be improved.

Figure 5. The distribution of China's GDP and Revenue from software business



Source: own construction based on CSMAR database

5.3. Two-way fixed effects model

This study examines how energy demand and supply structures affect the digital economy. In contrast to previous literature focused on one side of energy, this paper incorporates energy production and consumption into a model that includes fixed effects to determine whether they facilitate or inhibit the growth of the digital economy's income (Li, 2023).

The most common panel regression models consist of POOL, fixed effects, and random effects models. It is necessary to perform the Hausman test on the data before applying the fixed effects model (Hausman, 1978). A p-value of less than 0.05 indicates that the FE model is superior to the RE model and vice versa for the RE model. In contrast to random effects, fixed effects assume that individual effects within groups are fixed and that individual differences are reflected in specific intercept terms. The random-effects model assumes that all individuals have the same intercept term and that differences between individuals are random, as reflected, in part, in the random interference term.

The Hausman test (Table 3) presented a significance chi (4) =13.55 at a 5 percent level, $p=0.000<0.05$, implying that the FE model is superior relative to the RE model. With the above analysis, Stata recommended the FE model as the final result.

Table 3. Hausman test

	Coefficients (b) FE1	(B) RE1	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
Electr~ption	1.479779	1.729886	-.2501066	.2132553
Hydropower~n	-1.14248	-1.021253	-.1212269	.1887279
ThermalPow~n	-1.207244	-1.1448	-.0624432	.189766
TotalPopul~d	1.084045	-.2431236	1.327169	.4014389
GrossOutpu~i	.0000228	.0000264	-3.59e-06	2.04e-06

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                 b = Consistent under H0 and Ha; obtained from regress.
  B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

    chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =  13.35
Prob > chi2 = 0.0097
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Source: own computation

In this paper, 353 data volumes are used to fix the time and province. The ‘Between’ group data is beyond 1, which means that there is a great difference in individual provinces. The same situation happens here ‘within’ the group. Fixing by province is to reduce individual variation due to the energy portfolio. This will enable us to examine better the impact of energy supply and consumption on the income of the digital economy. The primary purpose of fixing time is to reduce the impact on digital economy income due to economic cycles over ten years. Therefore, this paper places constraints on time and individuals to control for confounding factors so that the impact of each factor on income can be more clearly determined. The P-value of the model is 0.000, significantly showing that this model made a success for the modeling. Table 4 contains the summary of the indicators.

Table 4. The summary of indicators

Variable		Mean	Std. dev.	Min	Max	Observations
Revenu~s	overall	1630.468	2828.783	.268	20382.1	N = 357
	between		2395.8	1.64539	8151.074	n = 30
	within		1553.326	-4075.528	14043.87	T-bar = 11.9
El~ption	overall	2025.59	1478.549	159.02	7867	N = 360
	between		1411.499	279.35	5653.017	n = 30
	within		504.8028	204.7979	4289.338	T = 12
Hydrop~n	overall	360.962	641.5986	.0317	3724.458	N = 360
	between		615.8063	2.885333	2575.681	n = 30
	within		209.8827	-1001.299	1509.739	T = 12
Therma~n	overall	1555.386	1284.436	91.8	6197.961	N = 360
	between		1218.813	152.5341	4554.864	n = 30
	within		458.0272	4.122106	4287.242	T = 12
TotalP~d	overall	4570.407	2759.491	563	12684	N = 356
	between		2801.837	586.3618	11174.98	n = 30
	within		193.9682	3836.387	6079.422	T-bar = 11.8667
GrossO~i	overall	6.43e+07	6.32e+07	1994842	3.82e+08	N = 360
	between		5.75e+07	3127111	2.57e+08	n = 30
	within		2.80e+07	-6.85e+07	1.90e+08	T = 12

Source: own computation

The FE model is used as the final result of this study. According to Tables 5 and 6, electricity consumption shows a sign at 0.01 level (t=3.94, p=0.000<0.01), and the regression coefficient value is 1.4798>0, indicating that electricity consumption has a positive effect on revenue from the software business. For hydropower generation, it shows a 0.01 level of significance (t=-3.38, p=0.001<0.01), and the regression coefficient value is -1.1425<0 demonstrating that hydropower generation has a significant negative effect on revenue from the software business. Thermal power generation shows significance at 0.01 level (t=-3.64, p=0.000<0.01), and the regression coefficient value is -1.2072<0 proving that thermal power generation has a significant negative effect on revenue from the software business. For the total population (year-end), it shows a 0.01 level of significance (t=2.58, p=0.010<0.05), and the regression coefficient value is 1.0840>0, referring to the fact that the total population (year-end) has a significant positive effect on revenue from the software business. The business will have a significant positive effect on relationships. For gross output value of the construction industry, it shows significance at the 0.01 level (t=6.09, p=0.000<0.01), and the regression coefficient value is 0.000>0, highlighting that the gross output value of the construction industry will have a significant positive relationship with revenue from the software business.

Table 5. The results of the fixed effect model

Fixed-effects (within) regression		Number of obs =	353
Group variable: ProvinceSign		Number of groups =	30
R-squared:		Obs per group:	
Within	= 0.5284	min =	9
Between	= 0.3803	avg =	11.8
Overall	= 0.3530	max =	12
		F(5,318) =	71.27
corr(u_i, Xb)	= -0.8413	Prob > F =	0.0000

Source: own computation

Table 6. The results of the fixed effect model

RevenuefromSoftwareBusiness	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
ElectricityConsumption	1.36974	.3410589	4.02	0.000	.6987227	2.040757
HydropowerGeneration	-1.02334	.3257544	-3.14	0.002	-1.664246	-.3824336
ThermalPowerGeneration	-.8743075	.2976183	-2.94	0.004	-1.459857	-.2887577
TotalPopulationYearEnd	.9946784	.4139523	2.40	0.017	.1802472	1.80911
GrossOutputValueOfConstructi	.0000251	3.53e-06	7.12	0.000	.0000182	.000032
_cons	-5615.159	1751.573	-3.21	0.001	-9061.295	-2169.023
sigma_u	3790.6338					
sigma_e	1125.9843					
rho	.91891915	(fraction of variance due to u_i)				

F test that all u_i=0: F(29, 318) = 19.82 Prob > F = 0.0000

Source: own computation

6. Discussion

6.1. China's energy structure

In China, the distribution of power resources is uneven geographically, with economically developed eastern coastal regions possessing substantial power resources. In contrast, western regions have limited power resources, requiring more investment in developing clean energy. Coal is the primary thermal power source, and China is the world's first coal producer. Coal resources are primarily concentrated in North China, Northeast China, and Northwest China, including Shanxi, Shaanxi, Inner Mongolia, and other provinces. China is rich in hydropower resources, and hydropower generation occupies a prominent share. The use of hydropower is gradually replacing thermal power for the generation of electricity as a clean energy source. Most hydroelectric resources are located in China's southwestern, southern, and northwestern regions, such as Yunnan, Sichuan, Guangxi, Gansu, etc. Aside from hydropower and thermal power, China is currently developing wind, nuclear, and solar power to diversify the energy supply caused by difficulties due to resource depletion. Wind and solar resources are costless to obtain, but their supply is unstable and seasonal. Wind power is more abundant in winter and spring and is mainly located in the northwestern part of China. Solar resources are mainly at high altitudes and collected in daytime. Wind and solar power currently faces storage and transmission difficulties.

As a result of the Russian-Ukrainian war, China is intensifying its plans to establish an ecological energy supply system. The Chinese government released a strategic plan for East Digital and West Computing in 2022, which aims to connect and combine computing power and digital resources. Data computing centers are established in the western region through a distributed energy supply approach that allows hydro- and wind power to supply power directly to the computers, optimizing the previous strategy for transmitting electricity from the west to the east. By taking advantage of the abundant power resources in the Western region, it advocates establishing computing centers there. Through this project, the eastern region's power congestion problem can be eased, and the western region's economic development is promoted to achieve the 14th Five-Year Plan's goal of coordinated regional development. However, distributed power generation requires a high level of infrastructure development in the region, which increases the pressure on the local government to invest in energy infrastructure.

6.2. The impact of energy strategies on the digital economy

It is possible to examine the impact of the energy structure on the digital economy by fixing the province and time. There is evidence that conventional energy production will reduce the income of the digital economy to some extent. The results of the study indicate that hydroelectric and thermal power production negatively affects the digital economy.

A thermal power plant generates electricity by burning fossil fuels like coal, oil, and natural gas. Due to the large amount of greenhouse gases, such as carbon dioxide released, this type of power generation has detrimental effects on the digital economy. Environmental issues can limit the manufacture and use of electronic devices and the energy consumption of the Internet, which can threaten the sustainability of the digital economy.

A hydroelectric plant is expensive to build and operate, especially in a remote or mountainous area. Consumers may be burdened with these costs through their electricity bills, which could negatively impact the cost of the digital economy. However, there may be negative impacts on the local environment, especially on rivers and fish habitats. In this case, communities and environmental groups may protest the construction of hydroelectric plants, adversely affecting the digital economy. Power supply stability is the most directly influencing factor. Weather and seasonal changes influence energy generation by hydropower plants. During low water levels or climate change, the power supply may become unstable, disrupting the digital economy.

It is important to note that the development of the digital economy depends on many computer calculations. Hence, the consumption of electrical energy contributes to its development. In contrast, from the energy consumption perspective, the higher the electric energy consumption, the greater the benefit to the digital economy. An inadequate or unstable power supply will have a detrimental effect on the normal functioning of the digital economy and may even result in its collapse. However, the digital economy will also affect electricity and energy consumption. Increasingly, people shop, watch videos, and play games online, all of which requires significant electricity. Consequently, as the digital economy develops rapidly, the demand for electricity in digital production, transportation, and other fields will also increase. Therefore, electric energy consumption directly affects the growth and operation of the digital economy.

As for demographic factors, this paper also examined the impact of the population on the digital economy. The population provides workers for the digital economy on the supply side. Denser populations raise the demand for digital life, lifting income for digital economies. The digital economy requires people to have specific digital skills to participate effectively. It is, therefore, crucial for the development of a digital economy that the population has a high level of computer literacy and digital skills. A country's digital economy may be limited if its population needs digital skills in general. From the market side, the population is a significant consumer of e-commerce. Consumer behavior can also significantly affect the development of the digital economy. Younger generations of consumers are more likely to shop online and pay digitally, contributing to the growth of the digital economy.

An adequate infrastructure construction provides an ideal hardware facility environment for the development of the digital economy, which in turn raises its income. The development of communication, cloud computing, and financial infrastructures all play crucial roles in facilitating the digital economy. High-speed and reliable communication networks are required to facilitate the transmission and exchange of large amounts of data in the digital economy. Communication infrastructure includes broadband, mobile, and satellite networks, fiber optics, etc. By providing these, people can use various digital technologies more efficiently and promote the development of the digital economy. The construction of cloud computing infrastructure can make it easier for digital economy enterprises to use cloud computing technology, reduce enterprise costs, and improve efficiency. Investment in education infrastructure can boost the development of the digital economy by cultivating more high-quality talents. The development of technologies such as electronic payment and virtual currency requires the support of financial infrastructure such as banks and payment institutions. This can improve the efficiency and security of the digital economy.

7. Summary and conclusions

This paper has analyzed the relationship between the energy portfolio and the digital economy, particularly the latest energy strategy. Using China's energy structure as a basis, it has provided some ideas and possible solutions for the energy security strategies of countries in Europe and the rest of the world. Electricity consumption has a significant positive effect on revenue from software business (satisfied at 1% level of significance, $p<0.01$), hydropower generation and thermal power generation have a significant negative effect on revenue from software business has a significant negative effect. The negative effect is mainly due to the distributional effect that leads to the allocation of government funds in the construction of power stations and subsidies for digital business economic activities. Both total population (Year-End) and gross output value of the construction industry have a positive effect on revenue from software business, i.e. population growth leads to an adequate labor force and strong consumer power, and a well-developed infrastructure helps accelerate the delivery of services across regions in the digital economy.

This study has led to the following conclusions. Distributed energy will become a mainstream way of getting the energy China needs in the future. This paper used a visual map to illustrate China's energy distribution structure and its structure of energy supply and demand. The energy structure was analyzed from the perspectives of energy product types, regional distribution, and energy supply and demand. The world's energy distribution structure is unbalanced, so inter-regional deployment has become the mainstream method for resource allocation. However, Russia's war against Ukraine has highlighted the vulnerability of resource distribution in cross-regional deployments. To reduce dependence on regional resources, the focus of the energy portfolio will be on exploring new energy sources and adopting new technologies. The establishment of an energy ecosystem was initiated by China very early on. Energy has been transformed from trans-regional transmission to local consumption through the early 'Western Electricity Transmission Strategy" and the current 'Eastern Data and Western Computing Strategy'. That is, a data computing center is established in the western region to send the data collected in the eastern region to the west for computing. European countries should take this idea as a point of reference. This approach reduces the damage of the energy crisis.

New energy generation methods, such as wind power, are expected to become the new trend. According to the supply and demand structure of energy, the higher the energy consumption, the greater the income. The traditional methods of generating power harm the digital economy, making it imperative that renewable energy and clean energy be promoted. As the digital economy develops rapidly, large amounts of energy will be required, and traditional energy sources will put increasing pressure on the environment. The use of new energy sources is more environmentally friendly and renewable, reducing the impact of energy consumption on the environment and promoting the sustainable development of the digital economy. To ensure the healthy development of the digital economy, it is necessary to strengthen the management and control of electric energy consumption. In addition, it is necessary to promote the sustainable development of energy consumption. Among these measures are initiatives to develop clean energy, improve energy utilization efficiency, and optimize the energy supply chain to synergistically develop the digital economy and energy consumption. Therefore, the state should implement new energy support policies, reduce taxes on energy companies for energy technology innovation, and increase incentives for new energy patents. It is anticipated that this will lead to the development of new energy sources. The digital economy is profoundly affected as the size of the population, and its characteristics change. As a result, the development of the digital economy must consider various factors within the population. This is to meet different populations' needs better and facilitate the digital economy's sustainable growth. Infrastructure development significantly impacts the digital economy, which benefits its efficiency and security, reduces costs, and promotes its development.

As a significant contribution of this paper, it organizes and summarizes China's past energy distribution structure, from which the problems in the past energy development are identified, and solutions are proposed. Furthermore, this paper used a fixed-effects model to analyze the relationship between energy structure and the digital economy in the context of China's digital transformation and new energy transformation.

There are, however, some limitations to this paper. Due to the delay in the collection of statistical data, the data in this paper extends only to 2021. Consequently, this paper will prove to be a valuable line of research for analyzing the future trend of energy more clearly after new data has been collected.

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