

The Digital Economy “Empowers” Carbon Productivity— Empirical Evidence from Chinese Cities

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Abstract: In the context of building a new development pattern, the digital economy plays an increasingly prominent role in promoting the “dual carbon” goal. Based on the urban panel data from 2011 to 2022, this paper deeply explores the impact and mechanism of digital economy on urban carbon productivity. The results show that: (1) The digital economy can promote the improvement of urban carbon productivity, which is still valid after a series of robustness tests. (2) From the perspective of mechanism path, the digital economy can improve urban carbon productivity through two channels: promoting technological innovation and industrial structure upgrading. (3) From the heterogeneity analysis, it can be seen that the promotion effect of digital economy on urban carbon productivity is more obvious in non-resource cities and peripheral cities. This study provides empirical evidence and policy reference for the digital economy to promote green development and achieve the “dual carbon” goal.

Keywords: Digital Economy; Carbon Productivity; Digital Infrastructure

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1. Introduction

Global climate change has become a common challenge facing human society. Reducing carbon emissions and improving carbon productivity have become the core issues to achieve sustainable development. As the largest developing country, China has promised to achieve peak carbon dioxide emissions by 2030 and carbon neutrality by 2060, which puts forward higher requirements for the green transformation of economy and society. The digital economy is regarded as an important engine to promote the improvement of carbon productivity by virtue of its ability of technology penetration and resource optimal allocation. For example, the National Big Data Comprehensive Test Area adopted green technological innovation^[1]. Robot application and industrial structure optimization^[2], significantly reducing the growth rate of urban carbon emissions and increasing carbon productivity. The digitalization of rural areas is achieved through technological innovation^[3], scale of operation and non-agricultural employment and other channels^[4], has a positive impact on agricultural total factor carbon productivity. However, the existing research focuses more on economics and management perspectives, and less on the issues of cost accounting, environmental accounting information disclosure and resource allocation efficiency optimization in the digital transformation from the accounting perspective. It is difficult to fully reveal the micro-mechanism of the correlation between digitalization and carbon productivity.

Existing research shows that digitalization mainly enhances carbon productivity through the effects of technological

innovation, industrial structure optimization and resource allocation. For example, the development of the Internet significantly increases carbon productivity in the mid-term of industrialization by improving the efficiency of resource allocation and in the late stage by promoting technological progress^[3]; Digital industry collaborative innovation promotes total factor carbon productivity by optimizing the allocation of capital and human factors^[5]. In addition, the platform economy plays a “cloak effect” in the digital construction, i.e. it may increase carbon emissions due to infrastructure investment in the short term, but it will suppress emissions through technology diffusion and industrial upgrading in the long term^[6]. These studies provide theoretical support for understanding the digital carbon emission reduction path, but lack attention to accounting issues such as cost accounting and carbon asset measurement.

2. Literature Review

Under the background of the global “double carbon” target, digital transformation has become the core engine to improve carbon productivity. The National Big Data Comprehensive Test Area policy significantly reduces the growth rate of urban carbon emissions and increases the growth rate of carbon productivity through three paths: green technology innovation, extensive application of robots and optimization of industrial structure. For example, the pilot area promoted the green transformation of high-energy consuming industries by integrating data resources and promoting industrial internet applications, resulting in a 7.09% decrease in the growth rate of carbon emissions and a 13.84% increase in carbon productivity^[7]. Rural digitalization improves agricultural total factor carbon productivity through technology diffusion effect. For example, panel data of 30 provinces in China show that for every 1% increase in rural digitalization level, agricultural total factor carbon productivity will increase by 0.629%, and this effect will be achieved through technology innovation, scale operation and non-agricultural employment^[8]. In addition, collaborative innovation in the digital industry promotes total factor carbon productivity more significantly in the eastern region and regions with higher levels of new infrastructure by optimizing the allocation of capital and human factors, such as improving capital mobility and attracting high-quality talents^[9].

In terms of technological innovation and efficiency improvement, digitalization directly improves carbon productivity by promoting green technological innovation. For example, the development of the Internet has a positive impact on carbon productivity by improving the efficiency of resource allocation in the middle stage of industrialization and promoting technological progress in the later stage, with the effect coefficient of technological progress reaching 0.0206 in the latter stage of industrialization^[10]. The number of green patent applications and green total factor productivity in the National Big Data Pilot Zone have significantly increased, which proves the mediating role of technological innovation^[11]. In terms of industrial structure optimization and agglomeration effect, digitalization enhances carbon productivity through rationalization, agglomeration and digitalization transformation of industrial structure. For example, the collaborative innovation of digital industry promotes the collaborative agglomeration of manufacturing industry and producer service industry. The decrease of theil index indicates that the industrial structure is more reasonable^[12]. The digitalization of rural areas can reduce the energy consumption and transaction cost of logistics and realize the coordination of virtual agglomeration and geographical agglomeration by promoting industrial clusters such as “Taobao Village”^[13]. In terms of spatial spillover and platform economic effect, the impact of digitalization has spatial spillover. The dynamic spatial doobin model shows that the rural digitalization not only improves the local agricultural total factor carbon productivity, but also has a positive indirect effect on the neighboring regions through the technology diffusion. the short-term and long-term indirect effects are significantly 0.946 and 1.303 respectively^[14]. The platform economy has shown a “masking effect” in the digital construction: in the short term, the platform infrastructure investment may increase carbon emissions, but in the long term, emissions are suppressed through the circulation of data elements and industrial upgrading. after the implementation of the “two-carbon” strategy, the masking effect of the platform economy is weakened, and the positive impact of digitization is enhanced^[15].

The effect of digitalization has significant regional heterogeneity. Due to the perfect digital infrastructure and intensive innovation elements in the eastern region, the promotion effect of digital industry collaborative innovation on carbon productivity is significantly higher than that in the central and western regions^[16]. From the perspective of the evolution of industrialization stage, the impact of internet development on carbon productivity is “double threshold effect”. In the early

stage of industrialization, there was a negative impact due to inadequate technological adaptation, while in the middle and later stages, carbon productivity was significantly improved through resource allocation and technological progress^[17]. The new infrastructure level and financial development level adjust the digital effect. The synergetic innovation of digital industry in regions with higher level of new infrastructure will promote carbon productivity by three times as much as in regions with lower level^[18]; There is a “threshold effect” in the development level of rural finance. Only in areas with high financial level, the rural digitalization has a significant effect on the improvement of carbon productivity^[19]. In addition, after the implementation of the “double carbon” strategy, the masking effect of platform economy is weakened and the direct effect of digitalization on carbon productivity is enhanced^[20].

3. Theoretical Analysis and Research Hypotheses

The digital economy drives the improvement of carbon productivity through four dimensions of technology, structure, efficiency and space. Its mechanism can be summarized as the progressive path of “technological innovation breakthrough-reshaping industrial structure-optimizing resource allocation-spatial collaborative diffusion”.

The Impact of Digital Economy on Carbon Productivity From a Theoretical Perspective, Digital Economy integrates data resources through the effect of technological innovation to drive research and development and application of green technologies^[1]. For example, the National Big Data Comprehensive Test Area promoted the green transformation of energy-intensive industries through the industrial internet platform, increasing the green patent application volume by 0.9197% and the green total factor productivity by 6.82%; Relying on the effect of industrial structure optimization, digital technology permeates into the traditional manufacturing industry to promote industrial synergy. As non-resource-based cities have higher elasticity of industrial structure, the effect of digital economy on carbon productivity is significantly higher than that of resource-based cities^[11]; Through the effect of resource allocation efficiency, Digital inclusive finance alleviates the financing constraint of green enterprises. Each 1% increase in capital factor allocation efficiency can drive the growth of carbon productivity by 0.679%. At the same time, rural digitalization transfers labor to low-carbon industries through non-agricultural employment channels, and non-agricultural income is increased by 0.235%^[13]; With the help of spatial spillover effect, the short-term indirect effect of rural digitalization on carbon productivity in neighboring regions reaches 0.946. In the eastern region, due to the improvement of new infrastructure and the concentration of innovation elements, the promotion effect of digital industry collaborative innovation on carbon productivity is more significant. Based on this, hypothesis 1 is proposed.

Hypothesis 1: The digital economy significantly increases carbon productivity.

The digital economy accelerates the research and application of green technologies through the integration of data elements and the innovation of ecological construction. Big Data, cloud computing and other technologies have reduced information asymmetry and pushed interdisciplinary green innovation projects to the ground. For example, the National Big Data Comprehensive Test Area has optimized production processes through industrial internet platforms^[5], increased the green patent application volume by 0.9197% and green total factor productivity by 6.82%^[15]. At the same time, the extensive application of robot technology^[1], such as industrial robot installation density increase, directly replace the high energy consumption production link, reduce carbon emissions per unit output^[5]. Based on this, hypothesis 2 is proposed.

Hypothesis 2: Technological Innovation Is the Mediating Path of Digital Economy Affecting Carbon Productivity

Digital Economy Promotes Green Transformation of Traditional Industries and Agglomeration of Emerging Industries. On the one hand, the Internet of Things, artificial intelligence and other technologies penetrate into high energy-consuming industries, and reduce the intensity of energy consumption through intelligent transformation. For example, rural digitalization increases agricultural carbon productivity by 0.629% through scale operation^[3]; On the other hand, the digital industry’s own low-carbon characteristics promote the industrial structure to lean towards low-carbon. The non-resource-based cities have a more flexible industrial structure, and the digital economy has a significantly higher promotion effect on carbon productivity than the resource-based cities^[8]. Based on this, hypothesis 3 is proposed.

Hypothesis 3: Optimization of industrial structure is the transmission channel for digital economy to affect carbon productivity.

4. Research Design

4.1 Model Design

4.1.1 Baseline regression model

This paper constructs a double fixed effect model for empirical test, and uses the previous practice of domestic scholars for reference to set up the following benchmark linear regression model:

$$Y_{it} = \alpha_0 + \alpha_1 X_{it} + Controls_{it} \alpha_2 + \gamma_i + \theta_t + \xi_{it} \quad (1)$$

In the formula (1), Y_{it} is an explanatory variable, X_{it} is an explanatory variable and C_{it} is a control variable; γ_i and θ_t represent fixed effects of city and year respectively, and ξ_{it} represents random disturbance term.

4.2 Variable Description

4.2.1 Dependent variable

Carbon productivity (lnCP). Referring to the research of Kaya et al. (1997), the natural logarithm of GDP output level per unit of carbon emission is used as the proxy indicator of carbon productivity, and the carbon dioxide emissions of each city are calculated by the emission factor method published by the United Nations Intergovernmental Panel on Climate Change (IPCC). The specific formula is:

$$\ln CP = \ln(GDP/CDE) \quad (2)$$

In formula (2), GDP is the actual GDP of each region; CDE is carbon dioxide emissions. In this paper, the method in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories is used to calculate the carbon dioxide emissions, which are converted from the consumption of 8 major fossil energy sources.

4.2.2 Explanatory variables

Digital economy (digi). At present, there is no final conclusion on the calculation of the digital economy. This paper refers to Zhao Tao et al.^[20] (2020) and selects five indicators, namely, the number of Internet users per 100 people, the proportion of computer service and software employees, the total number of telecommunication services per capita, the number of mobile phone users per 100 people and the Peking University Digital inclusive finance Index, and finally obtains the digital economy index by entropy method, as shown in Table 1.

Table 1 Evaluation System of Digital Economy Development Level

Level 1 indicators	Secondary indicators	Indicator description	Indicator attribute
Internet development	Internet penetration	Internet users per 100 population	+
	Number of Internet-related employees	Percentage of Computer Service and Software Professionals	+
	Internet-related outputs	Total telecom business per capita	+
	mobile Internet	Number of mobile phone users per 100 population	+
digital financial inclusion	Digital inclusive finance Development	Peking University Digital inclusive finance Index	+

4.3 Control Variables and Intermediate Variables

Education level (lnedu) is controlled by logarithm of education expenditure, government environmental regulation (lnErs) is controlled by logarithm of sewage treatment rate, research and development investment (lnrd) is controlled by logarithm of number of R&D personnel, industrial structure (lnis) is controlled by logarithm of total value of secondary industry as a proportion of GDP, and population density (pop) is controlled by ratio of number of people to area. In this paper, technology innovation (lninno) is selected as an intermediate variable to test the mechanism, and the number of patents granted in each region is added to 1 for logarithmic processing.

4.4 Data Sources

This paper selects the panel data of 274 prefecture-level cities in China from 2011 to 2022, with a total of 3288 observations.

The digital inclusive finance data are derived from the Digital Finance Research Center of Peking University, and all other original data are derived from China Statistical Yearbook, Local Bureau of Statistics and statistical yearbooks of various regions. Some missing values are supplemented by linear interpolation.

5. Empirical Results Analysis

5.1 Descriptive Statistics

The descriptive statistics of the variables are shown in Table 2. As can be seen from Table 2, the average value of carbon productivity in all samples is 0.0969, the maximum value is 0.4581, and the minimum value is only 0.006. The standard deviation represents the degree of dispersion of variables. The maximum standard deviation in the above table is 9.9059, which reflects the uneven development of digital economy among regions and may have heterogeneous impact on carbon productivity.

Table 2 Variables and Descriptive Statistics

Variable type	variable	Number of observations	average/mean value	standard deviation	minimum value	maximum
Explanatory variable	digi	3288	0.0969	0.0812	0.006	0.4581
Interpreted variable	lnCP	3288	8.2644	0.8499	6.3559	10.4243
	lnis	3288	3.7741	0.2756	2.4596	4.4073
	lnedu	3288	13.2143	0.7868	9.9059	16.2761
Control variable	lnErs	3288	4.475	0.1779	2.8903	4.804
	lnrd	3288	8.7753	1.6887	2.5649	13.2609
	pop	3288	5.7681	0.9137	1.6094	7.9423
mediator variable	lninno	3288	5.3672	1.8934	0	11.3866

The high difference between research and development investment and education level (lnedu) in the control variables may lead to collinearity, which needs to pass the VIF test. Therefore, the VIF test is used to perform multicollinearity test on all variables before regression. The results are shown in Table 3, with VIF of all variables less than 10, indicating that there is no multicollinearity when the test passes.

Table 3 Multivariate Collinearity Test

variable	VIF	1/VIF
pop	1.610	0.620
digi	1.210	0.829
lnErs	1.120	0.890
lnis	1.080	0.926
lnedu	1.060	0.944
MeanVIF		1.330

5.2 Baseline Regression Results

This paper selects two-way fixed effect model to test the impact of digital economy on urban carbon productivity. The specific results are shown in Table 4. The above regression results show that the digital economy has a significant positive impact on carbon productivity, and with the gradual addition of control variables, the coefficient and significance of the digital economy show a stable and increasing trend. Columns (1) to (6) of Table 4 are the regression results after adding the control

variables in turn. The coefficient of Digital Economy (digi) is still significantly positive, and adding all the control variables is significant at the 5% level. This indicates that the digital economy can significantly promote carbon productivity, which verifies Hypothesis 1.

Table 4 Benchmark Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
digi	0.434*	0.433*	0.537**	0.542**	0.560**	0.557**
	(1.80)	(1.79)	(2.25)	(2.27)	(2.36)	(2.34)
lnedu		0.0343	0.00785	0.00844	0.00615	0.00536
		(0.84)	(0.19)	(0.21)	(0.15)	(0.13)
lnis			0.439***	0.438***	0.436***	0.433***
			(7.62)	(7.61)	(7.54)	(7.37)
lnErs				-0.0183	-0.0177	-0.0181
				(-0.28)	(-0.27)	(-0.27)
pop					0.162	0.160
					(0.97)	(0.97)
lnrd						0.00669
						(0.49)
_cons	8.222***	7.769***	6.451***	6.528***	5.631***	5.606***
	(331.21)	(14.43)	(11.82)	(10.28)	(4.82)	(4.80)
City	control	control	control	control	control	control
year	control	control	control	control	control	control
N	3288	3288	3288	3288	3288	3288
r2	0.908	0.908	0.910	0.910	0.910	0.910
r2_a	0.899	0.899	0.902	0.902	0.902	0.902

T statistics in parents, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, the following table is the same.

5.3 Heterogeneity Analysis

Due to the significant heterogeneity in resource endowments, location conditions and scale levels of each city in China, this heterogeneity is not only the objective basis for differentiation of urban development, but also shapes the uniqueness of different cities in industrial layout, growth model and transformation path. Therefore, we examine the impact of digital economy on carbon productivity under the heterogeneous resource and city scale. According to the regional planning standard of China, the city is divided into two regions: resource-based city and non-resource city. Municipalities directly under the central government, provincial capital cities and sub-provincial cities are divided into central cities and the rest are peripheral cities.

5.3.1 Analysis of resource heterogeneity

Table 5(1)(2) shows the heterogeneous results of resource-based cities and non-resource-based cities respectively. It is found that the digital economy only has a positive significant impact on non-resource-based cities, while the impact on resource-based cities is not significant. This is mainly because the economy of resource-based cities is highly dependent on a single natural resource, such as mineral resources and energy, with a single industrial structure, difficult industrial transformation and upgrading, backward construction of digital infrastructure and poor circulation of data, capital and talents, which will restrict the promotion of the digital economy on the carbon productivity of resource-based cities. Rather than a resource

city, it will gather more universities, scientific research institutions and some innovative enterprises, have better digital infrastructure, can quickly realize the digital transformation of manufacturing industry, improve production efficiency and energy use efficiency, and can better meet the needs of the development of digital economy, so that the digital economy has a significant positive effect on its carbon productivity.

5.3.2 Analysis of resource heterogeneity

From (3)(4), it can be seen that the digital economy has a positive impact on the carbon productivity of peripheral cities, but this effect is not significant for central cities. This may be due to the low operating cost of constructing data centers in peripheral cities, which attracts the business transfer of digital economy enterprises to realize a significant decrease in carbon emissions and an increase in economic benefits at a lower cost. However, central cities often face more land and labor costs, and it is difficult to reduce carbon and increase efficiency in the digital economy because of land and energy costs. On the other hand, the industries in the central cities are more inclined to the high-tech industries, and their own carbon emissions may be low, while the industrial structure in the peripheral cities is mainly dominated by the traditional high energy consumption, thus the space for carbon reduction is larger, and the marginal utility brought by the emission reduction in the digital economy is larger.

Table 5 Results of Heterogeneity Analysis

	(1)	(2)	(3)	(4)
	Resource-based city	Non-resource city	key city	Peripheral cities
digi	0.298 (0.90)	0.770** (2.40)	0.762 (1.34)	0.522** (2.01)
lnis	0.231** (2.55)	0.577*** (7.68)	0.721*** (5.49)	0.401*** (6.31)
lnErs	0.0550 (1.03)	-0.0673 (-0.71)	0.0653 (0.69)	-0.0231 (-0.33)
lnrd	0.0231 (0.91)	-0.00496 (-0.32)	-0.00096 (-0.04)	0.00344 (0.21)
lnedu	0.109* (1.68)	-0.0492 (-0.94)	0.111 (1.00)	-0.0144 (-0.33)
pop	-0.319 (-1.05)	0.352* (1.76)	0.438 (1.48)	-0.0197 (-0.09)
_cons	7.356*** (3.91)	4.930*** (3.29)	1.197 (0.47)	7.054*** (4.80)
City	control	control	control	control
year	control	control	control	control
N	1152	2136	396	2892
r2	0.924	0.902	0.929	0.908
r2_a	0.915	0.892	0.918	0.899

5.3 Robustness Test

In the three models, the coefficient of digi is positive, and significant at least at 5%, indicating that the positive impact of digital economy on carbon productivity is robust. Table 6(1) shows that after excluding the municipalities directly under

the central government, the coefficient slightly decreased (0.518), but the significant increase may be due to the special economic structure of the municipalities directly under the central government, such as policy inclination and concentration of resources, and the results after excluding more reflect the general laws of ordinary regions. Table 6(2) shows that after replacing the standard error, the coefficient slightly increased (0.557), but the significance decreased. It may be because the original standard error underestimated the error. After replacing the robust standard error, the value of T was close to the critical value and remained marginal significance. Table 6(3) After adjusting the sample period, the coefficient increased significantly (1.049), which should be due to the fact that specific events in the sample period strengthened the effect of digitalization, or excluded the data of interference period, highlighting the core effect.

Table 6 Results of Robustness Test

	(1)	(2)	(3)
	Excluding municipalities directly under the central government	Replacement standard error	Adjust sample period
digi	0.518** (2.17)	0.557* (1.96)	1.049** (2.54)
Control	control	control	control
City	control	control	control
year	control	control	control
N	3240	3288	2740
r2	0.910	0.910	0.900
r2_a	0.901	0.902	0.888

5.4 Mechanism Analysis

Table 7, column (1), reports the results of the mechanism test of technological innovation as an intermediate variable. The results show that the positive correlation between digital economy and technological innovation is significant. The coefficient of digital economy (digi) is 0.139, which is significant at the statistical level of 1%, indicating that for every unit of increase in the level of development of digital economy, the level of technological innovation will increase by 0.139 units on average. This result directly verifies the promotion effect of digital economy on technological innovation, which is in line with the logic of “digital economy promotes research and application of green technology through data element integration and interdisciplinary innovation ecological construction” in the theoretical mechanism. After adding the control variables, the research and development investment (lnrd) is significantly positive, indicating that research and development investment is an important driver of technological innovation and forms a synergistic effect with the digital economy; Population density (pop) is significantly negative, which may reflect the crowding-out effect of overpopulation on innovation resources. Generally, hypothesis 2 can be proved to be true.

Table 7 (2) reports the results of the mechanism test of industrial structure upgrading as an intermediate variable. The results show that the positive correlation between digital economy and industrial structure upgrading is significant. The coefficient of Digital Economy (digi) is 0.00238, which is significant at 1% of the statistical level, indicating that the development of digital economy can promote the transformation of industrial structure to low-carbon and service-oriented. This is consistent with the expectation of “digital technology permeates traditional industries and promotes industrial synergy” in the theoretical mechanism. After adding the control variables, the industrial structure (lnis) is significantly negative at 10%, which may reflect that the proportion of high-energy consuming industries in the current industrial structure is still high, and it has certain inhibitory effect on upgrading, but the positive effect of digital economy can partially offset this effect. Generally, hypothesis 2 can be proved to be true.

Table 7 Mechanism Test Results

	(1)	(2)
	technical innovation	upgrading of an industrial structure
dig	0.139*** (4.79)	0.00238*** (4.88)
lnis	-0.337 (-0.62)	-0.0111* (-1.72)
lnErs	0.00849 (0.26)	0.000347 (0.62)
lnrd	1.043*** (2.90)	0.00413 (0.69)
lnedu	0.624 (1.47)	0.00662 (1.50)
pop	-3.99*** (-3.89)	-0.00927 (-0.62)
_cons	5.878 (1.44)	0.0511 (1.16)
City	control	control
Year	control	control
N	3288	3288
r2	0.973	0.635
r2_a	0.968	0.573

6. Conclusions and Implications Recommendations

6.1 Conclusion

The digital economy has significantly promoted the growth of total factor carbon productivity through green technological innovation and industrial structure optimization. For example, the National Big Data Comprehensive Test Area policy has effectively reduced the growth rate of urban carbon emissions and increased the growth rate of carbon productivity by promoting green technological innovation, extensive application of robots and optimization of industrial structure^[5]. The impact of the development of the Internet on carbon productivity has a double-threshold effect. In the mid-term of industrialization, the carbon productivity is increased through resource allocation efficiency, and the effect is further strengthened through technological progress in the later stage. Rural digitalization promotes agricultural total factor carbon productivity through technological innovation, scale operation and non-agricultural employment, and there is a significant spatial spillover effect^[13]. In terms of regional differences, the promotion of digital economy is more significant in the eastern region and regions with higher levels of new infrastructure. For example, the enhancement effect of carbon productivity is more prominent in the eastern region due to the high level of collaborative innovation and the strong ability of factor agglomeration in the digital industry; In regions with high levels of new infrastructure, the integration of digital technology and industry is more efficient, and the efficiency of resource allocation has been significantly improved. In the middle stage of industrialization, the digital economy mainly improves carbon productivity by optimizing the allocation of resources; In the latter stage of industrialization, technological progress has become the main driving force^[10]. Platform economy has a “masking effect” in the impact of digital construction on carbon productivity, but after the implementation of the “double carbon” strategy, the effect is weakened and the positive effect of digital is significantly enhanced.

6.2 Revelation suggestion

First, at the government level, we must first improve the layout of the digital infrastructure. Increase investment in digital

infrastructure in the central and western regions to narrow the regional “digital divide.” For example, reference is made to the experience of building a green data center in the National Big Data Comprehensive Test Area^[5], to lay out low-carbon data centers in the central and western regions, promote the application of renewable energy and reduce the energy consumption of data centers. At the same time, we will speed up the construction of 5G, industrial Internet and other new infrastructure to support the industry’s digital transformation^[11]. Thirdly, differentiated policy guidance and regional coordination. For the eastern region, we will focus on supporting the construction of digital industry collaborative innovation clusters, and give full play to its advantages of technology spillovers and factor agglomeration^[7]; For the central and western regions, relying on the opportunity to undertake industrial transfer, we will promote the digital transformation of traditional industries, such as using big data to optimize the agricultural production process^[20]. It is also necessary to establish a trans-regional digital economic cooperation mechanism. For example, regions such as the Yangtze River Economic Belt can amplify the spatial spillover effect through data sharing and technology collaboration. It is also very important to strengthen policy incentives and environmental regulations. The government has formulated carbon productivity assessment indicators, incorporated the digital economy into the green development policy system, and granted tax relief and financial subsidies to enterprises in their digital transformation^[11]. With the help of the “two-carbon” strategy, the platform economy will be forced to become green, the expansion of its high-energy consumption business will be restrained, and the flow of resources to low-carbon industries will be guided.

Second, at the social level, we must first promote collaborative innovation in Industry-University-Research. Encourage universities, scientific research institutions and enterprises to cooperate, establish a digital technology innovation alliance, and focus on tackling low-carbon technologies. Such as intelligent energy management and green manufacturing technology. Thirdly, it is to enhance public awareness of low carbon and digital literacy. Through popular science publicity and education guidance, enhance the awareness of enterprises and the public on the low-carbon value of the digital economy. For example, the “green consumption” model in internet plus was promoted, e-commerce platforms were encouraged to carry out green product traceability, and consumers were guided to choose low-carbon goods^[19]. The society also needs to perfect the financial support system. Through the development of digital inclusive finance, the financing constraints of the digital transformation of small and medium-sized enterprises will be eased. For rural areas, scale operations and green technology applications can be supported through digital financial instruments.

Third, at the enterprise level, it is first necessary to promote the application of production intelligence and green technology^[21]. Manufacturing enterprises should introduce industrial robots, internet of things and other technologies to optimize production processes to reduce energy consumption. For example, learn from the experience of robot application in the big data test area To reduce carbon emissions from highly polluting sectors through automated production. Agricultural enterprises can rely on the rural digital platform to achieve accurate fertilization and intelligent irrigation, and improve the efficiency of resource utilization^[13]. Thirdly, optimize the industrial structure and coordinate agglomeration. Traditional enterprises are transforming to service-oriented manufacturing and developing digital service industries with high added value and low energy consumption, such as industrial internet platforms. Participate in industrial synergy, such as joining the “manufacturing-producer services” collaboration network, and reduce overall carbon emissions through division of labor and technology sharing^[1]. But also to strengthen data-driven carbon management capabilities. Establish an enterprise carbon footprint monitoring system and optimize the energy consumption structure by using big data analysis. For example, logistics companies can reduce transportation carbon emissions through intelligent scheduling systems, and e-commerce platforms can reduce packaging waste through supply chain digitization^[22].

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