The Digital Economy and Carbon Intensity: Empirical Evidence from Chinese Cities

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Abstract. This study examines how the development of the digital economy affects urban carbon intensity. Using a sample of 281 prefecture-level cities in China from 2011 to 2021, we employ principal component analysis and entropy weighting analysis to assess the comprehensive level of digital economic development. Various models, such as benchmark regression, variable substitution, interactive fixed effects, robust standard errors with double clustering, and instrumental variables, are employed to empirically analyze the impact and mechanisms of digital economic development on carbon intensity in multiple Chinese cities. The results indicate that the development of the digital economy can reduce urban carbon intensity. Based on these findings, this paper puts forward policy recommendations to promote digital economic development and reduce carbon intensity, including increasing efforts in digital economic development and related infrastructure construction, narrowing the regional disparities in digital economic development, improving regulations and systems related to low-carbon development in the digital economy, and adapting to international economic and political development trends, in order to contribute to the achievement of the "dual carbon" goals.

Keywords: Digital economy, carbon intensity, robust standard errors with double clustering, benchmark regression, dual carbon strategy.

1. Introductory

Since the Industrial Revolution, the extensive spread of mechanized production methods has led to the increasing concentration of greenhouse gases (GHGs), which has led to the increasingly serious problems of climate change, sea level rise, extreme weather events, and ecosystem destruction (Iyer et al., 2022). Therefore, controlling and reducing carbon dioxide-based greenhouse gas emissions, lowering carbon intensity, and realizing carbon neutrality is necessary to promote the sustainable development of the global economy and society (Yu Guirui et al., 2022). At present, China's economic development is facing the double pressure of slowing down and green transformation, and the "double carbon" target has become the main task of the new development stage and one of the important strategies to realize China's high-quality development. Carbon intensity refers to the amount of carbon dioxide emitted per unit of GDP output (Ding Fanlin, 2022), which is an indicator of the impact of economic activities or energy use on climate change. Climate change can be mitigated, and sustainable development and economic growth can be promoted by reducing carbon intensity, improving resource utilization efficiency and promoting clean energy transition (Liu et al., 2020). Therefore, reducing carbon intensity while reflecting China's responsibility as a great power and demonstrating its commitment as a great power also demonstrates China's determination to follow the path of sustainable development actively and to join hands with all countries in the world to build a community of shared destiny for humankind.

As the most active field in China's economic development, the digital economy has been expanding the breadth and depth of its integration with various fields of the economy and society. It has played an important role in stimulating consumption, boosting investment, and creating employment. Digital economy refers to the economic form of production, distribution, exchange and consumption based on digital technology through digital, networked and intelligent means (Guo Feng et al., 2023). As a new economic form, digital economy takes digital technology as the core driving force and promotes the digital transformation and high-quality development of the global economy through three paths: new technology forms new industries, new industries give rise to new models, and new technology empowers traditional industries. At the macro level, Han Zhaoan et al. (2021) analyze the non-equilibrium and regional differences of the digital economy in China and the three major regions based on the Kernel density estimation and the Dagum Gini coefficient method. At the micro level, more researchers have studied the impact of the digital economy on boosting the modernization and development of agriculture and rural areas, the green transformation and upgrading of industry, and the development of innovative science and technology industries (Cao and Zheng, 2023; Shiprun et al. 2022; Wang et al. 2023). Based on this, the purpose of this paper is to summarize the existing domestic and international literature and research progress related to the digital economy, and to distill the relationship between the digital economy and carbon intensity to provide doctrinal support for promoting the development of the digital economy and the sustainable development of cities.

With the continuous development of digital technology and the deep integration of the digital economy and the real economy, researchers have found that the development of the digital economy is conducive to improving the efficiency of energy utilization, thereby reducing carbon intensity. Chen Xiaohong et al. (2021) elaborated on the relevant theoretical research and application of digital technology on carbon emission reduction and problems by combing and analyzing the impact of digital technology on the field of carbon footprints and carbon sinks from the aspects of energy supply, consumption, application, and innovation. Xie Yunfei (2022) examined the effect and mechanism of digital economy affecting regional carbon emission intensity by establishing the panel model, panel quantile and mediating effect model at provincial level, and found that the digital economy can effectively promote the decline of carbon emission intensity, and that the optimization of energy structure and biased technological advancement are the important mechanisms. Most of the related research literature finds that under the influence of policy guidelines, the positive impact of digital economy development on carbon emissions has an inverted "U" shape, with an increase followed by a decrease (Fei et al. 2022; Hou and Zhou, 2023; Wang, 2023). However, the digital economy does not only have a carbon reduction effect but its development process will also be accompanied by a large amount of energy consumption, thus showing a carbon increase effect. At the same time, some literature believes that the development of digital economy does not have a significant impact on reducing the carbon emission intensity of central cities and resource cities (Fan Hejun et al., 2023). To summarize, the current research on digital economy and carbon intensity by scholars is more extensive, respectively arguing from different perspectives, which also provides an effective reference for the subsequent research of this paper.

2. Literature review and theoretical mechanisms

As a new economic form, the existing research literature on digital economy mainly focuses on its economic and environmental effects. In terms of economic effects, Liu Lingbo and Liu Jun (2023) combed and reviewed the research results related to industrial digitalization from the connotation of industrial digitalization, measurement methods, and economic effects, and found that the promotion of industrial digitalization can promote industrial technological innovation, improve productivity, capacity utilization, labor efficiency, and promote the country to achieve a high level of open economy. Zhu Heliang and Wang Chunjuan (2020) argue that the digital economy can expand the size and scope of the domestic market, boost the upgrading of domestic demand, enhance the supply capacity of enterprises, create market dynamics, enhance the dynamics of domestic demand, change the mode of production, and then drive the formation of a strong domestic market. Zhang Xun et al. (2019) combine China's digital financial inclusion index with data from China's household tracking survey, and find that the development of digital finance in China has equalized entrepreneurial opportunities, which can significantly boost household income and promote entrepreneurial behavior with low material capital, thus promoting inclusive growth in China.

In terms of environmental benefits, Deng Rongrong and Zhang Aoxiang (2022), based on panel data of 285 Chinese cities from 2011-2018, using fixed-effects model, spatial Durbin model, mediated-effects model and other methods of testing found that the development of the digital economy significantly reduces the emission of various types of environmental pollutants in cities. There are some differences in the reduction of the role of different pollutants. Green innovation and industrial structure optimization are important mechanisms for digital economy to reduce urban environmental pollutant emissions. Yang Youcai et al. (2022) and Wang Qiaoran (2023) focus on the green value of the digital economy, and through empirical tests found that the digital economy can improve the green total factor productivity, of which the most significant improvement is in the central city. Liang Qi et al. (2021), based on the industrial structure upgrading intermediary perspective, take 285 Chinese cities as samples from 2011 to 2018, and find that the development of digital economy can significantly improve the eco-efficiency of cities. This shows that both the economic and environmental effects of digital economy are more significant, which provides a useful reference for this paper's subsequent research on the role of digital economy on carbon intensity.

Climate change is a major and urgent global challenge facing humanity. The academic community has been concerned about carbon intensity for a long time, and many scholars have already studied carbon intensity from different perspectives. First, in addition to some scholars directly studying carbon intensity from the aspects of key influencing factors (Liu Weidong et al., 2019), changing factors (Dong et al., 2019), and spatial correlation (Sun Yaohua, 2021). Some scholars have found that China's carbon emission intensity as a whole shows an upward trend, and exhibit the dynamic evolution characteristics of "high in the east and low in the west" (Wang et al., 2021). Related studies show that the level of economic development, population size, energy consumption, industrial structure upgrading, scientific and technological innovation, and environmental regulation all have different degrees of influence on carbon intensity. Other scholars have assessed the carbon emission reduction effects of policy factors such as low-carbon pilot policies, carbon emission trading rights, and eco-province construction (Li et al., 2021). Second, some other scholars all study carbon intensity from different entry points. Yang et al. (2019) and others quantitatively clarify the key role of technological progress in the process of carbon dioxide emission reduction, quantitatively analyze the relationship between carbon dioxide emissions and technological progress in different industries in China. And they find that Chinese carbon dioxide emissions will be in a relatively fast declining trend in the future. Ma et al. (2018) and other scholars study China's energy transition and economic development through cross-country comparisons and CGE modeling, and find that per capita carbon dioxide will enter the "decline period" in 2035 or even earlier. Finally, many scholars have studied the relationship between digital financial inclusion (Ding, 2022), manufacturing servicization (Wang Hongsen et al., 2022), and carbon trading rights (Ji & Yang, 2021) from micro perspectives and carbon intensity. In summary, most scholars have provided a more detailed description of carbon intensity, providing a research basis for the subsequent impact of digital economy on carbon intensity.

After the outbreak of the new crown pneumonia epidemic, it has become a general consensus of the international community to realize economic recovery through green and low-carbon development. The effect of the digital economy on reducing carbon intensity is mainly reflected in the following three aspects: first, the digital industry has environmentally friendly characteristics and causes less negative effects on the environment. The digital industry is dominated by information enterprises such as Internet enterprises and information service industry, and its greening level is generally higher than that of traditional manufacturing industry. In addition, due to their strong economic strength, digital enterprises tend to pay more attention to environmental benefits. Secondly, as the industrial foundation of the digital economy, the digital industry can promote other industries to reduce carbon emissions. The digital industry can use the penetration and derivation of digital technology to transform traditional industries and promote the development of industries towards intelligence and greening, as well as to improve the added value of industries and reduce energy consumption and carbon emissions. Thirdly, the development of digital economy is conducive to establishing a carbon market, which in turn reduces carbon emissions. Since the National Development and Reform Commission (NDRC) issued the Notice on Carbon Emission Trading Pilot Work in 2011, carbon emission trading has been carried out in a number of pilot provinces and cities, and many scholars have recognized its policy effect. Although China's carbon dioxide emissions continue to decline through a series of policies and measures, China's low-carbon development and transformation still has a huge development space and development potential but also faces great challenges. Digital technology will undoubtedly become a breakthrough in solving the above technical difficulties. By improving the carbon trading market through digital technology, enterprises with higher energy efficiency can sell their excess emission rights to other enterprises, and carbon trading can encourage enterprises to take the initiative to save energy and reduce emissions. Currently, the existing literature confirms that the development of digital economy can significantly reduce carbon emissions. The elasticity of emission reduction is positively correlated with the level of economic development of each country (She and Wu, 2022), and its economic and environmental effects should not be ignored (Wang et al., 2023; Deng et al., 2022; Zhu et al., 2020). In terms of digital economy and urban carbon intensity, literature has shown that digital economic development can significantly promote urban carbon performance (Liu et al., 2023). The impact of digital economic development on urban carbon emissions has an inverted U-shaped characteristic of increasing and then decreasing (Wang, 2023). The construction of smart cities in the perspective of digital empowerment significantly reduces the level of carbon emissions (Wang et al., 2023). The construction of smart cities in the perspective of digital empowerment significantly reduces the level of carbon emissions (Qin et al., 2023). However, the research literature on digital economy and urban carbon intensity is relatively small, and it is necessary to do further research on the relationship between the two. To this end, synthesizing the above analysis, this paper proposes the following research hypotheses:

H1: Increased level of development of the digital economy contributes to the reduction of carbon intensity levels.

3. Research design

3.1. Sample selection

3.1.1 Dependent variable

Referring to previous studies (Cheng et al., 2023; Ding Fanlin, 2022; Wang Yali et al., 2022), carbon emission intensity is expressed as the ratio of total carbon emissions to GDP. Human activities are the main source of carbon emissions, and the nighttime lighting index can effectively reflect the intensity of human activities (Chen Yingbiao et al., 2019). Based on the judgment that the nighttime lighting index can reflect the level of human activities, the light brightness is used as a weighting parameter to decompose the provincial carbon emissions on a "top-down" downscaling scale. Specifically, the linear relationship between nighttime lighting and carbon emissions is constant within a given province. Regional differences within the province are expressed only in terms of light intensity. The coefficients of the regression equations for each city within each province are estimated using provincial carbon emissions data. Provincial carbon emissions were accounted for using provincial energy consumption data, and the ratio of city and provincial carbon emissions was obtained by inverting with the nighttime lighting index to obtain city-scale carbon emissions (Bingbing Zhang et al., 2022).

3.1.2 Key independent variable

Considering the availability of data at the city level, drawing on the methodology of Zhao Tao et al. (2020), the Internet penetration rate (the number of Internet broadband access users per 100 people), the related employees (the proportion of employees in the computer services and software industry in the employees in urban units), the related outputs (the total amount of telecommunication services per capita), and the cell phone penetration rate (the number of cell phone subscribers per 100 people) are selected to represent the level of Internet development at the city level. The Internet development level of cities is represented by Peking University, and the digital financial development level of cities is characterized by Peking University. The index of comprehensive development of digital economy is calculated by the principal component method, denoted as DIGE.

3.2. Methodology

In order to test the contribution of the digital economy to the reduction of carbon intensity, the following benchmark model is constructed in this paper:

$$CAI_{it} = \alpha_0 + \alpha_1 DIGE_{it} + \alpha_2 Z_{it} + \mu_i + \delta_t + \varepsilon_{it} \tag{1}$$

Where CAI_{it} is the carbon intensity of city *i* in period *t*, and $DIGE_{it}$ is the level of digital economy development of *i* in period *t*. In order to solve the interference of endogeneity problem caused by omitted variables, this paper introduces the control variables Z_{it}. regional economic development level (pgdp), which is expressed as the logarithm of gross domestic product per capita. Population density (pnd), expressed as the ratio of total population to the area of urban area at the end of the year. Foreign direct investment (fdi), expressed as the ratio of the amount of foreign investment actually used in the year to GDP. Degree of financial development (fin), expressed as the ratio of the amount of loans from financial institutions to GDP. Urbanization rate (urban), is expressed as the ratio of the number of urban residents to the total population at the end of the year. Environmental regulation (REGULATION): this paper uses the natural logarithm of the number of regional environmental protection personnel to measure regional environmental regulation. μ_i is a city-level fixed effect, δ_t is a time-level fixed effect, and ε_{it} is a random disturbance term.

3.3. Data sources and descriptive statistics

This paper takes 281 prefecture-level cities in China from 2011 to 2021 as the research sample, and the relevant data come from the China Urban Statistical Yearbook and EPS and other databases. The descriptive statistics of each indicator are shown in the table below. In order to prevent the influence of the scale as well as the outliers on the accuracy of regression, this paper has carried out the scale transformation treatment for some variables, the logarithmic treatment for some variables, and the shrinking of both ends of 1% for all variable values. Meanwhile, the Spearman correlation test indicates that there is no serious multicollinearity problem between the main variables, and thus they can be added together into the regression equation. On this basis, this paper carries out a series of subsequent analysis and discussion.

Table1. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max.
DIGE	3091	6.902	0.522	4.470	8.552
CAI	3091	0.349	0.745	-2.118	3.245
pgdp	3091	8.688	0.988	6.744	17.280
pnd	3091	7.372	4.021	0.043	15.435
fin	3091	1.677	3.638	0.025	49.500
fdi	3091	0.016	0.017	0.000	0.192
urban	3091	0.405	0.212	0.083	1.091
regulation	3091	3.315	1.454	-0.139	8.157

4. Results and discussion

4.1. Baseline model

Based on the above model design and variable selection, Table 2 shows the linear estimation results of the study on the effect of digital economy on reducing carbon intensity. Column (1) shows the regression results without the introduction of fixed effects and control variables; column (2) shows the regression results without the introduction of fixed effects but with the introduction of control variables; column (3) shows the regression results with the introduction of fixed effects but without the introduction of control variables while fixing city and year effects; and column (4) shows the regression results with the introduction of fixed effects and control variables while fixing city and year effects. Synthesizing the data in the four columns of the table, it can be found that the estimated coefficients of DIGE in the four models are significantly negative, indicating that the development of digital economy is conducive to the reduction of urban carbon intensity. In addition, the decidable coefficients in the four models are, in descending order, 0.964>0.951>0.255>0.162, indicating that the models with fixed effects and control variables are better and more reliable than those without fixed effects or control variables.

Therefore, this paper uses the regression results in column (4) as a benchmark to observe the control variables. The coefficient estimates of the control variables pgdp, pnd and fdi all pass the 1% significance test and have negative signs, implying that an increase in the level of regional economic development, population density, and foreign direct investment can reduce carbon intensity. The coefficient estimates of the control variable regulation are negative, which means that the enhancement of environmental regulation can be realized by increasing the number of environmental protection personnel, thus reducing carbon intensity. The coefficient estimates of the control variables fin and urban are both positive and pass the significance test at the 1% level, indicating that the higher the degree of financial development and urbanization rate, the higher the carbon intensity.

Table2. Benchmark regression

	(1)	(2)	(3)	(4)
	OLS		fixed effect	
DIGE	-0.575***	-0.302***	-0.211***	-0.125***
	(0.023)	(0.029)	(0.050)	(0.041)
pgdp		-0.197***		-0.073***
		(0.022)		(0.027)
pnd		-0.032***		-0.025***
		(0.004)		(0.006)
fdi		-1.540**		-1.525***
		(0.663)		(0.564)
fin		0.017***		0.033***
		(0.005)		(0.007)
urban		0.494***		2.323***
		(0.059)		(0.455)
regulation		0.056***		-0.005
		(0.008)		(0.113)
_cons	4.316***	3.988***	1.804***	1.070*
	(0.159)	(0.191)	(0.348)	(0.610)
City FE	N	N	Y	Y
Year FE	N	N	Y	Y
N	3091	3091	3091	3091
adj. R^2	0.162	0.255	0.951	0.964

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively, with robust standard errors in parentheses.

4.2. Robustness test results

4.2.1 Replacing variables

In order to avoid the bias caused by the measurement of the explanatory variables, the entropy method is applied to obtain the comprehensive development index of the digital economy, which is labeled as *DIGE2*, through the objective assignment of weights.The results are shown in columns (1) and (2) of Table 3. The coefficients of the core explanatory variables are still significantly negative and pass the 1% significance test, indicating that the development of the digital economy can have a suppressive effect on the carbon intensity of the city, which is completely consistent with the benchmark results.

4.2.2 Using interactive fixed effects

Industries with a very high level of technology or cities with a high level of economic development may have relatively well-developed digital infrastructures and have a greater advantage in the development of the digital economy. Based on this, this paper adds the interaction fixed effect of province and year to control the effect of province-level factors that vary with year. The results of the robustness tests are shown in column (3) of Table 3, where the coefficients of the core explanatory variables are negative, consistent with the benchmark results.

4.2.3 Double Clustering Robust Criterion Error

Considering the intrinsic correlation between different firms, we adjust for the double clustering of standard errors in individual and time, which can overcome the impact of problems such as autocorrelation and heteroskedasticity on statistical inference (Tao et al., 2023). The results are shown in column (4) of Table 3. The coefficients on the core explanatory variables remain significantly negative, consistent with the benchmark results.

4.3. Endogeneity test

The existence of certain unobservable factors as well as bidirectional causation, can lead to endogeneity problems, thus this paper utilizes the instrumental variable method to do endogeneity testing to circumvent these problems. First, this paper draws on existing research to choose urban topographic relief as an instrumental variable (Niu et al., 2021). The reasons are as follows: first, the degree of topographic relief can reflect the complexity of regional topography, which has an impact on the installation and commissioning of digital infrastructure. Generally speaking, an increase in terrain relief will correspondingly increase the difficulty and cost of digital infrastructure construction, which satisfies the correlation condition of the instrumental variable. Second, the degree of terrain relief is a natural geographic factor not directly related to other economic variables, which satisfies the condition of exogeneity as an instrumental variable. It is worth noting that the raw data of the instrumental variable of terrain relief are in cross-sectional form, which cannot be used for the econometric analysis of panel data. Therefore, this paper refers to Nunn and Qian's (2011) treatment of this issue and introduces a time-varying variable to construct the panel instrumental variable. Specifically, the number of Internet users in the country in the previous year is constructed as an interaction term with the degree of topographic relief of each city respectively, which serves as an instrumental variable for the city's digital economy index in that year.

Columns (5) and (6) of Table 3 show the regression results using terrain relief (Iv_land) as an instrumental variable. It can be seen that the first-stage estimation results of the model show that there is a significant negative correlation between urban topographic relief and the digital economy variables, and the coefficients of the digital economy variables in the second-stage estimation results are significantly negative at the 1% level, which is consistent with the baseline estimation results. In addition, for the test of the original hypothesis, "insufficient identification of instrumental variables", the p-value of LM statistic is 0.000, which significantly rejects the original hypothesis; in the test of the weak identification of instrumental variables, the Wald F-statistic is larger than the critical value of Stock-Yogo's weak identification test at the 10% level. Overall, the above tests prove the rationality of the instrumental variables selected in this paper, and thus, the role of digital economy in reducing carbon intensity is more robust.

Table3. Robustness analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	Substitution of variables		interaction fixed effect	Double Clustering Robust Criterion Error	IV_land	CAI
DIGE2	-0.021***	-0.013***				
	(0.004)	(0.003)				
DIGE			-0.081**	-0.125**		-0.627***
			(0.039)	(0.041)		(0.017)
IV_land					-0.883***	
					(0.023)	
pgdp		-0.073***	-0.012	-0.073**	0.049***	-0.020*
		(0.027)	(0.011)	(0.028)	(0.015)	(0.011)
pnd		-0.024***	-0.008**	-0.025***	-0.013***	-0.023***
		(0.006)	(0.004)	(0.007)	(0.004)	(0.003)
fdi		-1.513***	1.017**	-1.525**	-1.117**	-1.170***
		(0.562)	(0.417)	(0.630)	(0.516)	(0.344)
fin		0.033***	0.012***	0.033***	0.027***	0.035***
		(0.007)	(0.003)	(0.007)	(0.004)	(0.003)
urban		2.288***	0.801**	2.323***	1.533***	2.621***
		(0.449)	(0.335)	(0.470)	(0.173)	(0.123)
regulation		0.002	-0.198*	-0.005	-1.286***	-0.048
		(0.112)	(0.104)	(0.095)	(0.079)	(0.045)
_cons	1.366***	0.799	1.390***	1.070*		
	(0.194)	(0.567)	(0.503)	(0.567)		
Anderson LM						993.510***
Wald F						1533.072***
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
*Pro*Year FE*			Y			
N	3091	3091	3036	3091	3091	3091
adj. R^2	0.952	0.964	0.981	0.964	0.371	0.371

5. Conclusions and Implications

The development of the digital economy can improve the efficiency of energy use, promote the upgrading of industrial structure, and better promote the digitalization of industries, thereby reducing urban carbon intensity. This can bring environmental effects and reduce urban carbon intensity, while also promoting urban economic development and helping China's low-carbon and high-quality economic development. This paper mainly draws the following conclusions: based on the China Urban Statistical Yearbook and databases such as EPS. This paper utilizes the data of 281 prefecture-level cities in China from 2011 to 2021 and employs the models such as baseline regression, substitution variables, interaction fixed effects, double clustering robust standard errors and instrumental variables and other models to empirically test the impact of the level of digital economy development on carbon intensity and the mechanism of its effect in several Chinese cities, and come to the following conclusion: the increase in the level of digital economy development is conducive to reducing urban carbon intensity, and the conclusion still holds after a series of robustness tests.

In addition, this paper concludes that increasing the level of regional economic development will lead to a reduction in carbon intensity, contrary to existing research (Bingbing Zhang et al., 2022). The possible reason for this is that high-quality development of the regional economy will promote economic transformation towards green and low-carbon. At the same time, the improvement of technological level leads to the increase of energy utilization, thus reducing carbon emissions.

Based on the above research findings, this paper offers the following insights and recommendations:

Increase the development of the digital economy and improve the construction of infrastructure for the development of the digital economy, such as 5G networks, cloud services and artificial intelligence. First, focus on the research and development and application of green and low-carbon technologies, actively cultivate relevant talents, and strengthen the development of relevant digital technologies. Secondly, promote the integration of digital technologies with traditional industries, carry out the accurate transformation of traditional industries in the whole chain, in an all-round and all-angle manner, break path dependence and lock-in effect, improve production efficiency, and change the way of energy consumption through digital technologies; promote the cross-border integration and development of the digital economy and emerging industries, and jointly push forward the reduction of carbon emission intensity, and then push the transformation of the industry as a whole to intelligentization and low-carbonization.

Narrowing the differences in the development of the digital economy between regions and implementing differentiated governance strategies. First, based on the differences in the level of economic development, resources, industrial layout and the level of impact of the digital economy on carbon emissions in each city, adjust the pace of digital economic development in each region and promote the digital transformation of each city. Second, encourage the circulation of digital economy-related talents among regions, appropriately tilt digital resources to less developed regions such as central and western China, and enhance the synergy of digital economy governance in each city. Third, construct a layered digital governance system and build a digital governance platform to realize the synergistic development of carbon reduction.

Improve regulations related to the low-carbon development of the digital economy. First, formulate industry carbon emission standards, measure the carbon footprint of the industry and require information disclosure, so as to improve the initiative and enthusiasm of enterprises to reduce carbon and consumption. Second, strengthen the supervision of carbon emissions, through tax adjustment and other means to require enterprises to assume the responsibility of carbon emission reduction, to realize the overall low-carbon development of the industry. Thirdly, improve the mechanism for fair distribution of carbon allowances, and build a unified, three-dimensional, and coordinated development management system to promote the synergistic development of carbon equity and carbon emission reduction. Fourth, based on the strategy of "quantitative decision-making of soft elements," they actively implement the practice of urban ESG governance, improve the three-dimensional competitiveness of the city. They enhance the attractiveness of the city to talents, capitals, and enterprises. They can also reduce the carbon intensity of the city in multiple dimensions while providing the city with the opportunities of policy support, the opening of the capital market, and technological advancement. This will provide cities with opportunities for policy support, capital market opening, and technological progress.

Conform to the form of international economic and political development, rely on relevant national policies and seize the opportunities of the era of digital economic development. First, in the new period, China proposes to accelerate the construction of a strong network country and a strong digital country. Therefore, the construction of digital infrastructure should be strengthened, industrial efficiency and public service level should be improved through advanced technology, and the carbon intensity of the city should be reduced while building a smart city and improving the level of economic development, thus helping the realization of the dual-carbon goal. Second, relying on the "One Belt, One Road" initiative and the Silk Road, connecting China with neighboring countries and European countries, and learning from the relevant advanced development experience of other countries. Seize the dividends of the rapid development of the digital economy, actively learn advanced technologies and environmentally friendly production methods, further enhance the level and quality of opening up to the outside world, and through comprehensive and effective inter-regional cooperation and reciprocal assistance, release the dividend effect of the development of the digital economy, promote the coordinated development of the digital economy in various cities, and lay a good foundation for the realization of China's comprehensive and sustainable development.

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