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The Impact of Financial System on Carbon Intensity: From the Perspective of Digitalization

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Abstract: Financial system reforms are important for developing regions in the period of structural transformation. In the face of climate change, which is an important issue for all mankind. This paper empirically explores the impact of financial structure on carbon intensity based on China's provincial level data from 2005 to 2019, and discusses the intermediary effect of digitalization. The results show that: (1) Market leading financial system can significantly reduce the carbon intensity, which is more prominent in Northeast China. (2) The improvement of the digital level has accelerated the development of financial marketization and helped to reduce the carbon intensity. (3) The construction of digital talents and digital infrastructure have partial intermediary effects between market leading financial system and carbon intensity. However, there is no intermediary effect in the construction of digital ecological environment. This paper provides empirical research on the environmental effects of market leading financial system, which is helpful to the construction of green finance and digital financial system, and contributes to the market transformation of the financial system in China.

Keywords: financial system; carbon intensity; digitalization; sustainable development

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1. Introduction

The main reason for global warming is that in the past century, human beings have used a large amount of fossil fuels (such as coal, oil, etc.) in economic production, emitted a large amount of CO_2 (Carbon dioxide emissions) and other greenhouse gases [1]. Since these greenhouse gases are permeable to visible light from solar radiation, and absorb long-wave radiation reflected from the earth, global warming is caused. It will lead to the melting of glaciers, permafrost, and the rise of sea levels, which not only endangers the balance of natural ecosystems, but also threatens human food supply and living environment [2]. According to the International Energy Agency, China's overall carbon dioxide emissions have nearly doubled from 5.407 billion tons in 2005, to 13.9 billion tons in 2020. In 2021, China's carbon emissions account for 31% of the world's total emissions [3]. Based on this, in 2020, the Chinese government has pledged to achieve carbon peaking by 2030 and carbon neutrality by 2060 [4]. In 2022, the 27th United Nations Climate Conference (COP27) agreed to establish a fund mechanism to compensate for losses and damages caused by climate change. However, how to improve the fiscal, taxation, price, finance and other policy mechanisms to achieve carbon peaking and neutrality goals, and to complete the strategic task of low-carbon transformation is the main topic of this paper.

The financial system plays an important role in the country's economic growth. Its basic function is to establish a connection between the capital surplus and the demander, improve the efficiency of capital use, and build a matching mechanism for investors and capital users [5]. With the acceleration of industrialization and urbanization in developing countries, the energy consumption and carbon emissions continue to increase, and the contradiction between environmental pollution and financial development has become increasingly prominent [6]. Most studies believe that the financial system will help the development of industrial economy, promote enterprises to expand production scale,

and instead cause resource consumption and energy pollution [7]. However, with the improvement of economic development and the optimization of financial structure, it may promote the flow of funds to clean industries and mitigate environmental pollution [8]. Therefore, for developing China, the impact of its financial structure on carbon emissions still needs to be further explored.

The existing literature divides the financial structure into two categories: one is the bank-dominated financial structure, typically represented by Japan and Germany [9]. It means that the total assets of the banking industry far exceed that of other financial institutions including insurance and pensions, and the changes of banking industry also dominates the bond and stock market [10]. The other is the market-oriented financial structure, typically represented by the United States and the United Kingdom [11]. Since the proportional relationship between banks and the financial market directly affects the types of financial services of micro-enterprises, as well as the availability and services of financial [12]. Therefore, changes in the financial structure directly affect the stability of the financial system. From the perspective of dynamic structural changes, in different stages of economic development, enterprises in different industries have different financing needs and environmental characteristics, so the impact of financial development on environmental pollution will also have structural differences [13]. For example, the problem of China's banking structure dominated by large banks, and it's difficult to get financing for small and medium-sized enterprises. This is a typical structural mismatch [14]. Then, with the improvement of China's industrialization, can the market-led financial system be able to reduce carbon emissions? There is considerable heterogeneity in the resource endowment, economic development, and the level of scientific and technological innovation in different regions of China. Is the impact of financial structure on carbon emissions different in different regions?

Under the influence of the carbon peaking and carbon neutrality goals, energy conservation, carbon reduction and emission reduction with the theme of industrial Internet and digital transformation have received widespread attention [15]. In 2020, the Exponential Climate Action Roadmap released by the Global Climate Action Summit proposes that the adoption of digital technologies in energy, manufacturing, agriculture and land use, buildings, services, transport and traffic management, will help reduce up to 15% of global carbon emissions [16]. At present, the digital economy has risen to China's national development strategy, and the scale of data in areas such as government affairs, finance, and industry has maintained rapid growth. According to data released by China's Ministry of Industry and Information Technology, in 2020, China's digital economy accounted for 38.6% of the Gross Domestic Product (GDP), ranking second in the world. It is estimated that by 2025, the digital economy will account for more than 50% of China's GDP [17]. As a new factor of production, data is the basis for digitization, networking, and intelligence. It has been rapidly integrated into all aspects of production, distribution, circulation, consumption, and social service management, profoundly changing production methods, lifestyles, and social governance methods [18]. Therefore, will increased digitization help market-led finance reduce carbon emissions? What is its impact mechanism?

In order to answer the above questions, this paper uses entropy method to determine the measurement of financial structure and digitalization level, constructs the provincial panel data of China from 2005 to 2019, and empirically explores the impact of financial structure on carbon emissions. Secondly, it discusses the mediating effect of digitalization between financial structure and carbon intensity, and examines the mediating mechanism of digital infrastructure, digital ecological environment construction and digital talents. This paper focuses on the relationship between the financial structure and carbon emission, as well as the mediating effect of digitalization. The research results prove that the optimization of financial structure will help more capital flow to the green industry, reduce the financing dependence on the high-carbon project, and promote low-carbon, green and sustainable economic development. The marginal contribution mainly focuses on the following three points: (1) previous literature studied the impact of financial development on

carbon emissions from a static perspective. This paper analyzes the impact of the changing financial structure on carbon emissions, from a dynamic perspective, which is closer to the reality of the changing financial structure in developing countries. (2) Compared with the previous literature, which only measured the financial structure and the degree of digitalization from a single indicator, this paper constructs the indicator systems from multiple aspects, so as to more comprehensively measure the core explanatory variables. (3) Most of the previous literatures studied the impact of digital finance on carbon emissions, which is relatively macro. This paper discusses the intermediary effect of digitalization from the three dimensions of digital talent, digital infrastructure and digital environment construction, researches the impact of digitalization on carbon emissions from a more detailed perspective, and help to put forward more targeted recommendations for the development of digital enabling finance and carbon emission reduction.

2. Literature Review

2.1. Financial Development and Environmental Pollution

The current mainstream literature has accumulated a lot of research on the impact of financial development on environmental pollution, which can be roughly divided into three viewpoints: first, financial development helps to provide enterprises with funds support such as pollution treatment, environmental protection technology R&D, and helps to improve environmental quality [19]. Sharif et al. (2022) empirically tested the panel data of G7 countries from 1995 to 2019 and found that green financing plays a significant role in reducing carbon emissions [20]. Green technology innovation is the core factor affecting carbon emission [21], by providing low-cost financing, green finance guides market players to increase investment in green research and development funds. After technological innovation and upgrading, resource utilization efficiency can be improved and unit carbon emissions can be ultimately reduced [22]. Second, financial development provides financing channels for enterprises to expand production scale and improve production efficiency, accelerate the rapid growth of high-pollution and high-emission enterprises, and exacerbate environmental degradation [23]. Third, the impact of financial development on the environment shows heterogeneity in different stages of economic development [24,25]. Among them, part of the research focuses on incorporating environmental factors into the financial system, and studying green financial issues [26]. For example, Dogan et al. (2016) argued that the impact of financial developments on carbon emissions is not linear but an inverted U-shaped relationship [27].

2.2. Financial Structure and Environmental Pollution

Another part of the study mainly considers the impact of financial system structure on environmental pollution. Since green finance is also a new dimension of the financial structure that emerges from the financial system with the stage of economic development, its ultimate purpose is to solve environmental problems [28]. Therefore, this paper will focus on the impact of financial structure on environmental pollution. In view of the important role of technological innovation in environmental governance, the influence of different financial structures on technology financing has been studied. The market leading financial system cannot handle the non-dispersive risks, while the bank reserves of the bank leading financial system can act as a buffer against macroeconomic shocks and better guarantee the inter-period risk sharing [29]. On the other hand, bank leading financial systems are often not very good at financing new technologies, and markets are better suited to deal with the financing of new technologies by divided investors [30]. The market leading financial system cannot handle the non-dispersive risks, while the bank reserves of the bank leading financial system can act as a buffer against macroeconomic shocks and better guarantee the inter-period risk sharing. On the other hand, bank leading financial systems are often not very good at financing new technologies, and markets are better suited to deal with the financing of new technologies by divided investors [31]. In addition, generally speaking, the market-oriented financial structure can promote a higher

level of FDI flows and further exert the technological spillover of FDI [32]. On the whole, a developed financial system can reduce financing costs and promote FDI, thus dispersing innovation risks, promoting technological innovation and reducing carbon emissions in energy production and consumption sectors. Furthermore, a developed financial system is more conducive to the construction of carbon markets, promoting carbon trading and reducing carbon emissions [33].

2.3. Summary

It can be found that existing research has not reached a unified conclusion on the impact of financial development on environmental pollution. In different stages of economic development, industrial development has different needs for financing, so there will be different financial arrangements; that is, different financial structures. Nowadays, human society has ushered in the digital era, and digital technology and the digital industry have become the new driving forces for future social and economic growth. In this context, it is meaningful to study the carbon intensity of financial system from the perspective of digitalization.

3. Theoretical Analysis and Hypotheses

At present, the financial system of many developing countries is dominated by the banking system [34]. In the process of financial development, the financial structure directly determines the financial services and products required by the economy. This can have a direct impact on consumer welfare effects through economic growth and income distribution: on the one hand, the bank-led financial system has the advantages of integrating funds, risk management, resource allocation, etc., which helps to promote green economic growth and reduce carbon emission levels. For example, Tamazian et al. (2009) [35] took the panel data of BRICS countries from 1992 to 2004 as a sample, and characterized financial development from the dimensions of capital market and financial openness. The empirical study found that the improvement of financial development level can reduce carbon emissions and improve environmental governance. However, a bank-led financial system will always lead to a low proportion of direct financing, a high concentration of the banking market, and a prominent financial structure imbalance [36]. When financing channels and capital allocation can no longer meet the needs of corporate financing, technological innovation and industrial structure, such financial arrangements will increase carbon emissions. For example, Zhang et al. (2011) [37] argue that bank loans provide solid support for Chinese companies to obtain external financing and expand investment, which promotes economic growth and carbon emissions.

On the other hand, the market-oriented financial system has advantages in solving information asymmetry, risk management, technological innovation, etc. [38], so it is possible to reduce carbon emissions and improve residents' welfare. For example, Tamazian and Rao (2010) [39] found that market-led financial development can provide more financial services for some environmentally friendly projects and promote lower-cost investment in environmental projects. However, from the perspective of dynamic changes in industrial structure, at different stages of economic development, due to different factor endowment structures and corresponding optimal industrial technology structures, and enterprises in different industries have different financing needs and environmental characteristics. Then, there will also be structural differences in the impact of financial development on environmental pollution [40]. At a relatively low level of financial development, the scale of capital required for industrial development is small, and a bank-led financial system is conducive to improving residents' welfare. At a relatively high level of financial development, a market-led financial system can help reduce the negative externalities of economic and reduce carbon emissions [41]. At this stage, most developing countries are in a period of economic transformation: the upgrading of industrial structure is accelerating, and the financing needs of regions and industries are stronger, so direct financing is needed as a strong supplement [42]. Especially in developing countries, the contradiction between

environmental pollution and economic growth is prominent. The control of environmental pollution also requires market-oriented financial power to guide more green credit and green investment from high-polluting industries to environment-friendly industries, and guide green technology innovation and industrial structure changes. For example, Tamazian et al. (2009) [35] argue that financial development promotes technological innovation of enterprises by reducing financing costs and diversifying risks, thereby enabling the energy production sector to reduce carbon emissions. Therefore, China in the process of economic transformation and development, the market-led financial system improves consumer welfare by promoting economic growth and increasing residents' income, and the increase in the proportion of direct financing is more conducive to improving residents' welfare and reducing the carbon intensity. In summary, this paper proposes the first hypothesis:

Hypothesis 1. *Market-led financial systems help curb carbon intensity.*

With the process of the fourth scientific and technological revolution, human production methods have changed, which is embodied in the application of automation in industrial production and the deep integration of the digital economy with the real economy. The further development of digital science and technology industrialization will guide the combination of digital science and technology with traditional industries, and enable traditional businesses and enterprises through "Internet" and "artificial intelligence" [43]. On the one hand, with the development of market-oriented finance, the development of the digital industry will receive more financial support, which will also continuously promote the digital transformation of the financial industry, broaden financing channels and improve financing efficiency [44]. On the other hand, the application of digital technology can effectively improve production efficiency and reduce energy consumption and carbon emissions in the production and operation stages of basic equipment. In addition, digital technology can drive the industrial structure optimization and intelligent development of different industries, and reduce the consumption of materials and energy through the transformation of the upstream and downstream of the industrial chain [45].

Hypothesis 2. *The market-oriented financial system can reduce the carbon intensity through the improvement of the digital.*

The market-led financial system will have a significant positive impact on the development of the digital economy. This is mainly because the development of the digital economy will reduce carbon emissions in economic production activities through high-quality human capital [46]. A market-oriented financial system can enrich and improve the supply of financial products and services in the financial market, broaden the sources of household consumption funds and improve the availability of household credit funds [47]. For families, the market-led financial structure can easily obtain credit support, which helps to strengthen human capital investment such as basic education, improve the ability of the labor force to acquire skills, knowledge, innovative learning and professional quality, thereby improving the labor force. group level. For high-quality labor, with the increase of income level, low-level labor groups may be forced to increase their willingness to invest in education, and gradually approach the level of education investment of high-level labor, forming the leading role of high-level labor groups to low-level labor groups [48]. On the other hand, higher-quality labor also has higher creativity, which can save the production cost of enterprises through the spillover effect of digital technology, improve production efficiency, and reduce energy consumption and carbon emissions in the production process of high-polluting industries [49].

In addition, this paper argues that a market-led financial system can also help to promote corporate and government investment in digital infrastructure, because the financial system can promote the continuous upgrading of the industrial structure [50]. Different industrial structures determine different levels of productivity: factors of production will

shift from low-productivity industries to high-productivity industries, thereby promoting economic growth. Since the factor endowment structure of an economy directly determines the industrial structure, when the factor endowment structure is improved, the industrial structure will also be upgraded. In the primary stage of economic development, developing countries often show that mature labor-intensive industries occupy the main position in the industrial structure [51]. At this time, the scale of financing required for economic development is small, and the bank-led financial structure can effectively play the role of intermediary in banking services and promote faster economic growth. With the continuous improvement of the level of economic development, the scale of financing required for the development of the economy is relatively large, and the risks faced by the upgrading of the industrial structure increase [52]. The development of a market-led financial structure can effectively share risks and support enterprise technology R&D and product innovation in a long-term and sustained manner, thereby increasing enterprise productivity. Therefore, the market-oriented financial system is conducive to promoting the upgrading of the industrial structure. In turn, companies and governments have more funds to invest in digital infrastructure. Above, this paper proposes the third hypothesis:

Hypothesis 3. *Market-driven financial system can reduce the carbon intensity through investment in digital infrastructure and the cultivation of digital talents.*

4. Model Construction and Data Selection

4.1. Model Construction

Benchmark Regression

The benchmark regression mainly uses the fixed effect model of panel data to capture the correlation between variables. Most economics and management literature use fixed effect model to research, which is the most commonly used regression method in panel data. The advantages of this method are: (1) it can remove the differences between individuals, solve the problem of missing variables and improve the accuracy of regression results, (2) because panel data has both cross section and time dimensions, it can provide more individual dynamic behavior information and solve problems that cannot be solved by single section data or time series data. However, the main disadvantage of this method is impossible to estimate the variable coefficients that do not change with time. In the empirical research, this paper has also done a lot of robustness tests to test the empirical regression results.

Therefore, construct the benchmark regression equation to test the impact of financial marketization on carbon emission intensity:

$$Y_{it} = \beta_1 X_{it} + \beta Control_{it} + t + \mu_i + \varepsilon_{it} \quad (1)$$

Among them, Y represents the explained variable, which refers to carbon intensity; X represents the explanatory variable, which refers to the marketization degree of the financial system, t represents the time fixed effect, μ represents the individual fixed effect, ε represents the random interference term, β is the estimated coefficient and *control* is the control variables.

Secondly, based on the mediation effect model proposed by Hayes (2009) [53], this paper verifies the transmission mechanism of the digital economy between the degree of financial marketization and carbon emissions. The equations are as follows:

$$\sum_{j=0}^{3} Z_{it}^{j} = \beta_1 X_{it} + \beta Control_{it} + t + \mu_i + \varepsilon_{it} \quad (2)$$

$$Y_{it} = \beta_1 X_{it} + \beta_2 \sum_{j=0}^{3} Z_{it}^{j} + \beta Control_{it} + t + \mu_i + \varepsilon_{it} \quad (3)$$

Among them, Z is the mediating variable, and Z_1, Z_2 and Z_3 represent the three dimensions of digitization level. The basis for judging whether there is a mediation effect is: the coefficient β_1 in Formula (2) is significant, the coefficient β_2 in Formula (3) is significant,

and the coefficient β_1 in Formula (3) The degree of significance decreases or the value of the coefficient decreases, then it proves that Z is a mediator variable.

4.2. Variable Selection

4.2.1. Explained Variables (Carbon Intensity, Cabi)

China's existing statistics and data cannot directly query the relevant data on the total carbon emissions of different regions and industrial sectors. Currently, the internationally accepted calculation is the reference method in the Greenhouse Gas Emissions Inventory Guidelines developed by the IPCC [54] (International Panel on Climate Change) in 2006. The basic steps are to estimate the energy consumption, unify the energy units, multiply the carbon content coefficient to calculate the total carbon amount, deduct the carbon amount used as raw material and non-energy use, and finally correct it with the oxidation coefficient and convert it into carbon emissions.

According to the accounting method, the energy consumption is calculated by investigating the regional energy balance sheet, and then the carbon dioxide emissions generated by the energy consumption in each region are calculated, and then divided by the urban gross national product GDP, the regional carbon intensity can be obtained:

$$E_{CO2} = \frac{\sum_i A_i * C_i}{GDP} \quad (4)$$

Among them, A_i is the consumption of the ith energy (unit: ton) and c_i is the carbon dioxide emission coefficient of this energy (unit: kg-CO_2/kg).

$$A_i = F_i + H_i + N_i \quad (5)$$

Among them, F_i is the terminal consumption of the i_{th} energy in the region, T_i is the consumption of the i_{th} energy in the region for power generation, H_i is the consumption of the i_{th} energy in the region for heating and N_i is the consumption of the i_{th} energy in the region for power generation. The consumption of industrial raw materials refers to the use of fuels as non-energy sources, such as chemical raw materials, industrial or building materials, and activities where carbon eventually enters the product and does not emit or immediately emit. In order to avoid the influence of dimensional differences, this paper takes the logarithm of carbon emissions.

4.2.2. Explanatory Variable (Degree of Marketization of the Financial System, Finm)

The degree of marketization of the financial system reflects the vitality, scale and efficiency cost of the stock market relative to banks and other financial institutions, and represents the vitality, scale and efficiency of the financial market. Therefore, this paper refers to the practice of Levine (2002) [55], and measures the following indicators: financial marketization vitality, financial marketization scale and financial marketization efficiency, respectively. The above three indicators are respectively expressed by the ratio of total stock market transactions to credit balance of financial institutions, the ratio of credit balance of financial institutions to market capitalization, and the ratio of total stock market transactions to GDP multiplied by the ratio of net profits to total assets of financial institutions.

This paper calculates the three indicators according to the principal component analysis method to obtain the value of the marketization degree in the financial system, and uses Acrgis12.0 to display the schematic diagram of the marketization degree of the financial system, as shown in Figure 1. The left picture is in 2005, and the right picture is 2019. From a vertical perspective, it can be found that the degree of financial marketization in various regions of the country has continued to increase over time. On the one hand, this stems from China's continuous reforms and opening up and the system of learning from Western countries; On the other hand, the development and prosperity of small and medium-sized enterprises have promoted the market-oriented reforms of the financial system. From a horizontal perspective, it can be found that the center of gravity of the

degree of financial marketization has shifted eastward and northward, and the level in the central region has been kept at a relatively low level. Since (1) there are a large number of heavy industry-based businesses in the central region, this may hinder the financial marketization reform. (2) With the continuous advancement of Western development, the state has assisted the construction of many infrastructures in the Western region, which is beneficial to the development of large enterprises and state-owned enterprises but not conducive to the financial market change.

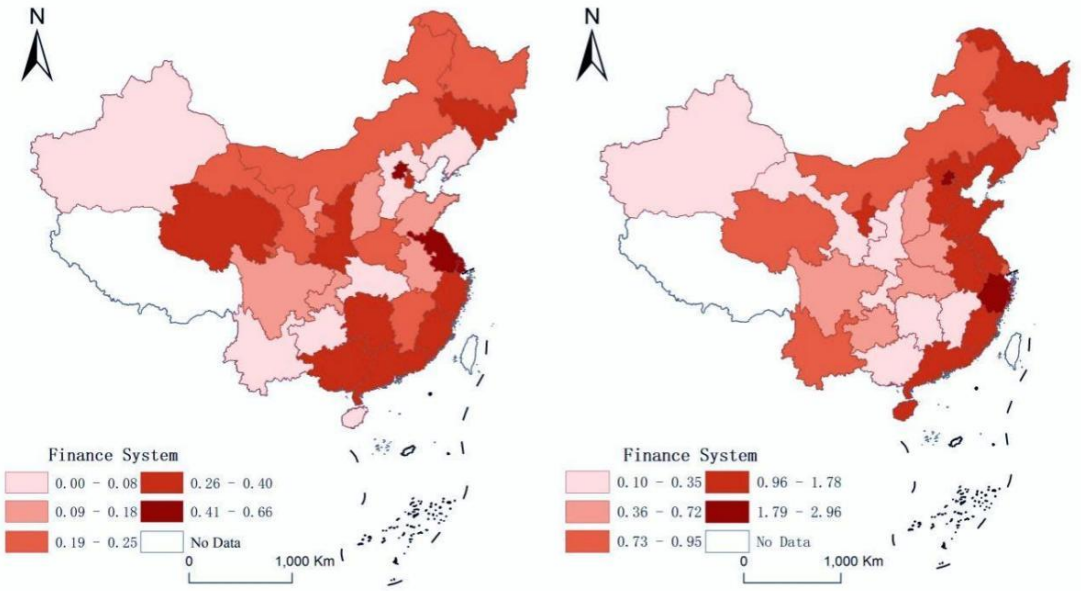

Figure 1. Schematic diagram of China's market leading financial system (2005 and 2009).

4.2.3. Mediating Variable (Digitization, Digt):

Considering the availability of data and the actual situation of China's social and economic development, this paper takes the Internet development as the core of measurement, and constructs an evaluation index system for China's digital economy from the perspectives of digital economy infrastructure, digital ecology and digital talents [56,57]. The index system is shown in Table 1.

This paper calculates the indicators according to the principal component analysis method to obtain the development level of China's digital economy and uses Acrgis 12.0 to display a schematic diagram of the degree of marketization of the financial system, as shown in Figure 2. The left picture is 2005, and the right picture is 2019. It can be found that during the period from 2005 to 2019, the development level of China's digital economy has improved significantly, and its average value has increased from 0.34 to 1.31; eastern China, with its unique economic development advantages, is the most dynamic region in China's digital economy, especially Zhejiang Province. In addition, Shanghai, Jiangsu Province, Guangdong Province, Fujian Province and Beijing also rank among the top in the country in terms of digitalization.

Table 1. The indicator system for the development level of digital economy.

First-Level Indicator	Secondary Indicators	Three-Level Indicator	Calculation Method
Digital economy development level	Digital economy infrastructure	Internet penetration Mobile phone penetration	Netizens per 100 people Number of mobile phones per 100 people
		Internet port access	Internet ports per hundred people
		Internet cable access density	Long-distance cable length/regional area
	Digital ecology	Investment level	Fixed investment/fixed asset investment in information transmission, software and information technology services
		Software business level	Software business revenue
		Telecom business level	Telecom business revenue
	Digital talent	Proportion of employment of information service practitioners	Information transmission, computer services and software workers per 1000 employed persons
		Digital Higher Education Talent	Number of college students majoring in "computer", "Internet" or "software"
		Level of digital innovation	Number of invention patents granted related to "computer", "Internet" or "software"

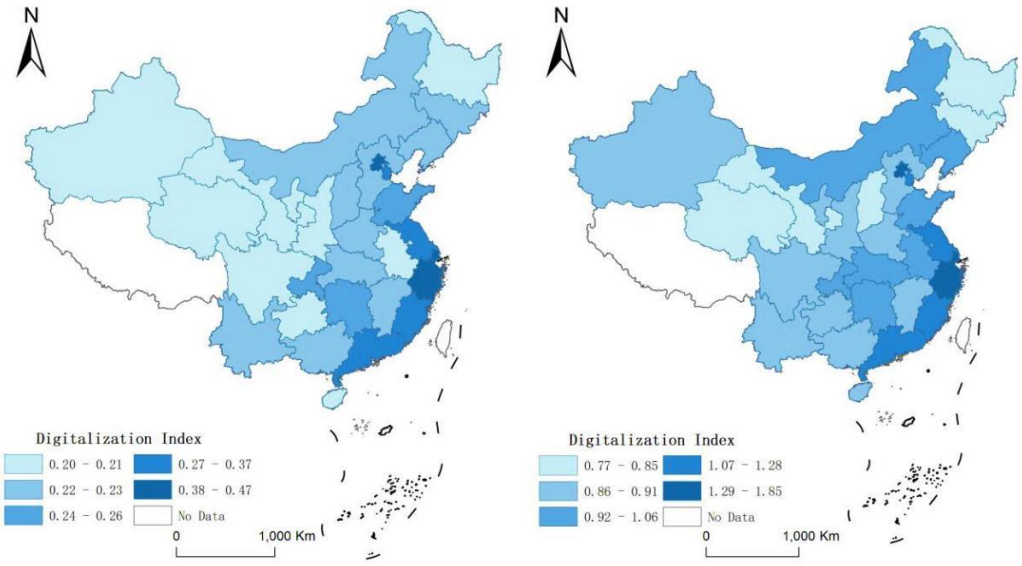

Figure 2. Schematic diagram of China's digital economy development level (2005 and 2009).

4.2.4. Control Variable

In order to control the impact of other variables on carbon intensity, this paper selects control variables from four dimensions: economic development, industrial structure, opening up and technological innovation: (1) economic development, the faster economic development, the more energy consumption will be brought, which will lead to the increase of carbon emission intensity [58]. Therefore, this paper uses the logarithm of GDP and GDP per capita as control variables. (2) In terms of industrial structure, regions with a high

proportion of the secondary industry may have more carbon emissions, so this paper selects the proportion of the secondary industry and the tertiary industry in GDP as the control variable [59]. (3) In order to introduce foreign capital and expand the pace of opening up, the region may pay more attention to energy and environmental issues. In addition, the higher the degree of opening up, the more likely it will lead to the introduction of clean technology, which may have a negative impact on carbon emissions. Therefore, this paper selects the proportion of foreign capital in GDP as the control variable [60]. (4) Technological innovation: cities with a higher level of scientific and technological innovation will show more green technological innovation at the same time, thus contributing to energy conservation and emission reduction. Therefore, this paper selects the logarithm of the number of patent applications and innovation efficiency [61] as the control variables.

4.3. Data Sources

The original data of variables calculation, selection and description are shown in Table 2.

Table 2. Data selection and description.

Variable Type	Index	Sign	Source
Explanatory variable	Carbon intensity	Cabi	Calculated by Equations (4) and (5)
Core explanatory variable	Degree of marketization of the financial system	Finm	Financial marketization vitality, financial marketization scale and financial marketization efficiency
Control variable	Total GDP	Gdp	China Statistical Yearbook (2006–2020) China Environmental Statistics Yearbook (2006–2020) China Industrial Statistics Yearbook (2006–2020)
	GDP per capita	Gpp	
	The secondary industry in GDP	Ssr	
	The tertiary industry in GDP	Tsr	
	Foreign capital in GDP	Fdi	
	Patent applications	Pat	
	Innovation efficiency	Ine	
Mediating variable	Digital economy infrastructure	Digt1	
	Digital ecology	Digt2	
	Digital talent	Digt3	

5. Empirical Results and Analysis

5.1. Benchmark Regression Results

Before conducting the empirical analysis, this paper conducts a normality test to ensure that the residuals conform to a normal distribution. The normality is to test whether the basic assumption that the residuals follow a normal distribution with zero mean is true. After testing, the assumption that the residuals do not obey the normal distribution is rejected, and the OLS model can be used for regression analysis. The residual distribution of the benchmark regression is shown as the Figure 3.

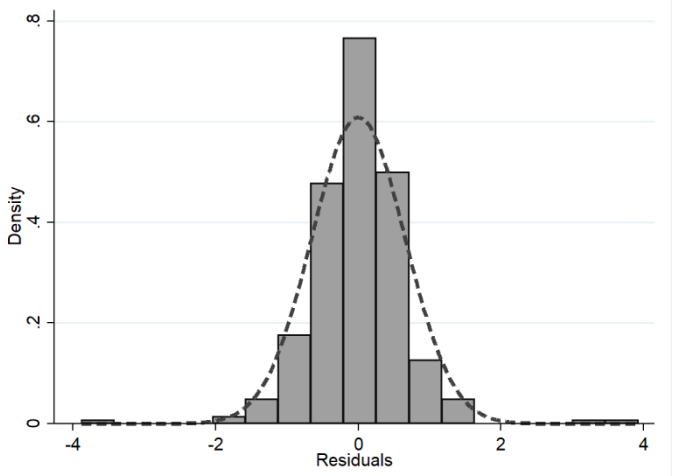

Figure 3. Residual distribution diagram.

The regression results of the benchmark model of the impact of financial structure on carbon emissions are shown in Table 3. Column (1) is the regression result of the OLS model before adding control variables. It can be found that for each unit increase in the degree of financial marketization, the carbon intensity will decrease by 1.378 units. This empirical result shows that China's financial system has implemented gradual reforms, gradually developing from a bank-led one to a securities market, which has roughly adapted to the needs of the real economy and has also achieved sustained and rapid economic development. As a typical representative of developing countries, China's experience can be widely used for reference. With the improvement of the level of economic development, green environmental protection has become the theme of sustainable social development. A higher level of financial marketization helps guide the flow of funds to environment-friendly industries, thereby reducing the share of high pollution emission industries in economic development, and also has a positive effect on carbon emission reduction. Column (2) is the regression result using a two-way fixed effect model and adding control variables. The two-way fixed effect means that the time and space dummy variables are controlled, which can alleviate the deviation of the regression results caused by missing variables to a certain extent. Column (3) is the regression result of replacing the T-test with the D-K standard error in order to eliminate the influence of heteroscedasticity and cross-sectional correlation on the regression result. It can be found that the impact of financial marketization on carbon intensity does not change significantly at this time. Column (4) is the regression results of the system GMM model, using the explanatory variables with a two-period lag and a three-period lag as the instrumental variables. The core of the model is to use the difference equation and the horizontal equation as an equation system, so that the difference variable and the horizontal variable are mutually related. Instrumental variables are systematically estimated to make parameter estimation more efficient. It can be found that the regression results are still robust. Column (5) is the de-extremum value. We remove the samples with the highest 5% and the lowest 5% of carbon intensity and then perform the regression again, which can eliminate the adverse effect of outliers on the results, and the regression results are still robust.

Table 3. Benchmark regression results.

	(1) OLS	(2) FE	(3) D-K	(4) GMM	(5) Drop Extreme	(6) 2SLS
Finm	−1.378 ***	−1.345 ***	−1.345 ***	−2.742 ***	−1.355 ***	−1.463 ***
	(−5.21)	(−4.44)	(−4.44)	(−5.43)	(−2.91)	(−3.46)
Gdp		0.243 ***	0.243 ***	0.351	0.457 ***	0.336
		(4.25)	(4.25)	(1.38)	(3.53)	(1.42)
Gpp		0.452 ***	0.452 ***	0.049 ***	0.234 ***	0.202 ***
		(4.34)	(4.34)	(3.04)	(3.45)	(3.96)
Ssr		2.532 ***	2.532 ***	0.344	2.630 ***	2.575
		(5.10)	(5.10)	(0.84)	(4.75)	(0.34)
Tsr		2.597 ***	2.597 ***	0.392 ***	1.842 ***	5.024 ***
		(7.71)	(7.71)	(5.37)	(6.43)	(7.58)
Fdi		−0.713	−0.713	−0.163 **	−0.574	−0.098 **
		(−1.23)	(−1.23)	(−2.11)	(−0.02)	(−2.74)
Pat		−0.420	−0.420	−0.484	−0.034	−0.042
		(0.65)	(0.65)	(−0.34)	(−0.44)	(−0.46)
Ine		−0.257 ***	−0.257 ***	−0.344 ***	−0.456 ***	−0.042 ***
		(−3.75)	(−3.75)	(−4.32)	(−5.67)	(−3.98)
Time-FE & Individual-FE	Control	Control	Control	Control	Control	Control
Cons	6.265 ***	4.138 ***	4.138 ***	4.432 ***	5.833 ***	6.410 ***
	(5.04)	(4.06)	(4.06)	(5.92)	(4.43)	(4.92)
R2	0.3045	0.7171	0.7171	0.7046	0.5675	0.6829
Obs	420	420	420	330	378	420
AR(1)						0.0671
AR(2)						0.7619

Note: *t*-values are in parentheses, and *** and ** indicate significance at the 1%, 5% and 10% levels, respectively.

There may be a two-way endogenous problem between the level of financial marketization and carbon emissions, because the carbon intensity of a region is closely related to the level of local economic development. This is because regions with more developed economies tend to have higher levels of green development and consumption. On the one hand, in the more developed regions of China, the demand for financing is stronger, so direct financing is needed to supplement the lack of indirect financing. It can be seen that the proportion of direct financing in economically developed regions is relatively high, and at the same time, it is accompanied by high carbon emission intensity. Therefore, there may be an endogeneity problem with bidirectional causality in the benchmark regression results. In order to eliminate the influence of this endogeneity on the regression results, we adopt the method of two-stage least squares regression of instrumental variables, and use the policy variable of financial liberalization to construct the instrumental variables of the financial structure. In addition, in empirical research, scholars have widely used the marketization of real interest rates as a instrumental variable of financial liberalization. This paper refers to the methods of Bekaert et al. (2005) [62] and Gamra (2009) [63], and sets the dummy variable of financial liberalization accordingly: it takes a value of 0 before financial liberalization, and a value of 1 after that, and finally obtains the instrumental variable of financial structure. In order to verify the rationality of the instrumental variables, we used the AR test. It can be found that the *p* value of AR1 is less than 10%, and the AR2 is greater than 10%, which passed the rationality test of the instrumental variables. The sixth column

is the result of using the two-stage least squares regression. It can be found that after using the instrumental variable regression, the benchmark regression results are still robust.

For the control variables, we can find that: (1) The increase of GDP per capita will significantly increase the carbon intensity, which means that China's economy is still dominated by high carbon and environmental-unfriendly, and economic development will have a significant adverse impact on carbon emissions. (2) The increase in the proportion of the tertiary industry will also increase the carbon intensity, which is not consistent with common sense. From the analysis of characteristic facts, for China, the tertiary industry has gradually become the main "contributor" of carbon emissions. According to Ke et al. (2022) [64], from 2011 to 2018, the growth rate of carbon emissions in the primary industry was 14.41%, that in the secondary industry was 12.58%, and that in the tertiary industry was 50.43%. The carbon emissions of residents' lives increased by 52.68%, and that of transportation, warehousing and postal services increased by 46.89%. (3)The improvement of innovation efficiency can significantly reduce the carbon intensity, which is similar to the research results of Ma et al. (2021) [65] and Qin et al. (2021) [66]. The main reason is that the improvement of technology level also improves the level of green technology innovation, which helps to adjust the energy structure, improve labor productivity and reduce carbon emissions.

5.2. Regional Heterogeneity Analysis

Since the 21st century, following the opening up of the eastern coast, China has successively formed regional development strategies such as Western Development, revitalization of the old industrial bases in Northeast China, and the rise of the central China. The four regional plates are designed on the basis of China's physical geography and economic geography, based on the traditional east, central, west and northeast plates, in order to narrow the gap between regions. Therefore, it is of broad theoretical and practical significance to analyze the relationship between the degree of financial marketization and carbon intensity in these four sectors.

The subregional regression results of the impact of financial marketization on carbon intensity are shown in Table 4. It can be found that the degree of financial marketization can reduce the carbon emission intensity in all four regions of China. From the regression coefficient, the degree of financial marketization in Eastern, Central and Western China has a similar impact on carbon intensity, which is far less than that in northeast China. This may be related to the large carbon emission values in Northeast China. Northeast region is the cradle of China's industry and an important industrial base. After the founding of the People's Republic of China, the state has concentrated its lager investment of strategic industries and key enterprises focusing on equipment manufacturing, energy and raw materials in Northeast China, which has made important contributions to the formation of a complete, independent and integrated industrial system. However, this has led to a lot of environmental pollution and carbon emissions. Therefore, the Northeast of China is in urgent need of industrial transformation and upgrading. For the control variables, the results are similar to those of the benchmark regression, which will not be repeated here.

5.3. Intermediary Effect Test

5.3.1. The Intermediary Effect Test of the Development Level of Digital Economy

Table 5 shows the regression results of the intermediary effect test of the development level of the digital economy. In order to verify the significance of the intermediary effect, this paper uses the Sobel test method.

Table 4. Subregional regression results.

	(1) Eastern Region	(2) Central Region	(3) Western Region	(4) Northeast Region
Finm	−1.343 ***	−1.327 **	−1.269 ***	−2.231 ***
	(−3.40)	(−2.23)	(−5.26)	(−3.21)
Gdp	0.044 ***	0.761 ***	0.216 **	0.121
	(3.46)	(3.35)	(2.30)	(0.43)
Gpp	0.453	0.518 **	0.624	0.064
	(1.43)	(2.25)	(1.25)	(1.33)
Ssr	0.467 ***	2.954 ***	1.378 ***	3.043 ***
	(3.27)	(3.27)	(4.26)	(4.54)
Tsr	4.572 ***	0.376 ***	1.462 ***	3.276 ***
	(4.53)	(5.37)	(8.61)	(5.21)
Fdi	−0.182 *	−0.236	−0.207	−0.267 *
	(−1.88)	(−0.21)	(−0.52)	(−1.76)
Pat	−0.126	−0.105	−0.251	−0.126
	(−0.54)	(−0.01)	(−0.21)	−0.270
Ine	−0.171 ***	−0.271	−0.112 ***	−0.030
	(−4.25)	(−1.26)	(−3.02)	(−1.29)
Time-FE & Individual-FE	Control	Control	Control	Control
Cons	4.021 ***	5.261 ***	6.013 ***	5.821 ***
	(4.16)	(6.17)	(6.23)	(3.44)
R2	0.6256	0.5518	0.5056	0.4321
Obs	140	84	154	42

Note: *t*-values are in parentheses, and ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

The first and second columns show the results of OLS regression, the third and fourth columns show the regression results using D-K standard errors, and the fifth and sixth columns show the regression results of instrumental variables. It can be found that the improvement of the digital level has a significant part of intermediary effect in the inhibition of financial system marketization on carbon intensity. This is because the marketization of the financial system is an important means for a region to accumulate resources, as well as an important booster for the regional digital process and technological innovation. First, digitalization is one of the key directions of supply side structural reforms of the real economy. The market-oriented optimization of the financial system's resource allocation function makes more financial resources incline to the digital economy, thus promoting the development of the digital economy, allowing enterprises with technological innovation to obtain more financial resources and promoting the transformation of science and technology into social productivity. Secondly, the improvement of financial inclusiveness has lowered the financing threshold for digital economy enterprises, thus accelerating technological innovation of enterprises. In the process of digital development, data is the core element of digital development. However, due to the attributes of the data itself and the limitations of time and space, data security problems exist for a long time. A safer financial system provides a tool to disperse and transfer risks in the digital economy, thus promoting the promotion of digital technology innovation.

Table 5. The intermediary effect test of the development level of digital economy.

	(1) Digt OLS	(2) Cabi OLS	(3) Digt D-K	(4) Cabi D-K	(5) Digt 2SLS	(6) Cabi 2SLS
Digt		−0.382 *** (−3.21)		−0.537 *** (−4.01)		−0.352 *** (−2.77)
Finm	3.183 *** (4.48)	−1.374 ** (−2.26)	2.482 *** (3.21)	−1.354 *** (−3.19)	3.213 *** (4.41)	−1.272 ** (−2.44)
Gdp			0.521 *** (3.21)	0.364 *** (4.35)	0.323 *** (4.45)	0.227 *** (4.23)
Gpp			0.262 *** (3.27)	0.462 *** (4.45)	0.164 *** (4.41)	0.542 *** (4.63)
Ssr			−2.281 *** (−4.91)	2.543 *** (5.46)	−2.461 *** (−3.10)	2.426 *** (4.72)
Tsr			2.727 *** (3.20)	2.466 *** (6.53)	2.294 *** (4.29)	2.354 *** (4.21)
Fdi			0.791 ** (2.01)	−0.442 (−1.43)	0.728 * (1.76)	−0.274 (−1.32)
Pat			0.883 (0.27)	−0.553 (−0.62)	0.453 (0.32)	−0.380 (0.39)
Ine			0.273 *** (2.79)	−0.342 *** (−3.23)	0.892 *** (2.69)	−0.672 *** (−3.37)
Time-FE & Individual-FE	Control	Control	Control	Control	Control	Control
Cons	1.265 *** (5.04)	4.345 *** (3.31)	1.342 *** (3.28)	4.281 *** (3.07)	1.642 *** (4.03)	4.363 *** (4.18)
R2	0.2811	0.3824	0.5846	0.7931	0.6073	0.7221
Obs	420	420	420	420	420	420
Sobel	Sobel Z = 2.609 ***		Sobel Z = 2.505 **		Sobel Z = 2.345 **	
Intermediary effect	Partial mediation effect		Partial mediation effect		Partial mediation effect	

Note: *t*-values are in parentheses, and ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

5.3.2. The Intermediary Effect Test of the Digital Infrastructure Construction

Table 6 verifies the first dimension of the digital level—namely, the intermediary effect test of digital infrastructure construction. In order to verify the significance of the intermediary effect, this paper uses the Sobel test method.

The empirical results show that digital infrastructure construction has a partial intermediary effect between market leading finance and carbon emissions. This means that the marketization of the financial system helps enterprises and governments to invest in digital infrastructure, so as to drive the digital economy and reduce the carbon intensity. Therefore, the government should play a positive role in the process of the impact of financial marketization on carbon intensity, and promote the synchronous development of digital economy and financial industry. Strengthen the function of financial services, provide effective financial support for enterprises by using various financial means and improve the level of technological innovation of enterprises, so as to achieve the effect of low-carbon economic development.

Table 6. The intermediary effect test of the digital infrastructure construction.

	(1) Digt OLS	(2) Cabi OLS	(3) Digt D-K	(4) Cabi D-K	(5) Digt 2SLS	(6) Cabi 2SLS
Digt1		−0.472 *** (−2.71)		−1.465 *** (−2.94)		−0.833 * (−1.90)
Finm	1.342 *** (3.71)	−1.171 ** (−2.10)	1.673 *** (3.38)	−1.327 ** (−2.04)	3.542 *** (3.35)	−2.341 *** (−2.78)
Gdp			0.137 *** (4.25)	0.582 *** (4.25)	0.237 *** (4.21)	0.412 *** (4.24)
Gpp			0.022 *** (3.21)	0.782 *** (4.45)	0.089 *** (3.18)	0.285 *** (3.58)
Ssr			1.361 ** (2.15)	1.591 *** (4.22)	1.532 *** (2.70)	2.358 ** (2.55)
Tsr			2.121 *** (3.17)	2.174 ** (2.48)	2.547 *** (3.18)	2.352 ** (2.58)
Fdi			−0.223 (−1.12)	−0.271 (−1.22)	−0.581 (−1.21)	−0.458 (−1.21)
Pat			0.240 (0.25)	−0.479 (0.37)	−0.548 (0.27)	−0.582 (0.92)
Ine			0.257 *** (2.95)	−0.582 *** (−3.22)	−0.372 *** (−3.24)	−0.372 *** (−2.84)
Time-FE & Individual-FE	Control	Control	Control	Control	Control	Control
Obs	1.463 *** (7.17)	4.279 *** (3.38)	1.342 *** (4.57)	4.325 *** (4.04)	1.128 ** (2.38)	4.253 *** (3.76)
R2	0.3507	0.3463	0.6682	0.7464	0.5729	0.7811
Obs	420	420	420	420	420	420
Sobel	Sobel Z = 2.188 **		Sobel Z = 2.218 **		Sobel Z = 1.652 *	
Intermediary effect	Partial mediation effect		Partial mediation effect		Partial mediation effect	

Note: *t*-values are in parentheses, and ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

5.3.3. The Intermediary Effect Test of the Digital Ecological Environment Construction

Table 7 verifies the second dimension of the digital level—namely, the intermediary effect test results of digital ecology. In order to verify the significance of the intermediary effect, this paper uses the Sobel test method.

Through the Sobel test, the intermediary effect of digital ecology is not significant. This means that although financial marketization can drive business income in the digital economy, it will not have a significant impact on carbon intensity. The reason may be that although digital economy can bring a lot of business income, most of the income is invested in high carbon sectors. In China's practice, the amount of funds needed to deal with climate change is very large. Due to the limited capacity of the private sector in emission reduction and zero carbon transformation, decision-making guidance and financing support from major global financial institutions have increasingly become an important lever for raising funds and leveraging the low-carbon transformation of the whole society. The top asset management institutions in the world are all foreign institutions in Europe and the United States. In recent years, they have continued to pour into the Chinese market with a strong momentum, and have increased their weight in the asset allocation portfolio. The investment and financing actions of the head asset management institutions in China are similar to wind vanes, which have an important impact on China's carbon neutral process and even the completion of the world's carbon neutral goal.

Table 7. The intermediary effect test of the digital ecological environment construction.

	(1) Digt2 OLS	(2) Cabi OLS	(3) Digt2 D-K	(4) Cabi D-K	(5) Digt2 2SLS	(6) Cabi 2SLS
Digt2		−0.842 (−1.01)		−0.821 (−1.13)		−0.745 (−0.77)
Finm	0.346 ** (2.38)	−1.271 *** (−2.81)	0.475 *** (3.19)	−1.333 ** (−2.12)	0.573 *** (3.14)	−1.425 *** (−3.04)
Gdp			0.526 *** (3.64)	0.214 *** (4.25)	0.443 *** (3.65)	0.245 *** (4.65)
Gpp			0.357 *** (5.54)	0.452 *** (4.34)	0.333 *** (5.34)	0.459 *** (4.53)
Ssr			1.152 *** (3.39)	2.562 *** (5.10)	1.532 ** (2.46)	2.337 *** (3.90)
Tsr			3.134 *** (3.34)	2.481 *** (6.27)	1.387 *** (3.18)	2.436 *** (5.29)
Fdi			−0.275 (−1.11)	−0.713 (−1.23)	−0.713 (−1.23)	−0.344 (−1.43)
Pat			−0.323 (0.35)	−0.340 (0.62)	−0.561 (0.16)	−0.452 (0.77)
Ine			−0.227 (−0.24)	−0.553 *** (−3.33)	0.224 (0.75)	−0.245 *** (−3.76)
Time-FE & Individual-FE	Control	Control	Control	Control	Control	Control
Cons	1.372 *** (4.18)	5.345 *** (3.34)	1.455 *** (3.52)	3.186 *** (3.73)	1.248 *** (3.55)	4.138 *** (4.06)
R2	0.4301	0.3744	0.6566	0.7527	0.6624	0.7245
Obs	420	420	420	420	420	420
Sobel	Sobel Z = 0.929		Sobel Z = 1.065		Sobel Z = 0.747	
Intermediary effect	Not significant		Not significant		Not significant	

Note: *t*-values are in parentheses, and *** and ** indicate significance at the 1%, 5% and 10% levels, respectively.

5.3.4. The Intermediary Effect Test of the Digital Talent

Table 8 verifies the third dimension of the digital level, namely, the intermediary effect test of digital talents. In order to verify the significance of the intermediary effect, this paper uses the Sobel test method.

The empirical regression results show that digital talents have some intermediary effects between market dominated finance and carbon emission intensity. Human capital is the main body of production and life in the economic society, and also the implementer of in-depth promotion of green and low-carbon transformation. Human capital is the key factor to promote economic endogenous growth. On the one hand, with the accumulation of human capital and the optimization of industrial structure, its effect on promoting economic growth and reducing carbon dioxide emissions is further highlighted; On the other hand, in regions with high levels of human capital, due to the increased demand for energy consumption due to industrial agglomeration and population concentration, the improvement of human capital level has intensified the increase of carbon emission density. Through this part of the study, we can see that the inhibition of human capital on carbon intensity is significantly greater than its promotion.

Table 8. The intermediary effect test of the digital talent.

	(1) Digt3 OLS	(2) Cabi OLS	(3) Digt D-K	(4) Cabi D-K	(5) Digt3 2SLS	(6) Cabi 2SLS
Digt3		−0.346 ** (−2.51)		−0.521 ** (−2.35)		−0.432 ** (−2.74)
Finm	0.368 *** (2.99)	−1.01 ** (−2.11)	0.246 *** (3.78)	−1.23 ** (−2.10)	0.463 *** (2.81)	−1.63 ** (−1.97)
Gdp			0.173 ** (2.44)	0.256 *** (3.59)	0.171 ** (2.44)	0.301 *** (4.32)
Gpp			0.284 ** (2.23)	0.543 *** (4.34)	0.258 ** (2.43)	0.464 *** (4.21)
Ssr			1.124 *** (4.01)	2.464 *** (5.34)	1.152 *** (4.53)	2.353 *** (5.27)
Tsr			0.716 *** (3.28)	2.643 *** (8.31)	0.457 *** (3.53)	2.114 *** (7.59)
Fdi			0.321 *** (3.83)	−0.463 (−1.42)	0.343 *** (3.85)	−0.433 (−1.30)
Pat			0.612 (0.31)	−0.603 (0.53)	0.416 (0.97)	−0.525 (0.64)
Ine			0.411 (0.46)	−0.562 *** (−3.34)	0.472 (0.53)	−0.898 *** (−2.79)
Time-FE & Individual-FE	Control	Control	Control	Control	Control	Control
Cons	1.836 *** (3.92)	4.295 *** (3.24)	1.252 *** (3.63)	4.134 *** (3.79)	1.562 *** (3.53)	4.380 *** (4.06)
R2	0.3306	0.3751	0.7101	0.7754	0.7458	0.7303
Obs	420	420	420	420	420	420
Sobel	Sobel Z = 1.922 *		Sobel Z = 1.995 **		Sobel Z = 1.961 **	
Intermediary effect	Partial mediation effect		Partial mediation effect		Partial mediation effect	

Note: *t*-values are in parentheses, and ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

6. Conclusions and Policy Recommendations

In a series of "supporting system supplies" of developing countries, whether the structural arrangement of the financial system can provide more support for the real economy is the key to a country's rapid technological progress. Deeply understanding the relationship between financial structure and carbon intensity is not only conducive to explaining the important issues of people's livelihood, but also conducive to promoting the reforms of the financial system in the current economic transition period. In view of this, from the perspective of digital infrastructure and digital human capital, based on the theoretical basis that the change of financial structure should match the economic industrial structure and human capital accumulation, this paper proposes three important theoretical hypotheses about the impact of financial structure on carbon intensity, and constructs an intermediary model for empirical testing. The research findings of this paper:

6.1. Conclusions

1. With the improvement of China's economic development level, finance should adapt to the regional industrial structure and human capital accumulation in order to better serve the development of the real economy; Therefore, market-oriented finance can help reduce the carbon intensity. By dealing with the robustness tests such

as endogeneity among variables and hysteresis of test variables, the conclusion is still robust.

2. The market-oriented financial structure helps to reduce the carbon emission intensity in Eastern, Central, Western and Northeastern China, and has a more significant inhibition effect in northeastern China. It shows that Northeast China needs to further transform into the market economy, broaden the financing channels for industrial development, and provide impetus for the development of green industries.
3. The improvement of the digital level can significantly enhance the inhibition of financial structure on carbon intensity, mainly through the application of digital talents and the construction of digital infrastructure.

6.2. Policy Recommendations

First, financial development should take competition as means, and constantly promote the market-oriented transformation of financial structure. We should promote the matching between the financial structure and the industrial structure, continue to improve the financing support for high-tech industries and knowledge intensive industries in the industrial structure, and reduce the regional carbon emission intensity through industrial transformation and upgrading.

Second, accelerate the training and introduction of digital talents. We can build a diversified talent model of universities, scientific research mechanisms and enterprises to jointly cultivate talents, carry out order system, apprenticeship system, etc., and cultivate application-oriented, technical and skilled talents.

Third, accelerate the construction of digital infrastructure. Strengthen the construction of key infrastructure such as 5G base stations, data centers and cloud computing centers in various regions, gradually encourage the market to create high-quality conditions for attracting market players, and promote the development of industries with low energy consumption and low emissions in the region.

6.3. Discussion

Compared with previous studies, this paper discusses the impact of different national financial system arrangements on carbon emission intensity from the perspective of financial structure. Chen and Chen (2021) believed that the development of green finance is conducive to carbon emission reduction. This study was different from Chen and Chen (2021) in that it believed that green finance is also one of the development dimensions of market-led financial structure, and the positive role of green finance in carbon emission reduction also benefits from the market economics [67]. In addition, Ye et al. (2022) believed that financial development is not conducive to carbon emission reduction. The difference between Ye et al. (2022) is that this paper discusses the structural characteristics of finance; that is, market-oriented finance is more conducive to carbon emission reduction [68].

This paper currently uses provincial panel data, which can be used to collect urban panel data in the further to explore the impact of urban financial structure on carbon emissions from a more micro perspective. Moreover, it does not explore the impact of market leading financial structures on carbon emission intensity under different levels of economic development. The threshold regression model can be used for further research.

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