

Digital economy empowers urban green transformation for sustainable development

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Abstract: With the continuous acceleration of urbanization, the urban population continues to grow, and the problems of resource consumption and environmental pollution have become increasingly prominent. The development of cities is facing severe challenges. Against this backdrop, China is actively exploring and accelerating the transformation towards a digital and green economic development model. The aim is to promote a systematic transformation of urban operation methods through the deep integration of digital technology and the green development concept. The digital green economic model relies on cutting-edge technologies, which can not only enhance the efficiency of urban operation but also effectively reduce resource waste and carbon emissions. This model strives to build a new balance between economic growth and environmental protection, enabling cities to achieve high-quality development while truly improving the quality of life and happiness of residents. Although certain progress has been made in promoting the digital green economy, with the continuous improvement of digital infrastructure and the continuous expansion of the green industry scale, there are still multiple challenges in the actual implementation process, such as the digital divide, fiscal pressure, and imperfect environmental supervision. This paper selects data from 2008 to 2022 for research and uses Eviews software for multiple linear regression analysis and testing. The purpose is to explore the application of digital technology in urban management, promote the development of the green economy, analyze and improve the problems existing in the digital green economy, and thereby promote sustainable urban development.

Keywords: urban green transformation; digital economy; green development index; sustainable development; dual carbon target

1. Introduction

1.1. Research background

Since the reform and opening up, China has created a remarkable development miracle, but it also faces prominent environmental problems. Nowadays, the serious environmental problems are restricting the high-quality development. The traditional urban development model is often dominated by economic growth, leading to excessive consumption of resources, environmental pollution, and ecological damage. These problems not only affect the sustainable development of the city but also pose a great threat to human health and the survival environment [1]. The “either-or” dilemma of economic development and ecological protection needs to be solved urgently. China’s economic development has entered a new normal since the 18th National Congress of the CPC. The main feature is that economic development clearly reflects the new

development concept of “innovation, green, coordinated, open, and sharing”; economic development has shifted from the stage of high-speed growth to the stage of high-quality development, and the green and intelligent production mode has gradually become a trend. According to the 2022 Global Environmental Performance Index Report jointly released by Yale University and others, China ranked 160th among the 180 countries and regions participating in the evaluation, which means that China’s economy is facing severe environmental challenges behind its impressive achievement of rapid growth [2]. In order to solve prominent environmental problems, more than 30 relevant national laws have been issued, and governments at all levels have also issued a series of rules and regulations to control environmental pollution, striving to fight a tough battle against pollution. The digital economy has gradually become a new engine of high-quality development. Under the strategic background of the carbon peak and carbon neutrality, the development of the digital economy plays an important role in urban carbon emission reduction [3]. The scale of China’s digital economy already accounts for a third of GDP, showing strong growth, according to the White Paper on China’s Digital Economy [4]. This rapidly developing digital economy is profoundly changing the way of production, life, and governance, and giving birth to many new forms of business and new industries. This change has not only driven up efficient economic growth but also provided new opportunities to reduce carbon emissions. With increasing global attention to climate change, carbon peak and carbon neutrality have become common global goals. In this context, China has responded positively to promote the innovative development of green technologies to reduce urban carbon emissions and implement the strategic deployment of the carbon peak and carbon neutrality. This is not only an inherent requirement for high-quality economic development, but also an inevitable choice for us to promote ecological progress [5]. In order to meet these challenges, urban digital green development has emerged. Digital green development is a new development model combining the digital economy with the concept of green development, aiming to promote the green transformation and sustainable development of cities through digital means [6]. This mode takes information and intelligence as the core, promotes the digital transformation of various fields of the city, improves the efficiency of resource utilization, reduces environmental pollution, improves the ecological environment, and promotes the coordinated development of the urban economy and society [7].

1.2. Research significance

1.2.1. Theoretical significance

First, studying the role of urban digital green development will help us deepen our understanding of both economic growth and environmental protection [8]. Traditional economic theories often focus on the quantity and speed of economic growth, while ignoring the impact on the environment. By studying the integration of the digital economy and carbon emission reduction, we can re-examine the connotation and mode of economic growth, and promote the development of economic theory to a more comprehensive and sustainable direction [9]. Second, it can expand the green economy theory, which emphasizes the coordinated development of economic

activities and environmental protection. As an emerging economic form, the digital economy has the characteristics of green and low-carbon development. By studying the application of the digital economy in carbon emission reduction, the connotation and extension of green economy theory can be further expanded, and theoretical support can be provided for the formulation and implementation of green economy policies. Third, to promote the development of the theory of technological innovation. The digital economy is an economic form driven by technological innovation [10]. By studying the technological application and innovation mode of the digital economy in carbon emission reduction, we can have an in-depth understanding of the role of technological innovation in promoting economic development, and further promote the development and improvement of technological innovation theory. Finally, it can provide theoretical support for global sustainable development, and the integration of the digital economy and carbon emission reduction is one of the important ways to achieve global sustainable development [11]. Through this study, we can provide theoretical support and experience reference for global sustainable development, and promote the development of the global economy to a greener, low-carbon, and sustainable direction.

1.2.2. Practical significance

This study provides two countermeasures. On the one hand, it is conducive to promoting the green transformation and upgrading of industries and realizing high-quality economic development. As an emerging economic form, the digital economy has strong innovation ability and market potential. The study of its practical application in urban green development will help to promote the transformation of traditional industries to a green and low-carbon direction, and cultivate new economic growth points [12]. This can not only reduce carbon emissions but also promote the optimization and upgrading of the industrial structure and improve the overall quality and efficiency of the economy. On the other hand, it is the reference value of the government's work and the research on urban digital green development. The government can formulate targeted industrial transformation and upgrading policies based on the research results. Through policy guidance, enterprises will be encouraged to increase their investment and application in digital technologies, and promote the transformation of traditional industries to green and low-carbon directions. At the same time, special funds can also be set up to support the innovation and development of green industries, provide strong support for high-quality economic development, and promote the digital green development of cities [13].

2. Literature review

2.1. Urban green development

Green development refers to a development model that promotes sustainable economic growth while reducing the consumption of natural resources and environmental damage, and enabling economic development and environmental improvement to mutually reinforce each other. Sun et al. (2025) discovered through the modified coupled coordination degree model that industrial structure upgrading

has a U-shaped impact on it, while government attention has an inverted U-shaped impact, providing an important perspective for understanding the institutional driving factors of urban green development [14]. Chen et al. (2025) constructed a digital economy index and found that the digital economy can significantly promote corporate green innovation by reducing agency costs and improving financial leverage, revealing the transmission mechanism of urban micro-subjects' green transformation [15]. Chen and Xing (2025) confirmed that the digital economy can directly or indirectly promote economic high-quality development through stimulating green innovation, and particularly distinguished the different roles of substantive green innovation and strategic green innovation, deepening the understanding of the urban green growth path [16]. Wang et al. (2025) started from the two dimensions of digital industrialization and industrial digitalization, finding that although industrial digitalization increases carbon emissions in traditional industries, it reduces carbon intensity and carbon inequality [17]. Li et al. (2025) discovered that the digital economy can promote green economic growth, and environmental regulations play a positive regulatory role, with the regulatory effect having significant regional heterogeneity, emphasizing the importance of policy combinations in urban green governance [18]. Wang and Wang (2025) found through a dynamic panel model that the digital economy promotes the green economic growth of Chinese provinces by improving technological innovation levels and industrial structure upgrading, while foreign direct investment weakens this positive effect, and R&D intensity has the opposite effect, providing a reference for urban optimizing factor allocation [19]. Guo (2025) proposed that the digital economy becomes a key driving force for urban green and low-carbon transformation, guided by the "dual carbon" goal [20]. Jiang et al. (2025) found that the digital economy can significantly enhance resource allocation efficiency, and has a nonlinear characteristic of marginal returns increasing, among which green innovation is an important transmission mechanism [21]. Xu et al. (2025) found that the digital economy can significantly promote the development of new quality productive forces, and green innovation efficiency plays a mediating, regulating, and threshold effect role, providing a new idea for cities to build a green and efficient productive system [22]. Wong et al. (2025) used the wavelet-based quantile regression method to find that the long-term impact of the digital economy on environmental sustainability is positive, but the short-term effect varies by quantile [23]. Cui and Li (2025) found that the digital economy can have significant differences due to different urban population sizes and geographical locations, reflecting the local characteristics of urban green transformation [24].

2.2. Digital economy

The digital economy has become an important engine of global economic development and has attracted the attention and research of many scholars. Scholars have conducted in-depth studies on the digital economy from different perspectives, including its definition, development momentum, impact, challenges, policies, and regulations.

Firstly, scholars focused on the definition and connotation of the digital economy.

The digital economy is defined as a new economic form based on digital technologies and information communication technologies, featuring innovation, efficiency, and globalization. Tapscott (1996) formally proposed the concept of the digital economy in his book "The Digital Economy: Opportunities and Challenges in the Network Intelligence Era" [25]. Dahlman et al. (2016) believes that the digital economy is a series of economic and social activities based on a combination of various general technologies [26]. Liu and Wang (2025) used the microdata from the China Family Panel Studies (CFPS) from 2016 to 2020 to discover that the development of the digital economy significantly enhanced the occupational mobility of rural labor force and overcame the obstacles to mobility caused by risk aversion through the preference effect, providing micro evidence for understanding how the digital economy reshapes the labor market structure [27]. Doğan et al. (2025) used the panel quantile method to find that the development of the digital economy significantly promoted energy transformation and emphasized the key role of renewable energy innovation in it, providing international experience for the greenization of urban energy systems [28]. Liu et al. (2025) found through the fixed effect model that the level of digital economy has a significant positive impact on enterprises' green technological innovation, and R&D investment plays a positive mediating role [29]. Dogan et al. (2025) used the FMOLS and DOLS methods to discover that green technologies and R&D investment can positively promote renewable energy innovation, providing policy implications for cities to develop green technologies in an open context [30]. Li et al. (2025) found that regional digital economic development is positively correlated with enterprises' green performance, and the dynamic ability of enterprises can significantly enhance this relationship, emphasizing the importance of enterprise organizational capabilities in leveraging digital technologies [31]. Liu et al. (2024) through the construction of an evaluation index system, discovered that the level of digital economic development in China shows a spatial heterogeneity characteristic of "high in the east and low in the west", and its combination with diversified industrial agglomeration has a positive impact on the efficiency of green innovation, providing a basis for cities to formulate differentiated digital development strategies [32]. Shabur (2024), through systematic literature review and bibliometric evaluation, identified multiple potential cross-cutting fields, including renewable energy technology progress and smart city development, providing a macro knowledge map for understanding the sustainable transformation of the digital economy [33]. Shu (2025) found that agricultural digitalization contributes the most, but there are gradient differences in the development speed of each region, providing a reference for understanding the urban-rural digital divide and the starting point of rural green transformation [34]. Che (2025) confirmed that substantive digital technological innovation can significantly improve the ESG performance of enterprises and pointed out that intellectual property protection plays an important role in it□ providing a new perspective for cities to promote enterprises to achieve green and inclusive growth through digital technology [35].

To sum up, scholars' research on the digital economy involves many aspects, including definition and connotation, development impetus and mechanism, influence and challenge, etc. These studies not only help us to deeply understand the nature and

development of the law of the digital economy, but also provide theoretical support and policy guidance for the practice of the digital economy [36]. In the future, with the continuous development of digital technology and the expansion of its application scope, the digital economy will continue to become a hot field for scholars. Despite the extensive attention and research in recent years, there are still some places where scholars have insufficient research or few scholars. This paper uses metrological tools to establish a multiple linear regression model to analyze the influence of the digital economy on the green development index. We hope to improve the utilization rate of resources and improve the environmental quality to promote economic and social development through urban digital green development.

3. Current situation of urban digital green development

3.1. Current situation of urban digital development

3.1.1. Digital infrastructure development

Digital infrastructure construction can be reflected by computer services, software workers, and the total number of telecommunications services. As can be seen from **Figure 1**, since 2008, the number of employees in China's computer service and software industry has been increasing, which shows the rapid development of China in the field of information technology and also reflects the rapid development of China's digital transformation. With the increase in employees in the computer service and software industry, the construction of digital infrastructure in China has been continuously improved and optimized, providing strong support for economic development and social progress.

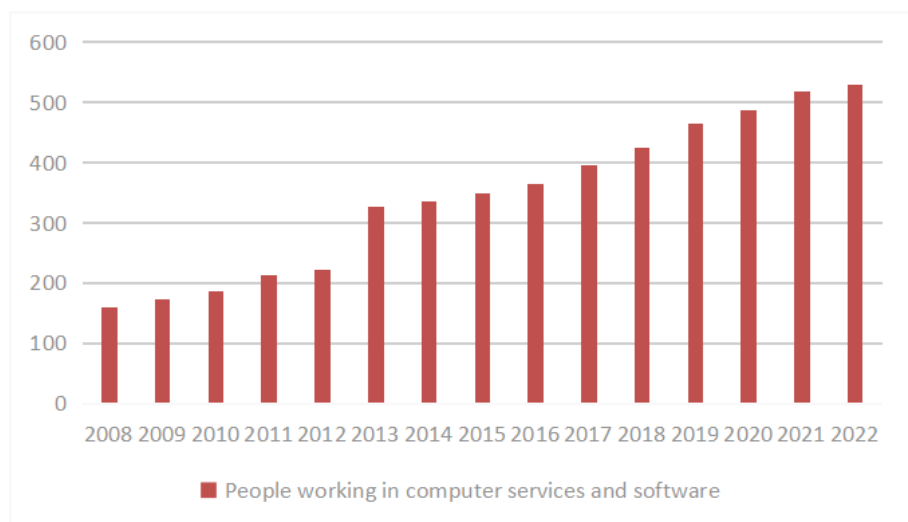


Figure 1. Employed in the computer services and software industry from 2008 to 2022.

As can be seen from **Figure 2**, the total volume of telecom business in China also shows an upward trend, among which 2018 is a turning point with a very rapid growth. This shows that China's investment and construction in the telecommunications field is constantly strengthened, especially in the context of the rapid development of new-generation information technologies such as 5G, cloud computing, and big data. The demand and scale of telecommunications services are expanding. It reflects

the rapid development of China’s telecom industry and the promotion of digital transformation, and also provides strong support for the construction of China’s digital infrastructure.

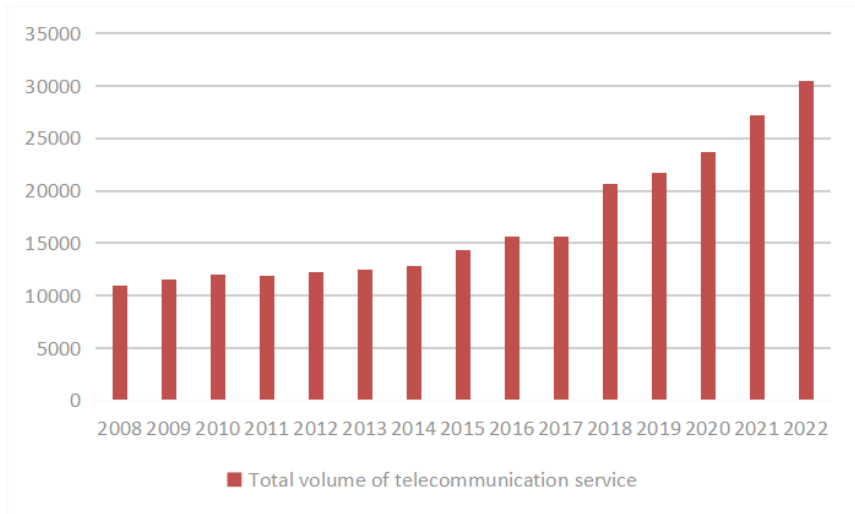


Figure 2. Total volume of telecommunication service from 2008 to 2022.

3.1.2. Elements of digital innovation

The green elements of digital innovation can be reflected by the number of Internet broadband users and mobile phone users. As can be seen from **Figure 3**, since 2008, the number of Internet broadband users in China has been increasing continuously, reaching 589.648 million in 2022. With the increase in the number of broadband users, the application scope of the Internet is also expanding, from the initial simple web browsing to the current online office, online education, telemedicine, and other diversified applications, which are inseparable from the support of broadband. The popularity of broadband networks has enabled more businesses and individuals to access the Internet, thus driving the innovation and application of digital technology.

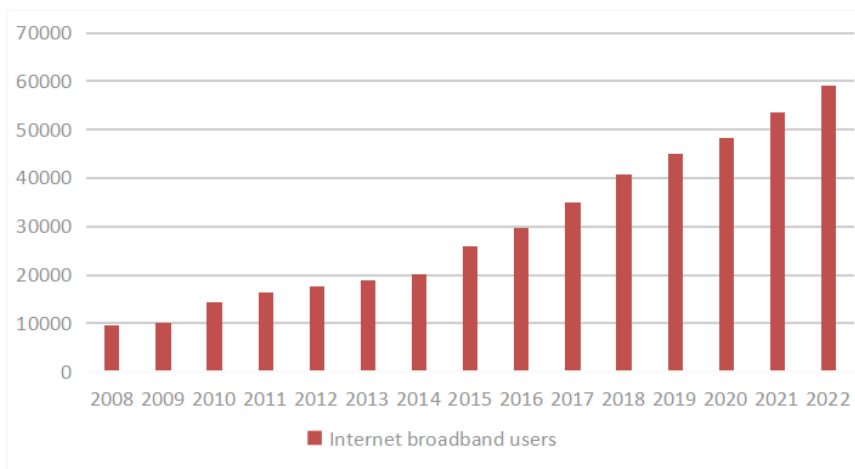


Figure 3. The number of internet broadband users in China from 2008 to 2022.

As can be seen from **Figure 4**, the number of mobile phone users in China is also rising. The increase in the number of mobile phone users not only reflects the continuous progress of mobile communication technology in China, but also promotes the development of mobile Internet applications. Now, people can access the Internet

anytime and anywhere through their mobile phones and enjoy a variety of convenient services, such as online shopping, mobile payment, social media, and so on. This has further promoted the development of the digital economy and also brought great convenience to people’s lives.

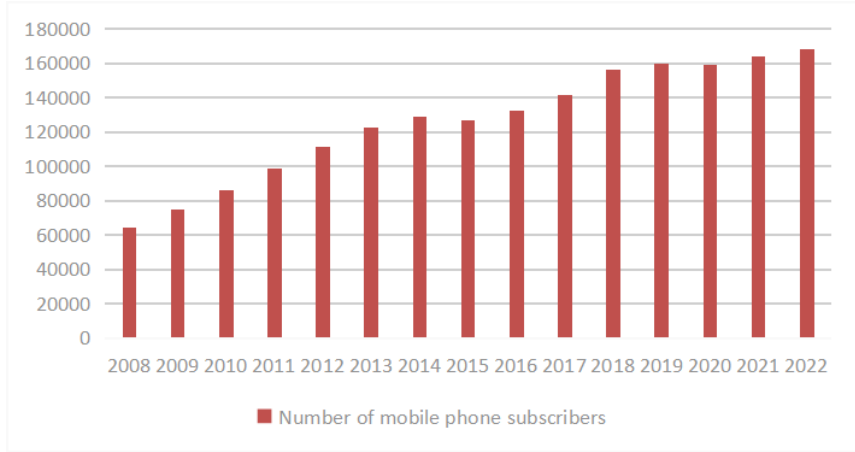


Figure 4. Number of mobile phone users in China from 2008 to 2022.

3.2. Current situation of urban green development

The green development index is selected to represent the current situation of urban green development, and the green development index index system is constructed from the four dimensions of material capital, labor capital, land capital, and resource consumption. The green development index is comprehensively evaluated by the entropy method. As can be seen from **Figure 5**, the degree of green development in China is constantly improving, which reflects that China’s efforts have achieved remarkable results in promoting green development and ecological civilization construction. At the same time, it also shows that China is gradually shifting to a greener and more sustainable development path in urban planning, industrial structure adjustment, and resource conservation and utilization. This trend is of great significance to the realization of sustainable economic and social development and the construction of a beautiful China.

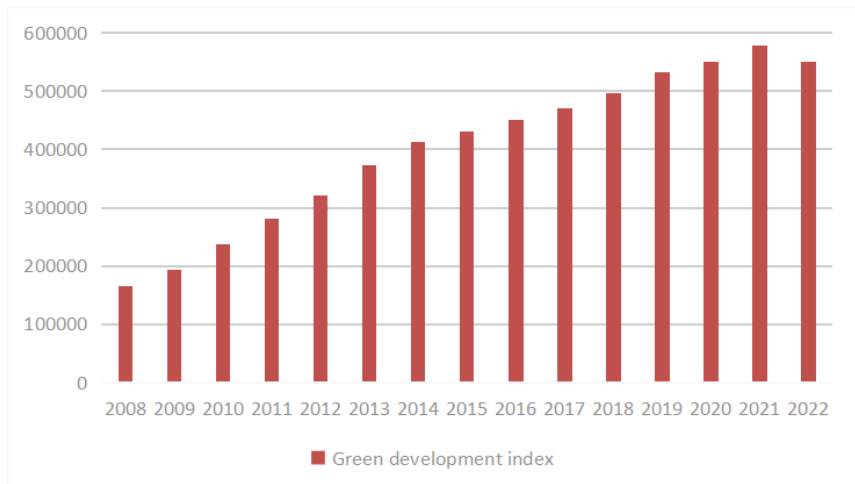


Figure 5. China’s green development index from 2008 to 2022.

4. Variable selection

Be explanatory variables: select green development index as explanatory variables, from the material capital, labor capital, land capital, resource consumption four dimensions to build green development index index system, including the stock of fixed assets, at the end of the city employment, urban proper area, and make electricity four sub dimension specific indicators see **Table 1**.

Table 1. Green development index system.

Level 1 indicators	Level 2 indicators	Indicator attributes	Weight
Physical capital	Stock of fixed assets	+	0.421
Labor capital	City employment at the end of the year	+	0.0436
Soil capital	Urban built-up area	+	0.3348
Resource consumption	Make electricity consumption	+	0.2006

In this paper, the entropy method is used to comprehensively evaluate the green development index.

Core explanatory variables: select the digital economy as the core explanatory variables, digital economy with network, information as the carrier, in this paper, refer to relevant literature, digital economy development level index including Internet users, mobile Internet users, computer services and software industry practitioners, telecom business, this paper from the digital infrastructure construction, digital innovation elements two dimensions build digital economy comprehensive evaluation index system, specific indicators see **Table 2**.

Table 2. Digital economy development measures.

Level 1 indicators	Level 2 indicators	Indicator attributes
Digital infrastructure construction	Computer services and software industry practitioners	+
	Total telecom business	+
Digital innovation elements	Number of Internet users	+
	Number of mobile Internet users	+

See **Table 3** for the specific variable selection and description.

Table 3. Selection of variables and their description.

Variable	Variable declaration	Expected direction
Y: Green Development Index	The green development index composite score is calculated by the entropy value method	
X1: Number of Internet users	Number of Internet users in China from 2008 to 2022	+
X2: Number of mobile Internet users	The number of national mobile Internet users from 2008 to 2022	+
X3: People working in the computer services and software industry	Employees in computer services and software from 2008 to 2022	+
X4: Total telecom business volume	The total number of national telecom services from 2008 to 2022	+

5. Empirical analysis

5.1. Specification of model

In reality, there is often more than one factor affecting the explained variable, so multiple linear regression models are needed. Multivariate linear models, e.g.,

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \mu.$$

Where Y is the explained variable; X_j ($j = 1, 2, \dots, k$) is a k explanatory variable; β_j ($j = 0, 1, 2, \dots, k$) is an unknown parameter; μ is a random error term. The expected value of the explained variable Y and the explanatory variable X_1, X_2, \dots, X_k of the linear equations, e.g.,

$$E(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k.$$

For the n group of observations $Y_i, X_{1i}, X_{2i}, \dots, X_{ki}$ ($i = 1, 2, \dots, n$), the system of equations in its form is

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} + \mu_i \quad (i = 1, 2, \dots, n)$$

$$\begin{cases} Y_1 = \beta_0 + \beta_1 X_{11} + \beta_2 X_{21} + \dots + \beta_k X_{k1} + \mu_1 \\ Y_2 = \beta_0 + \beta_1 X_{12} + \beta_2 X_{22} + \dots + \beta_k X_{k2} + \mu_2 \\ \dots \\ Y_n = \beta_0 + \beta_1 X_{1n} + \beta_2 X_{2n} + \dots + \beta_k X_{kn} + \mu_n. \end{cases}$$

Its matrix form is

$$\begin{bmatrix} 1 & X_{11} & X_{21} & \dots & X_{k1} \\ 1 & X_{12} & X_{22} & \dots & X_{k2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & X_{1n} & X_{2n} & \dots & X_{kn} \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_k \end{bmatrix} + \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_n \end{bmatrix}$$

$$Y = X\beta + \mu$$

5.2. Model parameter analysis

Combining the above analysis, the econometric model is used for analysis and research. In this paper, a multiple linear regression model was established using EVIEWS 10.0:

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \mu_i$$

Through the EVIEWS 10.0 software, the OLS regression equation was obtained as:

$$\hat{Y} = -79552.09 - 1.106473x_1 + 2.886644x_2 + 447.8088x_3 - 0.130361x_4$$

$$(-2.942294)(-1.127176)(4.821688)(2.124502)(-0.715666)$$

$$R^2 = 0.990283 \quad F = 254.7691 \quad DW = 1.658414$$

As can be seen, $F = 254.7691 > (4,7)$, the green development index and the explanatory variables are significant, but some of the t -values are not very ideal, and the model has severe multicollinearity. The Frisch synthesis method is used to solve the problem of multicollinearity. Since DW passed the test, there is no time series problem, and the final correction of the model is made:

$$\hat{Y} = -64447.92 + 2.869517x_2 + 305.6308x_3$$

$$(-2.594571)(5.101396)(2.072084)$$

$$R^2 = 0.988326 \quad F = 507.9735 \quad DW = 1.359184$$

From the perspective of economics, the green development index should be positively correlated with the number of mobile Internet users, which is also proportional to the computer service and software industry practitioners. The regression results show that the coefficient is 2.869517, and the coefficient of 447.8088 is consistent with the expected symbol, and the economic significance passes the test. According to the regression results, the fitting effect is better, and according to the test, the equation is significantly higher, and there is no sequence-related problem. So the equation passed the test.

5.3. Regression result analysis

According to the data of 2008–2022 listed in this paper, the national green development index and the development degree of digital economy are steadily improving, and the value of China's industrial green development index gradually increased during the "10th Five-Year Plan", "11th Five-Year Plan" and "12th Five-Year Plan" period, indicating that the level of China's industrial green development is constantly improving. China's digital economy is also developing rapidly. The government has introduced a series of policies to promote the healthy development of the digital economy. At the same time, China's digital technology innovation ability is also constantly improving.

According to the model, computer services and software industry practitioners increase 1 person, will make the green development index increased 305.63, so in 2022, a total of computer services and software industry 5.292 million people, will drive the green development index greatly increased, can reflect the computer services and software industry employees increase will have a significant impact on the green development index, with the increase of computer service practitioners, the innovation ability in the field of will be improved, to promote the research and development and application of green technology. These technologies help to reduce resource consumption, improve energy efficiency, reduce pollution emissions, and promote the industry to green, low carbon, circular transformation, the transformation of the industry directly affect the growth of green development efficiency in China, according to the model, mobile Internet users every 1 people, the green development index increased 2.87, with the increase of mobile Internet users, the speed and scope of information dissemination has been greatly expanded, this means that information

about environmental protection, green way of life can faster spread to a wider audience. Mobile Internet users increase, and computing services and software industry employees represent the development of the digital economy. The development of the digital economy, through the optimal allocation of resources, energy conservation, and emissions reduction, promotes the development of the green industry, improves the efficiency of resource utilization, and promotes information sharing and cooperation, to promote the green development index.

6. Conclusion

Nowadays, the economic development has shifted from the stage of rapid growth to the stage of high-quality development, and the green and intelligent production mode has gradually become a trend. This paper selected data from 2008 to 2022 and examined them through multiple linear regression analysis and tests with EVIEWS software. The results of the regression analysis provide a quantitative link between the two, which have a significant positive link. With the booming development of the digital economy, the green development index also shows a steady upward trend. This shows that the digital economy not only provides a new impetus for economic growth but also promotes the green development of cities. Therefore, in order to achieve high-quality economic development, we must pay attention to the green transformation. The digital economy is an important force to promote green development, and further strengthening the deep integration of the digital economy and green development is conducive to promoting the sustainable development of China's urban economy.

6.1. Countermeasures and suggestions

With the continuous development of China's digital economy, the consumption concept and consumption structure are changing, which provides conditions for the improvement of China's green development index. Based on the above model and the current situation, this paper puts forward the following suggestions:

6.1.1. Strengthen the training and introduction of computer practitioners

According to the measurement model, the number of computer practitioners increased by 1, and China's green development index increased by 305. Therefore, more efforts should be made to train professionals in the field of computer, and actively introduce overseas talents to meet the needs of the development of the digital economy, strengthen the skill training of computer practitioners, improve their professional skills and innovation ability, and promote the research, development, and application of green technology.

6.1.2. Promote the popularization and application of mobile internet users

Expand the scale of mobile Internet users: According to the measurement model, the number of mobile Internet users increased by one person, and China's green development index increased by 2.87. Therefore, more efforts should be made to promote the popularization of mobile Internet and improve the coverage of users, so as to expand the dissemination scope and influence of green information. Encourage the development of more green-themed mobile applications, provide convenient and

efficient green lifestyle information and services, guide users to actively participate in green consumption and green action, safeguard user information security and privacy rights and interests, improve user trust in mobile Internet and usage, and promote the effective dissemination of green information and applications.

6.1.3. Promote the deep integration of the digital economy and green development

The government should introduce relevant policies to encourage and support the deep integration of digital economy and green development, promote the research and development and application of green digital technology; promote the integration and cooperation between digital economy and green industry, promote the application of green digital technology in energy conservation, environmental protection, circular economy, and other fields; establish and improve the green evaluation system of digital economy, and integrate the green development index into the digital economy evaluation system, to promote the coordinated progress of digital economy and green development.

6.1.4. Strengthen the innovation, promotion, and application of green technologies

We will encourage enterprises and research institutions to increase investment in green technology research and development, and promote the innovation and application of green technologies. Promote the application of green technology, strengthen the promotion and application of green technology, encourage enterprises to adopt green technology, improve the efficiency of resource utilization, and reduce environmental pollution; establish a green technology innovation platform, promote the research and development, exchange and promotion of green technology, and promote the wide application and popularization of green technology.

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