Eco Cities (2023) Volume 4 Issue 2
doi: 10.54517/ec.v4i2.2680

ORIGINAL RESEARCH ARTICLE

Digital economy empowers urban green transformation for sustainable development

Yiran Wang, Xiaolu Lv, Shi Yin*

College of Economics and Management, Hebei Agricultural University, Baoding 071000, China

*** Corresponding author:** Shi Yin, shyshi0314@163.com

ABSTRACT

With the acceleration of urbanization and the intensification of environmental issues, China is actively transitioning to a digital green economy development model, covering the application of digital technologies, sustainable economies, environmental protection, green infrastructure and transportation, digital management, and social inclusion. The model aims to improve urban efficiency through digital innovation, reduce resource waste, achieve a balance between economic growth and environmental protection, and improve residents' quality of life. Despite some progress, challenges remain, such as the digital divide, financial pressures, and inadequate environmental regulation. This paper selects the data from 2008 to 2022 for research and uses Eviews software to conduct multiple linear regression analysis and testing. It aims to explore the application of digital technology in urban management, promote the development of the green economy, and analyze and improve the problems in the digital green economy so as to 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 also faces prominent environmental problems. Nowadays, serious environmental problems are restricting high-quality development. The traditional urban development model is often dominated by economic growth, which leads 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 green and intelligent production modes have 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

ARTICLE INFO
Received: 2 April 2024 | Accepted: 3 May 2024 | Available online: 29 May 2024

CITATION
Wang Y, Lv X, Yin S. Digital economy empowers urban green transformation for sustainable development. *Eco Cities* 2023; 4(2): 2680. doi: 10.54517/ec.v4i2.2680

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 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 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 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 its 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, society, and ecological environment[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 in 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 digital economy to 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 gain 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 references for global sustainable development and promote the development of the global economy in 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 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 the development mode that reduces the use of natural resources and the damage to the ecological environment and mutually promotes both economic development and environmental improvement while promoting sustainable economic development. From the focus of the green development degree, Li and Xu mentioned that academic circles have not reached consensus on the level of green development. Although the existing research will use green total factor productivity or green economic efficiency as an important factor of green development and refer to the green development level, the assessment dimension is too single and vulnerable to extreme factors, and green efficiency is in the middle of the development of green and cannot fully reflect the real state of green development, as the agent of green development variables already cannot fully reflect the real state of green development, as the agent of green development variables already cannot meet the needs of the current research[14]. Academic research on the green development index began in the 1970s. Based on the discussion of the international community on the "limit of growth" by the United Nations at that time, other international organizations tried to calculate green GDP, but the actual progress was relatively slow and the degree of promotion and application was not high. Bob et al. have established a green index to assess the environmental quality of various states across the country. Although this index system is quite different from the actual situation in China, it still has some reference significance[15].

From the perspective of the current situation of urban green development, Zhou mentioned that China's economy has shifted from the stage of high-speed growth to the stage of high-quality development. Promoting green and low-carbon economic and social development is the key link to achieving high-quality development and an essential requirement of Chinese modernization[16]. Zhu et al. mentioned that green development is the result of the interaction of multiple factors. The current research results mainly believe that the green development index is influenced by industrial structure, science and technology, city scale, economic development level, level of opening up, urbanization level, and other aspects[17]. Zhang et al. selected five indicators of city scale, economic development level, industrial structure, science and education investment, and openness to discuss the influence mechanism of green development in the major node cities of "Belt and Road"[18]. Wang et al. took 285 cities at prefecture-level and above as samples to explore potential influencing factors such as city scale, industrial structure, economic development level, financial development level,

economic growth rate, property rights structure, wage level, and scale of foreign investment utilization[19]. Wang et al. mentioned that to achieve green development, it is necessary to deal with the relationship between man and nature, and make efforts in industrial transformation and upgrading, optimizing resource allocation, improving production efficiency, and reducing pollution emissions[20].

In the perspective of influencing factors of urban digital development, Rugman and Verbeke studied the influencing factors of environmental efficiency in various provinces and regions in China based on the Tobit regression analysis method, and concluded that the economic scale and the degree of opening to the outside world have a positive impact on environmental efficiency, while the impact of industrial structure is not significant[21]. We discussed the influence mechanisms on green development from the perspective of financial development and used the SBM model and the spatial Dubin model to conclude that green development affected not only capital investment but also the supervision of the use of funds[22]. In the study on the green development of the Yangtze River Economic Belt, Wu et al. reached the conclusion that environmental rules have a positive effect on green development[23]. However, Zeng believed that the role of environmental regulation has volatility and has much to do with the policy implementation of regional governments, while the competition between regional governments will lead to insufficient environmental regulation, which negatively affects local green development[24]. In terms of the role of urban green development, Huang et al. mentioned environmental regulation as an important means and tool to drive green and low-carbon development, which is of great significance to promote the green transformation of economic development[25]. Li et al. mentioned that green development can drive green technology innovation and promote the redistribution of green technology resources between different regions. Green technology innovation can improve production and economic efficiency, improve the quality of the ecological environment, promote coordinated regional development, narrow the income gap, and promote common prosperity[26]. Yu et al. mentioned that green development can improve the utilization rate of resources, reduce production costs, and reduce pollution emissions. Enterprises can improve production methods, product quality, and total factor productivity through green technology innovation[27].

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.

Scholars first pay attention to the definition and connotation of the digital economy. The digital economy is defined as a new economic form based on digital technology and information and communication technology that is characterized by innovation, high efficiency, and globalization. Tapscott formally put forward the concept of the digital economy in the book Digital Economy: Opportunities and Challenges in the Era of Network Intelligence[28]. Ding pointed out that the narrow sense of digital economy mainly refers to the transformation of the traditional business model by digital information technology. The broad digital economy covers almost all economic activity in the operation of society[29]. Dahlman believed that the digital economy is a series of economic and social activities based on a combination of various universal technologies[30]. The digital economy involves the production, exchange, and consumption of digital products, digital services, and digital platforms, and it has changed the traditional economy of operation and business model. Chen and Li pointed out that the digital economy mainly takes digital information as the key data resource, the Internet platform as the main information carrier, digital technology innovation as the driving force, and is a form of economic activity through the upgrading of a series of emerging business models and industrial forms[31].

Scholars have conducted an in-depth study on the driving force and mechanism of the development of the digital economy. They generally believe that technological progress is the core driving force for the development of the digital economy, including the continuous innovation and application of cloud computing, big data, artificial intelligence, and other technologies. Li pointed out that in the important stage of the transformation of the digital economy from the consumer Internet to the industrial Internet, the continuously enhanced innovation capacity, the huge demand for the upgrading of the real economy, and the rich digital scenarios and data resources will become an important driving force for the high-quality development of China's digital economy[32]. The digital economy, with digital knowledge and information as its core, has gradually become a new driving force to promote regional economic development by improving resource allocation and use efficiency. Each region must break through the restrictions of the geographical environment. Cultivate new drivers and realize new breakthroughs and important channels for overtaking on corners[33]. Digital technology will promote the recombination of rural tourism resources in time and space, reshape the state of rural tourism, and help rural tourism conduct digital marketing and management to achieve high-quality development[34]. The deep integration of the digital economy and the real economy has become an important driving force for the high-quality development of China's cultural industry in the new era. It is highlighted in the four aspects of science and technology involved in the whole process of cultural production: innovation becoming the new core of industrial development, integration and opening up new space for industrial development, and the new vitality of talent enabling industrial development[35].

Scholars have extensively explored the impact and challenges of the digital economy. The digital economy has had a positive impact on economic growth, employment structure, industrial structure, and other aspects, and has improved economic efficiency and competitiveness. However, the digital economy also faces challenges such as data security, privacy protection, and technological ethics. Zhou pointed out that the digital economy has a "double-edged sword" effect; capital logic, technical logic, market logic, and other disadvantages affect the process of common prosperity[36]. Xie and He need to deal with the market risks of the digital economy in a law-based way. First of all, standardize the technology, use standards, and use methods of the digital economy in a legal way. Secondly, to promote the compliance construction of digital economy subjects by law and, at the same time, the legal supervision of the digital economy market[37]. Scholars have researched these challenges and put forward the corresponding solutions and policy recommendations. Tang proposed that the fault-line interaction between technology and supervision intensifies the impact of technology security risks, flow security risks, and service security risks on national data sovereignty. A systematic supervision mechanism should be built through legal incentives and technical guidance[38].

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 laws of the digital economy but also provide theoretical support and policy guidance for the practice of the digital economy. 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[39]. 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 the environmental quality to promote economic and social development through urban digital green development[40].

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 and 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 of 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.

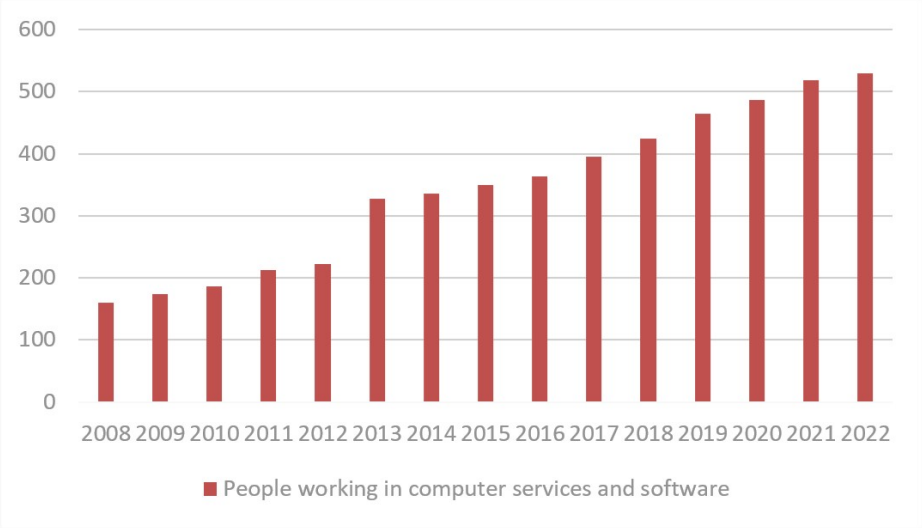

Figure 1. Employed in the computer services and software industry from 2008 to 2022.

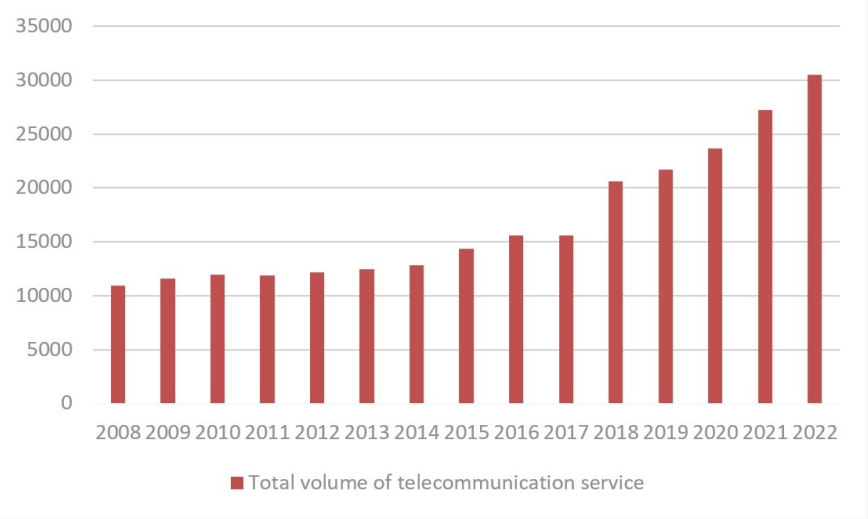

Figure 2. Total volume of telecommunication service from 2008 to 2022.

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 very rapid growth. This shows that China's investment and construction in the telecommunications field are 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 it also provides strong support for the construction of China's digital infrastructure.

3.1.2. Elements of digital innovation

The green elements of digital innovation can be reflected in 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 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.

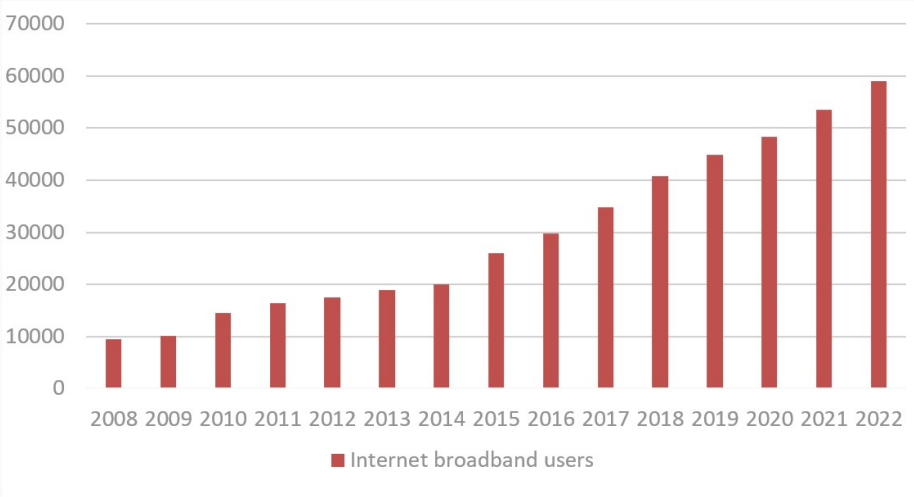

Figure 3. The number of internet broadband users in China from 2008 to 2022.

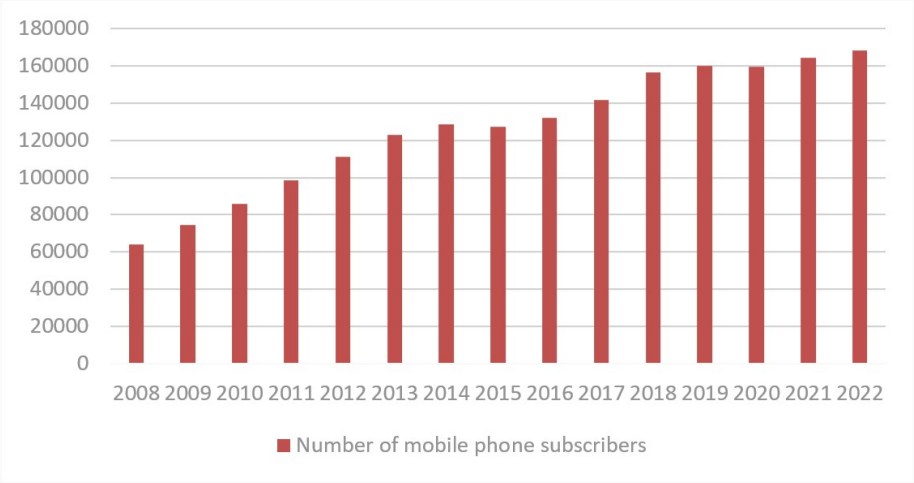

Figure 4. Number of mobile phone users in China from 2008 to 2022.

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 payments, social media, and so on. This has further promoted the development of the digital economy and also brought great convenience to people's lives.

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 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.

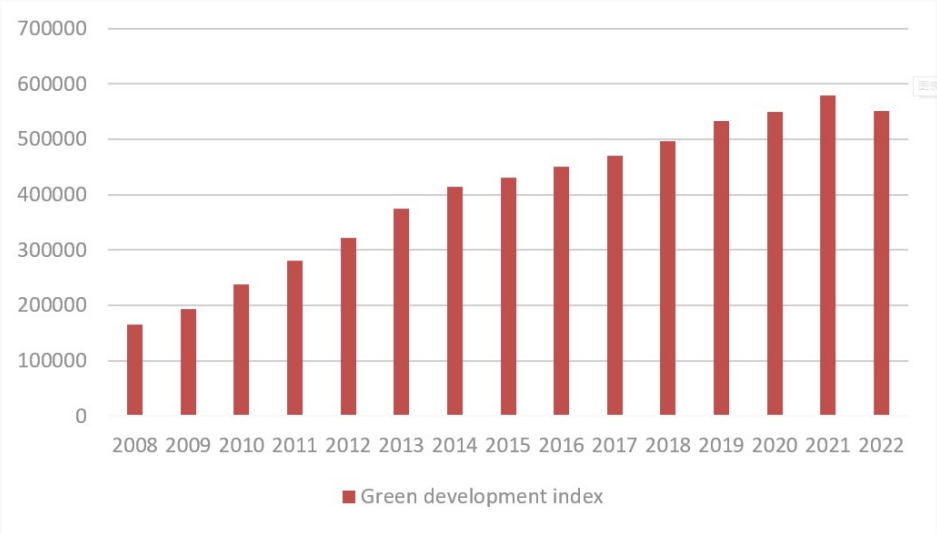

Figure 5. China green development index from 2008 to 2022.

4. Variable selection

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

Table 1. Green development index 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 variable; 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 the 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.

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

where Y is the explained variable; X_j (j = 1, 2, ..., k) is a k explanatory variable; β_j (j = 0, 1, 2, ..., 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, ..., X_K of the linear equations e.g.

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

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

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_{Ki} X_{Ki} + \mu_i (i = 1,2,\ldots,n)$$

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

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

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

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 Eviews10.0:

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

Through the EVIEWS10.0 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 fririch 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, it shows that 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 for 2008–2022, listed in this paper, the national green development index and the development degree of the 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" periods, 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 will increase by 1 person, making the green development index increase by 305.63. So in 2022, a total of 5.292 million people in the computer services and software industry will drive the green development index greatly, reflecting that the increase in computer services and software industry employees will have a significant impact on the green development index. With the increase in computer service practitioners, the innovation ability in the field will be improved, promoting the research, development, and application of green technology. These technologies help to reduce resource consumption, improve energy efficiency, reduce pollution emissions, and promote the industry toward green, low-carbon, circular transformation. The transformation of the industry directly affects the growth of green development efficiency in China. According to the model, with mobile Internet users per

person, the green development index increased by 2.87. With the increase in mobile Internet users, the speed and scope of information dissemination have been greatly expanded, which means that information about environmental protection and a green way of life can spread faster to a wider audience. Mobile Internet users increase, and computing services and software industry employees represent the development of the digital economy through the optimal allocation of resources, energy conservation, and emissions reduction, promoting the development of the green industry, improving the efficiency of resource utilization, and promoting information sharing and cooperation to promote the green development index.

6. Conclusion and countermeasure

6.1. Conclusion

Nowadays, 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 testing 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.

6.2. 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:

6.2.1. 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 computers, actively introduce overseas talents to meet the needs of the development of the digital economy, strengthen the skill training of computer practitioners, and improve their professional skills and innovation abilities so as to promote the research, development, and application of green technology.

6.2.2. 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 a more green themes for 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, and improve user trust of mobile Internet and use so as to promote the effective dissemination of green information and applications.

6.2.3. 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, so as to promote the coordinated progress of digital economy and green development.

6.2.4. 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.

Author contributions

Writing—original draft preparation, YW and XL; writing—review and editing, SY and YW. All authors have read and agreed to the published version of the manuscript.

Availability of data and materials

The data presented in this study are available on request from the corresponding author.

Funding

This research was funded by Philosophy and Social Sciences Planning Project of the Ministry of Education grant number [21YJCZH203].

Conflict of interest

The authors declare no conflict of interest.

References

1. Cao K, Long S. Space and temporal differentiation and spatial spillover effect analysis of the green development efficiency of urban tourism in China (Chinese). *Resources and Environment in the Yangtze Basin* 2024; 33(1): 1–13.
2. Li L. *Research on the Influence of Digital Economy Development on the Green Transformation of Manufacturing Industry* (Chinese) [PhD thesis]. Jilin University; 2023.
3. Yin S, Zhao Y. Digital green value co-creation behavior, digital green network embedding and digital green innovation performance: Moderating effects of digital green network fragmentation. *Humanities and Social Sciences Communications* 2024; 11(1). doi: 10.1057/s41599-024-02691-5
4. Wang X, Li J. Is the digital economy effective in promoting energy conservation and carbon emission reduction (Chinese). *China Population, Resources and Environment* 2022; 32(11): 83–95.
5. Zhang N, Yin J, Zhang N, et al. Artificial intelligence-driven photovoltaic building materials industry: Greenization and digitization innovation conversion of photovoltaic technology based on a novel interval fuzzy field theory decision-making model. *Journal of Intelligent & Fuzzy Systems* 2024; 46(3): 6411–6437. doi: 10.3233/jifs-234838
6. Zou Y, Han B. Research on China's economic green development index in the new era (Chinese). *Administration Reform* 2022; 9: 31–43. doi: 10.14150/j.cnki.1674-7453.2022.09.009

7. Yin S, Gao Z, Mahmood T. Artificial intelligence-driven bioenergy system: Digital green innovation partner selection of bioenergy enterprises based on interval fuzzy field model. *Kybernetes* 2023. doi: 10.1108/k-08-2023-1495
8. Zhao X, Wei X. Research on the effect and mechanism of regional green development in digital economy—Based on the intermediary effect of technological innovation and industrial upgrading (Chinese). *Journal of Southwest University (Natural Science Edition)* 2023; 45(8): 21–30. doi: 10.13718/j.cnki.xdzk.2023.08.003
9. Yao Y, Zhang Y, Xie Y. Evaluation system and empirical study of green development in urban and rural construction (Chinese). *Intelligent City* 2023; 9(9): 64–67. doi: 10.19301/j.cnki.zncs.2023.09.019
10. Huang J, Xu Z. Spatial effect and transmission mechanism of technological innovation on green development: Based on the empirical evidence of the Yangtze River Delta urban agglomeration (Chinese). *Journal of Industrial Technology and Economy* 2024; 43(2): 98–105.
11. Yin S, Liu L, Mahmood T. New trends in sustainable development for Industry 5.0: Digital green innovation economy. *Green and Low-Carbon Economy* 2023. doi: 10.47852/bonviewglce32021584
12. Lv W. Create institutional mechanisms and policy environment conducive to green development (Chinese). *Economic Review Journal* 2016; 2: 4–8. doi: 10.16528/j.cnki.22-1054/f.201602004
13. Lv X, Wang Y, Liu L, et al. Digital green innovation economy for Industry 5.0. *Sustainable Economies* 2024; 2(1): 8. doi: 10.62617/se.v2i1.8
14. Li J, Xu B. "Curse" or "Gospel": How does resource abundance affect China's green economic growth (Chinese). *Economic Research Journal* 2018; 53(9): 151–167.
15. Bob H, Mary L. *1991-1992 Green Index: Evaluation of Environmental Quality in US States* (Chinese). Beijing Normal University Press; 2011.
16. Zhou W. Does regional market integration improve the efficiency of urban green development: Empirical analysis based on the unified large market in the Yangtze River Delta (Chinese). *Lanzhou Academic Journal* 2024; 3: 28–45.
17. Zhu J, Wang T, Du Y. Study on the efficiency and influencing factors of green development in Shandong Province (Chinese). *Territory & Natural Resources Study* 2024; 2: 37–41. doi: 10.16202/j.cnki.tnrs.2024.02.008
18. Zhang W, Deng L, Yin C. Evaluation of green economic efficiency and analysis of influencing factors in major node cities of "Belt and Road" (Chinese). *Inquiry into Economic Issues* 2017; 11: 84–90.
19. Wang X, Wei Q, Yang X. Dynamic evaluation of urban green economy efficiency and influencing factors—Based on the data analysis of 285 cities at or above the prefecture level (Chinese). *Ecological Economy* 2017; 33(2): 68–71.
20. Wang Q, Hu A, Xin Y. Can the digital economy promote green development: Empirical test based on energy saving, emission reduction and efficiency enhancement mechanism (Chinese). *Journal of Business Economics* 2022; 11: 44–59. doi: 10.14134/j.cnki.cn33-1336/f.2022.11.004
21. Rugman AM, Verbeke A. Corporate strategies and environmental regulations: An organizing framework. *Strategic Management Journal* 1998; 19(4): 25–36. doi: 10.1002/(SICI)1097-0266(199804)19:4<363::AID-SMJ974>3.0.CO;2-H
22. Wang D, Zhu B, Tao Z. The coupled coordination study of green development and common prosperity (Chinese). *Journal of Nanning Normal University (Philosophy and Social Sciences Edition)* 2024; 45(1): 63–80. doi: 10.16601/j.cnki.issn2096-7349.2024.01.006
23. Wu L, Chen W, Lin L, Feng Q. Research on the influence of innovation and green technology innovation on enterprise total factor productivity (Chinese). *Journal of Applied Statistics and Management* 2021; 40(2): 319–333. doi: 10.13860/j.cnki.sltj.20200818-007
24. Zeng X. Regional environmental efficiency and its impact factors in China (Chinese). *Economic Theory and Business Management* 2011; 10: 103–110.
25. Huang J, Lu H, Wang L. The mechanism of financial development affecting regional green development is based on ecological efficiency and spatial measurement (Chinese). *Geographical Research* 2014; 33(3): 532–545.
26. Li S, Zhou T, Fan L. Urban green development and influencing factors of the Yangtze River Economic Belt (Chinese). *Statistics & Decision* 2019; 35(15): 121–125. doi: 10.13546/j.cnki.tjyjc.2019.15.028
27. Yu Y, Yin S, Zhang A. Clean energy-based rural low carbon transformation considering the supply and demand of new energy under government participation: A three-participators game model. *Energy Reports* 2022; 8: 12011–12025. doi: 10.1016/j.egyr.2022.09.037
28. Tapscott D. *The Digital Economy: Promise and Peril in the Age of Networked Intelligence*. Mc Graw-Hill; 1996.
29. Ding Z. Reform of traditional industries driven by information consumption: Basic connotation and internal mechanism (Chinese). *Economist* 2020; 3: 87–94. doi: 10.16158/j.cnki.51-1312/f.2020.03.009
30. Dahlman C, Mealy S, Wermelinger M. Harnessing the digital economy for developing countries. *OECD Development Centre Working Papers* 2016; 3: 11–15.
31. Chen X, Li Y, Song L, Wang Y. The theoretical system and research prospect of digital economy (Chinese). *Journal of Management World* 2022; 38(2): 208–224+13–16. doi: 10.19744/j.cnki.11-1235/f.2022.0020

32. Li X. The endogenous impetus for the development of digital economy in China (Chinese). *People's Tribune* 2023; 17: 26–30.
33. Zhang K, Yang D, Zhao H, et al. Digital economy is a new driving force to promote regional economic development (Chinese). *Regional Economic Review* 2022; 3: 8–19. doi: 10.14017/j.cnki.2095-5766.2022.0061
34. Li W. Digital economy enables high-quality development of rural tourism: Research on dynamic mechanism and path (Chinese). *Foreign Economic Relations & Trade* 2024; 2: 78–81+157.
35. Che S, Wang Q. Change and path selection of the high-quality development of cultural industry in the era of digital economy (Chinese). *Academic Exchange* 2022; 1: 114–125+192.
36. Zhou Y. Digital economy promotes common prosperity: Advantage of development, risks and challenges, and practical paths (Chinese). *Journal of Hubei University of Economics (Humanities and Social Sciences)* 2024; 21(3): 10–13.
37. Xie P, He Z. Structure development, causes analysis and legal response of market risks of digital economy (Chinese). *Journal of Yunnan University for Nationalities (Philosophy and Social Sciences Edition)* 2024; 41(2): 108–114. doi: 10.13727/j.cnki.53-1191/c.20240305.007
38. Tang J. Risk performance and rule of law strategy in the sustainable development of digital economy (Chinese). *The Journal of Humanities* 2024; 2: 121–130. doi: 10.15895/j.cnki.rwzz.2024.02.003
39. Yin S, Zhao Y. An agent-based evolutionary system model of the transformation from building material industry (BMI) to green intelligent BMI under supply chain management. *Humanities and Social Sciences Communications* 2024; 11(1). doi: 10.1057/s41599-024-02988-5
40. Yin S, Zhao Z. Energy development in rural China toward a clean energy system: Utilization status, co-benefit mechanism, and countermeasures. *Frontiers in Energy Research* 2023; 11. doi: 10.3389/fenrg.2023.1283407