Study on the Impact of Digital Economy on Eco-efficiency-Based on Panel Data from 30 Provinces in China

Shuangshuang Han

School of Economics and Management, North China University of Technology, Beijing, China
Email: 1626665630@qq.com (S.S.H.)
Manuscript received September 27, 2023; revised October 26, 2023; accepted November 29, 2023; published April 23, 2024.

***Abstract*—At present, the digital economy has become an important factor of production in China, which is a new driving force for economic development. Ecological efficiency is an important indicator to measure the sustainable development of economy. Studying the impact of digital economy on ecological efficiency is of great significance for high-quality economic development. This paper mainly studies the impact mechanism of digital economy on ecological efficiency. The research finds that: (1) the level of digital economy development has been on the rise since 2011, and the average of digital economy development in China's provinces will reach a medium level in 2021. (2) Digital economy has a positive impact on ecological efficiency, and can have a mediating impact on ecological efficiency through technological progress.**

***Keywords*—digital economy, economic development, ecological efficiency, technological progress**

I. Introduction

Since the reform and opening up, China's economy has achieved rapid sequential growth, making China the world's second largest economy with a GDP of 5.75 trillion US dollars in 2010, and China's per capita GDP of 12,700 US dollars in 2022. However, behind the rapid development of China's economy is high energy consumption and high pollution as the price, its characteristics include the inefficient rate of energy use, backward production technology and low coordination of resource allocation, resulting in China's economic development accompanied by high-intensity waste emissions and energy waste, which has caused great pressure on China's ecological environment.

After the third industrial revolution, the rapid development of the Internet, digital economy has become a new factor of production after labor, land, capital and other traditional factors of production, which gradually occupies an important position in people's production activities and life activities: According to the "China Digital Economy Development Index White Paper 2023" shows that the scale of China's digital economy has reached 50.2 trillion yuan, the proportion of digital economy has reached 41.5%, and the sequential nominal growth rate is higher than the sequential nominal CDP nominal growth rate for 11 consecutive years. This indicates that the digital economy has a driving effect on China's economic growth and has occupied a position that cannot be ignored in the economic development. The report pointed out that the development of the digital economy should be accelerated, and efforts should be made to build internationally competitive digital industrial clusters. It also mentioned ecological protection several times. In this context, it is of practical significance to study the impact of digital economy on ecological efficiency to solve the current deterioration of ecological environment.

II. Literature

A. Digital Economic

Different from traditional economic forms, the digital economy relies on the popularization of the Internet as the foundation, and speeds up the flow of information between producers and consumers, between producers and consumers, and between consumers. "Digital economy" first appeared in 1996, Canadian economist, Don (1996) mentioned in the book "Digital Economy", he systematically analyzed the mechanism of Internet for economic development and the changes it brings to economic development. Chinese economist Jiang (1998) argued in his book The Emerging Digital Economy that information elements will promote economic development, and the change of information technology will cause a great change in economic operation mode. Zhang *et al.*, (2018) and Liu *et al.*, (2020) both believe that digital economy is an emerging economic form that uses digital technology to provide information products or services and transactions under the support of the development of the Internet. Kang (2008) pointed out that the development of digital economy is not independent of traditional industries, but will establish a close relationship with the traditional economy to promote the common development of both. The measurement indicators of digital economy are not consistent. Some scholars use the Peking University Digital Financial Inclusion Index to represent digital economy; Some scholars believe that the development of digital economy is based on the popularization of the Internet, and choose the Internet penetration rate to represent the digital economy. For example, Yang (2023) uses the number of Internet broadband access ports to measure the digital economy; Zhao *et al.*, (2020) measured the digital economy by five indicators, including digital financial inclusion index and Internet penetration rate.

B. Ecological Efficiency

Eco-efficiency expresses the connotation of getting more economic utility with less environmental cost. As eco-efficiency is of great significance to sustainable economic development, there are abundant researches on eco-efficiency evaluation by scholars in various countries. At present, the evaluation of ecological efficiency mainly includes the following methods: ratio method, parameter estimation method, comprehensive index method, data envelopment analysis method, life cycle method, etc. At present, the main

doi:10.18178/joebm.2024.12.2.786

method is to use Data Envelopment Analysis (DEA) to study ecological efficiency. Dyckhoff *et al.,* (2001) used DEA model to evaluate eco-efficiency. Yu *et al.,* (2008) used C2R model in DEA model to evaluate and analyze eco-efficiency in various regions of China. Wei *et al.,* (2022) used the super-efficiency SBM model with non-expected output to estimate the regional eco-efficiency indicators of 30 provinces in China from 2007 to 2019. Qiu (2022) used the GML index to evaluate the ecological efficiency of the Yangtze River Economic Belt and the Yellow River Basin, and found that the ecological efficiency of the Yangtze River Economic Belt was higher than that of the Yellow River Basin. In the evaluation of eco-efficiency, the input factors were mostly water resources, energy resources, land resources, labor resources and capital resources involved in production, while the output factors were expected output GDP and non expected output of waste gas, wastewater and solid waste.

C. Digital Economy and Eco-efficiency

At present, most scholars have studied the impact of digital economy on industrial structure, innovation efficiency and economic development. For example, Zhong *et al.* (2023) studied the relationship between digital economy and industrial upgrading of the service industry, and found that digital economy will significantly promote the structural upgrading of the service industry. Wen *et al.,* (2023) found that the digital economy has a significant positive impact on regional innovation efficiency, while the inter-regional spillover effect is not obvious. He (2022) found that digital finance has a positive impact on economic development through empirical analysis. Some scholars also study the impact of digital economy on ecological efficiency. Hao *et al.,* (2022) believe that digital economy can improve ecological efficiency by promoting industrial upgrading. He *et al.,* (2022) studied the relationship between ecological efficiency and digital economy and found that digital economy can promote ecological efficiency.

there are few researches on the impact of digital economy on ecological efficiency, and they are not perfect. On the basis of previous studies, this paper studies the direct impact of digital economy on ecological efficiency and the intermediary impact of digital economy on ecological efficiency.

III. Theoretical Hypothesis and Model Setting

A. Theoretical Hypothesis

The meaning of eco-efficiency is the ratio of economic added value to the negative impact on the environment. The eco-efficiency value reflects the efficiency of resource use in a region, which aims to improve the level of satisfying human needs and reduce the negative impact on the environment under the condition of limited resource input. First of all, the digital economy, with its own characteristics of "low energy consumption, low pollution emission and high speed" of digital information transmission, can promote the rational allocation of production factors. For example, producers can establish supply chain platforms to contact upstream suppliers and downstream consumers, adjust production in time and finally improve the utilization level of production factors through information exchange. Thus can effectively promote the improvement of ecological efficiency; Secondly, the digital economy can effectively reduce the asymmetry of information in the production process and accelerate the flow of resources, technology and talents to improve production efficiency. Finally, for consumers, they can use the Internet to get familiar with environment-friendly products and guide consumers to consume green.

H0: The digital economy has a positive impact on ecological efficiency.

Secondly, the digital economy can promote technological advances to impact ecoefficiency. By digitizing technology, the digital economy speeds up the information transmission mechanism, thereby gradually lowering technological barriers. Sheng (2023) proposed that digital economy can improve technological progress by reducing information asymmetry and optimizing the allocation of human capital, capital, information and other factors, and finally improve labor productivity and ecological efficiency by means of technological progress.

H1: The digital economy can affect eco-efficiency by influencing technological progress.

B. Model Setup

To examine the impact of the digital economy on eco-efficiency, the following models were developed:

$$EEF = \beta_0 + \beta_1 DED + \beta_2 OPEN + \beta_3 EI + \beta_4 UR + \beta_5 PGDP + \lambda_t + \mu_i + \varepsilon_{it} \quad (1)$$

In Eq. (1), EEF is the explained variable ecological efficiency, DED is the core explanatory variable digital economy development level, and $OPEN$, EI, UR and $PGDP$ are control variables, respectively representing the level of opening to the outside world, the level of environmental regulation, the rate of urbanization and the level of economic development. $\beta_0$is the intercept term, β_1, β_2, β_3, β_4, and β_5 are the coefficients of each dependent variable , λ_t represents the time effect that does not change with the individual, μ_i represents the individual effect that does not change with the time, and ε_{it} is the random disturbance term.

In order to test the mediating effect of whether digital economy can affect eco-efficiency by influencing technological progress, the following model is set up: where is TI technological progress, only when γ_1, γ_2 and α_1 are significantly positive can it be proved that digital economy affects eco-efficiency by influencing technological progress.

$$TI = \alpha_0 + \alpha_1 DED + \alpha_2 OPEN + \alpha_3 EI + \alpha_4 UR + \alpha_5 PGDP + \lambda_t + \mu_i + \varepsilon_{it} \quad (2)$$

$$EEF = \gamma_0 + \gamma_1 DED + \gamma_2 TI + \gamma_3 OPEN + \gamma_4 EI + \gamma_5 UR + \gamma_6 PGDP + \lambda_t + \mu_i + \varepsilon_{it} \quad (3)$$

IV. Variable Selection

A. Explained Variable: Ecological Efficiency

In this paper, the super-efficiency EBM model is selected, which combines the advantages of radial DEA and non-radial DEA, and can calculate the nearest distance from DMU value to the front surface. The super-efficiency model can compare DMU on the front surface, so this paper adopts the super-efficiency EBM model for calculation.

Table 1. Ecological efficiency indicators

	Name of indicator	Indicator description	Unit
Input indicators	Water consumption	Total water use	Billion cubic meters
	Labor input	Number of employed persons at year-end	10,000
	Energy consumption	Tons of standard coal	Tons of standard coal
	Land use area	Agricultural land and construction land area and	10 thousand hectares
	Capital stock	Current capital stock	Hundred million yuan
Desired output indicator	GDP	Gross Domestic Product	Billion yuan
Non-desired output indicator	Effluent discharge	Total discharge of industrial and domestic wastewater	Tons
	General industrial solid waste emissions	Industrial solid waste discharge	Tons
	Composite exhaust emission index	Carbon dioxide, sulfur dioxide, dust emissions	Tons

In this paper, for the input variables and output variables of ecological efficiency, on the basis of referring to previous studies, since China currently takes "low carbon emission reduction", "carbon peaking" and "carbon neutrality" as the focus of environmental governance, this paper adds carbon dioxide emission as the non-expected output. For the input index, starting from resource input, labor input and capital input, combined with the current situation of production factor input in China, water resource consumption, energy consumption and land use area are selected as resource input, employed population is selected as labor input and capital stock is selected as capital input. For the output index, GDP is selected as the expected output index, and waste water, waste gas and industrial solid waste contained in the "three wastes" are selected as the non-expected output index. Since units have no influence on the measurement of ecological efficiency, the units of input and output indicators are consistent with those in China Statistical Yearbook. The input-output indicators are shown in the table below:

Data sources and processing: The data in this paper are mainly from China Statistical Yearbook and provincial Statistical Yearbook, and the provincial carbon emission data are from MEIC database. Due to the serious lack of data in Tibet, the sample of this paper is selected from 31 provinces except Tibet, Hong Kong, Macao and Taiwan, and the study period from 2011 to 2021 is selected. The values related to the GDP deflator are treated as the data expressed with the year 2000 as the base period. The missing values of water resources consumption, energy consumption and land use area are supplemented by the interpolation method. The comprehensive exhaust gas emission index is obtained by the entropy weight method of carbon dioxide emission, sulfur dioxide emission and dust (particulate matter) emission. The weights are 0.33, 0.33 and 0.34 respectively. The capital stock is calculated with the fixed capital price as the base period of 2000, so as to obtain the real fixed capital investment. The treatment of the capital stock refers to the calculation method of the capital stock proposed by Ke and Juan (2013) and Zhang (2021), and the capital investment cycle is set at three years. The capital is divided into fixed assets of buildings, fixed assets of production equipment and other equipment and tools. The depreciation life of fixed assets of buildings is 38 years, the depreciation life of fixed assets of production equipment is 16 years, the depreciation rate is 8.12% and 17.08% respectively, and the depreciation rate of other equipment and tools is 12.01%. As shown in Eq. (4) and (5), where, K_t, K_{t-1} respectively, is the capital stock of period t and period $t-1$, δ_{t-1} is the capital depreciation rate of period $t-1$, w_{1t}, w_{2t}, w_{3t}, is the proportion of building fixed assets, production equipment fixed assets and other equipment and tools assets in the total assets of period t, and δ_1, δ_2, δ_3 is the depreciation rate of three types of assets respectively, $Kt-1$ thus obtaining a more accurate capital stock.

$$K_t = K_{t-1}\,(1-\delta_{t-1}) + (I_t + I_{t-1} + I_{t-3})/3 \quad (4)$$

$$\delta_t = w_{1t}\delta_1 + w_{2t}\delta_2 + w_{3t}\delta_3 \quad (5)$$

B. Core Explanatory Variable: Digital Economy Development Level (DED)

The connotation of digital economy includes the popularization of Internet and the output of digital economy. For the measurement of the development level of digital economy, this paper refers to the index measurement method of Tao (2020) and measures the digital economy from the Internet penetration rate, the number of Internet-related employees, Internet-related output, the number of mobile Internet users and the digital financial inclusion index. The next two indexes of the index are shown in Table 2:

Table 2. Digital economy development indicators

	First-level indicators	Indicator Description	Indicator Properties
Level of Development of Digital Economy (DED)	Internet penetration	Number of Internet users per 100 people	+
	Number of Internet related employees	Percentage of employees in computer services and software	+
	Internet-related output	Total telecommunications services per capita	+
	Number of mobile Internet users	Number of mobile phones per 100 people	+
	Inclusive development of digital finance	China Digital Financial Inclusion Index	+

Data source and processing: The above five indicators are from the China Statistical Yearbook and the Digital Financial Inclusion Index report compiled by Peking University. Since entropy weight method is an objective method of empowerment and is suitable for the evaluation of the development level of digital economy, entropy weight method is adopted to empower each index. As the dimensions of the above five indicators are different and the difference is large, before the entropy weight method, all the five indicators are standardized. The standardization formula is as follows, where is the observation value of the first observation object of the first indicator, X_{imin} is the minimum observation value of the first indicator, and X_{imax} is the maximum observation value of the i indicator.

(1) Data standardization processing:

$$X_{ij} = \frac{x_{ij} - X_{imin}}{X_{imax} - X_{imin}} \tag{6}$$

(2) The entropy weight method determines the weight of each index, Calculate the entropy of information:

$$\mathrm{H_j} = -\mathrm{k} \sum \mathrm{p_{ij}} \ln \mathrm{p_{ij}} \tag{7}$$

where, $\mathrm{p_{ij}} = \frac{\mathrm{x_{ij}}}{\sum_{i=1}^{m} \mathrm{x_{ij}}}$; $\mathrm{k} = \frac{1}{\ln \mathrm{m}}$.

(3) Define the weight of indicator j:

$$\mathrm{w_i} = \frac{1 - \mathrm{H_j}}{\sum_{j=1}^{n} (1 - \mathrm{H_j})} \tag{8}$$

(4) Construct weighting matrix $R = (r_{ij})_{m*n}$, where $r_{ij} = w_j \times x_{ij}$ $(i = 1,2,\dots,m; j = 1,2,\dots,n)$.

(5) Determine the optimal solution S_j^+ and the worst solutionS_j^-:

$$S_j^+ = max(r_{1j}, r_{2j}, \dots, r_{nj}) \tag{9}$$

$$\mathrm{S_j^-} = \min(\mathrm{r_{1j}}, \mathrm{r_{2j}}, \dots, \mathrm{r_{nj}}) \tag{10}$$

(6) Euclidean distance from the calculation scheme to the optimal solution and the worst solution:

$$\mathrm{sep_i^+} = \sqrt{\sum_{j=1}^{n} (\mathrm{s_j^+} - \mathrm{r_{ij}})^2} \tag{11}$$

$$\mathrm{sep_i^-} = \sqrt{\sum_{j=1}^{n} (\mathrm{s_j^-} - \mathrm{r_{ij}})^2} \tag{12}$$

(7) Calculate the comprehensive evaluation index:

$$\mathrm{C_i} = \frac{\mathrm{sep_i^-}}{\mathrm{sep_i^+} + \mathrm{sep_i^-}}, \mathrm{C_i} \in [0,1] \tag{13}$$

C. Mediating Variables

Technological progress (TI) is the intermediary variable. The digital economy affects technological progress and then affects ecological efficiency by reducing information asymmetry, optimizing talent allocation and promoting resources. The technological progress variable is expressed by the number of 10,000 patent grants.

D. Control Variables

Level of opening to the outside world: Foreign export is conducive to solving the contradiction of insufficient effective demand in China. Foreign investment helps to upgrade China's industrial structure, and brings China's technology level into line with international standards. It also brings many jobs, helps to upgrade China's industrial structure, technological progress, and ultimately reduces pollutant emissions, improves resource utilization efficiency and GDP, and ultimately helps to improve ecological efficiency. Opening to the outside world includes import and export and investment, limited to the availability of data, this paper will use the proportion of import and export and foreign investment to express, and adopt the entropy weight method to obtain the final index.

Environmental regulation level (EI) refers to the extent to which the government adopts environmental protection tax, environmental governance investment and other means to carry out environmental governance. The adoption of environmental tax will directly affect the production cost of enterprises, so that enterprises must optimize the energy structure and improve the technical level to reduce pollutant emission in order to reduce the production cost, so as to achieve the improvement of ecological efficiency. The adoption of environmental governance investment can directly reduce pollutant emissions and promote ecological efficiency.

Urbanization Rate (UR) The ratio of urban population to total population of each province indicates that urbanization means industrial agglomeration, population agglomeration and economic agglomeration, which will have an impact on ecological efficiency. According to Li (2022), the impact of urbanization rate on ecological efficiency has a threshold effect.

The level of economic development (PGDP) will directly affect the ecological efficiency. Per capita GDP is used to represent the level of economic development. According to previous studies, the level of economic development has a positive impact on ecological efficiency, and the higher the level of economic development, the higher the ecological efficiency will be.

V. Analysis of Results

A. Ecological Efficiency

The ecological efficiency of 30 provinces was measured by MAX.DEA software and EBM model with super efficiency, global reference and variable scale was selected for calculation. The evolution process of ecological efficiency over time was shown in the following figure: As can be seen from Fig. 1, the eco-efficiency values of the eastern provinces of Beijing, Tianjin, Shandong, Jiangsu, Zhejiang, Shanghai, Fujian, Guangdong and Hainan have always been at a high level, which is speculated to be mainly due to the high level of economic development and industrial structure in these provinces, so the eco-efficiency is high. In the west, Qinghai and Ningxia always have high eco-efficiency, because these regions are in the state of low emission and low pollution, so they have high eco-efficiency; In the northeast, the ecological efficiency was at the medium level in 2011, and then gradually decreased, and its average ecological efficiency was at a low level, which is speculated to be due to the high emission of pollutants and the relatively small proportion of the tertiary industry. In other regions, such as Xinjiang, Inner Mongolia, Hunan, Hubei, Henan and Hebei, eco-efficiency was at a medium level in 2011, then gradually decreased, and was at a low level in 2015, and then gradually increased. It is speculated that from 2011 to 2015, the proportion of the secondary industry was still in the process of increasing, and the proportion of the tertiary industry increased after 2015. Subsequently, the eco-efficiency gradually increased.

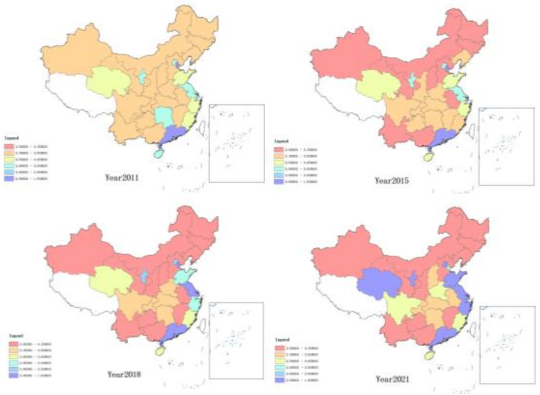

Fig. 1. Evolution of provincial eco-efficiency.

B. Development Level of Digital Economy

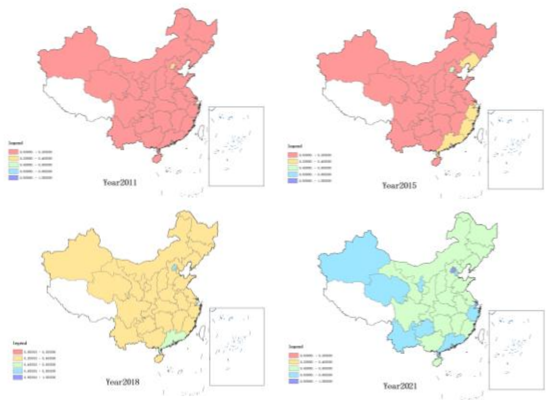

Fig. 2. The evolution trend of the development level of the digital economy.

The development level of digital economy is measured by entropy weight method, and its calculation results are shown in Fig. 2. below. It can be seen that the development level of China's digital economy shows a gradual rising trend from 2011 to 2021, from the average level of digital economy development in 2011 to the average level of digital economy development in 2021 is 0.567. It can be seen that the development level of China's digital economy has achieved a qualitative leap in the past ten years. Among them, Beijing and Shanghai have a higher level of digital economy development. Beijing and Shanghai are both cities with a higher level of economic development, and their Internet penetration rate and Internet enterprises are more, so the development level of digital economy is higher.

C. Analysis of Benchmark Regression Results

Stata was used to perform regression processing on the data. Before regression, descriptive statistics were performed on the data. This empirical analysis included 330 samples from 30 provinces and 11 years. The mean value of Ecological Efficiency (EEF) is 0.636, and the standard deviation is 0.219, indicating that the average ecological efficiency in China is at a medium high level and the degree of dispersion is low. The mean value of Digital Economic Development level (DED) is 0.188, indicating that China's digital economic development level is in the developing stage from 2011 to 2021, and its standard deviation is 0.225, indicating a low degree of dispersion. The mean value and standard deviation of intermediate variable technology progress (TI) were 13.056 and 15.415, indicating a higher degree of dispersion. The standard deviation of other control variables is small, the mean level of environmental regulation (EI) is 0.137, the mean level of opening to the outside world (OPEN) is 0.091, the Urbanization Rate (UR) is 0.596, and the mean level of economic development (PGDP) is 10.294.

Table 3. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EFF	330	0.636	0.219	0.318	1.137
DED	330	0.188	0.225	0.010	1.01
TI	330	13.056	15.415	0.872	90.808
EI	330	0.137	0.119	0.008	0.829
OPEN	330	0.091	0.109	0.001	0.707
UR	330	0.596	0.121	0.350	0.896
PGDP	330	10.294	0.418	9.218	11.43

In order to define the panel regression model, the Hausman test was carried out in this paper and passed the 5% significance test level. The individual fixed effect model was used for panel regression in this paper. The regression results are shown in Table 4 below: Among them, the development level of digital economy has a positive promoting effect on the improvement of ecological efficiency, and it is effective at the significance level of 95%, so the H0 hypothesis is correct. Among the control variables, environmental regulation level (EI), opening to the outside world (OPEN) and economic development level (PGDP) all have a positive impact on ecological efficiency, while urbanization level (UR) has a negative impact on ecological efficiency. The higher the surface urbanization level, the lower the ecological efficiency.

Table 4. Basic regression results

	(1)	(2)	(3)	(4)	(5)
	EFF	EFF	EFF	EFF	EFF
DED	0.062*** (2.73)	0.0550** (2.40)	0.0517** (2.28)	0.0571** (2.05)	0.0595** (2.16)
EI		0.294*** (2.68)	0.303*** (2.79)	0.312*** (2.79)	0.318*** (2.88)
OPEN			0.250*** (2.93)	0.253*** (2.94)	0.214** (2.48)
UR				−0.000492 (−0.34)	−0.00546** (−2.38)
PGDP					0.0014*** (2.78)
−cons	0.624*** (94.16)	0.585*** (52.01)	0.562*** (34.42)	0.560*** (7.21)	0.551*** (6.87)
R2	0.774	0.773	0.754	0.778	0.801

Note: *p < 0.10, **p < 0.05, ***p < 0.01, t-statistic values in parentheses (the same as below)

D. Regression Results Analysis of Intermediate Effects

The intermediate effect test results are shown in Table 5, where the development level of digital economy has a positive impact on technological progress and is significant at the 90% level, and the impact of technological progress on ecological efficiency is positive and is significant at the 95% level, and the test results of the last Eq. (3) are also significant. Therefore, digital economy can affect ecological efficiency by influencing technological progress.

Table 5. Regression results of intermediary effect

	(1)	(2)	(3)	(4)
	TI	EFF	TI	EFF
TI		0.017***		0.018**
		(3.59)		(2.18)
DED	0.092***	0.040*	0.0516*	0.082*
	(5.33)	(1.69)	(1.96)	(1.92)
EI			0.0343	0.207**
			(0.65)	(2.41)
OPEN			0.351***	0.253***
			(5.18)	(2.94)
UR			−0.126	−0.520**
			(−0.89)	(−2.28)
PGDP			0.193***	0.103*
			(6.13)	(1.91)
−cons	12.039***	0.407*	11.098***	−0.416*
	(11.91)	(1.94)	(34.42)	(−1.85)
R2	0.762	0.735	0.801	0.724

E. Robustness Test

Robustness tests are carried out in the following two ways: First, the periods are divided into 2011–2015 and 2016–2021 respectively to test the stability of the model, and it is found that the baseline regression results are still significant at the 5% level; Secondly, the core explanatory variables were replaced by the digital economy development index, which was replaced by the digital transformation index released by Tencent Research Institute. The results of the benchmark regression were still significant.

VI. Conclusions and Suggestions

This paper analyzes the impact of digital economy on eco-efficiency through individual fixed effect model. The empirical result shows that digital economy can promote ecoefficiency at 95% significance level. In addition, the level of environmental regulation, opening to the outside world and economic development all have a positive impact on ecological efficiency, while the level of urbanization has a negative impact on ecological efficiency. Through the intermediary effect model, it is found that the digital economy can act on technological progress, and then have an intermediary effect on ecological efficiency.

According to the above conclusions, this paper puts forward the following two suggestions: First, vigorously develop the digital economy. The digital economy can effectively optimize the allocation of resources, influence the level of technological innovation, and promote the improvement of ecological efficiency. Internet penetration is the foundation for the development of digital economy. Although China's current level of Internet development is at a relatively high level, there is still room for progress. The popularization of the Internet is the foundation of the development of the digital economy, and the digital economy is the direction of future economic development. Therefore, the popularization of the Internet to the government, enterprises, organizations and individuals should be supported by policies to promote the further development of the digital economy. Second, we should give play to the role of digital economy in promoting technological innovation. Let the digital economy run through the whole process of technological innovation, and promote the synergy of all aspects of technological innovation.

Conflict of Interest

The author declares no conflict of interest.

References

Bingzhou, W., Zhuang, N. 2023. A study on the impact of digital economy on regional innovation efficiency: A test analysis based on provincial panel data. ***East China Economic Management***, 07(22):1–9.

Chengying, H., Cong, L. *et al.* 2022. Research on the influence of digital finance on local economic development. ***Procedia Computer Science***, (202): 385–389.

Dyckhoff, H., Allen, K. 2001. Measuring ecological efficiency with data envelopment analysis (DEA). ***European Journal of Operational Research***, 132(2): 312–325

Haowei, S., Ruzhong, W. 2023. The impact of digital economy on industrial ecoefficiency: An empirical analysis based on the Yangtze River Delta urban agglomeration. ***Finance***, 07(15): 1–12.

Jun, L, Yuanjun, Y. *et al.* 2020. The digital economy measure of China and the driving factors. ***Journal of Shanghai Economic Research***, (6): 81–96.

Liangliang, Z., Xiaofeng, L. *et al.* 2018. Strategic thinking on China's digital economy development. ***Modern Management Science***, (05):88–90.

Mingyue, Y., Yu, X. 2023. The impact of digital transformation on total factor productivity of China's educational service industry. ***Tsinghua University Educational Research***, 44(01): 76–89.

Qiping, J. 1998. Emerging digital economy. Beijing: China Renmin University Press, 25–26.

Shanzi, K., Juan, X. 2012. Estimation of China's urban fixed capital stock from 1996 to 2009. ***Statistical Research***, 29(07):19–24.

Shaohui, Z., Yongze, Y. 2021. Estimation of urban fixed capital stock and productivity convergence analysis in China: 1988-2015. ***China Soft Science***, (07):74–86.

Tao, Z., Zhi, Z. *et al.* 2020. Digital economy, entrepreneurial activity and highquality development: Empirical evidence from Chinese cities. ***Management World***, 4(10): 65–76.

Tapscott, D. 1999. [BOOK REVIEW] The digital economy, promise and peril in the age of networked intelligence. ***Journal of Policy Analysis and Management***, 18(1): 156–168.

Tiexiang, K. 2008. Research on digital economy and its accounting. ***Statistics and Decision***, (05):19–21.

Wei, S., Zebin, J. *et al.* 2022. Spatial effects of environmental regulation on regional eco-efficiency: The moderating effect based on fiscal decentralization. ***Journal of Finance and Economics***, 10:1–12.

Weida, H., Jialong, W. *et al.* 2022. Study on the impact of digital economy development on green eco-efficiency in China: Based on two-way fixed effect model. ***Economic Issues***, 01: 1–8.

Xiaojun, Z., Hu, K. L., Liu, D. X. 2023. Digital economy can assign service industry structure upgrade: Theoretical mechanism and empirical test. ***Journal of Statistics and Decision***, 33 (12)6:11–16.

Xiaoli, H., Yuhong, L. *et al.* 2020. The role of digitalization on green economic growth: Does industrial structure optimization and green innovation matter? ***Journal of Environmental Management***, 325:10–19.

Yu, Z, Qingguo, L. 2008. Data envelope analysis of regional eco environmental economic efficiency. ***Industrial Engineering***, (4):93–98.

Zhaolin, Q. 2022. Analysis on the difference of ecological efficiency between Yangtze River Economic Belt and Yellow River Basin and its influencing factors. ***Contemporary Economic Management***, 44(6): 39–49.

Copyright © 2024 by the authors. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (CC BY 4.0).