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Study on the Impact of Digital Economy on the Development Efficiency of Green Economy under the New Development Pattern

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Abstract: This paper is based on the development data of China's digital economy and green economy from 2012 to 2018, including 30 provinces and cities. Using fixed effect model and intermediary effect model analysis, it is concluded that China's digital economy level has been increasing from 2012 to 2018, and the overall trend of green economy is increasing. At the same time, the development of digital economy promotes technological innovation, which in turn promotes the improvement of green economy efficiency; The development of the digital economy promotes the upgrading of industrial structure, which in turn promotes the improvement of the efficiency of the green economy.

Keywords: Digital economy, Green economy, Industrial structure upgrading, Technological innovation.

1. Introduction

1.1. Research Background

The Party's 20 major development concepts adhere to green development and sustainable development, and green economy has gradually become an important part of economic development. In previous studies, Schou added environmental quality to the utility function to better reflect the economic externalities of cleaning up the environment [1]. Xu Ling Liu applied digital technology to green buildings and brought great economic benefits to green buildings [2]. Holmstrom believes that the recombination capabilities of digital technologies can facilitate the nesting and integration of various elements in the production field [3]. Ling leverage the role of digital technology to enhance corporate awareness, promote product innovation and industrial environment innovation [4]. Rosa Misso elaborated the concept of sustainable development of green tourism and concluded that combining green development and the digital age is an important means to promote sustainable development [5]. Therefore, there is still much room for progress in the study of the impact relationship between digital economy and green economy.

1.2. Research Significance

In the context of China's severe environment and industrial structure, the green economy is taken as a starting point to explore the internal mechanism of digital economy to improve it. Creating a new industrial structure through the digital economy acts on the green economy and expands the potential demand of the market. At present, under the consensus of green cooperation and development reached in the world, protecting the environment, developing new energy and building a sustainable development society has become the general trend.

2. Empirical Research on the Impact of Digital Economy Level on Green Economy Efficiency

2.1. Research Design

2.1.1. Variable selection

(1) Explained variables and explanatory variables

Green Economy Efficiency (Gee). The green economy efficiency is measured by the non-expectation-super efficiency SBM model. Digital Economy Development Level Index (Dig). The entropy value method is used to calculate the digital economy development level index [6].

(2) Control variables

In this paper, 6 factors are selected as control variables. They are environmental regulation (ER), economic development level (GDP), population education level (PEA), foreign direct investment (FDI), government intervention level (Gvn) and urbanization level (UL) [7].

(3) Intermediary variables

Technological innovation (Tech): expressed in terms of R&D expenditure. R&D expenditure is an important index of national technological innovation activities and scale, which reflects the level of independent innovation in a region from one side [8].

Industrial structure (Ind): Value added of tertiary industry/Value added of secondary industry [9].

2.2. Measurement of Digital Economy Level

2.2.1. Selection of Indicators

Select 4 first-level indicators and 16 second-level indicators of the level of digital economy. From this, the comprehensive development index is calculated, as shown in the table.

Table 1. Digital economy index system and its direction

	Primary index	Secondary index	Direction
Digital Economy	Digital technology innovation	R&D appropriation expenditure	+
		Number of patent applications granted	+
		R&D Full-time equivalent of personnel	+
	Industrial digital application	Proportion of telecom business transactions in GDP	+
		Number of employed persons in urban units	+
		Information technology services revenue	+
		The proportion of online retail sales in consumer goods	+
		Number of websites per 100 companies	+
	Digital environment infrastructure	Cable length per unit area	+
		Number of Domains	+
		Number of mobile phone base stations	+
		Broadband access port	+
	Digital terminal application	Mobile phone penetration	+
		Broadband subscriptions	+
		Digital TV penetration	+
		Internet penetration rate	+

2.2.2. Measurement of comprehensive index of digital economy level

(1) Weight of each indicator

The entropy method is used to measure digital economy indicators, and then descriptive statistical analysis of indicators at all levels is carried out to finally draw relevant conclusions, as shown in Table 2.

Table 2. Weights of digital economy indicators

	Primary index	Secondary index	Weight
Digital Economy	Digital technology innovation	R&D appropriation expenditure	0.08988701
		Number of patent applications granted	0.06307751
		R&D Full-time equivalent of personnel	0.07453527
	Industrial digital application	Proportion of telecom business transactions in GDP	0.08033961
		Number of employed persons in urban units	0.08030354
		Information technology services revenue	0.13777325
		The proportion of online retail sales in consumer goods	0.02633427
		Number of websites per 100 companies	0.03881379
	Digital environment infrastructure	Cable length per unit area	0.02754235
		Number of Domains	0.04559247
		Number of mobile phone base stations	0.02572802
		Broadband access port	0.02933665
	Digital terminal application	Mobile phone penetration	0.13043275
		Broadband subscriptions	0.02193046
		Digital TV penetration	0.01350553
		Internet penetration rate	0.11486752

(2) Spatial dimension

From 2012 to 2018, the national digital economy level has been rising, and all regions are in a state of rise. The results show that the digital economy index of the eastern region is the highest, and the digital economy ranks first, followed by the central region, and the western region again, and the eastern region > the country > the central region > the western region.

Table 3. Average development of regional digital economy and its ranking

Area	2012	2013	2014	2015	2016	2017	2018	Average	Ranking
East	0.15	0.21	0.26	0.3	0.32	0.34	0.37	0.28	1
Middle	0.06	0.08	0.13	0.17	0.2	0.22	0.25	0.16	2
West	0.05	0.07	0.09	0.11	0.14	0.16	0.19	0.12	3
Nationwide	0.09	0.13	0.17	0.2	0.23	0.25	0.28	0.19	

(3) Time dimension

The level of China's digital economy has been rising from 2012 to 2018, and the average value of the digital economy has been growing over the years, ranking always in the eastern, central and western regions. The eastern region is leading the digital economy, always above the national average level, and the central and western regions are always below the national average level.

2.3. Calculation of Green Economy Efficiency

2.3.1. Selection of Indicators

This paper selects 2 output indicators and 3 input indicators.

Table 4. Green economy indicators

Primary index	Secondary index	Three-level index
Input index	Labor input	Employment at the end of the year in each province
	Energy input	Total energy consumption
	Capital input	Total fixed assets of society
Output indicator	Undesirable output	Waste Water Discharged
		SO_2 emission
		Solid waste discharge
	Expected output	Added value of production by provinces and regions

2.3.2. Measurement of green economy efficiency

The non-expected output-superefficiency SBM model is used to measure the efficiency of green economy, and the following table is obtained.

Table 5. Average regional green economy development and its ranking

Area	2012	2013	2014	2015	2016	2017	2018	Average	Ranking
East	1.05	1.12	1.08	1.06	1.28	1.24	1.35	1.17	1
Middle	1.02	1.05	0.97	1.14	1.22	1.01	1.04	1.06	3
West	1.08	1.15	1.25	1.03	1.01	1.1	1.1	1.1	2
Nationwide	1.05	1.11	1.1	1.07	1.18	1.13	1.18	1.12	

(1) Spatial dimension

By comparing the average level of green economy between the region and the whole country, we can see that the digital economy index in the eastern region is the highest, and the digital economy ranks first, followed by the second place in the western region, and the third place in the central region, and the eastern region > the whole country > the western region > the central region.

(2) Time dimension

The development of China's green economy was not stable from 2012 to 2018, and the overall trend was increasing. From 2012 to 2014, the western region had the highest efficiency and the fastest development of green economy, but the development trend gradually decreased from 2014 to 2016, but at this time, the development of green economy in the country, eastern and central regions showed a significant increase.

2.4. Model Design

In this paper, the bidirectional fixed effect model is adopted as the benchmark regression, and the specific formula is as follows:

$$Gee_{ij} = \alpha_0 + \alpha_1 Dig + \alpha_2 CL_{ij} + \sigma_i + \mu_j + \omega_{ij} \quad (1)$$

By adding intermediate variables, the formula is obtained:

$$Med_{ij} = \beta_0 + \beta_1 Dig + \beta_2 CL_{ij} + \sigma_i + \mu_j + \omega_{ij} \quad (2)$$

The final baseline regression formula is obtained:

$$Gee_{ij} = \lambda_0 + \lambda_1 Dig + \lambda_2 Med_{ij} + \lambda_3 CL_{ij} + \sigma_i + \mu_j + \omega_{ij} \quad (3)$$

i and j represent province and year respectively, Gee is the explanatory variable, Dig is the explained variable, CLij is the control variable (including ER, GDP, PEA, FDI, Gvn, UL), Medij is the intermediate variable (Tech, Ind), σ_i is the individual fixed effect, μ_j is the time fixed effect, and ω_{ij} is the random disturbance term.

If α_1 is significantly positive, it means that the development of digital economy has promoted the efficiency of green economy; If β_1 is significantly positive, it means that the development of digital economy has a positive impact on the intermediary variable. If λ_2 is significantly positive, it proves that the development of the digital economy effectively promotes the efficiency of the green economy through the upgrading of industrial structure and technological innovation.

Mechanism of mediation effect model:

X is the independent variable, Y is the dependent variable, and M is the intermediate variable. Mediating effect: X affects Y by indirectly influencing M.

$$Y = cX + E_1 \quad (4)$$

$$M = aX + E_2 \quad (5)$$

$$Y = c_0 X + bM + E_3 \quad (6)$$

2.5. Analysis of Empirical Results

2.5.1. Baseline regression

In order to accurately measure the impact of digital economy and control variables on the development of green economy, this paper uses a fixed-effect model to regression the explained variables and the core explanatory variables separately. The regression results are shown in Table 8.

Table 6. Results of baseline regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dig	0.4033*** (7.2)	0.5954*** (5.27)	0.5237*** (5.30)	0.5422*** (5.13)	0.5467*** (5.43)	0.4785*** (5.97)	0.5862*** (6.46)
ER		-0.2237** (0.2683)					
GDP			-0.3369** (0.6418)				
PEA				0.3372** (2.31)			
FDI					0.6449*** (8.57)		
Gvn						0.0926*** (3.58)	
UL							-0.012 (-1.98)
Control variable	YES	YES	YES	YES	YES	YES	YES
Individual fixation effect	YES	YES	YES	YES	YES	YES	YES
Time-fixed effect	YES	YES	YES	YES	YES	YES	YES
R^2	0.2979	0.3323	0.2936	0.2949	0.3152	0.3132	0.3297

Note: *, ** and *** are significant at the 10%, 5% and 1% levels respectively.

Column (1) of Table 8 examines the impact of digital economy on the efficiency of green economy. At the significant level of 1%, its digital economy coefficient is positive, which means that digital economy has a positive promoting effect on the development of green economy. (2) - (7) are the regression results of explained variables and core explanatory variables. The results of digital economy all pass the test of 1% significance level, which further promotes the development of green economy.

The results show that environmental regulation plays a positive role in the development of green economy. The level of green economy is not affected by the level of urbanization, which may be because even if the urban population increases, its high-end scientific and technological talents do not increase. The level of economic development has a promoting effect on green economy, but the effect is weak compared with digital economy. Foreign direct investment can effectively promote the development of green economy, and foreign direct investment can bring new technology and new talents, which is beneficial to the development of green economy. Government regulation also plays a positive role in the development of green economy. The promulgation of relevant laws and regulations by the government encourages the green development of the whole people, improves the reward and punishment system, and effectively promotes the development of green economy. The education level of the population has a positive promoting effect on the green economy, and the improvement of the education level is conducive to the better training of high-tech talents, which is beneficial to the development of green economy.

2.5.2. Intermediary effect

The intermediate variable technological innovation index is brought into the model, and the results in column (2) Tech in the table are obtained. The results show that the development level of digital economy has a significant positive impact on technological innovation. Then, the intermediate variables are substituted into the formula of the benchmark regression model, and (3) Gee results are obtained. The results show that the development of digital economy promotes technological innovation, which in turn promotes the improvement of green economy efficiency.

Table 7. Regression results of intermediary effect of technological innovation

Explaining variable	(1) Gee	(2) Tech	(3) Gee
Dig	0.0635*** (0.0211)	1.5323** (0.7723)	0.3112*** (0.0731)
Control variable	YES	YES	YES
Tech			0.183*** (0.052)
Cons	1.22*** (0.24)	0.898*** (0.268)	2.5362*** (0.336)
Sobelstatistic			1.254

By bringing the industrial structure index into the model, the result data of column (2) Ind in the table can be obtained. The results show that the level of digital economy has a significant positive impact on the upgrading of industrial structure. The intermediate variables are then substituted into the formula of the baseline regression model, and (3) Gee results are obtained. The results show that the development of digital economy promotes the upgrading of industrial structure, and then promotes the improvement of the efficiency of green economy.

Table 8. Regression results of intermediary effect of industrial structure upgrading

Explaining variable	(1) Gee	(2) Ind	(3) Gee
Dig	0.0662*** (0.0288)	0.5323** (0.175)	0.812** (0.317)
Control variable	YES	YES	YES
Ind			0.364** (0.32)
Cons	1.31*** (0.15)	0.762*** (0.201)	1.513*** (0.225)
Sobelstatistic			1.164

2.5.3. Robustness test

(1) Change the measurement method of explanatory variables. The principal component analysis method was used for weight assignment to replace the original number weight assignment method to re-estimate the development level of digital economy. The results in Table (1) show that after the change of calculation method, the coefficient of Dig is

significantly positive (5%), and the regression results are robust.

(2) Tail reduction treatment. After 1% indentation for all variables, the results in column (2) show that the coefficient of Dig is significantly positive (1%).

(3) Change or increase control variables. In this paper, the level of foreign direct investment is replaced by human capital (expressed as the proportion of students in ordinary colleges and universities to GDP), and the results in column (3) show that the coefficient of Dig is still significantly positive at the level of 1%. In addition, by adding government behavior and informatization level to the original control variables, the results in column (4) still support the results of baseline regression.

Table 9. Robustness test results

	Change measurement method (1)	1% tail reduction (2)	Change control variable (3)	Increment control variable (4)
Dig	1.4323** (0.7925)	1.8320*** (0.3389)	2.1563*** (0.4421)	1.9629*** (0.5244)
CL	YES	YES	YES	YES
Individual fixation effect	YES	YES	YES	YES
Time-fixed effect	YES	YES	YES	YES

3. Basic Conclusions and Countermeasures

3.1. Basic Results

The level of urbanization does not play a role in the process of green economy development, possibly because even if the urban population increases, its high-end scientific and technological talents do not increase; Environmental regulation, economic development level, foreign direct investment, government regulation and population education level have positive effects on green economy.

The development of the digital economy has promoted technological innovation and industrial structure upgrading, and through technological innovation and industrial structure upgrading, it has promoted the improvement of the efficiency of the green economy.

3.2. Countermeasures and Suggestions

3.2.1. Strengthen the impact of digital economy development on green economy development

By strengthening the application of digital terminals, improving the innovation of digital science and technology, strengthening the digitalization of industries, and strengthening the digital environmental infrastructure, the development of digital economy will be enhanced, thus affecting the green economy. At the same time, environmental regulation, economic development level, population education level, foreign direct investment and other efforts will be improved, supplementing the shortcomings of the development of digital economy in various regions, and ultimately enabling the development of green economy.

3.2.2. Strengthen innovation and development of science and technology

By increasing the investment in technological innovation, attracting high-tech talents, eliminating backward technological machines and other methods, the pollution to the environment will be reduced. Combine big data and the Internet to enhance competitiveness and promote green economic development.

3.2.3. Optimize the industrial structure

By adjusting and optimizing the industrial structure, focus on emerging industries, transform traditional industries, create new industries, promote the coordinated development of nature and economy, and achieve sustainable economic development.

References

[1] Poul Schou. Pollution Externalities in a Model of Endogenous Fertility and Growth [J]. International Tax and Public Finance. 2002, 9(6): 709-725.

[2] Xu Ling Liu. Study on Technology of Green Construction Material-Saving and Material Resources Utilization [J]. Advanced Materials Research. 2014, 2784: 374-379.

[3] Holmstrom J. Recombination in digital innovation: Challenges, opportunities, and the importance of a theoretical framework [J]. Information and Organization, 2018, 28(2):107-110.

[4] Li, Ling. China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0" [J]. Technological Forecasting and Social Change, 2018:66-74.

[5] Rosa Misso, Zacharoula Andreopoulou, Gian Paolo Cesaretti, Safwat Shakir Hanna, Ioakeim Tzoulis. Sustainable development and green tourism: new practices for excellence in the digital era [J]. J. for International Business and Entrepreneurship Development. 2018, 11(1): 65-74

[6] Dongbei Bai, Meng Li, Yongqi Wang, Sabrine Mallek, Umer Shahzad, Impact mechanisms and spatial and temporal evolution of digital economy and green innovation: A perspective based on regional collaboration within urban agglomerations,

[7] Technological Forecasting and Social Change, Volume 207, 2024, 123613, ISSN 0040-1625.

[8] Lei Wu, Chengao Zhu, Guonian Wang, The impact of green innovation resilience on energy efficiency: A perspective based on the development of the digital economy, Journal of Environmental Management, Volume 355, 2024, 120424, ISSN 0301-4797.

[9] Xu Dong, Kejia Guo, Xiaomeng Zhao, Does digital economy promote regional green innovation? An empirical study based on the transmission effect and threshold effect of marketization, Journal of Digital Economy,Volume 3, 2024, Pages 47-61, ISSN 2773-0670.