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Analysis and Research on Total Factor Productivity of China's Coastal Cities Based on Big Data Analysis

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Abstract: *We explore and discuss the mechanism of the impact of digital economy on marine and green total factor productivity (TFP). We build a regulatory effect model by using the data of provinces and cities on the coast of China (11 in total) from 2009 to 2018 to measure the development level of the digital economy and marine green total factor productivity in coastal areas of China and evaluate the relationship between them. It is shown that the digital economy has significantly improved the marine green total factor productivity, and environmental regulation acts positively.*

Keywords: *digital economy, environmental regulation, marine economy, total factor productivity*

1. Introduction

China is committed to integrating the digital and the real economy, as deepening digital economy empowerment is a new impetus and direction for sustainable economic growth. The China Ocean Agenda 21 issued in 1996 proposed a sustainable development strategy for China's marine industry, implementing the sustainable development strategy and utilization. Now, the marine economy in China is turning into a new growth stage for the terrestrial economy by providing new space and resources. When new digital technology and the economy are effectively combined with marine space and new resources, it inspires unprecedented vitality in the economy.

However, the status quo of the marine ecological environment in China is still serious. The water quality of estuaries and bays still needs to be improved, and the marine ecosystem is still in a sub-health state, which has become a bottleneck restricting sustainable economic development. Therefore, environmental governance and regulation are continuously strengthened as required in the Implementation Outline for the Construction of a Government Ruled by Law (2021-2025), and legal enforcement of pollution in the ecological environment is comprehensively upgraded.

Therefore, in this critical period of ecological civilization construction and economic and social transformation, it is of great significance for the marine economy to take the opportunity of developing the digital economy and taking environmental regulation as the guarantee and guide of green development. Then, it is possible to achieve the goal of minimizing environmental pollution and other undesirable negative output and maximizing economic positive output with minimum resource consumption.

2. Theoretical Analysis and Hypothesis

2.1. Influence of Digital Economy on Marine Green TFP

As a pro-environment new economic form, the digital economy can reduce industrial energy consumption, increase output, and overcome the problem of “high pollution, high energy consumption, high emissions”. Theoretically, the mechanism of the digital economy influences marine green TFP mainly through the following channels.

First, digital technology creates a new service in financial business (hereinafter referred to as digital finance), which is an important engine for economic development and environmental governance. Digital finance alleviates the constraints of environmental investment and financing, optimizes the allocation of credit funds, increases the financing cost of heavily-polluting enterprises [1], restricts the flow of funds to energy-consuming and high-emission companies [2], and guides the fund flow to the pro-environment and pollution-controlling industry. The purpose is to increase the production of pro-

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environment and pollution-controlling equipment and green infrastructure.

Second, a high level of informatization and digitalization solves the problem of information asymmetry in the financial market [3]. Effective information for the investment and financing of high-tech manufacturing enterprises is provided, which then contributes to the improvement of the environment of technology-intensive manufacturing industries. This leads to green technology innovation in enterprises and green transformation of the macro-economy [4].

Third, industrial sectors apply big data technology to capture accurate information to predict the input and output of production [5], and authorities use the data platform to improve the efficiency of environmental supervision [6], contribute to deteriorating the ecological environment, and finally spread the concept of green environmental protection to the public through the Internet media. Thus, the green development of economies is ensured to realize the green transformation of production and improve the efficiency of the green economy as a whole. Therefore, we propose the first research hypothesis.

(H1) The digital economy affects marine green TFP positively.

2.2. Moderating Effect of Environmental Regulation on Impact of Digital Economy on Marine Green TFP

The digital economy promotes the green transformation of industry and realizes the win-win of ecological and economic benefits with efficient environmental regulation [7]. On the one hand, when authorities strictly implement sound environmental regulation policies and market incentive environmental regulations such as environmental subsidies and sewage charges. Digital finance helps environmental-protection and pollution-controlling of enterprises, guides the allocation of capital, promotes green credit, and encourages green technology innovation [8], thus forming a positive feedback mechanism of ecological environmental, economic and social return [9]. Big data technology makes up for the disadvantage of information asymmetry, providing information screening for financial institutions and pushing the green transformation and upgrading of high-pollution industries through environmental financing constraints. Big data technology shutdowns and rectifies "three high" industries, and accelerates the transformation from labor- to technology-intensive. Thus, it realizes the transformation of economic growth from resource factors driven by high pollution and high energy consumption to innovative technology driven by green environmental protection. Thus, opportunities are given for energy conservation, emission reduction, and environmental improvement [10].

On the other hand, in the macro context of environmental pollution control, big data technology and the Internet of things are applied to realize online monitoring of ecological environment dynamics, and real-time feedback on pollution situations and pollution sources. In addition, early warning and preventive measures are more effective.

Finally, under the guidance of environmental regulation, enterprises carry out adjustments with the support of the digital economy to promote traditional industry's development towards intelligent and automated transformation and upgrading and transform and upgrade industries to medium and high-end [11]. Then, the purpose of reducing energy consumption is achieved, and the industry's green production chain is reshaped to improve green efficiency. Therefore, the third research hypothesis is proposed.

(H2) Environmental regulation has a moderating effect on the process of the digital economy and marine green TFP.

3. Research Design

3.1. Empirical Model

For the above hypothesis, we test the impact of the digital economy on marine green TFP by setting the following benchmark regression model.

$$TFP_{i,t} = \alpha_0 + \alpha_1 lnDige_{i,t} + \alpha_2 lnER + \alpha_c Z_{i,t} + \mu_i + \varepsilon_{i,t} \quad (1)$$

where TFPi,t is marine green TFP of province and city i in period t, $Dige_{i,t}$ is the development level of the digital economy in province and city i in period t, ER is the intensity of environmental regulation, $Z_{i,t}$ is a series of control variables, μ_i is an individual fixed effect, and $\varepsilon_{i,t}$ is a random disturbance term.

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To explore whether environmental regulation is the moderating variable of the digital economy affecting marine green TFP, a moderating effect model is used for analysis. Therefore, based on Eq. (1), the interactive variable of the digital economy and environmental regulation is introduced as follows.

$$TFP_{i,t} = \alpha_0 + \alpha_1 lnDige_{i,t} + \alpha_2 lnDige_{i,t} \times ER_{i,t} + \alpha_c Z_{i,t} + \mu_i + \varepsilon_{i,t} \quad (2)$$

3.2. Variable Measurement and Description

3.2.1. Marine Green TFP

Based on the System Theory, capital input, labor input, and resource input are input variables, and expected and unexpected outputs are output variables. The marine green TFP of 11 provinces and cities on the coast of China from 2008 to 2018 is calculated by using the global DEA Malmquist index, recorded as TFP [12, 13]. Taking 2008 as the base, the results are multiplied to obtain comparable efficiency to represent the green development quality of the marine economy.

3.2.2. Environmental Regulation Intensity

Based on the ideas of Chen [14], we adopt a method of text analysis to segment the frequency of environmental vocabulary in government reports. The same approach is applied to calculate the proportion of the word frequency related to the environment (including environmental protection, pollution, emission reduction, sewage discharge, energy consumption, ecology, green, chemical oxygen demand, sulfur dioxide, carbon dioxide, PM10, PM2.5, and low carbon, air). The total frequency of the words in the full text of the government report is represented as the intensity of environmental regulation (Table 1).

3.2.3. Development Level of Digital Economy

Since there is no widely recognized evaluation index system for the level of the development of the marine digital economy, we referred to the research of Zhao [15] for defining the level of digital infrastructure, data-sharing media, industrial digitization and digital industrialization as indexes to set an index system and calculating the level of the development of the digital economy in the provinces and cities from 2009 to 2018 based on the Global entropy method (Table 1).

Table 1: Index system of marine economy and digital economy development evaluation

Variable	Index	Sub-index	Data Sources
Marine economy	**Input Index**	Land: Statistical Yearbook of Urban and Rural Construction	Statistical Yearbook of Urban and Rural Construction, China Statistical Yearbook and Guo-tai'an database
		Capital: Investment in fixed assets of the whole society in the sea area	China Ocean statistical Year-book
		Labor: Number of employees in three industries	China Ocean statistical Year-book
		Technology: Number of patent applications accepted	Statistical Annual Report of the State Intellectual Property Office
	Output index	Expected outcome: GOP	China Ocean statistical Year-book
		Unexpected outcome: Discharge	China Statistical Yearbook
Digital economy	**Devel-opment basis**	Industrial digital mobile phone switch capacity	
		Capacity of office switch	
		Long-distance optical cable length	
		Broadband Internet access port	
	Data sharing media	Number of mobile phone subscribers	
		Total telecommunication business	
		Express business volume	
	Digital indus-trializa-tion	Number of software and information technology service enterprises	Guotai'an database
		Software product revenue	
	Indus-trial Digi-taliza-tion	Expenditures for technological transformation of Industrial Enterprises above Designated Size in various regions	
		Expenditure of domestic technology purchase by industrial enterprises above Designated Size in various regions	
		Number of websites	Statistical Report on the Development of Internet in China
		Internet penetration	

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3.3. Control Variables

To analyze the mechanism of the impact of the digital economy on marine green TFP comprehensively, the control variables are set. They have an impact on marine green TFP including foreign investment (FDI), expressed as the proportion of total investment of foreign-invested enterprises in GDP, and science and technology input (MT), expressed by the proportion of science and technology expenditure in general public budget expenditure.

4. Results and Analysis

4.1. Summary Analysis

In order to prevent heteroscedasticity from affecting the regression results, logarithmic processing is adopted for the data. Table 2 presents the descriptive statistics of the variables.

Table 2: Descriptive statistics of variables

	Variable	Sample Size	Maximum	Minimum	Standard Deviation	Mean
Explained variable	TFP	110	1.364	0.550	0.176	0.958
Explanatory variables	Dige	110	0.930	0.004	0.230	0.336
Adjusting variable	ER	110	0.011	0.003	0.007	0.002
Control variable	FID	110	0.270	4.24e-06	0.539	0.049
	MT	110	0.720	0.008	0.150	0.027

4.2. Analysis

Table 3: Benchmark Regression and moderating Effect Regression Results of Digital Economy Affecting Marine Green TFP

	Benchmark Regression	Moderating Effect
	(1)	(2)
Variable	**TFP**	**TFP**
lnDige	0.115** (0.03)	0.461*** (0.00)
lnER	0.058* (0.09)	0.196*** (0.00)
lnDige×lnER		0.273** (0.03)
FDI	0.328** (0.01)	2.946** (0.01)
MT	2.502** (0.04)	0.076*** (0.00)
Con.	1.279***	1.889***
Regional fixed effect	YES	YES
N	110	110
Adj. R2	0.784	0.804

STANDARD ERRORS IN PARENTHESES * P<0.05, ** P<0.01, *** P<0.001

Table 3 presents the results of the regression of the digital economy and marine green TFP with the fixed effects regression. Results reveal that the estimation coefficient of the digital economy is significantly positive, so research hypothesis 1 is verified. Thus, the digital economy is confirmed to improve the marine green TFP significantly. Environmental regulation (ER) has a significant positive correlation with marine green TFP as a moderating variable. The possible reasons include the implementation of environmental regulations eliminating the backward production capacity with high pollution and the restriction of the emission of heavy industrial pollutants. The intensity of environmental regulation stimulates the marine industry sector to carry out technological innovation and efficiency improvement under the condition of reasonable policy design, which forms the “Porter Hypothesis” effect [16]. A significant positive correlation between the control variable MT and marine

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green TFP indicates that increasing marine science and technology investment can effectively improve marine green TFP. This result is related to the precise investment of R&D funds and the high quality of science and technology investment, which promote technological progress and efficiency. The positive effect of FDI shows that foreign capital significantly improves marine green TFP, which may be because the introduced foreign capital is mostly concentrated in high-end industries with low energy consumption and high output.

Moderating effects in Table 3 show that the interaction between the digital economy and environmental regulation is correlated positively. This shows that with the strengthening of environmental governance, environmental regulations such as market regulation further promote and apply to the industry. Under the guidance of such policies, the digital economy is developing in the direction of benefiting marine green TFP. The digital finance industry promotes the green transformation of industries by forming green credit, optimizing capital allocation, and easing financing constraints. Environmental regulation supports the promotion and application of digital technology, further expands the scale of digital industrialization, and optimizes the marine industrial structure. Then, opportunities are provided for green technology innovation and ultimately improve marine green TFP. That is, environmental regulation also has a moderating effect on the digital economy to improve marine green TFP.

5. Conclusion

Based on the background that the digital economy has gradually driven strong economic growth, we empirically test the digital economy's impact on marine green TFP by using the panel data of 11 coastal provinces and cities in China from 2009 to 2018 from the perspective of environmental regulation. This study has the following policy implications.

First, the marine industry needs to pursue the development of the digital economy, deeply integrate the digital and the real economy, and maintain innovation by speeding up the cultivation of marine strategic emerging industries. The application of the digital economy needs to be promoted in the development of the marine industry with a series of support policies for the digital economy to tap a new blue ocean of intelligent marine industry and consolidate the dividend advantages of the new generation of information technology for the high-quality development of the marine economy.

Second, under environmental regulations, the digital economy has effectively improved the marine green total factor productivity. The government must formulate environmental regulation policies according to local conditions while promoting green technology innovation and a dual approach to environmental regulations in the digital economy. Collaborative innovation between the two needs to be achieved for promoting win-win ecological and economic benefits. Specifically, we need to improve the regulation and supervision system of the marine environment. On the one hand, it is necessary to strengthen environmental protection monitoring and punishment for violations. It is also demanded to guide relevant departments and introduce the Internet of Things technology into marine environmental monitoring for dynamic information sharing of the marine environment. On the other hand, we need to strengthen preferential policies such as tax relief and financial subsidies and guide local governments to use digital finance and alleviate capital mismatch and financing constraints, thereby generating the incentive effect of green innovative technologies.

Third, the government must comprehensively develop the digital economy and release the impetus of the digital economy for marine green TFP. This study finds that - 0.1950 is the critical scale to realize the network effect of the digital economy on marine green TFP, but most coastal provinces and cities in China do not reach this value. The future development of the digital economy in the marine field is focused on three aspects: first, improving the digital infrastructure, increasing the research and development of the digital economy and financial support, and accelerating the construction of smart marine engineering. Secondly, we need to formulate supportive policies for the development of the digital economy, cultivate market players, and strengthen the development platform. Finally, we need to strengthen opening up, absorb advanced foreign technologies, and use key core technologies.

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