

Digital Economy and Green Innovation in the Context of Dual Cycles: Mechanism of Action and Empirical Identification

Lei Ye

School of Economics, Anhui University of Finance and Economics, China

Abstract

This project explores the effect mechanism of digital economy in promoting urban green innovation by measuring the efficiency level of digital economy and green innovation in 283 prefecture-level cities in China from 2011 to 2019. First, the robustness test is carried out by introducing nighttime light data and green patent data obtained by matching listed companies according to longitude and latitude, and using terrain relief and digital economy word frequency as instrumental variables for endogeneity test. Secondly, testing the specific mechanism of the digital economy to promote urban green innovation through regional innovation capabilities, optimization of industrial structure and advanced human capital is conducive to discussing the low-carbon value and compatibility and feedback efficiency of the digital economy, and promoting green and high-quality economic development.

Keywords

Dual Circulation; Digital Economy; Green Innovation; Domestic Circulation.

1. Background of the Problem

The digital economy, also known as the "smart economy", is a new economic form based on big data and Internet technology. It is a series of economic activities that use digital knowledge and information as key production factors, modern information networks as an important carrier, and the effective use of information and communication technology as an important driving force for efficiency improvement and economic structure optimization. At present, many domestic and foreign studies have classified both "digital industrialization" and "industrial digitization" as the category of digital economy. The former refers to the information technology industry, while the latter includes emerging industries and formats formed after the integration and innovation of digital technologies. As a historical category, digital economy is the macro-emergence of the interaction process of technology, organization and institution in an economic system.

Since the reform and opening, China's rapid economic development has made remarkable achievements, but at the same time, it is also facing the dual pressure of serious resource consumption and environmental pollution. In September 2020, General Secretary Xi Jinping proposed at the United Nations General Assembly: "China will increase its nationally determined contribution to achieve carbon peaking by 2030 and carbon neutrality by 2060." The Fifth Plenary Session of the 19th Central Committee of the Communist Party of China proposed: "Deeply implement the sustainable development strategy, improve the overall coordination mechanism in the field of ecological civilization, build an ecological civilization system, promote a comprehensive green transformation of economic and social development, and build a modernization where man and nature coexist in harmony." (Chen Ruosong and Yu Wentao, 2021). The comprehensive green transformation in the new development stage has become the common interest expectation of the people and the demand for a better green life. In March 2021, my country's "14th Five-Year Plan" proposed the concept of green

transformation many times based on the "dual-carbon" strategic goal, and clearly pointed out that it is necessary to vigorously develop green technology innovation and promote the green transformation of key industries and fields (Fan Yixia and Xu Hao), 2021).

At the same time, under the tide of the digital age, the digital economy has become a vast fertile ground and support carrier for realizing regional high-quality innovation and green development. On the one hand, the digital economy improves the efficiency of resource allocation and reduces the pollution emissions caused by ineffective production (Weishiwei et al., 2022); on the other hand, the integrated development of the digital economy and the real economy promotes innovation output, improves innovation efficiency and reduces innovation. Cost has become an important starting point for solving environmental problems (Guo Bingnan et al., 2022). Therefore, discussing the impact of the digital economy on green innovation and its mechanism has also become the core point of this paper.

2. Empirical Research

The research content of this project includes the basic characteristics of the development level of digital economy in 283 prefecture-level cities in China, its economic explanation, and the impact mechanism of digital economy on green innovation. Drawing on the methods of Huang Qunhui et al. (2019) and Zhao Tao (2020), the city's digital economy development level was calculated. Referring to the research of Wang Qiao et al. (2020), an input-output model of urban green innovation efficiency in China was constructed based on the super-efficiency SBM model, and a scientific and reasonable calculation of urban green innovation efficiency was carried out.

At the same time, the green patent data at the city level is obtained by matching the latitude and longitude of the listed company's location, and it is used as a proxy variable for green innovation for robustness testing. This project deeply explores the development mechanism of urban green innovation in the digital age without breaking the relationship between the two. It can be said that the research content of this project not only involves theoretical basic research, but also pays more attention to empirical research and simulation analysis, not only to the research of local problems, but also to systematic research from the whole.

Green innovation efficiency is the key to implementing green innovation. Based on the connotation of green innovation and referring to existing research (Wang Qiao et al., 2020), this paper constructs an index measurement system for green innovation efficiency in Chinese cities. Referring to the existing literature, the input variables are capital input, labor input and energy input. Among them, the capital investment at the city level is measured by the sum of scientific and technological expenditures and the investment in environmental governance; labor input is measured by the sum of the number of employees in the information transmission, computer services and software industries and the number of employees in the scientific research, technical services and geological exploration industries. Proxy variables (Peng Wenbin et al., 2019); energy input adopts urban power consumption proxy: on the one hand, the GDP elasticity value of electricity demand is very close to the GDP elasticity value of energy demand; is significantly underestimated in total consumption. The output variable consists of two parts: expected output and unexpected output: the expected output variable is measured by economic output (city industrial output value) and technological output (the number of patent applications granted in each city); the unexpected output variable The three variables of industrial wastewater, sulfur dioxide and industrial solid waste are mainly selected in each city, and weights are assigned to each index by the entropy method, and finally the environmental pollution index is synthesized to measure. The specific indicators are shown in Table 1.

Table 1. Input-output index system of green innovation efficiency

Level 1	Level 2	Calculate
put in	capital investment	Government expenditure on scientific business + investment in environmental governance
	labor input	Number of employees in the information transmission, computer services and software industries
	energy input	energy consumption
output	GDP	actual GDP
	patent	Invention patents granted
	Sulfur dioxide emissions	Industrial SO2 Emissions
	Wastewater discharge	Industrial wastewater discharge
	Solid Waste	Industrial solid waste

In the presence of undesired outputs, the relationship between resources, energy consumption and pollution emissions are "inseparable" and "radial", while the relationship between traditional input elements other than energy, such as labor, capital, etc., and output is A "separable", "non-radial" relationship. Based on this, this paper adopts the EBM model including undesired outputs to measure the green total factor productivity of cities (Tone and Tsutsui, 2010). Compared with the traditional CCR model under fixed scale returns and the SBM model based on slack variables, the EBM model can effectively avoid the problem that the CCR model does not take into account the slack variables and the results are higher than the actual efficiency level, and can avoid the SBM model due to ignorance. The linear relationship between the input factors makes the result lower than the actual efficiency level.

$$\gamma^* = \min \frac{\theta - \varepsilon_x \sum_{i=1}^m \frac{\omega_i^- s_i^-}{x_{il}}}{\varphi + \varepsilon_y \sum_{r=1}^s \frac{\omega_r^+ s_r^+}{y_{rl}} + \varepsilon_b \sum_{p=1}^q \frac{\omega_p^{b-} s_p^{b-}}{b_{pl}}} \quad (1)$$

$$s.t. \begin{cases} \sum_{j=1}^n \lambda_j x_{ij} + s_i^- - \theta x_{il} = 0, i = 1, \dots, m \\ \sum_{j=1}^n \lambda_j y_{rj} - s_r^+ - \varphi y_{rl} = 0, r = 1, \dots, s \\ \sum_{j=1}^n \lambda_j b_{pj} + s_p^{b-} - \varphi b_{pl} = 0, p = 1, \dots, q \\ \lambda_j \geq 0, s_i^- \geq 0, s_r^+ \geq 0, s_p^{b-} \geq 0 \end{cases} \quad (2)$$

Among them, represents the optimal efficiency value of DEA measured by EBM; represents the efficiency value under radial conditions; represents the slack of the i th input factor under non-radial conditions; represents the relative weight of the input factor; represents the input output of the 1th DMU Out vector; represents the weight of the i -th input element, reflects the importance of input element i , and is satisfied; represents the core parameter that includes both the radial variation ratio and the non-radial relaxation vector. Parameters and needs are determined before building the EBM model. If, the representative decision-making unit technique is valid.

①Innovation effect: Refer to the "China Regional Innovation and Entrepreneurship Index" compiled by the Enterprise Big Data Research Center of Peking University. The index examines

the actual output of innovation and entrepreneurship of enterprises within the region, to form a more objective and true evaluation of innovation and entrepreneurship.

②Industrial structure upgrade effect: Industrial structure upgrade is divided into industrial structure rationalization and industrial structure advanced. Industrial structure rationalization refers to the ability of structural transformation between industries and the degree of effective utilization of resources. This paper uses the inverse of Theil index to measure the rationalization level of industrial structure, its calculation formula is:

$$ris = \frac{1}{TL} = \frac{1}{\sum_{i=1}^3 \left(\frac{Y_i}{Y}\right) \ln \left(\frac{Y_i}{L_i} / \frac{Y}{L}\right)} \quad (3)$$

Among them, the Theil index, the output value, the employment, the industry, and the number of industrial sectors. The smaller the value, the higher the rationalization level of the industrial structure. For the advanced industrial structure, referring to the method of Fu Linghui (2010), by measuring the ratio of the output value of the primary industry, the secondary industry, and the tertiary industry to GDP, and using it as a component of the space vector to find that one, a set of three-dimensional vectors. Then, measure the included angle, and the vectors, which are arranged from low to high, respectively.

$$\theta_j = \arccos \left(\frac{\sum_{i=1}^3 (x_{ij}, x_{i0})}{\left(\sum_{i=1}^3 (x_{ij}^2)^{1/2} \sum_{i=1}^3 (x_{i0}^2)^{1/2} \right)} \right) \quad (4)$$

$$W = \sum_{K=1}^3 \sum_{j=1}^K \theta_j \quad (5)$$

③The effect of advanced human capital: The vector angle method is used to measure the degree of advanced human capital structure at the provincial level in China, and then the proportion of the number of students in higher education in prefecture-level cities in the number of students in higher education in the province is taken as The weight is multiplied by the advanced index of provincial human capital structure, and finally the advanced index of human capital structure of prefecture-level cities is obtained (Liu Zhiyong et al., 2018). The second is the construction of the measurement model. In order to identify the specific path, we intend to construct a mediation effect model by drawing on the step-by-step test method of Wen Zhonglin (2014) to capture the impact mechanism of the digital economy on green innovation.

3. Conclusions and Recommendations

Increase support for the digital industry. Increase investment in the construction and application of information networks, upgrade and improve the conditions of new digital infrastructure such as big data centers, cloud platforms, and 5G base stations in various regions, and fully release the dividends of digital economic development.

Considering the heterogeneity of the digital economy in regions and cities at different levels, it is necessary to adapt measures to local conditions, scientifically guide, implement differentiated development policies, steadily promote the development of the digital economy, and avoid blind expansion and disorderly development. Realize the deep integration of

advantageous industries in late-developing regions under the low-carbon economy and the digital economy.

Strengthen policy guidelines for green innovation. Strengthen the dominant position of enterprises in green technology innovation, and improve the ability of green technology innovation and research and development. Optimize the market environment and provide a level playing field for enterprise green technology innovation. Improve the all-round public services targeted for green innovation, strengthen intellectual property protection, and improve the matching degree and precise focus of policy support through the continuous improvement of the digital service management platform.

Innovate the system and mechanism of digital economy and green technology innovation, gather advantages and shape new kinetic energy for industrial optimization. Further promote the driving effect of the digital economy on green technology innovation by cultivating high-end production factors, improving the efficiency of resource allocation, and reducing innovation costs, so that the digital economy and green technology innovation can form a synergy to promote the upgrading of the industrial structure.

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