Research Article

Research on the Role and Mechanism of Digital Finance in Improving the Performance of Industrial Green Innovation

Haojie Wang

School of Finance and Accounting, Henan University of Animal Husbandry and Economy, Zhengzhou 450000, China

Correspondence should be addressed to Haojie Wang; 201084@hnuahe.edu.cn

Received 23 April 2022; Accepted 16 May 2022; Published 3 June 2022

Academic Editor: Di Feng

Copyright © 2022 Haojie Wang. 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.

The slack-based measure–Malmquist index model (SBM Malmquist) including unexpected output was used to calculate the performance of China’s provincial industrial green innovation from 2011 to 2019, and a systematic general moment method (GMM) with a dynamic panel model was constructed to empirically test the effect and mechanism of digital finance on the performance of industrial green innovation. The results show that the performance of China’s industrial green innovation has shown an upward trend in recent years, mainly due to improvements in technical efficiency. Digital finance can significantly promote the performance of industrial green innovation, and the improvement of technical efficiency is greater than that of technological progress. From the perspective of structure, the coverage, use depth, and digitization degree have significantly promoted the performance of industrial green innovation, and the digitization degree has the greatest effect. In areas with backward and traditional financial development, digital finance can better promote the improvement in the performance of industrial green innovation and technical efficiency, and the role of the universal benefit is obvious. The mechanism test found that financial efficiency played a partial intermediary effect in the process of digital finance, affecting the performance of industrial green innovation, while residents’ consumption mainly played a masking role. This provides a useful reference for the development and optimization of digital finance and the realization of the drive towards regional industrial green innovation.

1. Introduction

In 2019, China’s wastewater discharge was 25.2 billion tons, representing an annual decrease of 33.3%. However, due to the long-term use of an extensive economic development model based on high energy consumption and high pollution, when comparing the emissions of five major pollutants in the United States, China, and the European Union in 2016 and 2017, China’s emissions are still 2–5 times those of the European Union and the United States. As China’s economy enters a new normal, problems such as resource shortages, environmental pollution, and ecological damage caused by the traditional extensive economic growth model have increasingly become the bottleneck constraints restricting sustainable economic development. Under the background of high-quality development, the key to China’s economic growth lies in improving the level of industrial green innovation, and cleaner production can deal with practical development problems such as imbalance in the industrial structure and the deterioration of the ecological environment. It is of great benefit for promoting the transformation of the economic growth model and the adjustment of the economic structure. Green innovation refers to the use of advanced technology to save energy [1]. As the direct embodiment of the high-quality innovation of the industrial economy, the performance of industrial green innovation is the production efficiency shown by a certain amount of innovation resource input and innovation achievement output. There is no doubt that the transformation of the financial development model is important to the performance of industrial green innovation. Digital finance is a combination of science, technology, and finance. With the help of big data and the Internet, it provides economic subjects with wide coverage, as well as sustainable, convenient, and efficient financial support, which helps to achieve the important goal of financial services in the real economy. Digital finance generally refers to traditional financial institutions and Internet companies using digital technology to
realize financing, payment, investment, and other new financial business models [2]. This new financial development model meets the needs of industrial green innovation for financial services; that is, it is based on the premise of promoting the stable operation of the macroeconomy, to achieve the common improvement of economic and environmental benefits. How to match the development of emerging finance with industrial green innovation and explore the role path between digital finance and the performance of industrial green innovation is the key for deeply understanding the mechanism of promoting high-quality and sustainable economic growth in finance.

Through the allocation of financial resources, financial development not only meets the financial needs of the real economy but also inevitably affects the quality of macroeconomic operations. Combined with environmental regulation and innovation, most scholars have investigated the impact of financial development on green economic growth. For example, a single financial development and environmental regulation can promote green total factor productivity [3, 4]. Moreover, financial agglomeration can improve green total factor productivity by promoting coordinated economic growth and technological progress in energy conservation and emission reduction [5]. Environmental issues are becoming increasingly important, in the field of natural science, scholars have carried out extensive relevant research [6, 7]. The environmental effect of finance had also attracted extensive attention. Financial development can reduce the scale of carbon emissions and improve the efficiency of carbon emissions to a certain extent [8]. From the perspective of industry segmentation, the mitigation effect of the development of the financial industry on environmental pollution is more significant in the low-end manufacturing industry [9].

Existing research shows that green development is inseparable from financial support, but the disadvantages of traditional financial services are becoming increasingly prominent. In recent years, driven by bottom-up scientific and technological progress, Internet development, and other factors, financial technology and new financial development models have increased rapidly. The existing research on the innovation effect of digital finance has covered many levels, such as enterprises, industries, macroeconomies, and regions. In terms of enterprises, there is a significant positive correlation between digital finance and the innovation performance of high-tech enterprises. The higher the level of enterprise debt financing, the stronger the role of digital finance in promoting innovation performance [10]. At the industry level, digital finance has promoted the upgrading of the manufacturing industry by improving the innovation intensity and digital level and has played a great role in promoting the service level of the manufacturing industry [11]. At the macrolevel, digital finance can promote urban innovation by improving the allocation of credit resources, consumption, and industrial upgrading [12]. The development of digital finance also promotes regional economic growth by promoting technological innovation and regional entrepreneurship [13]. At the same time, from sustainable development to coping with climate change and developing the green economy, environmental protection is gradually becoming a hot issue studied by scholars at home and abroad. Existing studies have also found that digital finance can improve environmental quality. Specifically, the development of digital finance will promote enterprise green technology innovation by reducing financing costs and improving financial flexibility [14]. Both digital financial technology and urban ecological efficiency have significant spatial spillover effects. Digital financial technology and urban ecological efficiency promote each other [15]. Digital finance, a new form of finance, helps to reduce carbon emissions [16]. From the perspective of spatial spillover, digital financial inclusion has a positive impact on the carbon dioxide emissions of local cities, but a negative impact on surrounding cities [17]. On the whole, digital finance has a certain impact on innovation and the improvement of environmental quality. The performance of industrial green innovation takes into account innovation and environmental protection, but existing studies have ignored the relationship between digital finance and the performance of industrial green innovation.

For the measurement of green innovation performance, scholars have mainly used stochastic frontier analysis (SFA) and data envelopment analysis (DEA) [18, 19]. Although data envelopment analysis overcomes the disadvantage of stochastic frontier analysis, wherein it is necessary to set a specific production function form and single output, it tends to overestimate the efficiency level of the evaluation object, and its calculation results are not comparable. Based on this, this paper attempts to make contributions in the following three aspects: (1) in view of the shortcomings of stochastic frontier analysis and data envelopment analysis, the advanced Malmquist measurement model based on the SBM model is used to measure the performance of industrial green innovation; (2) this paper interprets the performance of industrial green innovation from the new perspective of digital finance and subdivides digital finance into three aspects: coverage, use depth, and digitization degree, which enriches the research scope of the impact of digital finance on the performance of industrial green innovation; (3) based on the dual perspectives of the supply side and demand side, this paper constructs the intermediary mechanism of digital finance affecting the performance of regional industrial green innovation from two indirect channels, financial efficiency and residents’ consumption, in order to clarify and verify the differential path of digital finance and how it affects the performance of industrial green innovation.

2. Theoretical Analysis

2.1. Analysis of the Direct Effect of Digital Finance on the Performance of Industrial Green Innovation. Digital finance has the advantages of affordable cost, sustainable business, and a wide range of services, which is consistent with the concept of high-quality innovation in the regional economy. According to the attributes and characteristics of digital finance and regional industrial green development, industrial enterprises, as one of the important subjects driving regional economic innovation and growth, are also the main
objects of financial institutions. Therefore, this paper will discuss the direct impact of digital finance on the performance of regional industrial green innovation from the perspectives of industrial enterprises and financial departments.

2.1.1. Industrial Enterprises. On the one hand, digital finance improves the financing availability of industrial enterprises, enhances their risk tolerance, and is conducive to technological innovation. From the perspective of science and technology, digital finance is the transformation and upgrading of the financial model, which helps to improve the breadth and depth of financial services. Moreover, digital finance effectively makes up for the deficiencies of the financial system, optimizes the allocation of financial resources, and improves the financing environment of enterprises [14]. For industrial enterprises, an important subject of industrial green development, higher R&D investment, and a longer R&D cycle will increase the risk of enterprises innovating production technology and changing the production mode, while abundant liquidity means that enterprises have more funds to support green innovation activities, thus improving the risk tolerance of the green transformation of industrial enterprises. On the other hand, digital finance helps to alleviate the problem of information asymmetry and reduce the financing cost of enterprises and then helps to promote the progress of green technology. Relying on digital technologies such as cloud computing, big data, and mobile Internet, digital finance can establish a risk control system, information processing, and monitoring system and then mine and collect customers’ credit investigation data in a timely, quick, and efficient manner. This will help to comprehensively grasp the operation and credit rating of industrial enterprises and improve the allocation efficiency and service quality of credit funds. The customer credit investigation system based on Internet information can simplify the credit review procedure and shorten the credit review time, so as to reduce the cost of credit evaluation, offline review, and risk management. Moreover, it can reduce the nonperforming rate of credit and improve the effectiveness of financing, so that industrial enterprises can obtain financial services more efficiently, conveniently, and cheaply and then carry out industrial green innovation activities. In short, with the help of developed communication technology, digital finance can expand the boundary of financial services, enhance the ability of industrial enterprises to resist risks, improve information transparency, provide favorable conditions for industrial enterprises to realize green innovation, and help to realize the economies of scale of industrial green production.

2.1.2. Financial Institutions. By improving network technology and updating infrastructure, digital finance has a positive impact on financial stability, helps banks lend, widens financing channels for enterprises and individuals, and helps users shift from cash payment to noncash payment. Existing research results show that digital finance has a long-term positive impact on bank performance [20]. The efficiency and stability of industrial enterprises’ operations are favored by the financial sector, but they are deterred by the risks brought by green transformation and cleaner production. Digital finance uses digital technologies such as cloud computing and artificial intelligence to analyze the behavioral big data precipitated by industrial enterprises on the Internet, promote the innovation of financial products, simplify the financial service process, and improve the level of financial risk control, so as to accurately identify the financial needs of industrial enterprises and provide them with more targeted and applicable financial services.

Accordingly, this paper puts forward the following assumptions.

Hypothesis 1. The development of digital finance is conducive to promoting the performance of industrial green innovation.

2.2. Analysis on the Intermediary Effect of Digital Finance on the Performance of Industrial Green Innovation. This paper holds that the improvement of financial efficiency and household consumption are two important channels for digital finance to affect the performance of industrial green innovation. Industrial green innovation focuses on evaluating the environmental effects of industrial innovation, while cleaner production depends heavily on capital investment. Through the effect of improving financial efficiency, digital finance can broaden the financing channels of industrial green production, have a “crowding in effect” on Regional R&D investment, and then improve the level of industrial green innovation. In addition, it can also drive industrial green innovation by promoting residents’ consumption.

2.2.1. Financial Efficiency Improvement Effect. Bank credit is an important part of the supply of financial factors. China’s banking industry is dominated by large and medium-sized banks, and there is a certain degree of monopoly in the credit market. Under the incentive of pursuing high profits and the restriction of China’s prudent financial system, the banking industry tends to invest in enterprises and projects with less risk, while enterprises and projects with higher risk are having difficulty obtaining the support of banks. The green innovation of industrial enterprises undoubtedly intensifies the risk of enterprises. In areas with high development level of digital finance, the intensification of banking competition will enhance their willingness and scale of capital allocation for green production and then improve financial efficiency. Existing literature has also confirmed the role of digital finance in promoting the efficiency of the financial sector [21]. It can be said that the development of digital finance has impacted the development mode of banks to a certain extent and improved the enthusiasm of bank credit to support green innovation. Therefore, by intensifying the internal competition in the banking industry, digital finance is conducive to improve financial efficiency and industrial green innovation performance.

2.2.2. Residents’ Consumption Effect. The changes of production factors such as material capital and consumption demand are two important aspects to promote economic innovation and growth. Due to the bottleneck of
information acquisition, the development of traditional bank consumer finance business serving individual customers lags behind, and its role in promoting the economy is mainly reflected in the financing business on the supply side. Personal users are the main users of digital finance. Taking Alipay as an example, Alipay currently has 900 million active users in China. Under the joint action of new financial instruments, digital finance has greatly improved the convenience of residents’ consumption, alleviated the constraints of consumer funds, and promoted the expansion of consumer demand. On the one hand, the expansion of consumption scale can promote industrial subjects to carry out technological innovation for the purpose of expanding production scale and improving production efficiency. On the other hand, with the popularization of the concept of green consumption, residents’ consumption demand for products such as new energy vehicles and smart homes increases, and the consumption upgrading effect can stimulate industrial enterprises to enhance their ecological competitiveness to a certain extent. The development of digital finance is conducive to alleviate liquidity constraints and improve payment convenience and then provide an opportunity to improve the green development level of regional industry by promoting the expansion of consumer market and the upgrading of consumer demand. It can be seen that digital finance can affect the performance of industrial green innovation by stimulating the intermediary transmission mechanism of residents’ consumption.

Accordingly, this paper puts forward the following assumptions.

Hypothesis 2. Financial efficiency and household consumption are the intermediary channels for digital finance to affect the performance of industrial green innovation.

3. Performance Measurement and Evaluation of Industrial Green Innovation

3.1. SBM Model Method for Considering Unexpected Output. Since the traditional DEA model overestimates efficiency, does not consider the relaxation of the input–output, and ignores the existence of unexpected output, this paper uses the nonradial and nonangle SBM model in order to make up for the efficiency evaluation defects of the traditional DEA model. Traditional research focuses on total factor productivity, which only takes economic output as the expected output, and does not consider the unexpected output of environmental pollutants in the production process. The performance measurement of industrial green innovation is the production efficiency of achieving the maximum innovative output by reducing pollutant emissions under the premise of certain input factors and unexpected output constraints. At the same time, in order to realize the cross-period comparability of the calculation results, the Malmquist–Luenberger productivity index method is used to construct the SBM model to measure the performance of industrial green innovation (the growth rate of the industrial green total factor productivity) and its decomposition indicators. The performance of industrial green innovation is decomposed into the technical efficiency index (etc) and the technical progress index (tc), and we can further explore the growth source and causes of industrial green innovation.

3.2. Input and Output Index Selection. Based on the connotations of the performance of industrial green innovation (taking into account the economic and social benefits), the principle of index selection, and the availability of data, we selected input–output indicators based on industrial enterprises that are above the designated size.

Input variables include personnel input and capital input. Among them, the full-time equivalent of R&D personnel (person) is selected for personnel investment. In terms of capital investment, the perpetual inventory method is adopted and a depreciation rate of 15% of R&D stock is set to calculate the internal expenditure of R&D funds into capital stock.

Output variables include expected output and unexpected output. The expected output is expressed by the number of patent applications and the sales revenue of new products. The unexpected output indicators are the emission of sulfur dioxide in industrial wastewater and industrial waste gas.

3.3. Measurement Results of Industrial Green Innovation Performance Malmquist Luenberger Index Based on SBM Model. Table 1 reports the change trend of China’s industrial green innovation performance from 2011 to 2019. Overall, although the performance, technical efficiency, and technological progress of China’s industrial green innovation show some fluctuations, they all show an upward trend as a whole. Specifically, technical efficiency showed an upward trend from 2011 to 2014, then decreased twice in a row from 2014 to 2016, and began to rise again from 2016 to 2019. Technological progress declined only in 2013-2014 and 2018-2019 and showed an upward trend in other years. On the whole, technological efficiency is greater than technological progress, indicating that technological efficiency is the leading factor to promote the improvement of industrial green innovation performance. The change trend of industrial green innovation performance since 2011 can be roughly divided into three stages. From 2011 to 2014 is the upward stage of industrial green innovation performance, in which the technical efficiency also shows an upward trend, but there are certain fluctuations in technical progress. Due to the leading role of technical efficiency, the industrial green innovation performance rises slowly. 2014-2016 is the decline stage of industrial green innovation performance, which is specifically caused by the decline of technical efficiency index. From 2016 to 2019, the industrial green innovation performance entered the upward stage again. Although the previous stage showed an obvious downward trend, thanks to the improvement of environmental pollution control in 2016, the technical efficiency improved significantly, and the industrial green innovation performance increased significantly. To sum up, thanks mainly to the improvement of technical efficiency, the overall performance of China’s industrial green innovation has shown a certain upward trend in recent years.
Table 1: 2011-2019 industrial green innovation performance and its decomposition indicators.

<table>
<thead>
<tr>
<th></th>
<th>Industrial green innovation performance (Gip)</th>
<th>Technical efficiency (ec)</th>
<th>Technical progress (tc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-2012</td>
<td>1.0933</td>
<td>1.0843</td>
<td>1.0390</td>
</tr>
<tr>
<td>2012-2013</td>
<td>1.0972</td>
<td>1.0880</td>
<td>1.0390</td>
</tr>
<tr>
<td>2013-2014</td>
<td>1.0973</td>
<td>1.0885</td>
<td>1.0387</td>
</tr>
<tr>
<td>2014-2015</td>
<td>1.0968</td>
<td>1.0863</td>
<td>1.0418</td>
</tr>
<tr>
<td>2015-2016</td>
<td>1.0953</td>
<td>1.0848</td>
<td>1.0419</td>
</tr>
<tr>
<td>2016-2017</td>
<td>1.0992</td>
<td>1.0876</td>
<td>1.0427</td>
</tr>
<tr>
<td>2017-2018</td>
<td>1.1028</td>
<td>1.0900</td>
<td>1.0441</td>
</tr>
<tr>
<td>2018-2019</td>
<td>1.1032</td>
<td>1.0940</td>
<td>1.0439</td>
</tr>
<tr>
<td>Mean values</td>
<td>1.0994</td>
<td>1.0872</td>
<td>1.0425</td>
</tr>
</tbody>
</table>

4. Models, Variables, and Data

4.1. Construction of the Measurement Model. In order to verify the impact of digital finance on the performance of industrial green innovation, considering the elimination of endogenous problems, combined with China’s provincial regional panel data from 2011 to 2019, the systematic GMM method is used for dynamic model estimation. The dynamic panel data model’s setting in this paper is shown as follows:

$$Y_{it} = \alpha_0 + \alpha_1 Y_{it-1} + \alpha_2 \text{Dif}_{it} + \alpha_3 \text{Controls} + \epsilon_{it},$$  \hspace{1cm} (1)

where the explanatory variables $Y_{it}$ are the performance of regional industrial green innovation $\text{Gip}_{it}$ and its decomposition indicators, technical efficiency (ec) and technological progress (tc), which are expressed by the Malmquist index of industrial green innovation performance measured above. Malmquist index can not only comprehensively evaluate the development of industrial green innovation but can also be decomposed, which is conducive to observe the intertemporal dynamic changes of innovation performance. It is widely used in measuring performance.

4.2. Variable Selection and Data Description

4.2.1. Explained Variable. The explanatory variables of this paper are industrial green innovation performance (Gip) and its decomposition indicators, technical efficiency (ec) and technological progress (tc), which are expressed by the Malmquist index of industrial green innovation performance measured above. Malmquist index can not only comprehensively evaluate the development of industrial green innovation but can also be decomposed, which is conducive to observe the intertemporal dynamic changes of innovation performance. It is widely used in measuring performance.

4.2.2. Core Explanatory Variable. At present, the digital finance research center of Peking University released the first, second, and third phases of the “Peking University Digital inclusive finance index” in 2016, 2019, and 2021, respectively. The time span is 2011-2020. The index constructs a digital finance index system from three dimensions: coverage, use depth, and digitization, involving three levels of provinces, cities, districts, and counties in China. As a combination of digital technology and financial services, the index has high authority and provides a set of instrumental data reflecting the development status of digital inclusive finance for all sectors of society.

4.2.3. Control Variables. Infrastructure investment (Inf). According to the proportion of the total regional post and telecommunications business to GDP, infrastructure construction is conducive to creating a good innovation environment and providing a beneficial guarantee for industrial enterprises to carry out green innovation activities.

Environmental regulation (Env). Explored by the completed investment in industrial pollution control, both neo-classical economics and Porter Hypothesis pay attention to the impact of environmental regulation on green innovation, which shows that the impact of environmental regulation cannot be ignored.

Industrial structure (Ind). Explored by the proportion of tertiary industry, the upgrading of industrial structure represents the improvement of the service degree of industrial structure, which can affect industrial green innovation.

Industrial enterprise scale (Scale). Select the logarithm of the average assets of industries above designated size to reflect; the calculation method is to divide the total assets of industrial enterprises above designated size by the number of enterprises. Generally speaking, the larger the scale of industrial enterprises, the more conducive it is to carry out industrial green innovation.

Foreign direct investment (FDI). Explored by the proportion of total foreign investment in GDP, FDI can affect industrial green innovation by changing the total amount of regional funds.

Nationalization rate of industrial enterprises (Soe). Measurement of the proportion of assets of state-owned and state holding enterprises in the total assets of all above designated size industrial enterprises. It is generally believed that state-owned enterprises have more resource advantages of green innovation.

4.3. Data Sources. This paper mainly uses two sets of data. Firstly, the digital financial indicators are from the China digital inclusive financial development index (phase III) released by the digital finance research center of Peking University. Secondly, indicators other than digital finance come from “China Statistical Yearbooks,” “China Science and Technology Statistical Yearbooks,” “China Industrial Statistical Yearbooks,” “China Environmental Statistical Yearbooks,” and provincial statistical yearbooks over the years; individual missing values are supplemented by linear interpolation. In view of the availability of data, the research sample of this paper is the balanced panel data of 30 provinces in
China excluding Hong Kong, Macao, Taiwan, and Tibet from 2011 to 2019. Considering that the green innovation of industrial enterprises matches the scale of enterprises, the data at the level of industrial enterprises select industrial enterprises above the scale of each province. In this paper, the index of industrial enterprise scale (Scale) is logarithmized, and the other variables use the original value.

5. Empirical Analysis

5.1. Basic Regression Analysis. Firstly, this paper conducts a regression analysis on the benchmark measurement model. There may be a two-way causal relationship between the core explanatory variables and the explained variables; that is, digital finance can promote the performance of industrial green innovation, and the performance of industrial green innovation will also have an impact on digital finance, resulting in the possible endogeneity of the measurement model. In order to ensure the accuracy of the model’s regression results, this paper uses the systematic GMM method to carry out the model’s regression. In fact, in the following regression models, the Sargan test and AR(2) passed the test requirements of the GMM method, which also shows the rationality of choosing the GMM estimation method. It can be seen from the results in column (1) of Table 2 that the impact coefficient of digital finance on the performance of industrial green innovation is significant at the level of 1%, indicating that digital finance can promote the growth of the performance of industrial green innovation. As a combination of finance and technology, digital finance helps financial institutions accurately identify the capital needs of industrial enterprises and improve the risk management level of financial institutions, so as to reduce the financing cost of industrial enterprises by promoting the allocation of financial resources. It strengthens the technological innovation power of green production in industrial enterprises and contributes to the green development of industrial enterprises. Therefore, hypothesis 1 is proven. The first-order lag coefficient of the performance of industrial green innovation is positive and has passed the significance test, which shows that the performance of industrial green innovation has an obvious dynamic effect. The early performance of industrial green innovation has a significant impact on the current industrial green development, and there is a significant path dependence in time.

The Malmquist index method will further decompose the performance of industrial green innovation into the technical efficiency index (ec) and technical progress index (tc). The decomposition of the performance of industrial green innovation helps to more clearly identify the path of progress in industrial green technology. This paper makes a systematic GMM regression estimation of the impact effect of digital finance as a dependent variable. The estimation results are shown in columns (2) and (3) of Table 2. It is found that digital finance significantly promotes the technical efficiency index and technical progress index, and the impact coefficient on the technical efficiency index is larger, indicating that the improvement in the performance of industrial green innovation in digital finance is mainly driven by promoting the improvement of technical efficiency. However, the sign of the first-order lag term of the technical efficiency index and the technical progress index is negative, which indicates that the technical efficiency and technological progress of industrial enterprises have a decreasing effect, and the sustainability of the existing technological development model needs to be further improved.

In terms of control variables, based on the impact on the performance of industrial green innovation, it is found that only the nationalization rate of industrial enterprises has no significant impact, and the other variables have significant impact. Specifically, the production scale of industrial enterprises promotes the improvement of industrial green innovation performance, which shows that the larger the production scale of industrial enterprises, the more conducive it is for enterprises to form the scale effect of green production, because large-scale industrial enterprises can continue to carry out green technology innovation and realize the source treatment of industrial pollution, thus promoting the growth of industrial green innovation performance. The impact of foreign direct investment is positive, which shows that in the process of foreign direct investment, the introduction of foreign advanced green technology and learning foreign cutting-edge green production management experience will help industrial enterprises abandon the extensive production mode, carry out green technology innovation, and improve product competitiveness. The sign of infrastructure construction coefficient is negative, indicating that the production of materials such as steel and cement required for infrastructure construction is not conducive to the improvement of industrial green innovation performance. Industrial environmental regulation inhibits the improvement of industrial green innovation performance, which shows that the “Porter Hypothesis” is not tenable. The reason is that environmental regulation will increase enterprises’ investment in environmental protection, thus crowding out other investments such as R&D activities, so as to limit the production activities of industrial enterprises, which is not conducive to the improvement of industrial green innovation performance. The impact coefficient of industrial structure on industrial green innovation performance is negative, which shows that although the increase in the proportion of tertiary industry inhibits the development speed of traditional industry and reduces pollution to a certain extent, the service-oriented process of industrial structure brings changes in labor productivity with a large number of labor transferred to the service sector with low productivity, which is not conducive to the improvement of industrial green innovation performance. The nationalization rate has an insignificant negative effect on the improvement of industrial green innovation performance, indicating that although state-owned enterprises call for environmental protection more actively, it is difficult to form the scale effect of industrial green development transformation in the short term due to its relatively low proportion.

5.2. Structural Effect Analysis. It may not be comprehensive to only analyze from the perspective of the total index of
digital finance. Next, we will start from the subdivision dimension of digital finance to deeply investigate the structural effect of digital finance on the performance of industrial green innovation. The coverage, use depth, and digitization degree of digital finance investigate the new characteristics of traditional financial services and Internet financial services from the perspectives of the supply coverage of financial services, the deepening of the actual use of digital financial services, and the convenience and cost of digital financial services. Therefore, it is necessary to analyze the structural impact of digital finance on the performance of industrial green innovation. Table 3 shows the impact of coverage (COV), the depth of use (USA), and the degree of digitization (digital) on the performance of industrial green innovation and its decomposition indicators. It is easy to conclude that, first, the regression coefficients of columns (1), (4), and (7) are positive, indicating that the coverage, use depth, and digitization degree have significantly promoted the performance of industrial green innovation. In terms of the impact degree, the digitization degree has the greatest impact, followed by the coverage and use depth, which means that the application of advanced Internet technology has expanded the field of traditional financial services. By improving the convenience of financial services and reducing the cost of financial services, we can guide capital to industrial enterprises with higher levels of green development. Therefore, the improvement of digitization has a significant incentive effect on the performance of industrial green innovation. Second, from the perspective of decomposition indicators, it was found that the effect of coverage and use depth on the performance of industrial green innovation is mainly realized by driving technical efficiency, and the promotion effect of digitization on the performance of industrial green innovation mainly depends on technological progress, indicating that the increase in the supply of digital financial services and the deepening of the actual use of digital financial services are more conducive to improving the technical efficiency of industrial green development. The degree of digitization is brought about by the improvement in digital finance. The digital transformation of the financial system and the construction of digital financial facilities have promoted the technological progress of industrial green development to a certain extent.

5.3. Analysis of the Inclusive Effect. For a long time, the disadvantages of traditional finance have provided opportunities for the development of digital finance. Abiad et al. [22] measured the financial repression of 91 economies and found that the degree of financial repression in China is much higher than that in developed countries and significantly higher than the average level of developing countries. Previous studies have also paid attention to the inhibitory effect of financial repression on economic growth in recent years [23]. The high level of financial repression makes the traditional financial market unable to meet the huge financial needs of the real economy. Coupled with the application of the mobile Internet, big data, and other information technologies, digital finance has developed rapidly and has been recognized by the market. Along with making up for the shortcomings of traditional financial development, it serves the long-tail groups that traditional finance cannot cover, aiming to achieve the goal of financial inclusion. It can be said that digital finance has an obvious incremental, supplementary "inclusive effect." Along this line of thought, in areas where the development of traditional financial sectors is relatively weak, digital finance should be able to "deliver carbon in the snow" on the performance of industrial green innovation, so as to play the role of making up for weaknesses. Therefore, this paper will measure regional traditional financial development according to the ratio of the loan scale of each province to its GDP scale and take the average value of the level of traditional financial development as the division basis to investigate the inclusive effect of digital finance on the performance of industrial green innovation under different financial endowments. The results are shown in Table 4. The study found that, in areas

<table>
<thead>
<tr>
<th>Explained variable</th>
<th>(1) GMM</th>
<th>(2) GMM</th>
<th>(3) GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.Gip</td>
<td>0.1789*** (0.0075)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ltc</td>
<td>-0.2679*** (0.0043)</td>
<td>-0.2367*** (0.0050)</td>
<td></td>
</tr>
<tr>
<td>Dif</td>
<td>0.3033*** (0.0388)</td>
<td>0.1014*** (0.0280)</td>
<td>0.0947*** (0.0114)</td>
</tr>
<tr>
<td>Inf</td>
<td>-7.1873*** (0.7181)</td>
<td>-0.5472 (0.3724)</td>
<td>-4.3279*** (0.3237)</td>
</tr>
<tr>
<td>Scale</td>
<td>-1.0746*** (0.1020)</td>
<td>-2.1739** (0.1773)</td>
<td>0.0164 (0.0310)</td>
</tr>
<tr>
<td>Scale</td>
<td>-0.0666*** (0.0055)</td>
<td>-0.0750* (0.0062)</td>
<td>-0.0004 (0.0011)</td>
</tr>
<tr>
<td>Scale</td>
<td>0.6123*** (0.0475)</td>
<td>0.7003*** (0.0460)</td>
<td>-0.0028 (0.0276)</td>
</tr>
<tr>
<td>FDI</td>
<td>1.0636*** (0.0805)</td>
<td>0.3052*** (0.0571)</td>
<td>0.4669*** (0.0521)</td>
</tr>
<tr>
<td>Soe</td>
<td>-0.3501 (0.2474)</td>
<td>-1.2271*** (0.2056)</td>
<td>0.0701 (0.1420)</td>
</tr>
<tr>
<td>Constant</td>
<td>-8.7041*** (0.9133)</td>
<td>-8.3765*** (0.8435)</td>
<td>0.0082* (0.5224)</td>
</tr>
<tr>
<td>Sargan</td>
<td>0.6745</td>
<td>0.8082</td>
<td>0.6582</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.5856</td>
<td>0.7394</td>
<td>0.3293</td>
</tr>
</tbody>
</table>

Note: the coefficient values in brackets are standard errors; ***, **, and * are significant at the level of 1%, 5%, and 10%, respectively; the same below.
with a high development level of traditional finance, the impact coefficient of digital finance on the performance of industrial green innovation is positive, but it is not statistically significant. In areas with a low development level of traditional finance, digital finance shows an obvious positive driving effect on the performance of industrial green innovation (the coefficient is positive and passes the statistical significance test of 5%), indicating that in areas with a low development level of traditional finance, digital finance can effectively cover the needs of industrial green transformation in areas with a low development level of traditional finance. Thus, it has a more significant inclusive feature. In terms of decomposition indicators, it is found that the driving effect of digital finance on technical efficiency also has an inclusive effect, but compared with the impact of technological progress, it is found that the promotion effect is greater in areas with a high level of traditional financial development, and the inclusive characteristics are not obvious.

5.4. Robustness Check. In order to further test the robustness of the results, this paper tests the robustness of the effect of digital finance on industrial green innovation performance by replacing the core explanatory variables and changing the empirical model. In terms of replacing the core explanatory variables, referring to the practice of existing literature,

### Table 3: Structural effect analysis of digital finance on the performance of industrial green innovation.

<table>
<thead>
<tr>
<th></th>
<th>(1) Gip</th>
<th>(2) ec</th>
<th>(3) tc</th>
<th>(4) Gip</th>
<th>(5) ec</th>
<th>(6) tc</th>
<th>(7) Gip</th>
<th>(8) ec</th>
<th>(9) tc</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.Gip</td>
<td>0.1833*** (0.0077)</td>
<td>0.1638*** (0.0080)</td>
<td>0.1890*** (0.0080)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.ec</td>
<td>-0.2643*** (0.0041)</td>
<td>-0.2875*** (0.0040)</td>
<td>-0.2608*** (0.0032)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.tc</td>
<td>-0.2482*** (0.0061)</td>
<td>-0.2536*** (0.0084)</td>
<td>-0.2328*** (0.0039)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COV</td>
<td>0.0031*** (0.0003)</td>
<td>0.0011*** (0.0003)</td>
<td>0.0007*** (0.0001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>0.0019*** (0.0002)</td>
<td>0.0023*** (0.0002)</td>
<td>-0.0002*** (0.0001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit</td>
<td>0.0278** (0.0113)</td>
<td>-0.0941*** (0.0139)</td>
<td>0.0546*** (0.0026)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control variables</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Constant</td>
<td>-8.8420*** (0.8406)</td>
<td>-7.8205*** (1.0061)</td>
<td>3.257 (0.5309)</td>
<td>-9.7545*** (0.9500)</td>
<td>-6.8109*** (1.3204)</td>
<td>-2.7167*** (0.4792)</td>
<td>-11.7666*** (0.9785)</td>
<td>-11.3640*** (0.8897)</td>
<td>0.8712** (0.3961)</td>
</tr>
<tr>
<td>Sargan</td>
<td>0.6110</td>
<td>0.7722</td>
<td>0.8151</td>
<td>0.7155</td>
<td>0.7970</td>
<td>0.8415</td>
<td>0.8942</td>
<td>0.8042</td>
<td>0.5809</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.5769</td>
<td>0.7352</td>
<td>0.1924</td>
<td>0.5587</td>
<td>0.7165</td>
<td>0.1140</td>
<td>0.5576</td>
<td>0.6228</td>
<td>0.3392</td>
</tr>
</tbody>
</table>

### Table 4: Analysis of the inclusive effect of digital finance on the performance of industrial green innovation.

<table>
<thead>
<tr>
<th>The group with a higher level of traditional financial development</th>
<th>(1) Gip</th>
<th>(2) ec</th>
<th>(3) tc</th>
<th>(4) Gip</th>
<th>(5) ec</th>
<th>(6) tc</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.Gip</td>
<td>0.2873*** (0.0239)</td>
<td>-0.2696*** (0.0223)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.ec</td>
<td>-0.3038*** (0.0309)</td>
<td>-0.2262*** (0.0136)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.tc</td>
<td>-0.1560*** (0.0354)</td>
<td>-0.1478*** (0.0215)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dif</td>
<td>0.0278 (0.0941)</td>
<td>0.2162*** (0.0824)</td>
<td>0.1408** (0.0634)</td>
<td>0.1322* (0.0715)</td>
<td>0.0614* (0.0343)</td>
<td></td>
</tr>
<tr>
<td>Control variables</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Constant</td>
<td>-38.6171*** (11.2736)</td>
<td>-14.7773* (8.2160)</td>
<td>-0.0516 (6.4251)</td>
<td>1.0373 (1.5738)</td>
<td>-0.1161 (2.9191)</td>
<td>-0.6663 (2.7287)</td>
</tr>
<tr>
<td>Sargan</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>0.9904</td>
<td>0.9952</td>
<td>0.9877</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.3341</td>
<td>0.9810</td>
<td>0.7334</td>
<td>0.4204</td>
<td>0.5837</td>
<td>0.1405</td>
</tr>
</tbody>
</table>
this paper adopts financial development as the alternative variable of digital inclusive finance. The deposit and loan scale is a more common indicator to measure the degree of financial development. The robustness test results after taking logarithm of the deposit and loan scale are shown in Table 5. The impact of financial development (FD) on industrial green innovation performance, technical efficiency, and technological progress is significantly positive, consistent with the above conclusions. In terms of changing the empirical model, Ordinary Least Squares model (OLS) is used to replace the systematic GMM model used in the benchmark regression for robustness test. The regression results in column (1) of Table 6 show that digital finance plays a significant role in promoting financial efficiency (FE). In the regression results in column (2) of Table 6, the coefficients of digital finance and financial efficiency are significantly positive, indicating that digital finance can effectively improve the credit efficiency of finance and promote the performance of industrial green innovation. This means that the improvement of financial efficiency helps to alleviate the financing constraints of industrial enterprises, and the abundant funds of industrial enterprises can provide guarantee for green transformation, which is conducive to the improvement of industrial green innovation performance. The empirical results in Table 6 confirm that the development of digital finance can provide significant impetus to improve the performance of industrial green innovation by improving financial efficiency. Thus, a positive transmission path of “digital finance → (improve) financial efficiency → (promote) industrial green innovation performance” has been formed. In terms of decomposition indicators, this paper finds that financial efficiency also plays a complete intermediary role in the process of digital finance affecting technological progress, while it plays a masking role in the impact of digital finance on technological efficiency, indicating that with the improvement of financial efficiency, the increase of available funds is more conducive to promoting the improvement of cleaner production technology, while the effect of ecological governance cannot be significantly improved in the short term.

5.5. Impact Channel Analysis. The above research shows that the higher the development level of digital finance, the more conducive to the improvement of industrial green innovation performance, as well as technical efficiency and technological progress. The above research has fully tested the direct effect of digital finance on industrial green innovation performance but only discussed the direct effect between “digital finance—industrial green innovation performance,” in which the mechanism has not been analyzed. So it is necessary to further analyze the intermediary path. In this regard, this paper will select “financial efficiency” and “household consumption” to verify from the perspective of supply side and demand side. In order to describe the specific channel mechanism of digital finance affecting the performance of industrial green innovation, this paper uses the intermediary effect test procedure (equation (2)–equation (4)) for identification test.

\[ Y_{it} = a_0 + a_1 Y_{it-1} + a_2 \text{Dif}_{it} + a_3 \text{Controls} + \epsilon_{i,t}, \]  
\[ \text{Mediator}_{it} = b_0 + b_1 \text{Mediator}_{it-1} + b_2 \text{Dif}_{it} + b_3 \text{Controls} + \epsilon_{i,t}, \]  
\[ Y_{it} = c_0 + c_1 Y_{it-1} + c_2 \text{Dif}_{it} + c_3 \text{Mediator}_{it} + c_4 \text{Controls} + \epsilon_{i,t}. \]  

The variables' meanings of the above three equations are consistent with equation (1). Mediator, are the intermediary variables of this paper, including financial efficiency (FE) and residents’ consumption (Con). Among them, FE is expressed by the logarithm of various loan balances of urban financial institutions, and Con is expressed by the logarithm of average wages of employees in urban units. In the above three-step test procedure of mediating effect, if \( a_2 \) and \( b_3 \), and \( c_4 \) are significant, it indicates that there is mediating effect; if \( c_3 \) not significant, it indicates that there is complete mediating effect. If the symbol of \( b_2 c_3 \) is consistent with the symbol of \( c_2 \), it indicates that there is some intermediary effect, \( c_2 \) is the direct influence effect of digital finance, and \( b_2 c_3 \) is the intermediary effect of this paper. If the symbol of \( b_2 c_3 \) is not consistent with the symbol of \( c_2 \), it indicates that there is a masking effect.

5.5.1. Mechanism Test of Financial Efficiency. Through the previous theoretical analysis, we first try to test whether financial efficiency will play an intermediary role in the process of digital finance promoting the development of industrial green innovation performance. The regression results in the above three-step test procedure of mediating effect, if \( a_2 \), \( b_3 \), and \( c_4 \) are significant, it indicates that there is mediating effect; if \( c_3 \) not significant, it indicates that there is complete mediating effect. If the symbol of \( b_2 c_3 \) is consistent with the symbol of \( c_2 \), it indicates that there is a masking effect.

5.5.2. Mechanism Test of Residents’ Consumption. In Table 7, this paper examines the existence of residents’ consumption mechanism. As shown in the regression results in column 1 of Table 7, the coefficient of digital finance is significant at the level of 1%, indicating that digital finance plays a significant role in promoting residents’ consumption. The regression results in column 2 of Table 7 show that the impact coefficient of digital finance on industrial green innovation performance is significantly positive, but the impact coefficient of household consumption on industrial green innovation performance is significantly negative. Combined with the previous analysis, it shows that residents’ consumption has a certain conduction effect, but it shows a masking effect. This means that the improvement of the level of digital finance can effectively promote the development of industrial green innovation performance, but this promotion will be restrained under the influence of residents’ consumption. The possible reasons are as follows: on the one hand, with the increase of residents’ large rigid expenditure on education, medical treatment, and housing in recent years, residents’ consumption demand in other aspects, including industrial products, has been restrained, resulting in
insufficient power of domestic demand, unable to effectively promote the growth of industrial green innovation performance. On the other hand, the lack of information, high prices, lack of time, and consumption habits lead to the differences between consumers’ green consumption attitudes and behavior [24]. Moreover, the deviation between consumers’ green attitude and the actual purchase behavior of green products is considered to be one of the main obstacles to the development of the current green market. At present, the scale of green consumption in China is still very limited,
and there is a lack of green consumption power, while the low residents’ green consumption is obviously not conducive to the green transformation of industrial enterprises and the improvement of industrial green innovation performance. In terms of decomposition indicators, there are some differences in the role of residents’ consumption in the process of digital finance affecting technological progress and technological efficiency, indicating that residents’ consumption helps to produce scale effect and can significantly improve technological efficiency, but the effect of promoting technological progress is not good.

Based on the above analysis, it shows that financial efficiency and household consumption play an intermediary role in the process of digital finance affecting the performance of industrial green innovation. Hypothesis 2 is true. Industrial green innovation focuses on evaluating the environmental effects of industrial innovation, while cleaner production depends heavily on capital investment. Through the effect of improving financial efficiency, digital finance can broaden the financing channels of industrial green production, squeeze in regional R&D investment, and then improve the level of industrial green innovation. In addition, it can also drive industrial green innovation by promoting residents’ consumption.

6. Conclusions and Suggestions

Accelerating the green development of industry and promoting the reform of the ecological civilization system are the inevitable requirements of sustainable economic development. Green innovation has become a new yardstick and concept in China’s industrial economic development at this stage. There is a lack of research on digital finance and the performance of industrial green innovation in the existing literature. Therefore, this paper attempts to investigate the impact effect and mechanism of digital finance on the performance of China’s industrial green innovation from two aspects: mechanism analysis and empirical testing. At the theoretical level, we demonstrate the impact mechanism of digital finance on the performance of industrial green innovation from the perspectives of the direct impact and intermediary effect. At the empirical level, the empirical results of China’s provincial panel data and China’s digital financial development data from 2011 to 2019 show that, firstly, on the whole, digital finance significantly promotes the performance of industrial green innovation and its decomposition indicators, and digital finance mainly improves the performance of industrial green innovation by improving technical efficiency. Secondly, in terms of structure, coverage, the depth of use, and digitization degree have significantly promoted the performance of industrial green innovation, and the digitization degree has the greatest effect. Thirdly, in terms of the inclusive effect, digital finance effectively makes up for the shortcomings of traditional financial development. In areas with poor traditional financial development, digital finance can better promote the improvement of industrial green innovation performance and technical efficiency, which is inclusive. Fourthly, in terms of the mechanism test, financial efficiency has a partial intermediary effect in which the process of digital finance affects the performance of industrial green innovation, while residents’ consumption mainly plays a masking role in the process of digital finance, affecting the performance of industrial green innovation.

The conclusions of this paper have the following policy implications:

Firstly, effectively promote the development of digital finance and improve all dimensions of digital finance. As an important direction for China to deepen the development and reform of traditional finance, its role in improving the performance of industrial green innovation is obvious to all. Therefore, we should vigorously develop digital finance. However, the development of digital finance is a systematic project, which needs to clarify the specific development objectives of digital finance in the strategy. On the basis of steadily promoting the coverage and use depth, we should also vigorously promote the informatization development of financial infrastructure in the next step. Accelerate the construction of digital financial infrastructure such as network communication environment and settlement and payment system, so as to more efficiently and comprehensively improve China’s industrial green innovation system and improve China’s ecological welfare level.

Secondly, we should give full play to the role of digital finance in promoting and benefiting the performance improvement of industrial green innovation. On the one hand, since the development of digital finance can promote the performance improvement of industrial green innovation, it is necessary to continue to promote the development of digital finance, promote the improvement of technical efficiency and technological progress of industrial sectors, strengthen the incentive role of digital finance in industrial green innovation, and ensure the optimal allocation of scarce financial resources. On the other hand, areas with backward traditional financial development have late development advantages. The development of digital finance is more conducive to industrial green innovation in areas with backward traditional financial development. Therefore, the government should establish and improve the financial market and strengthen the construction of financial infrastructure according to local policies, so as to make digital finance an important help to balance regional development and industrial green transformation.

Thirdly, strengthen industrial green technology innovation and guide residents’ green consumption. Industrial transformation and upgrading should reflect the concept and connotation of environmental protection, take improving industrial green innovation performance as the fundamental goal of green development, give full play to the role of green technology progress in promoting green innovation performance, and achieve win-win economic and ecological benefits. Due to the "masking effect" of residents’ consumption, the transmission mechanism of digital finance affecting the performance of industrial green innovation through residents’ consumption effect is blocked. On the one hand, the correction of this transmission mechanism should stimulate residents’ consumption demand for industrial products and realize the scale effect of industrial innovation production by
expanding domestic demand. On the other hand, by improving the government’s assistance to promote the cultivation of residents’ environmental literacy, consumers should recognize the importance of green consumption behavior for environmental protection. Residents’ environmental values and environmental responsibility contribute to the transformation of industrial green development. The construction of the “Trinity” framework of government environmental education, enterprise green production, and residents’ green consumption will help to give play to the transmission role of residents’ consumption in the impact of digital finance on the performance of industrial green innovation.

Data Availability
The data used to support the results of this research can be obtained from the corresponding author upon request.

Conflicts of Interest
The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments
The author would gratefully like to acknowledge the support provided by the Doctor Start-up Fund of Henan University of Animal Husbandry and Economy (No. 2022HNUAHEDF001).

References