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Original Research

Does Digitalization Promote the Green and High-Quality Development of Logistics Industry in the Yellow River Basin of China?

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Abstract

The digital transformation is of great significance to green and high-quality development of logistics industry (L-GHD). This paper analyzes the theoretical mechanism of digitalization affecting the L-GHD. In the meantime, taking the urban data of China's Yellow River Basin as an example, a fixed effect model is established to empirically test the impact of digitalization on the L-GHD. The results show that: (1) digitalization can significantly promote the L-GHD. (2) Digitalization indirectly promotes the L-GHD through technological innovation input and output, optimized allocation of labor and capital elements. (3) The heterogeneity test of city types shows that the impact of digitalization on the L-GHD is more significant in non-resource-based cities. Urban location heterogeneity test shows that digitalization has a more significant impact on L-GHD in the middle and lower reaches of the Yellow River Basin. Finally, it puts forward suggestions to accelerate the healthy development of digitalization and help the L-GHD in the Yellow River Basin of China.

Keywords: digitalization, green and high-quality development, logistics industry, the Yellow River Basin of China

Introduction

Digital transformation is an important engine for global economic growth and an important driving force for industrial transformation in the post epidemic era. In the process of digital development, it provides "accelerator" for the whole society to achieve green and high-quality development through digital technology optimization. As the largest developing country in the world, the China Internet Development Report 2021 shows that China's digital level is the fastest growing country in the world. At the same time, the rapid development of digitalization in China is based on the wide coverage of Internet technology, accelerating the innovation of intelligent digital technology, and deeply integrating into the whole field of economic and social development, so as to promote the realization of green and high-quality development [1-2].

The Yellow River is the second longest river in China and the fifth longest river in the world. It is the birthplace of the Chinese nation and also known as the "mother river of the Chinese nation". Based on the

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background of economic development from high-speed growth to high-quality development, General Secretary Xi proposed to raise "ecological protection and high-quality development in the Yellow River Basin" to a major national strategy. Du et al. pointed out that the carbon emissions of the Yellow River Basin account for more than half of China's total carbon emissions [3]. It can be found that the development of the Yellow River Basin is also restricted by environmental resources. Therefore, the Yellow River Basin to achieve green and high-quality development is imminent. Logistics industry, as the basic, strategic and leading industry of national economy, is the key way to promote the green and high-quality development of the Yellow River Basin and even the whole social economy. In this context, this paper intends to take cities in the Yellow River Basin of China as samples to explore the effect and mechanism of digitalization on L-GHD, which has important value and practical significance to promote L-GHD and environmental protection.

Literature Review

Study on green and high-quality development of logistics industry. (1) The research on the connotation and evaluation system of L-GHD is divided into two aspects. On the one hand, study the development quality of logistics industry. Li et al. and Cao et al. evaluated the high-quality development of logistics industry from the angle of efficiency [4-5]. Wei et al. mapped the connotation of the development quality of logistics industry to the evaluation system, including development benefits, quality, potential etc. On the other hand, study the L-GHD [6]. Li et al. and Liu & Xu used the green total factor productivity of the logistics industry to measure the L-GHD [7-8]. Xiao believed that the high-quality development of the logistics industry includes green logistics and environmental protection [9]. Lin et al. established an evaluation index system for the high-quality development of the logistics industry in terms of the environmental development cost of the logistics industry [10]. There is still a lack of connotation analysis and evaluation system construction in the existing literature on the L-GHD. (2) Research on green and high-quality development of logistics industry. Yao et al. used the directionless distance function method to evaluate the green efficiency of China's provincial logistics industry [11]. Huang et al. and Wang et al. respectively analyzed the high-quality development level of green logistics industry in the Guangdong-Hong Kong-Macao Greater Bay Area and the Yangtze River Delta region [12-13]. Gan et al. used the three-stage DEA model to measure the green efficiency of logistics industry in Jiangxi Province [14]. The logistics industry in the Yellow River basin urgently needs to transform to green and high-quality development. However, there is still a lack of research on the Yellow River Basin.

At home and abroad, the literature revealing the connotation of digital concept has been very rich [15-20]. They believed that digitization is a series of production activities with information as the production factor and Internet as the infrastructure. Based on this, some scholars have also studied the impact of digitalization on the L-GHD. They found that digitalization has made an important contribution to productivity and innovation efficiency [21-22]. At present, the research on the impact of digitalization on the L-GHD is mainly reflected in the following two aspects. On the one hand, many scholars have found that digitalization can significantly improve the green and high-quality development of the economy [23-25]. On the other hand, technological innovation and digital technologies affect the green and high-quality development level of the logistics industry [7, 26-29].

Proposal of Research Questions

To sum up, scholars at home and abroad have rich research on digitalization, L-GHD and the impact of digitalization on green and high-quality development, which lays a solid foundation for this study. However, at present, there is a lack of achievements focusing on the impact of digitalization on the L-GHD. Compared with the existing literature, this paper has three possible marginal contributions. (1) On the basis of clearly defining the core concepts, deeply analyze the mechanism of digitalization affecting the L-GHD. (2) Establish an evaluation index system consistent with the connotation of L-GHD. Based on the data of the Yellow River Basin from 2011 to 2019, this paper empirically analyzes the impact of digitalization on the L-GHD and its mechanism. (3) Based on the research conclusions, suggestions are put forward to promote the healthy development of digitalization and improve the level of L-GHD in the Yellow River Basin.

Concept, Mechanism and Hypothesis

Concept Definition

What is the L-GHD? According to the definition of logistics industry in China's "Medium and long-term Development Plan for Logistics Industry (2014-2020)" and the "Innovation, coordination, green, open and shared development concept" proposed in the 18th CPC Central Committee. The special Action Plan for High-quality Development of Trade Logistics (2021-2025) jointly issued by the Ministry of Commerce and other nine departments in August 2021, it is required that "by 2025, China will initially establish a smooth and efficient, collaborative and sharing, intelligent and green, integrated and open modern trade of logistics system". Based on this, we define the L-GHD as a comprehensive and unified process of realizing green efficiency, technological innovation, structural

optimization, open cooperation and environmental sharing.

The Direct Impact of Digitalization on the L-GHD

Based on the concept of L-GHD, digitalization plays a direct role in logistics industry, enabling it to realize green efficiency, technological innovation, structural optimization, open cooperation and environmental sharing. (1) Digitalization can achieve green and efficient development through high output and low input of logistics industry on the premise of promoting environmental protection [30]. (2) Digitalization drives technological innovation in the logistics industry by facilitating the introduction, adoption and generation of new technologies [31]. (3) Digitalization promotes the structure optimization of logistics industry for the structure rationalization and advanced [32]. (4) In the process of "going global" and "bringing in", the digitalization has achieved open cooperation in the logistics industry. (5) Digitalization platform can promote the sharing of system environment and facility environment of logistics industry [1]. In this comprehensive process, it will promote the L-GHD.

The Indirect Impact of Digitalization on the L-GHD

Digitalization can promote green and high-quality development of national economy through technological innovation and factor allocation efficiency [23-24]. It will certainly promote the logistics industry, which is the basic, strategic and leading industry of the national economy.

Digitalization Promotes the L-GHD by Driving the Technological Innovation of the Whole Society

Firstly, the digitalization indirectly promotes the L-GHD by stimulating the investment potential of technological innovation in the whole society. The digital transformation not only drives the Internet platform to provide a basic operating environment for digital production, but also provides technical support for improving production and operation efficiency and stimulating market development potential. This provides a scientific basis for the government, the market and enterprises to accurately increase investment in technological innovation. By guiding the whole society to release innovation funds and stimulate innovation potential, enterprises will be further boosted to enhance technological innovation ability and optimize technological innovation path from the perspective of sustainable development. The precise release of technological innovation potential of the whole society is not only conducive to the improvement of efficiency in the production process, but also can promote the L-GHD [33]. Secondly, the digitalization promotes the L-GHD by accelerating the output of technological innovation in the whole society. Relying on the Internet platform, digital transformation provides condition beyond time and space for technological exchange. This is accompanied by the efficient connection between all links of the industrial chain in the process of physical logistics activities, and ensures the circular output of circulation data [34]. On the whole, the output level of technological innovation can be improved through the in-depth aggregation and two-way interactive. At the same time, technological innovation has a diffusion effect, which will promote the L-GHD as a whole.

Digitalization Promotes the L-GHD by Improving the Efficiency of Factor Allocation

Firstly, the digitalization indirectly promotes the L-GHD by improving the allocation efficiency of labor factors in the whole society. Technologies such as artificial intelligence, the Internet of things and big data have replaced a lot of repetitive labor inputs, transforming the division of labor. In other words, more workers will be assigned to positions with strong autonomy in production processes, such as technological innovation, emergency response, process optimization and production management. This can give full play to the initiative, enthusiasm and creativity of workers, in the process of improving the output value of unit logistics practitioners, to achieve L-GHD [35]. Secondly, digitalization indirectly promotes the L-GHD by improving the allocation efficiency of capital elements in the whole society. Digitalization is a production process that deeply integrates the production, exchange, distribution and consumption of material data on the basis of the collection, transmission, storage, processing and mining of social data. Through the mutual cooperation of information flow and material flow, to improve the efficiency of all kinds of production capital allocation. On the whole, it is to accelerate the turnover of social capital while improving the green and high-quality development level of logistics industry [36].

Based on the above theoretical analysis, we can summarize the action mechanism diagram of digitalization affecting the L-GHD (as shown in Fig. 1). At the same time, the research hypothesis of this paper is proposed: digitalization promotes the L-GHD through direct effect and indirect effect.

Methodology and Data

Model Building

Before establishing the model, Stata15 software was used to conduct Hausman test, and the result was P = 0.00. Therefore, the fixed effect model was selected to be established.

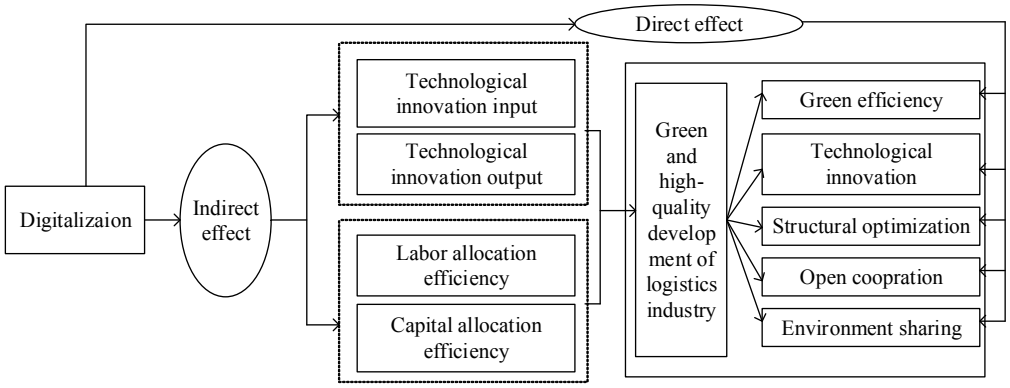

Fig. 1. The mechanism diagram of digitalization impact on the green and high-quality development of logistics industry.

Direct Effect Model

We establish a model for the direct effect of digitalization on the L-GHD, as shown in formula (1).

$$L-hqd_{it}=\alpha_0+\alpha_1 Dig_{it}+\lambda Control_{it}+\tau_i+\mu_t+\varepsilon_{it}$$

In formula (1), *i* and *t* represent different cities and years respectively. *L-GHD* is the green and high-quality development level of logistics industry, which is further divided into green efficiency of logistics industry (*L-geff*), technological innovation of logistics industry (*L-inno*), structural optimization of logistics industry (*L-stru*), open cooperation of logistics industry (*L-open*) and environmental sharing of logistics industry (*L-share*). *Dig* represents the development level of digitalization, and *Control* represents a series of control variables.τ_i and μ_t stand for fixed effect. ε is the residual term. α_0, α_1 and l are parameters to be estimated, where α_1 is the core parameter of the impact of digitalization on the L-GHD.

Indirect Effect Model

According to the theoretical analysis, the impact of digitalization on the green and high-quality development of logistics industry has indirect effects. In this regard, we establish a mediating effect model. Specifically, Equations (2) and (3) are added on the basis of model (1).

$$Middle_{it}=\alpha_0+\zeta Dig_{it}+\lambda Control_{it}+\tau_i+\mu_t+\varepsilon_{it} \quad (2)$$

$$L-hqd_{it}=\alpha_0+\beta Dig_{it}+\varphi Middle_{it}+\lambda Control_{it}+\tau_i+\mu_t+\varepsilon_{it} \quad (3)$$

In Equations (2) and (3), *Middle* is the intermediary variable, including technological innovation input (*Inno-in*), technological innovation output (*Inno-out*), Labor allocative efficiency (*Labor-eff*) and Capital factor allocation efficiency (*Capital-eff*). ζ, β and φ are the parameter that the mediation effect model focuses on. The meanings of other variables are consistent with formula (1).

Variable Measurement

Explanatory Variable – Digitalization (Dig)

There has been a lot of research on digitalization. Many scholars have measured the level of digitalization from digital infrastructure [1], digital resources [37], digital services [38], digital industry development [39-40] and digital economic value added [41]. On this basis, we constructed the evaluation index system of digital level from two aspects of Internet development and digital financial inclusion development respectively [1]. Specifically, the development of the Internet includes the Internet penetration rate (%), the number of employees in the information and communication technology industry (people), the output level of the telecommunications industry (ten thousand yuan) and the penetration rate of mobile phones (%). Digital inclusive finance consists of three dimensions: breadth of coverage, depth of use and degree of digitalization [29]. In order to ensure the objectivity and rationality of the calculated results, principal component analysis is used to measure the level of digitalization.

Explained Variable – Green and High-Quality Development Level of Logistics Industry (L-GHD)

Based on the conceptual definition, the evaluation index system of L-GHD is constructed from five aspects: green and efficiency, technological innovation, structural optimization, open cooperation and environmental sharing (as shown in Table 1). In order to avoid the subjective preference of expert weighting and weaken the influence of extreme values on the evaluation results, so as to make the results more scientific, we used the coefficient of variation method to measure L-GHD.

The secondary and tertiary indicators in Table 1 are further explained. (1) Green efficiency of logistics

Table 1. Evaluation index system of L-GHD.

Primary Indexes	Secondary Indexes	Tertiary Indexes	Index Attribute
Green efficiency	Green development	Carbon dioxide emission of logistics industry	-
		Green freight distribution	+
	Logistics efficiency	Freight volume / number of logistics employees	+
Technological innovation	technological innovation	Number of logistics patent applications	+
Structural optimization	Intra industry optimization	Railway freight volume / Road freight volume	+
		Transportation area / logistics area	+
	Inter industry optimization	Logistics GDP/GDP	+
Open cooperation	Open thrust	Opening of China Europe train	+
		Cross border e-commerce pilot zone	+
	Open pull	Total import and export trade	+
Environmental sharing	Institutional environment	Logistics node	+
		Demonstration Logistics Park	+
		Logistics hub	+
	Facility environment	Urban road area per capita	+
		Per capita highway mileage	+
		Number of high-speed rail lines opened	+

Note: the "+" and "-" in Table 1 represent positive indicators and negative indicators respectively.

industry is divided into green development and logistics efficiency. The green development is measured by the carbon dioxide emissions of the logistics industry (refer to the General Principles for the Calculation of Comprehensive Energy Consumption (GB/T 2589-2008) and the method of Chen et al. [42]) and the green freight distribution demonstration project (which is assigned a value of 1 in 2018 and later years due to the influence of policies, and the rest are 0) [43]. (2) Logistics technology innovation is expressed by the number of logistics patent applications. (3) Logistics structure optimization is divided into internal and external structure optimization. The internal structure is represented by the ratio of transportation area and logistics area and the ratio of railway freight volume and highway freight volume. The external structure is expressed by the value of logistics industry compared with the gross value of production [44]. (4) Logistics industry open cooperation including thrust and pull. We use whether to open China-Europe freight trains and whether to build cross-border e-commerce comprehensive pilot zone (the year of policy implementation and subsequent years are assigned 1, and the rest are 0) to represent the thrust. The pulling force is measured by the total value of imports and exports of goods. (5) Logistics industry environment sharing includes system environment and facility environment. The institutional environment is measured by the logistics industry construction policies, such as the establishment of logistics nodes, demonstration logistics parks and logistics hubs, etc. (the policy implementation year and subsequent years are assigned 1, and the rest are assigned 0). The infrastructure environment is measured by the per capita road area, per capita highway mileage and the number of high-speed railway stations opened by non-passenger dedicated lines.

Intermediary Variable

(1) Financial investment in science and technology is the basic guarantee and support of scientific and technological progress. Therefore, the level of technological innovation investment should be measured by financial expenditure on science and technology (ten thousand yuan). The number of patents can better reflect the output capacity of innovation activities. Therefore, we use the number of patent applications widely used in existing studies to measure the output level of technological innovation [45]. (2) Labor allocation efficiency and capital allocation efficiency are expressed by distortion degree of factor market. The specific measurement process is as follows. First, we set up a trans-log production function. Then, the marginal output levels of labor factors and capital factors are calculated. Finally, the ratio of marginal output of capital factor to bank lending rate is used to measure the distortion degree of capital factor market. The ratio of marginal output of labor factor to average wage level is used to measure the distortion degree of labor factor market [46].

Control Variable

There are many factors affecting L-GHD. Therefore, this paper introduces a series of control variables to solve the problem of possible missing variables [1]. Specifically, economic development provides the necessary material basis for the green and high-quality development of logistics industry. We use logarithm of GDP per capita to represent the level of economic development (*Eco*). Areas with higher population density, urbanization level and energy consumption per unit of GDP will be constrained by resources, which requires the logistics industry to shift to green and high-quality development. We measured population density (*Peo*), urbanization level (*City*) and energy consumption per unit of GDP (*Elec*) respectively by the number of people per unit area, the proportion of the municipal district to the city's population and the electricity consumption per unit of GDP. Financial pressure will to some extent limit the logistics industry to achieve green and high-quality development. We use the ratio of fiscal expenditure to fiscal revenue to express fiscal pressure (*Fisc*). The transformation and upgrading of industrial structure will drive the logistics industry to achieve green and high-quality development. We measure the industrial structure (*Indus*) by the ratio of tertiary industry to secondary industry. Wholesale and retail (*Sell*) is one of the driving forces for green and high-quality development of the logistics industry. We use wholesale and retail output as a percentage of GDP.

Data Sources and Descriptive Statistics

According to the provisions of the Outline of Planning for Ecological Protection and High-quality Development of the Yellow River Basin, this paper takes 99 cities in the Yellow River Basin as the research object, and assigns Laiwu City to Jinan City [47]. The data required are from China Urban Statistical Yearbook, China Urban Construction Statistical Yearbook, statistical yearbook of provinces (cities and districts), National Economic and Social Statistical Development Bulletin of prefecture-level cities, and the third issue of Peking University Digital Financial Inclusion Index (2011-2020) [29].

Many scholars point out that China's rapid digital transformation and the rapid development of digital technology are mainly manifested after 2010 [38, 48]. Therefore, this paper selected 99 cities in the Yellow River Basin from 2011 to 2019 as observed values. Stata15 is used for descriptive statistics of relevant variables in empirical research and the results are shown in Table 2.

Results and Discussion

Based on the established model, 99 cities in the Yellow River Basin from 2011 to 2019 are selected to empirically analyze the impact of digitalization on the L-GHD. The direct effect and indirect effect proposed in the research hypothesis are further examined.

Baseline Regression of the Impact of Digitalization on the L-GHD

Based on the model (1) established above, Stata15 is used to analyze the impact of digitalization on the L-GHD. As a baseline regression, the results are shown in Table 3.

Table 2. Descriptive statistics of main variables.

Variable type	Name	Obs	Mean	S.D.	Min	Max
Explained variable	*L-GHD*	891	0.053	0.103	0.003	0.949
Explanatory variable	*Dig*	891	0.061	0.052	0.000	0.516
Intermediary variable	*Capital-eff*	891	4.961	0.068	4.762	5.161
	Labor-eff	891	0.049	0.062	0.001	0.575
	Inno-in	891	12.273	1.160	1.358	16.174
	Inno-out	891	0.049	0.096	0.010	1.010
Control variable	*Peo*	891	0.154	0.117	0.001	0.483
	Fisc	891	0.200	0.162	0.024	1.021
	Sell	891	0.107	0.086	0.001	0.531
	City	891	0.340	0.200	0.048	1.001
	Elec	891	0.118	0.125	0.001	0.826
	Indus	891	0.010	0.006	0.001	0.063
	Eco	891	0.105	0.092	0.008	0.724

Table 3. Baseline regression results of the impact of digitalization on the L-GHD.

	(1)	(2)	(3)	(4)	(5)	(6)
	L- GHD(Vari)	*L- GHD*(Vari)	*L- GHD*(Vari)	*L- GHD*(Vari)	*L- GHD*(Entr)	*L- GHD*(Subj)
Dig	1.330***	1.076***	1.209***	1.068***	0.691**	0.636***
	(8.20)	(7.73)	(3.59)	(3.47)	(2.35)	(4.37)
Peo		-0.02		1.972**	1.758**	0.847**
		(-0.57)		(2.18)	(2.13)	(2.14)
Fisc		0.061**		-0.008	-0.024	0.005
		(2.39)		(-0.24)	(-0.85)	(0.26)
Sell		0.131*		0.056	0.073	-0.004
		(1.65)		(0.36)	(0.56)	(-0.06)
City		0.042**		0.092	0.069	0.037
		(2.15)		(0.82)	(0.82)	(0.63)
Elec		0.017		0.083**	0.059*	0.039**
		(0.65)		(2.12)	(1.96)	(2.13)
Indus		1.830**		1.167	0.606	0.992**
		(2.35)		(1.53)	(0.89)	(2.42)
Eco		0.261***		1.092***	0.621***	0.692***
		(3.42)		(3.47)	(3.08)	(3.79)
Constant	-0.028***	-0.098***	-0.026**	-0.455***	-0.366**	-0.038
	(-3.77)	(-4.74)	(-2.17)	(-2.92)	(-2.61)	(-0.55)
City FE	N	N	Y	Y	Y	Y
Year FE	N	N	Y	Y	Y	Y
Obs	891	891	891	891	891	891
R_2			0.299	0.375	0.258	0.54
F			11.446	9.679	6.604	15.741

Note: *, * * and * * * respectively indicate passing the test at the significance level of 10%, 5% and 1%. T value in parentheses (the same below).

Columns (1) and (2) in Table 3 are the regression results of whether control variables are increased under the random effects model. The results showed that digitization promoted L-GHD at a significant level of 1%. Time and city fixed effects are further controlled, and the results are shown in columns (3) and (4). The results show that the effect of digitization on L-GHD is also significantly positive at the 1% level. In order to further prove the robustness of baseline regression results, the L-GHD measurement methods were converted respectively in columns (5) and (6) on the basis of column (4). From coefficient of variation [L-ghqd-(Vari)] to objective comprehensive entropy [L-ghqd-(Entr)] and subjective equal weight method [L-ghqd-(Subj)]. The results still show that digitization can significantly promote L-GHD. The results in Table 3(1) to (6) all prove the research hypothesis proposed in this paper.

Furthermore, the regression results of control variables in column (4) are used to analyze their impact on the L-GHD. Firstly, population density, energy consumption per unit GDP and economic development level can significantly promote the L-GHD. Specifically, cities with higher population density will encourage L-GHD due to resource scarcity and development needs. Cities with higher energy consumption per unit GDP and economic development level have higher requirements for sustainable development and green energy utilization, which will also promote the L-GHD. Secondly, urbanization, industrial structure, wholesale and retail development level also have a positive impact on the L-GHD, but the impact is not significant. This shows that the wholesale and retail product structure and the development level of the whole city can't fully meet the needs of L-GHD. Finally, only financial pressure has a significant inhibiting effect

on the L-GHD, which is consistent with reality. Financial pressure will force capital to flow to more needed and urgent places, which will to some extent inhibit the transformation of L-GHD [10].

Mechanism Test of Digitalization on the L-GHD

Theoretical analysis found that the impact of digitalization on the L-GHD is shown as direct and indirect effects, and further empirical tests are carried out from these two aspects.

Direct Effect Test

Based on the hypothesis that digitalization has a direct effect on the L-GHD, the empirical test is conducted. The specific results are shown in Table 4.

Columns (1) to (5) in Table 4 show the impact of digitalization on the logistics industry in the realization of green efficiency, technological innovation, structural optimization, open cooperation and environmental sharing, and the results show that they are all positive. From the significance level, digitalization can significantly improve the level of green efficiency development, technological innovation, Structure optimization and environmental sharing in the logistics industry. However, digitalization can't significantly promote the logistics industry to achieve open cooperation in the Yellow River Basin. The possible reason is that the economic and social development of the Yellow River Basin is relatively backward and the level of opening-up is low. Therefore, the digitalization has little impact on the opening-up and cooperation of the logistics industry, and the effect is not significant. To some extent, these results can prove the research hypothesis and the baseline regression conclusion.

Indirect Effect Test

Based on the above theoretical analysis, digitalization can indirectly promote the L-GHD by improving the input and output of technological innovation, and the allocation efficiency of labor and capital factors. Combined with the mediating effect model, the indirect impact of digitalization on the L-GHD is empirically tested. The specific results are shown in Table 5.

The results in Columns (1), (3) and (5) of Table 5 show that the development of digitalization can significantly improve the efficiency of capital allocation, the efficiency of labor factors allocation and the input level of technological innovation. Further combining the baseline regression results with the results in columns (2), (4) and (6), it can be found that digitalization has partial mediating effect on the L-GHD. Specifically, digitalization can indirectly promote the L-GHD by improving the allocation efficiency of capital and labor factors and the input level of technological innovation. By comprehensive analysis of the results in columns (7) and (8), it can be seen that technological innovation output is the full mediating effect of digitalization on the L-GHD. All in all, both partial and full mediation effects prove the existence of indirect effects of digitalization on the L-GHD proposed in the hypothesis.

Heterogeneity Analysis

Heterogeneity Analysis of City Types

The Yellow River Basin is an ecologically fragile region, and overcoming the "resource curse" with digitization will be conducive to the green and high-quality development of the Yellow River Basin [49]. According to the National Sustainable Development Plan for Resource-Based Cities (2013-2020), nearly half of the Yellow River basin is resource-based cities. There is a gap between resource-based cities and non-

Table 4. Test results of the direct impact of digitalization on the L-GHD.

	(1)	(2)	(3)	(4)	(5)
	L-geff	*L-inno*	*L-opti*	*L-open*	*L-share*
Dig	0.042**	0.006*	0.154*	0.150	0.451***
	(2.35)	(1.79)	(1.71)	(1.42)	(3.49)
Control	Y	Y	Y	Y	Y
Constant	-0.007**	0.006***	-0.064**	-0.097**	-0.172**
	(-2.50)	(7.38)	(-2.02)	(-2.53)	(-2.62)
City FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
Obs	891	891	891	891	891
R_2	0.477	0.356	0.177	0.233	0.339
F	6.347	17.88	2.377	3.219	10.651

Table 5. Test results of the indirect impact of digitalization on the L-GHD.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Capital-eff	*L-GHD*	*Labor-eff*	*L-GHD*	*Inno-in*	*L-GHD*	*Inno-out*	*L-GHD*
Dig	0.050**	1.034***	0.575**	0.635***	2.336**	1.030***	1.121***	0.464
	(2.27)	(6.28)	(1.99)	(3.74)	(2.44)	(3.38)	(4.33)	(1.64)
Capital-eff		0.696**						
		(2.43)						
Labor-eff				0.754***				
				(7.32)				
Inno-in						0.016*		
						(1.86)		
Inno-out								0.539**
								(2.52)
Control	Y	Y	Y	Y	Y	Y	Y	Y
Constant	4.869***	-3.843***	-0.053	-0.416***	11.309***	-0.640***	-0.177*	-0.360**
	(435.87)	(-2.76)	(-1.33)	(-6.91)	(18.87)	(-3.21)	(-1.80)	(-2.57)
City FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Obs	891	891	891	891	891	891	891	891
R_2	0.972	0.379	0.269	0.415	0.272	0.383	0.37	0.423
F	884.434	27.875	17.125	32.354	18.388	9.284	9.66	12.715

resource-based cities in resource endowment and initial economic development. Therefore, we analyze whether the impact of digitalization on the L-GHD differs among cities to enhance the robustness of our conclusions. The results are shown in Table 6.

The results in columns (1) and (2) of Table 6 show that the digitalization of resource-based cities in the Yellow River Basin has a positive impact on the L-GHD, but the result is not significant. The results in columns (3) and (4) show that the digitalization of non-resource-based cities in the Yellow River Basin can significantly improve the L-GHD. By comparison, it can be found that there are obvious differences between resource-based cities and non-resource-based cities in the Yellow River Basin in the impact of digitalization on the L-GHD. The possible reason is that the economy

Table 6. The impact of digitalization on the L-GHD is based on the heterogeneity analysis of city types.

	(1)	(2)	(3)	(4)
Dig	0.623	0.794	1.192***	0.928***
	(1.12)	(1.47)	(3.42)	(2.72)
Control	N	Y	N	Y
Constant	-0.004	-0.069	-0.035**	-0.617***
	(-0.26)	(-0.32)	(-2.17)	(-3.49)
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Obs	450	450	441	441
R_2	0.268	0.284	0.341	0.484
F	5.763	4.855	8.469	11.313

Table 7. The impact of digitalization on the L-GHD is based on the heterogeneity analysis of urban location.

	(1)	(2)	(3)	(4)
Dig	1.571***	1.311***	0.769	0.698
	(9.25)	(5.48)	(1.17)	(1.30)
Control	N	Y	N	Y
Constant	-0.023**	-0.581**	-0.016	-0.475**
	(-2.25)	(-2.50)	(-0.62)	(-2.33)
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Obs	324	324	567	567
R_2	0.33	0.414	0.3	0.388
F	13.357	14.401	8.136	5.572

of non-resource-based cities develops in various ways, while the economic development of resource-based cities is relatively single. Specifically, non-resource-based cities have abundant production factors such as technology, capital and talents, which provide a certain foundation for the development of digitalization. However, resource-based cities have strong dependence on resources and weak innovation ability, which further restricts the development of digitalization and the L-GHD.

Heterogeneity Analysis of Urban Location

The Yellow River basin covers an area of 795,000 km^2, spanning nine provinces. Due to the influence of natural factors such as topography, geomorphology, hydrology and scientific protection and governance in the Yellow River Basin, unbalanced development exists among cities [49]. Then, will the impact of digitalization on L-GHD in the Yellow River Basin vary from city to city? Based on this, the study cities are divided into

Table 8. The results of endogeneity analysis on the impact of digitalization on the L-GHD.

	(1)	(2)	(3)	(4)
	Dig	*Dig*	*L- GHD*	*L- GHD*
Tele	0.457**	0.452**		
	(2.32)	(2.23)		
Dig			3.915***	3.482***
			(4.23)	(4.20)
Control	N	Y	N	Y
Constant	0.025***	0.009		
	(7.41)	(0.60)		
City FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Kleibergen-Paap rk LM statistic			11.983	12.367
			[0.000]	[0.000]
Kleibergen-Paap rk Wald F statistic			14.253	11.882
			{8.96}	{8.96}
Obs	891	891	891	891
R_2	0.723	0.731	0.068	0.201
F	139.027	98.411	15.699	10.87

Note: [] is the P value, and {} is the critical value at the 10% level of weak identification test.

upstream cities and middle and downstream cities for empirical analysis [49]. The results are shown in Table 7.

The results in columns (1) and (2) of Table 7 show that digitalization in the upper Reaches of the Yellow River Basin can significantly promote the L-GHD. The results in columns (3) and (4) show that the digitalization has a positive impact on the L-GHD in the middle and lower reaches of the Yellow River Basin, but the result is not significant. By contrast, the effect of digitalization on the L-GHD is more significant in the upstream region than in the middle and downstream region. The possible reason is that according to the law of diminishing marginal effect, the digitalization impact on the regions with higher level of logistics development may be limited to some extent, while the economic development and industrial structure level in the middle and lower reaches of the Yellow River Basin is better than that in the upper reaches. Therefore, the impact of digitalization on the L-GHD in the upper reaches of the Yellow River Basin is more significant than that in the middle and lower reaches. At the same time, this result also proves that the baseline regression conclusion is robust [49].

Endogenous Analysis

In order to better identify the causal relationship between the digitalization and the L-GHD, we adopted the instrumental variable method to alleviate the existing endogenous problems. Instrumental variables need to be both "exogenous" and "correlated". We select the number of telephones per 10,000 people in 1984 (unit: department, Tele) as the instrumental variable of digitalization [1]. On the one hand, the historical number of telephones is an "exogenous variable" relative to the residual term of digitalization impact on the green and high-quality development of logistics industry. On the other hand, the number of telephones used in history may affect the production, living and consumption habits of the present. Specifically, the regression results of instrumental variables are shown in Table 8.

In Table 8, the results in columns (1) and (2) show that there is a significant positive correlation between the number of telephone use per capita in 1984 and the digitalization. It indicates that the selection of the number of telephone use per capita in history as the instrumental variable has passed the correlation test. Columns (3) and (4) are the regression results of instrumental variables, showing that digitalization can significantly promote the L-GHD. Meanwhile, Kleibergen-Paap rk test results reject the null hypothesis of "insufficient recognition of instrumental variables" and the problem of weak recognition of instrumental variables. It further explains the rationality of the instrumental variables.

Conclusion and Policy Implications

Based on theoretical analysis, 99 cities in the Yellow River Basin from 2011 to 2019 are selected as observation objects to empirically analyze the impact of digitalization on the L-GHD. The main conclusions are as follows. (1) Digitalization has a positive and significant impact on the L-GHD. (2) Digitalization directly promotes the logistics industry to achieve green efficiency, technological innovation, structural optimization, open cooperation and environmental sharing. But the impact of digitalization on open cooperation of logistics industry is not significant. (3) Digitalization promotes the L-GHD by stimulating the input and output of technological innovation and the allocation efficiency of labor and capital factors. (4) The heterogeneity analysis shows that digitalization plays a more significant role in promoting the L-GHD in non-resource-based cities. And the digitalization plays a more significant role in L-GHD in the middle and lower reaches of the Yellow River Basin.

Based on the conclusions, we put forward the policy implications to further improve the L-GHD from the following aspects:

Enhance the green and high-quality development level of logistics industry by strengthening the construction of digitalization. First, enterprises should be guided by consumer demand and effectively link industry, education and research. We should not only increase input in digital innovation, but also enhance the application and diffusion of digital innovation achievements to meet consumers' demand for digital products and services while balancing supply and demand. Second, the government should promote the wide application of digital technology and the full popularization of big data through policy guidance, legal constraints and process supervision. On the basis of accelerating the layout of 5G base stations, it is necessary to advance the layout of 6G, Blockchain and other basic digital environments. Third, the government and the market work together to provide the digital foundation for the L-GHD. We will expand the application platform of digital technology facilities into the L-GHD through cloud sharing, cloud detection, cloud storage and other technologies.

Strengthen technological innovation and factor allocation efficiency to promote L-GHD. First, we need to promote technological innovation throughout society. We should promote the industrialization of new digital technology and the upgrading of industrial digitalization through incentive mechanism in the short term. More importantly, we will continue to strengthen the development of basic disciplines and investment in basic research in the long term to ensure the birth of basic, original and advanced technologies. Second, we should strengthen the cultivation of digital talents. On the basis of making full use of digital resources, increase digital talents through efficient training

and vigorous introduction. Third, we will improve the efficiency of capital allocation. Big data sharing platforms, big data application industrial parks, big data trading institutions and digital finance should be established to promote the efficiency of digital capital allocation.

Coordinate regional digital sharing to promote L-GHD. First, digitalization development in the Yellow River Basin should be fully integrated with the "Belt and Road" strategy and focus on sharing digitalization development opportunities with regions and countries along the "Belt and Road". At the same time, we should promote the opening-up and cooperation of logistics industry while comprehensively improving the level of digitalization. Second, for the digitalization development in resource-based cities, it is necessary to reduce the dependence of resource-based cities on natural resources. We should build modern infrastructure and digital networks that combine urban advantages and characteristics. Thirdly, the cities in the upper reaches of the Yellow River basin should make use of digital technology to enhance the information level of resource management. On the premise of protecting the ecological environment, we should promote the L-GHD in the Yellow River Basin of China through digitalization.

Conflict of Interest

The authors declare no conflict of interest.

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