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Original Research

Can the Digital Economy Enhance Ecological Resilience – Based on Empirical Data from 53 Cities in the Yellow River Basin of China

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Abstract

The preservation of the ecology in the Yellow River Basin (YRB) has become a major national strategy for China, so the study of the impact of the digital economy (Dige) on the ecological resilience (UER) of cities in the YRB is of great significance for sustainable development. Based on panel data from 53 prefecture-level cities in the YRB from 2011 to 2020, this paper studies the impact and transmission mechanism of Dige on UER in the YRB using fixed effect models, intermediary effect models, and spatial Durbin models. Empirical results show that Dige significantly improves UER in the YRB, and there is heterogeneity in the basin and city scales. Technological innovation (Inn) has a significant channel effect in improving the UER of the YRB with Dige. The Dige has spatial spillover effects and has the capacity to improve the UER of adjacent cities in the Yellow River Basin. So, to improve the UER of cities in the YRB, we should speed up the development of the Dige, promote Inn, and improve the level of economic development.

Keywords: sustainable development, Yellow River Basin, digital economy, ecological resilience

Introduction

The Yellow River is the second longest river in China, and the Yellow River Basin (YRB) plays a very important role in China's economic and social development and ecological security. The YRB is an important ecological security barrier in northern China. However, the fragile carrying capacity of the ecological environment has become a shackle to high-quality development in the YRB. The development of the YRB faces the task of enhancing ecological resilience (UER). In September 2019, General Secretary Xi Jinping convened a symposium in Zhengzhou to elevate the ecological protection and high-quality development of the YRB to a national strategy, presenting a major opportunity to enhance the UER of the basin. The issue of the ecological environment can be essentially attributed to the problems of the development mode and lifestyle. The booming digital economy (Dige) in the new era, with the help of new technologies such as big data and the internet, can transform traditional industries into green industries with low energy consumption and low pollution. This will expedite the green transformation of the developmental model, promoting the emergence of a green and low-carbon mode of production and way of life. UER, then, serves as a significant tool for urban areas

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to address environmental change and achieve sustainable development[1]. Is the Dige a “booster” or a “ tiger on the road” to the UER of the YRB? If Dige can enhance the URE of the YRB, what are the action mechanisms? Are there spatial spillover effects? By clarifying the above questions, not only does it contribute to enriching the research related to Dige and URE, but also useful policy insights are put forward for the sustainable development of the ecosystem in the YRB.

The Dige, as a frontier area of current world economic development, has become increasingly sophisticated in recent years in terms of research into its connotation, measurement, and impact on economic benefits. Since Canadian scholar Don Tapscott introduced the term “digital economy” in 1996, there has not been a systematic conception of its definition and connotation within the international community. In the early days, the Dige was often equated with the “Internet economy”. With the evolution of global economic form, its concept has been continuously enriched and deepened in this process. Existing studies are mainly discussed from two perspectives: First, the Dige is regarded as a novel economic form, with an emphasis on the economic change that is being driven by digital and information technology. For instance, Yi et al. [2] argue that the Dige represents a novel economic form that depends on cutting-edge data analysis technology, with data serving as the key production factor, and the formation of the eternal pursuit of new values by users through digitalization and intelligent means. According to Jian et al. [3], the Dige relies on information and communication technology to digitize transactions, exchanges, and collaborations via the Internet, mobile communication networks, the Internet of Things, and other means. This advancement promotes economic and social development. Second, some literature explains Dige by stratifying it. For example, Yang [4] believes that the Dige covers three aspects: digital industrialization, industrial digitalization, and governance digitalization. Regarding the measurement of the Dige, the relevant literature has largely utilized the value-added method [5, 6], the satellite account method [7, 8], and the construction of an indicator framework [9, 10] to measure the level of Dige development. Meanwhile, research on the impact and benefits of the Dige is also a focus for many researchers. In terms of reducing carbon emissions [11], driving common prosperity to achieve “making the cake bigger and distributing it well” [12], promoting high-quality economic development [13], and promoting the upgrading of industrial structure [14], the Dige has been widely recognized by academics.

The concept of resilience was first put forward by Western scholar Holling in 1973. He applied it to the field of ecology to create ‘ecological resilience’. It is defined as a system’s ability to resist external perturbations and maintain its original state [15]. Today, urban systems are exposed to external risks such as climate change, which negatively affects urban livability and requires resilient ecosystems [16]. This makes urban ecological resilience widely concerned by academia and society, but it is still an emerging research topic. The following summarizes the major findings of the pertinent studies: (1) In terms of research content, current research focuses on the creation of a quantitative assessment system for ecological resilience. The system involves the construction of an urban ecological resilience assessment based on the dimensions of sensitivity and adaptability [17], resistance, resilience, and robust-ness [18], and scale, density, and morphology [19]. Meanwhile, research into the spatiotemporal development of urban ecological resilience [20] and the identification of its influencing factors [21, 22] has also gradually emerged. (2) In terms of research scales, the scale of research on urban ecological resilience mainly focuses on the whole country [23], metropolitan areas [24], and urban agglomerations [17]. (3) In terms of research methods, scholars mostly use remote sensing technology [25], coupled coordination models [26], and other methods to conduct research.

Obviously, from the existing literature, research on Dige and UER has achieved relatively rich results, which provides a useful reference for further in-depth research in this paper, but there are a few shortcomings as well: Firstly, the literature on integrating Dige with environmental resilience is relatively scarce. Secondly, the existing literature only considers research expenditure and patent volume when selecting Inn as a mediating variable, which fails to fully reflect how much the region continues to innovate. Third, Existing literature rarely combines the characteristics of cities in the YRB and lacks consideration of the impact of Dige on the UER from a spatial perspective. The existence of these problems provides room for marginal contributions to this paper. In view of this, this paper examines the direct and spatial spillover impacts of the Dige on UER, looking at 53 prefecture-level cities across the YRB. The transmission mechanism between UER and Dige is further discussed from the perspective of Inn.

Research Hypotheses

The vulnerability of the ecological environment of the YRB has been highlighted. Improving UER is urgent. Dige is a product of the new era. It is increasingly becoming a powerful “foundation” for improving UER. Specifically, Dige tends to be environmentally friendly, relying on digital technologies such as big data and cloud computing. Its penetration and derivation of technology can transform the development mode adopted by traditional industries that rely excessively on resources and the environment. This shift can effectively eliminate ecological and resource conflicts in the YRB. In addition, the Internet of Things, big data, and other technologies are used to conduct real-time monitoring and intelligent early warning of environmental hazards in the air, water, soil, and other aspects of the YRB, which do a good job in ecological risk monitoring and assessment, build a smart and efficient ecological environment management information system, and avoid the phenomenon of "data chimneys" or information silos, so that the ecosystem can face the external impact with skill and ease. Hypothesis 1 is proposed based on the above analysis.

Hypothesis 1 (H1): The UER in the YRB can be enhanced by Dige.

As a representative of an economy that is driven by innovation, Dige has propelled Inn to previously unheard-of heights [27] and has obvious advantages in integrating innovation resources and breaking through innovation blockages. The Dige removes the barriers to information transmission, accelerates the circulation and diffusion of information resources on which innovation depends on its high permeability and sharing, makes the innovation process shift from closed to open, and enterprises in different industries and fields can carry out collaboration and innovation, share resources and experiences, break the traditional industry barriers, and realize greater scale effects and collaborative innovations. At the same time, the integration and classification of fragmented information knowledge, together with the elimination of non-innovative information knowledge, can increase the stock of useful and innovative knowledge [28], laying the knowledge base for Inn. In addition, the achievements of scientific and technological innovation brought about by Dige can be transformed into tangible productivity by improving production processes, developing new energy sources and low-pollution green production modes, and reducing pollutant emissions at the source, thereby improving environmental quality. Therefore, the second hypothesis of this paper is proposed:

Hypothesis 2 (H2): Through indirect pathways that foster Inn, the Dige contributes to UER.

Knowledge and information are characterized by low dissemination costs and high mobility, which means that a digital economy based on them can show strong spatial spillover effects in influencing UER. The physical barriers of time and space distance have been broken down by Dige, and with the aid of contemporary information technologies like big data and cloud computing, it has realized frequent dialogue and cooperation with the surrounding areas, affecting their level of digitalization and producing spatial spillover effects. Meanwhile, there can be a demonstration and learning effect from the Dige. Cities in the YRB are adjacent to each other and share similar ecological conditions. Successful experiences from the Dige in enhancing UER will also be taken up and absorbed by the neighboring "backward" regions, promoting the simultaneous enhancement of UER in nearby cities. In light of the analysis presented above, hypothesis 3 is considered in this paper.

Hypothesis 3 (H3): Through spatial spillovers, Dige has the potential to improve the UER of surrounding regions.

Methodology and Data

Model Settings

(1) Benchmark Regression

Aiming to test hypothesis 1 (H1), this paper constructs the baseline regression equation as formula (1):

$$\mathrm{UER}_{it} = \alpha_0 + \alpha_1\,\mathrm{Dige}_{it} + \alpha_3\mathrm{Z}_{it} + \lambda_i + \varepsilon_{it} \quad (1)$$

where Dige_{it} denotes the digital economy, UER_{it} represents ecological resilience, i and t indicate city and time, respectively, Z_{it} indicates the multiple control variables. Additionally, ε_{it} indicates random disturbance terms, and λ_i is the city-fixed effect used to control the impact of city-level factors that do not vary over time on the estimation results, such as the impact of each city's unique characteristics and development trajectory on the estimation results.

(2) Mediating Effect Model

In order to verify Hypothesis 2 (H2), model (2) (3) is constructed with reference to the method of Wen Z and Ye B. [29].

$$\mathrm{Innova}_{it} = \beta_0 + \beta_1\mathrm{Dige}_{it} + \beta_3\mathrm{Z}_{it} + \lambda_i + \varepsilon_{i,t} \quad (2)$$

$$UER_{i,t} = \gamma_0 + \gamma_1\mathrm{Dige}_{it} + \gamma_2\mathrm{Inn}_{it} + \gamma_3\mathrm{Z}_{it} + \lambda_i + \varepsilon_{i,t} \quad (3)$$

Where technological innovation (Inn) is the mediating variable, and the remaining variables agree with formula (1). The sign and significance of the coefficients β_1, γ_1, γ_2 can be used to determine whether the model has a mediating effect or not.

(3) Spatial Effects Model

$$UER_{i,t} = \alpha_0 + \alpha_1\rho WUER_{i,t} + \phi_1 W\mathrm{Dige}_{it} + \phi_C W\mathrm{Z}_{it} + \alpha_1\mathrm{Dige}_{it} + \alpha_n\mathrm{Z}_{it} + \lambda_i + \delta_t + \varepsilon_{i,t} \quad (4)$$

Where ρ and W are spatial autoregressive coefficients and spatial weight matrices respectively. The interaction terms of Dige and control variable space, respectively, have elastic coefficients of ϕ_1 and ϕ_C. Simultaneously, spatial correlation tests and spatial regressions are performed using the geographic adjacency matrix and the distance square matrix, and the global Moran's I index. The expression of the geographical adjacency matrix and distance square matrix is as follows:

$$w_{ij}{}^{a} = \begin{cases} 1, & i \neq j \\ 0, & i = j \end{cases} \quad (5)$$

$$w_{ij}{}^{b} = \begin{cases} 1/d_{ij}{}^{2}, & i \neq j \\ 0, & i = j \end{cases} \quad (6)$$

where d_{it} denotes the geographical distance between locations.

Table 1. Ecological resilience assessment indicator system.

Primary index	Secondary index	Tertiary index	Index attribute
Ecological resilience	Adaptation ability	Drainage pipe length	-
		Daily domestic water consumption per capita	-
		Centralized wastewater treatment rate	-
		Harmless treatment rate of domestic waste	-
	Resistance ability	Industrial wastewater discharge per unit of GDP	+
		Population density	-
		Industrial smoke (powder) dust emissions per unit of GDP	+
		Industrial SO_2 emissions per unit of GDP	+
	Recovery ability	Green space ratio in built-up areas	+
		Per capita green park area	+
		Green space coverage in built-up areas	+

Variable Description

(1) Explained variable

ecological resilience (UER). The Yellow River Basin ecological resilience level assessment indicator system was constructed from the three dimensions of adaptability, resistance, and resilience, based on relevant research[1, 30]. The indicators are shown in Table 1.

(2) Core explanatory variable

digital economy (Dige). This paper uses existing research [31]and combines the accessibility of city-level data to select indicators from the three levels of digital financial inclusion, digital industry, and digital infrastructure. To assess the level of Dige in a city, the indicators are weighted using the entropy method. The indicators are shown in Table 2.

(3) Mediating Variable

technological innovation (Inn). This paper selects the China Regional Innovation and Entrepreneurship Index compiled by Peking University's Enterprise Big Data Research Centre to represent technological innovation, covering five dimensions: access to foreign investment, the number of new micro-enterprises, trademark output, trademark output access to venture capital, and patent output. This avoids the drawbacks of the past, which only took into account the input of scientific research funding and the number of patents, and is more able to objectively show the degree of urban innovation in a multi-dimensional manner.

(4) Control variables

The following important variables influencing UER are controlled for in this paper: (1) The degree of export opening-up (Open), obtained by dividing foreign direct investment by GDP; (2) industrial structure (Ins), expressed as the proportion of tertiary to secondary output; (3) the level of economic development (Eco), measured by GDP per capita; (4) the proportion of industry (Inp), expressed as the ratio of the added value of the secondary industry to GDP.

Sources of Data

Taking data availability into consideration, the panel data of 53 cities in the YRB were selected for this study, covering a period from 2011 up to 2020. The data, except for the digital financial inclusion index, which is selected from the China Digital Financial Inclusion Index compiled by the Digital Finance Research Centre of Peking University [32], and the rest of the relevant data mainly come from China Urban Statistical Yearbook,

Table 2. The comprehensive index system of the digital economy.

Primary index	Secondary index	Tertiary index
The level of digital economy	Digital finance	Digital finance index
	Digital industry	Total telecommunication services per capita
		Percentage of persons employed in computer services and software
	Digital infrastructure	Internet broadband subscriber access per 100 population
		Number of mobile phone users per 100 people

Table 3. Benchmark regression results.

Variables	UER	UER
	(1)	(2)
Dige	0.3850000*** (3.70)	0.1930000*** (4.96)
Open		-0.1710000 (-0.98)
Ins		-0.0002710 (-0.02)
Eco		0.0000008*** (4.34)
Inp		-0.0017200** (-2.69)
Constant	0.4150000*** (30.09)	0.5100000*** (10.71)
N	530	530
R−squared	0.9071000	0.9167000

*** p<0.01, ** p<0.05, * p<0.1, the same below.

China Statistical Yearbook, Statistical Bulletin of the National Economy and Social Development, as well as the EPS database, etc., and the part of the missing values are determined by linear interpolation.

Empirical Analysis

Analysis of Benchmark Model Results

The empirical test of Equation (1) is conducted in this study using Stata 15.1 software to look at how directly Dige affects ecological resilience. The test findings are presented in Table 3. The impact of Dige on the UER of the YRB is positively significant at the 1% level regardless of the addition of control variables, as can be seen from columns (1) and (2). This shows that Dige contributes to the enhancement of the UER of the YRB, that is, hypothesis 1 (H1) is true. The findings also make it clear that the UER of the YRB is strongly influenced by the level of economic development. This may be because cities with higher levels of economic development are more active in advancing their digital economies, which enhances UER. The UER of the YRB is considerably decreased by Inp. Most of the cities within the YRB are located in the central and western underdeveloped regions and are dominated by traditional manufacturing and resource-based industries, which have lower industrial levels. The industrial structure of the heavy chemical industry is particularly prominent, and the environmental pressures from industrial waste discharges have been aggravated as a whole. This has negatively impacted the enhancement of UER in the basin.

Table 4. Test results of basin heterogeneity.

Variables	Upper reaches	Middle reaches	Lower reaches
Dige	-0.017 (-0.14)	0.171** (3.24)	0.420*** (5.58)
Control variables	Yes	Yes	Yes
_cons	0.632*** (5.37)	0.459*** (8.28)	0.627*** (3.40)
	0.901	0.886	0.870
N	120	250	160
R−squared	0.898	0.897	0.871

Heterogeneity Analysis

(1) Watershed heterogeneity test. Taking into account factors such as economic and geographic location, Dige may also have highly varying effects on UER in various YRB cities. To investigate whether the impact of Dige on UER of cities in the YRB varies depending on the different river basins, the study by Shi B et al. [33] was used to divide the 53 prefecture-level cities in the YRB into the upper, middle, and lower reaches of the river. Then, we conducted fixed-effects model regressions for each of these three basins.

As seen in Table 4, there are considerable disparities between upstream, midstream, and downstream cities in the effects of Dige on the UER. Specifically, Dige has not had an effective effect on UER in the upstream cities. This may be because, despite national policy support for the development of Dige in the western region, it is confined to poorer foundations and other reasons, and it will take longer for the environment to recover and improve so that the ecological dividend brought by Dige has not yet been revealed. The UER of cities in the middle and lower reaches of the YRB is significantly influenced by Dige, but the significance and coefficient of influence of the lower reaches are higher than those of the middle reaches. This may be because the downstream cities have more location advantages, better economic development than the middle reaches, and access to more cutting-edge digital technology, enabling them to fully release the dividends of Dige to enhance their UER.

(2) Heterogeneity test of urban development scale. The “Ranking of Chinese Cities' Business Attractiveness,” published by the New First-tier Cities Research Institute, is used to categorize and integrate 53 cities in the YRB. The heterogeneity test results are shown in Table 5 for various city sizes. The findings demonstrate that the level of UER is significantly impacted by Dige in the fourth- and fifth-tier cities, indicating that these cities gradually have the conditions and basis for unleashing the dividends of Dige through undertaking and absorbing the successful experiences

Table 5. Results of the test for heterogeneity in the scale of urban development.

Variables	New first-tier and first-tier cities	Second-tier cities	Third -tier cities	Fourth-tier cities	Fifth -tier cities
Dige	0.101 (0.64)	0.132 (0.59)	0.084 (1.25)	0.202*** (3.63)	0.161* (1.84)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	1.670 (1.81)	-1.011 (-1.37)	0.168 (1.36)	0.154 (1.32)	0.411*** (5.40)
N	20	30	140	140	200
R−squared	0.871	0.906	0.941	0.944	0.911

of more developed cities as well as government policy support. Dige development level coefficients of new first-tier cities, first-tier cities, and second-tier cities are positive and insignificant, which may be because the development level of Dige in these three types of cities is relatively mature, and the room for improvement is limited.

Mediation Mechanism Test

We investigated whether Inn mediates between the Dige and UER. This paper tests Equation (2)-(3) using the stepwise regression method based on the aforementioned theoretical analyses. From Table 6, the total effect of Dige on UER in column (1) is 0.193 (denoted as c). In column (2), the impact coefficient of Dige on Inn is 35.21(denoted as a), which is significantly positive at the 1% level. This shows that the Dige effectively promotes Inn. In column (3), the mediating variable Inn is added to the regression model of Dige on UER, then the coefficient of impact of effect of Dige on UER decreased from 0.193 to 0.169 and passed the significance test at the 5% level, indicating that Inn indeed plays a mediating effect between Dige and UER. Since the impact coefficient of Inn on UER is 0.0007 (denoted as b), the ratio of this mediating effect to the total effect is ab/c = 12.77%. Its intrinsic logic is that Dige allows knowledge to move naturally and be shared among different innovation subjects, breaking through time and space barriers, thereby improving the efficiency of Inn. The promotion of technological innovation can guide traditional industries to move towards low-energy and low-pollution emerging industries, realize the optimization of production modes and the enhancement of production efficiency, and alleviate the environmental burden within the basin, so as to improve the UER.

Table 6. Results of mediation effect test for Inn.

Variables	UER	Innova	UER
	(1)	(2)	(3)
Dige	0.1930*** (4.96)	35.2100*** (3.56)	0.1690** (3.13)
Inn			0.0007* (2.20)
Open	-0.1710 (-0.98)	38.3000 (1.87)	-0.1980 (-1.00)
Ins	-0.0003 (-0.02)	-5.3890* (-2.13)	0.0034 (0.29)
Eco	0.000000791*** (4.34)	0.000165*** (4.96)	0.0000007*** (3.71)
Inp	-0.0017** (-2.69)	-0.9970*** (-8.12)	-0.0010 (-1.43)
Constant	0.5100*** (10.71)	125.2000*** (13.72)	0.4240*** (7.32)
N	530	530	530
R−squared	0.9167	0.8271	0.9177

Robustness Test

(1) Replace explanatory variables. According to the practice used by Ma Q et al. [34], the explanatory variables in the benchmark regression were replaced with the digital financial index, and they were then substituted into the original model (1) in order to further verify the robustness of the conclusion that "Dige significantly enhances the UER of the YRB". Regression results where the explanatory variable is the digital financial inclusion index (Dige 2) are reported in column (1) of Table 7. Among them, the benchmark regression results of this paper have good robustness, as the coefficient of Dige 2 is significantly positive at the 1% level, showing that the promotion of Dige on the UER of the YRB is still significant.

(2) Instrumental Variable Method. While macro factors that affect the UER of the YRB are controlled, the empirical results may still be affected by potential problems of mutual causation and omitted variables in the model. Following the methods of Lin S et al. [35], the first-order lag term of the development level of the digital economy is used as an instrumental variable for regression, and the results are presented in Table 7. The CD Wald stat is significantly greater than 16.38 at the 10% level, demonstrating that the problem of weak instrumental variables does not exist, and the p-value of KP-LM is 0.000, rejecting the initial hypothesis of insufficient instrumental variable identification.

Table 7. Robustness test results.

Variables	Replace explanatory variable (1)	First (2)	Second (3)
	UER	Dige	UER
Dige			0.205*** (3.980)
Dige 2	0.925*** (5.850)		
Tool		0 .810*** (20.550)	
Control variables	Yes	Yes	Yes
Constant	0.461*** (9.360)	0.042*** (0.950)	0.492*** (10.440)
KP-LM			239.419 (0.000)
CD Wald			422.243 16.380)
N	530	477	477
R−squared	0.918	0.841	0.925

Spatial Spillover Effects

The global Moran's I index of the UER of the YRB from 2011 to 2020 was measured using the geographical proximity matrix and the distance square matrix in order to test the spatial spillover effect of the digital economy on the UER of the YRB. According to Table 8, Moran's I index indicates a significant positive spatial correlation of UER, as it is positive and passed the 1% significance test.

In this article, the Hausman test, LM test, and LR test are carried out sequentially to determine the applicability of the model, and it is determined that it is reasonable to use the SDM model with double fixation of the time of the city for the regression analysis. Table 9 shows the results of the regression analysis.

Observing the coefficient of the spatial lag term W × UER shows that it fails the significance test. However, such a simple point estimation result is difficult to reflect the marginal impact of Dige accurately and effectively on the UER and could contain errors. Therefore, to achieve a better interpretation, the estimated results are separated into direct and indirect effects using the partial differential method. The results show that the regression coefficients measuring the direct effect of Dige on the UER of the YRB are 0.169 and 0.177 in the geographic proximity matrix and the distance-squared matrix, respectively, and both of them are significantly and positively correlated at the 1% level. This suggests that Dige

Table 9. Spatial effects regression results.

Variables	(1) Geographical proximity matrix	(2) Distance square matrix
UER	0.163*** (3.65)	0.177*** (4.15)
W×UER	0.135 (1.41)	0.334* (2.05)
Control variables	YES	YES
Direct effect	0.169*** (3.63)	0.177*** (4.03)
Indirect effect	0.174* (1.71)	0.314* (2.11)
Total effect	0.343** (2.77)	0.490** (3.11)
N	53	53

Table 8. UER global Moran's I index.

Year	Ecological resilience			
	Geographical proximity matrix		Distance square matrix	
	Moran's I index	Z	Moran's I index	Z
2011	0.384***	4.443	0.235***	4.413
2012	0.460***	5.233	0.293***	5.361
2013	0.480***	5.408	0.281***	5.129
2014	0.508***	5.785	0.326***	5.962
2015	0.550***	6.398	0.394***	7.312
2016	0.502***	5.822	0.362***	6.706
2017	0.427***	4.960	0.301***	5.615
2018	0.364***	4.263	0.271***	5.088
2019	0.399***	4.616	0.288***	5.338
2020	0.425***	4.932	0.328***	6.081

can enhance local UER, the same conclusion as in the previous benchmark regression. Furthermore, the indirect effect regression coefficients are significantly positive, demonstrating that Dige has a favorable effect on UER of nearby regions, which may be due to the fact that the development of Dige makes the cost of factor exchange in the neighboring regions low by breaking through the barriers of factor flow, and the geographically adjacent regions have similar ecological conditions, and the willingness to carry out cooperation to improve UER is stronger, so the interactions are more frequent, and at the same time, the successful experience of Dige to improve UER has played a certain role in the demonstration "and promote learning and emulation by neighboring regions.

Conclusions and Recommendations

Conclusions

The panel data of 53 prefecture-level cities in the YRB, covering the period between 2011 and 2020, was used in this paper. An evaluation index system was constructed for the Dige development index and UER index. Then it investigates the impact and mechanism of Dige on UER through the SDM model and intermediary effect model. The following sections present the main results of the study:

(1) The Dige can improve the UER of the YRB. Furthermore, the robustness test results from our endogeneity analysis and the substitution of explanatory variables remain in line with the benchmark regression, indicating that our conclusions are robust.

(2) The heterogeneity results suggest that downstream regions are better equipped to release the dividends of the Dige, which in turn strengthens UER. Notably, the Dige has a more significant impact on UER in the fourth- and fifth-tier cities within the YRB.

(3) Mechanism tests show that Dige promotes UER through the indirect path of facilitating Inn.

(4) The Dige has a positive impact on the improvement of UER in neighboring regions, that is, there is a spatial spillover effect.

Recommendations

The following recommendations are made on the basis of the above conclusions:

(1) Encourage vigorously the expansion of Dige in the YRB while implementing the plan for a strong digital nation. On the one hand, it is essential to consolidate the construction and deployment of infrastructure including big data centers, IPV6, and 5G base stations to lay the foundation of the digital industry. On the other hand, Dige, which depends on the new generation of information technology, empowers traditional industries to move towards resource-saving and environment-friendly new industries, increases the effectiveness of energy use, and fundamentally alleviates environmental degradation.

(2) Based on the difference between the upper, middle, and lower reaches of the YRB, the help mechanism is established. Midstream and downstream cities should play the role of "pacesetters", speeding up their own digital construction while interacting positively with upstream cities, realizing optimal interoperability of resources, and thus gradually raising the level of development of Dige in the upper reaches.

(3) Actively promote technological innovation. The results indicate that technological innovation has a favorable effect in mediating between the Dige and UER. Therefore, the government ought to bolster investment in scientific research and innovation. At the same time, by the formulation of incentive policies, the willingness of local innovation entities to carry out technology research and development activities is enhanced.

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Conflict of Interest

The authors declare no conflict of interest.

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