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Unveiling the Dynamics: How Does the Digital Economy Influence the Development of New-Type Urbanization in China

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ABSTRACT: Digital economy is a vital driving engine for new-type urbanization and continues to promote the regional economy. In this study, it adopts the entropy weight method is adopted to measure the digital economy and new-type urbanization in 31 provinces in China from 2011 to 2021, and conducts an in-depth analysis on the relationship between them. The conclusions are: Digital economy has a significant role in promoting new-type urbanization and is regionally heterogeneous, especially the impact in eastern region; Moreover, through the mediating mechanisms analysis, it indicates that industrial structure and innovation level are important paths to promote new-type urbanization. Along with the increase of R&D intensity, the promotion effect shows a non-linear characteristic of "increasing marginal effect". In light of this, the following countermeasures are put forward to strengthen digital economy's impetus for new-type urbanization: promote the gradient development of digital technologies and innovate digital economy application scenarios to fuel new-type urbanization; establish a novel digital-industrial integration model and capitalize on the fundamental role of industrial transformation in new-type urbanization; and refine the innovation system and fully realize the marginal incremental effect of R&D intensity once it crosses the threshold.

Keywords: New-type urbanization; Digital economy; Industrial structure; Innovation systems; R&D intensity

1. Introduction

In the process of China's industrialization, the level of urbanization has increased rapidly as the population has continued to cluster in cities. According to demographic indicators, China's urbanization rate was only 20% in the early 1980s, whereas it exceeded 50% just two decades later. Nonetheless, problems such as distorted factor allocation and environmental damage have emerged since infrastructure and social governance capabilities lag behind the needs of urbanization [1], posing a great challenge to sustainable development. To solve these problems, China released the "National New-Type Urbanization Plan (2014–2020)", formally opening the prelude to the construction of new-type urbanization. Unlike traditional urbanization, new-type urbanization emphasizes a people-oriented approach. As a national plan announced in 2014, it seeks to find a better urbanization pattern, improve the current urban sustainability,

and promote the urban-rural coordination. Subsequently, the Implementation Plans were issued one after another, providing a strategic direction.

Since the implementation of the new-type urbanization strategy, the urbanization rate has risen from 54.77% in 2014 to 66.16% in 2023. In addition to population agglomeration in cities, the quality of urbanization has been on the rise. According to CEIdata, the per capita disposable income of urban residents was 24,100 yuan in 2012, and it increased to 51,800 yuan per capita in 2023. The urban infrastructure and public services have been steadily enhanced; transportation infrastructure, network infrastructure, and environmental governance infrastructure, as well as public service facilities, have witnessed remarkable progress. The quality of urban economic development has been upgraded, and industries are gradually transforming into digitalization, intelligence, and greening, creating diversified opportunities for the residents.

Meanwhile, the new information technology revolution has given rise to the digital economy. Digital economy, as a new economy model, it first came into use during the 1990s, and it refers to the economy that digital computing technologies are applied in those economy activities. Nowadays, it plays a crucial role in China's new-type urbanization. For instance, the platform economy features prominently large e-commerce platforms, such as Pinduoduo and Taobao. These platforms not only make consumption more convenient for residents but also enable merchants to reach a broader market regardless of geographic location, thereby significantly promoting integrated development. However, the digital economy has the advantage of reducing marginal costs [2,3] and opening new development pathways for a new-type urbanization model.

Although the role of the digital economy is becoming increasingly evident, few studies are directly related to its impact on new-type urbanization. Chen et al. (2022) contend that it empowers new-type urbanization, and there exist spatial spillovers [4]. Yang et al. (2024) assert that the digital economy also propels the new-type urbanization through industrial structure upgrading, and there is a non-linear "marginal effect" [5]. However, this research mainly makes expansions in two aspects. Firstly, it posits that the digital economy promotes the new-type urbanization not only through industrial structure upgrading but also through the enhancement of innovation. Secondly, this study argues that the degree to which it promotes the new-type urbanization varies depending on R&D inputs. In other words, there is a threshold effect.

Moreover, this paper first measures the digital economy and new-type urbanization and estimates the impact. Subsequently, it employs a mediated effects model to explore the mechanism by which it influences new-type urbanization. Finally, it delves deeper into the non-linear relationship. This paper aims to provide evidence for further leveraging the role in promoting new-type urbanization and to contribute to the acceleration of the integrated development. The structure of this paper is as follows: The first part serves as the introduction; the second part presents a literature review; the third part elaborates on theoretical mechanism and formulates hypotheses; the fourth part details research design; the fifth part reports the estimation results; the sixth part estimates the threshold effects; and the seventh part summarizes the main conclusions and proposes relevant countermeasures.

2. Literature Review

2.1. The Study on Digital Economic Empowerment

The digital economy is an economy based on digital technology [6,7], and provides digital technology to all sectors. Compared to the traditional economy, digital economy has several distinguishing features: first, it exhibits significant connectivity [8] and facilitates data-driven decision-making [9]; second, it can be identified through the use of numbers, and technological advances have facilitated the production and accumulation of data, which enhances the ability of firms to access consumer behaviors, industry trends, and other business information [10]; and third, the existence of the digital economy is capable of disruptive

technologies that accelerate innovation, thus having the ability to produce and introduce at an unprecedented rate.

While the digital economy serves as a powerful driver, it also presents a series of challenges. Undoubtedly, the digital economy plays a pivotal role in economic growth, enhancing productivity within existing industries and fostering new industries and markets. In the corporate realm, it spurs the widespread adoption of digital technologies among enterprises. This enables businesses to expedite their digitization efforts and facilitate digital convergence, thereby creating avenues for enterprises to secure a competitive edge [11]. From a governance perspective, it provides indispensable technical support for government functions and ultimately achieves superior performance in their administrative actions [12,13]. However, it is crucial to acknowledge that the digital economy encounters several issues during its development. These include the monopolistic tendencies of large digital platforms [14,15].

The digital economy empowers traditional economic and social development areas via technological innovation, the unlocking of data-element value, and business-model reconfiguration. It can remarkably enhance the economic development [16], drive the upgrading of the manufacturing industry [17], and cut down PM2.5 and carbon emissions in cities [18,19]. The digital economy substantially promotes the green foreign trade [20]. Moreover, it also empowers, for instance, the tourism sector [21] and the upgrading of the cultural industry [22].

2.2. The Study on Urbanization

Urbanization is a process that marks the transition from an agrarian economy to a modern economy. From this viewpoint, the global urban population increased from 3% in 1800 to 13% in 1900 and surpassed 40% by 1980. In line with the spread of the Industrial Revolution, countries like the UK and the U.S. reached an urbanization rate of over 70% in 1901 and 1970, respectively. Meanwhile, urbanization in developing countries started to progress in the mid-20th century. From 1950 to 2000, the annual growth rate of urbanization in developing countries was 1.62% [23]. Based on the development process of urbanization it exhibits, Northam (1979) categorized urbanization into three stages. In the first stage, cities have a small spatial scale and a low population density, and the urbanization rate grows slowly, with agriculture playing a dominant role. In the second stage, both the spatial scale of cities and the population increase simultaneously, and the industrial economy expands rapidly. In the third stage, cities shift from quantitative expansion to qualitative improvement.

Urbanization is not merely a crucial indicator of promoting economic development; it is also an indispensable prerequisite for driving social progress [24–26]. Urbanization represents the process of expansion and transformation from rural environments to urban communities [27]. In this process, individuals leave rural areas and agricultural activities behind, moving to cities to participate in the manufacturing and service sectors [28,29]. These non-agricultural sectors typically possess higher productivity levels and generate agglomeration effects, which in turn contribute significantly to further economic growth [30–32]. Building on this, it can be posited that urbanization's formation and development are intrinsically linked to industrialization. The urbanization trajectories in Europe and the U.S. exemplify this—cities emerged concomitantly with factories. However, despite this established relationship, many contemporary developing countries exhibit high urbanization rates yet lack a robust industrial base [33].

Recently, China has witnessed the largest-scale urbanization in human history over the past four decades. So, what are the reasons? Firstly, industrialization has played a crucial role. On the one hand, a vast number of peasants have been absorbed into the industrial and service sectors in urban areas. On the other hand, the government has introduced industrial enterprises into rural regions, thereby promoting local urbanization. Secondly, marketization has been a significant driving force. Through reforms in the market system, it has promoted the flow of production factors towards cities. This, in turn, has accelerated the urbanization process [34]. Thirdly, technological advancements have facilitated and propelled the

urbanization process [35]. In addition to these key factors, other elements such as higher education [36], transportation infrastructure [37], and climate change [38] also have an impact on the course of urbanization.

In recent years, as a new-type urbanization initiative has deepened, the functions of urbanization have been further enhanced. This has led to notable improvements in green total factor energy efficiency [39] and carbon emission efficiency [40]. Moreover, it has curbed haze pollution [41], thus addressing the environmental challenges that emerged during China's urbanization process. Simultaneously, it has also played a crucial role in narrowing the income gap between areas and enhancing residents' sense of well-being. Beyond exploring the impacts of new-type urbanization, several studies have started to shift their focus to the driving forces behind its development. Industrial agglomeration and the construction of smart cities have been found to make significant contributions to the advancement.

2.3. The Study on Empowering Urbanization with the Digital Economy

Even though plenty of studies have focused on the digital economy or urbanization, few studies have directly focused on how the digital economy empowers urbanization. Given that Information and Communication Technology (ICT) serves not only as the technological foundation but also as an enabler of the recent urbanization [35], relevant research on the digital economy's empowerment of urbanization is explored. The application of ICT injects new impetus into urban development. ICT not only creates more employment opportunities for both rural and urban residents but also blurs the boundaries between different areas by reducing transaction costs and accelerating the flow of information [42]. While driving economic growth, the utilization of ICT in cities can enhance efficiency, boost their competitiveness, and facilitate the related urban transformation. It not only improves the quality of life for urban residents but also propels urbanization towards a more intelligent direction. ICT plays a pivotal role in promoting social progress as well as economic and business activities. For instance, the adoption of cell phones has enabled more equitable access to information, enhancing the independence and dignity of all individuals and thereby facilitating their integration. Moreover, ICT proves to be effective in enhancing the environmental quality of urban areas. In summary, ICT positively influences urbanization and directly enhances the pace and efficiency of the urbanization process.

3. Theorized Mechanisms and Hypotheses

3.1. Digital Economy and New-Type Urbanization

On the one hand, the digital economy reconfigures urban factor resources. It matches production factors like data, labor, and capital, rectifies the mismatch degree of factor resources, and thereby boosts total factor productivity (TFP). On the other hand, urban social governance is compelled to break through the traditional governance model. It actively employs digital empowerment in areas such as government services and market supervision. This not only significantly optimizes the business environment but also eases people's daily lives, injecting more market vitality into new-type urbanization. Overall, the digital economy empowers new-type urbanization and promotes coordinated regional development of Chinese-style modernization. Accordingly, H1 is proposed:

Hypothesis 1 (H1). The digital economy promotes the development of new-type urbanization.

3.2. The Mediating Effect of Industrial Structure Upgrading or Innovation Level

If the digital economy exerts a substantial influence on new-type urbanization, then through what channels? This paper contends that there are two pathways. Firstly, it breathes new life into sectors. It gives rise to innovative forms and business models within the service industry. This, in turn, propels the upgrading of industrial structure, which speeds the process of transformation from a lower stage to higher

stages. Given that the service industry has a greater capacity for absorbing employment, it creates a larger number of job opportunities. This is of great significance in stimulating rural development and ultimately achieving common prosperity. Secondly, technological innovation is driven by various factors in society, such as market demand, social and environmental factors, and process improvement, but it is also driving the development of society. It unfolds new scenarios and new applications for the construction of new-type urbanization, thereby enhancing its quality. In this regard, it strengthens the cooperation between relevant departments and empowers innovation entities to generate more ideas. This not only quickens the tempo of new-type urbanization but also improves its development quality. Consequently, this paper mainly delves into the impact of two crucial dimensions: industrial structure upgrading and innovation, and proposes H2:

Hypothesis 2 (H2). The digital economy promotes the development of new-type urbanization by accelerating the upgrading of the industrial structure or improving the innovation level.

3.3. Threshold Effects of the Digital Economy's Impact

Given the rapid iteration of technology and the market, the digital economy needs to rely on a certain level of R&D intensity. According to the China Digital Economy Enterprise Development Report 2022, the average R&D investment intensity of China's top 500 digital economy enterprises was 2.9%, approximately 0.5% higher than the national R&D investment intensity. Among them, enterprises titled as National Specialized New Enterprises had an average R&D investment intensity of around 4.1%. When R&D intensity is low, the innovation scale of the digital economy is small and progresses slowly, which restricts the spillover effect, resulting in a limited promotion of new-type urbanization. However, when R&D intensity is increased to a certain threshold, the innovation of the digital economy begins to thrive, and it can offer a variety of application scenarios. When R&D intensity crosses a certain stage, the impact on the digital economy will have a qualitative change, as it has the typical scale effect and the marginal effect. Consequently, the spillover effect continues to expand, and the impetus to promote becomes stronger. There is a threshold effect in technological spillover. Therefore, changes in R&D intensity may influence the role in promoting new-type urbanization. Hence, Hypothesis H3 is proposed:

Hypothesis 3 (H3). R&D intensity has a threshold effect on the impact of the digital economy on new-type urbanization.

4. Research Design

4.1. Model Setting

Considering the impact of endogeneity on the regression outcomes and the dynamic nature that is a characteristic feature of new-type urbanization, this paper employs a two-way fixed effects model to assess the influence. Here, control variables are incorporated, as in Equation (1):

$$urb_{it} = \alpha_0 + \alpha_1 dig_{it} + \alpha_j X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

urb_{it} is the degree of new-type urbanization, dig_{it} represents the level of the digital economy. X_{it} are control variables. Here, i indicates the region, and t represents the period, which respectively signify the individual and time fixed effect. α_1 and α_j are parameters to be estimated. Specifically, α_1 captures the impact across regions. μ_i and γ_t denote the individual and the time effects respectively, α_0 is constant term, and ε_{it} is the error term.

To verify Hypothesis H2, Equation (1) employs a stepwise regression method to establish the mediation effect models as in Equations (2) and (3):

$$med_{it} = \beta_0 + \beta_1 dig_{it} + \beta_j X_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (2)$$

$$urb_{it} = \phi_0 + \phi_1 dig_{it} + \phi_2 med_{it} + \phi_j X_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (3)$$

med_{it} in Equation (2) serves as the mediating variable, which is represented by the innovation level. If β_1 in Equation (2) is positive, it implies that the digital economy can enhance innovation or expedite the industrial structure upgrading. Equation (3) incorporates the med_{it} variable based on Equation (1). At this juncture, ϕ_1 reflects the direct impact on new-type urbanization, whereas ϕ_2 represents the mediating effect of the innovation level or industrial structure upgrading on new-type urbanization.

To delve into whether there exists a non-linear influence, a threshold model is established in accordance with Hensan (1999). If there is a single threshold, it will utilize Equation (4):

$$urb_{it} = \delta_0 + \delta_1 dig_{it} \times I(rd_{it} \le \varphi) + \delta_2 dig_{it} \times I(rd_{it} > \varphi) + \delta_j X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (4)$$

rd_{it} represents the threshold variable, which is R&D intensity. $I(\cdot)$ is an indicator function, and φ is a threshold value. δ_1 is a coefficient that reflects the impact on new-type urbanization when $rd_{it} \le \varphi$, while δ_2 is the coefficient for the impact when $rd_{it} > \varphi$. If $\delta_1 \neq \delta_2$, it indicates a single-threshold effect, otherwise no.

If two thresholds exist, Model (4) is extended to a double-threshold model (5):

$$\begin{aligned} urb_{it} = \delta_0 + \delta_1 dig_{it} \times I(rd_{it} \le \varphi_1) + \delta_2 dig_{it} \times I(\varphi_1 < rd_{it} \le \varphi_2) \\ + \delta_3 dig_{it} \times I(rd_{it} > \varphi_2) + \varepsilon_{it} \end{aligned} \quad (5)$$

Here, φ_1 and φ_2 are two thresholds. δ_1, δ_2, and δ_3 are the coefficients of impact of the explanatory variable (dig_{it}) on explained variable (urb_{it}) within three intervals.

4.2. Variable Explanation

4.2.1. Explanatory Variable

In this study, 11 indicators across 4 dimensions were used to construct an index system for new-type urbanization (Table 1), and it was determined through the entropy weight method.

Table 1. Evaluation Index System for New-type urbanization.

Tier 1	Tier 2	Tier 3	Unit
New-type urbanization level	population urbanization	Percentage of urban population	%
		Percentage of Employment in Non-agricultural Sectors	%
		population density	Persons per km^2
	economic urbanization	Regional GDP	Billions of yuan
		Growth Rate of Regional GDP	%
	social urbanization	Area of Urban Roads per Capita	m^2
		Bus Ownership per 10,000 People	standard unit
		Number of Healthcare Workers per 10,000 People	People
	ecological urbanization	Number of College Enrollees per 10,000 People	People
		The Rate of Non-Hazardous Disposal of Domestic Waste	%
		Green Coverage Rate of Built-up Regions	%

4.2.2. Explanatory Variables

There is still no unified standard for measuring the level of the digital economy. Some measurement approaches predominantly rely on four dimensions [7,43]. Considering the real situation, this paper constructs an evaluation index system, as shown in Table 2.

Table 2. Evaluation Index System for the level of digital economy.

Tier 1	Tier 2	Tier 3	Unit
Level of the digital economy	Digital infrastructure	The penetration rate of mobile phones	Per 100 persons
		Length of long-distance fiber-optic cable routes	Kms
		Number of individuals subscribing to Internet broadband access	Ten thousand households
		Number of Internet domain names	Ten thousand
	Digital industrialization	Number of employees in the information transmission, software & information technology industry	Ten thousand
		Wages of employees in the information transmission, software & information technology industry	Yuan
		Number of legal entities in the information transmission, software, & information technology services industry	PCS
	Industrial digitization	Proportion of enterprises in e-commerce trading activities	%
		E-commerce sales	Billions of yuan
		E-commerce purchases	Billions of yuan
		Websites per 100 enterprises	PCS

4.2.3. Mediating Variables

Industrial structure upgrading $(cysj)$ is measured by "the ratio of the value-added of the tertiary industry to that of the secondary industry". Innovation level$(cxsp)$ is measured by the number of granted patents [44]. While it may vary in terms of quality and strategic behaviors in incentives and standards, it is widely used as an indicator for innovation.

4.2.4. Control Variables

To examine the influence of the digital economy on new-type urbanization, this paper incorporates four control variables, as in Table 3. Specifically, the digital financial inclusion index (ln $\_szph$) is represented by taking the logarithm of "Peking University Digital Financial Inclusion Index". The extent of government support (ln $\_gov$) is measured by taking the logarithm of the general government financial expenditure. The level of human capital (hum) is reflected by the number of local colleges and universities. Degree of trade openness ($open$) is expressed as a ratio of total local imports and exports to GNP. As for the level of infrastructure (ln $\_jcss$), it is measured by taking the logarithm of the length of fiber-optic cable lines.

4.3. Data Sources

In consideration of data continuity, scientific validity, and accessibility, this paper selects the sample data spanning from 2011 to 2021. For the few missing data points, linear interpolation is employed for supplementation. The GDP data mentioned in this article have been deflated using the GDP price index with a base year of 2000. Specifically, the digital financial inclusion index is from the "Digital Finance Research Center" of Peking University [45]. Raw data of other variables are from the "China National Bureau of Statistics" (CNBS). Basic statistical analysis of each variable is presented in Table 3.

Table 3. Basic statistical.

Variable	Name	Explanation	Mean	SD	Min	Max
Explained	urb	new-type urbanization	0.273	0.115	0.076	0.641
Explanatory	dig	Level of digital economy	0.159	0.136	0.007	0.837
Mediating	$cysj$	Upgrading of industrial structure	0.497	0.089	0.327	0.837
	$cxsp$	Innovation level	6.462	10.51	0.010	87.22
Control	$open$	the degree of trade openness	0.269	0.284	0.010	1.460
	hum	the level of human capital	83.59	40.93	6.000	167.0
	ln $\_szph$	Digital Inclusive Finance	5.562	0.691	2.026	7.742
	ln $\_gov$	the extent of government support	8.369	0.619	6.559	9.812
	ln $\_jcss$	the level of infrastructure	4.266	0.950	1.621	6.030

5. Empirical Analyses

5.1. Baseline Regression Analysis

At the outset of this study, correlation and stationarity tests were performed. The results of these tests indicate that there is no multicollinearity among the variables in Equation (1). Multicollinearity between digital economy indicators and control variables is assessed using VIF tests, with values below 10 indicating acceptable levels. Moreover, they confirm a long-run equilibrium relationship. The Hausman test outcomes suggest that a two-way fixed effects model is the choice for analysis. The specific results of the benchmark regression are presented in Table 4. Notably, the explanatory variable (digital economy) exhibits significance at the 1% level with a positive coefficient both before and after sequentially incorporating control variables. The R^2 is quite high, and it indicates that the model suits well. Moreover, this quite high R^2 is probably due to the model and the variable selection. This finding indicates that the digital economy plays a positive role in driving the new-type urbanization, thereby validating Hypothesis H1.

Simultaneously, digital inclusive finance, leveraging digital technologies like big-data mining and cloud computing, empowers inclusive financial services. It streamlines financial service processes and thereby offers crucial financial support for new-type urbanization initiatives. The growth in human capital enables more workers to secure employment. According to the efficiency-wage theory, human capital represents a pivotal means of enhancing labor productivity. Higher productivity leads to increased wages, attracting more highly educated individuals. This, in turn, provides impetus for economic prosperity. Trade openness mirrors the extent to which cities and towns integrate into the international economy and engage in the international division of labor. Typically, an upsurge in trade openness stimulates the urban and rural industries and serves as a driving force.

Table 4. Baseline regression.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	urb	urb	urb	urb	urb	urb
dig	0.154 ***	0.150 ***	0.139 ***	0.119 ***	0.164 ***	0.162 ***
	(0.027)	(0.028)	(0.031)	(0.027)	(0.025)	(0.025)
ln $\_szph$		0.005	0.006	0.007 **	0.008 **	0.008 ***
		(0.005)	(0.005)	(0.003)	(0.003)	(0.003)
ln $\_gov$			0.020	0.005	0.007	0.007
			(0.014)	(0.012)	(0.012)	(0.012)

hum				0.001 ***	0.001 ***	0.001 ***
				(0.000)	(0.000)	(0.000)
open					0.058 ***	0.059 ***
					(0.015)	(0.015)
ln *_jcss*						−0.005
						(0.005)
Province-fixed	YES	YES	YES	YES	YES	YES
Year-fixed	YES	YES	YES	YES	YES	YES
Sample	341	341	341	341	341	341
R^2	0.988	0.988	0.988	0.990	0.991	0.991

Note: ***, ** indicate 1%, 5% significance levels, respectively.

5.2. Heterogeneity Analysis

Considering the disparities among China's provinces and cities in terms of natural resources, human geography, and economic levels, this paper borrows the classification method adopted by the CNBS, which divides China's mainland into four regions. Accordingly, 31 provinces are classified into these four regions for conducting a heterogeneity test. Given that an overly small sample size might give rise to multicollinearity, only the year variable is fixed in the heterogeneity test (in Table 5).

Table 5. Estimates of heterogeneity.

Variables	(1) Eastern	(2) Central	(3) Western	(4) Northeastern
dig	−0.203 ***	0.414 ***	0.221 ***	0.397 ***
	(0.057)	(0.108)	(0.075)	(0.068)
Control variables	YES	YES	YES	YES
Province-fixed	NO	NO	NO	NO
Year-fixed	YES	YES	YES	YES
Sample	110	66	132	33
R^2	0.769	0.926	0.874	0.991

Note: *** indicates 1% significance level.

Overall, the digital economy demonstrates significance across all four samples. This finding indicates that it exerts a substantial influence on new-type urbanization, thus providing empirical support for Hypothesis H1. Empirical results show that the digital economy significantly impacts new-type urbanization development in the central, western, and northeastern regions. However, the magnitude of this impact varies among different regions. The central region experiences the most statistically significant impact, then followed by the northeastern region, with the western region being the least affected.

There are three primary reasons for these regional disparities: Firstly, the population urbanization and economic urbanization levels in the eastern region are high. Some of the indicators used to measure new urbanization exhibit slow growth or remain essentially stable. Under such circumstances, new urbanization in the eastern region experiences minimal changes, or even shows a slight decline. As a result, it seems that the digital economy poses a constraint on the new urbanization. As the impact, due to the high development in society, the gaps between the urban and rural regions are decreasing, the saturation effect and the structural transformations in the advanced regions become to appear, therefore the impact may show a negative influence. Secondly, compared to the eastern region, the central, western, and northeastern regions are in a phase of growth in most new-urbanization-measuring indicators. Therefore, new-type urbanization has increased accordingly. Additionally, with the implementation of national strategies such as the Revitalization of the Northeast and the spillover effect from the east, the digital economy has thrived. Thus, it has made significant contributions to new-type urbanization in the central, western, and northeastern

regions. Thirdly, relative to the western and northeastern regions, new-type urbanization and the digital economy in the central region are likely to develop at a rapid pace.

5.3. Robustness Tests and Treatment of Endogeneity Problems

Considering the impacts of heteroskedasticity and autocorrelation, the explanatory variables are re-measured. By adopting the TOPSIS method, a new explanatory variable (dig_new_{it}), is obtained, and then a regression is carried out. The findings, presented in column (1) of Table 6, indicate that the digital economy has a robust influence on new-type urbanization.

Considering it is a gradual process, there might exist a lag effect between the construction outcomes of urbanization and the impetus provided by the digital economy for urbanization. In this paper, the lagged period of the digital economy is incorporated into the model to conduct an endogeneity test. Meanwhile, to mitigate situations in which individual disparities have a substantial impact on results, the method of eliminating extreme values is employed. Specifically, Guangdong, which has the highest level, and Tibet, which has the lowest level, are excluded. Then, a regression analysis is performed on the remaining provinces. The results are presented in columns (2) and (3). Regardless of whether the explanatory variables are replaced with their one-period-lagged counterparts or extreme values are excluded, the coefficients of the explanatory variables with respect to new-type urbanization remain positive and significant. This validates Hypothesis H1.

Table 6. Results of Robustness and Endogeneity Tests.

Variables	(1) Replacing the Explanatory Variable	(2) Explanatory Variables with a One-Period Lag	(3) Excluding Extreme Values
dig			0.135 ***
			(0.033)
$L.dig$		0.153 ***	
		(0.024)	
dig_new	0.062 ***		
	(0.011)		
Control variables	YES	YES	YES
Province-Fixed	YES	YES	YES
Year-Fixed	YES	YES	YES
Sample	341	310	319
R^2	0.990	0.992	0.990

Note: *** indicates 1% significance level.

5.4. Analysis of Mediating Effects

To examine the influence mechanism through which the digital economy impacts new-type urbanization, an analysis is conducted by Equations (2)–(4), and the findings are in Table 7. Columns (2) and (4) represent the outcomes on the mediating variables: industrial structure upgrading and innovation level. The explanatory variable (dig) exhibits a positive coefficient at 1% significance level. This indicates that it has the capacity to drive the upgrading of the industrial structure or enhance innovation. Columns (3) and (5) respectively demonstrate the influence of new urbanization by means of upgrading the industrial structure and enhancing the innovation level. The coefficients of the digital economy are significant at the 1% level. It suggests that it propels the development by facilitating the upgrading of the industrial structure and the improvement of the innovation level. Consequently, H2 is validated.

Table 7. Results of the mediation effect.

Variables	(1)	(2)	(3)	(4)	(5)
	urb	***cysj***	***urb***	***cxsp***	***urb***
dig	0.162 ***	0.146 ***	0.142 ***	83.010 ***	0.121 ***
	(0.025)	(0.035)	(0.027)	(11.660)	(0.037)
$cysj$			0.140 ***		
			(0.037)		
$cxsp$					0.001 **
					(0.000)
Control variables	YES	YES	YES	YES	YES
Province-Fixed	YES	YES	YES	YES	YES
Year-Fixed	YES	YES	YES	YES	YES
Sample	341	341	341	341	341
R^2	0.991	0.958	0.991	0.917	0.991

Note: ***, ** indicate 1%, 5% significance levels, respectively.

6. Further Study: Analysis of Threshold Effects

To validate H3, a threshold effect model is constructed. R&D intensity, denoted as rd, is chosen as the threshold variable. It is represented by taking the logarithm of the R&D expenditure of large-scale enterprises. The *p*-value of the single, double, and triple thresholds tests are 0.03, 0.053, and 0.533, respectively. These values imply that there exists a single threshold and a double threshold, while a triple threshold does not exist. Hence, H3 is confirmed.

The results indicate the existence of a double threshold effect. Subsequently, a double-threshold analysis is carried out, and the outcomes are in Table 8. As in Column (1), prior to the R&D intensity (rd) surpassing the first threshold value of 2.460, the coefficient estimate is negative and fails the significance test. Conversely, once the first and second thresholds have been exceeded, the coefficients representing the impact are positive and statistically significant, and these coefficients are progressively increasing. This suggests that as the R&D intensity grows, accompanied by more complete infrastructure construction and an escalating proportion of high-tech personnel, the digital economy exerts an increasingly potent impetus on the new urban areas in China. Thus, H3 is further validated.

Table 8. Estimation of threshold effect.

	urb
$rd_{it} \leq \varphi_1$	−0.069
	(0.101)
$\varphi_1 < rd_{it} \leq \varphi_2$	0.131 ***
	(0.024)
$rd_{it} > \varphi_2$	0.201 ***
	(0.018)
Control variables	YES
Province-Fixed	YES
Year-Fixed	YES
Sampple	341
R^2	0.824

Note: *** indicates 1% significance level.

7. Conclusions, Policy Implications, Research Limitations, and Future Directions

7.1. Conclusions, Policy Implications

Based on the theoretical analysis, this paper uses the entropy weight method to evaluate the digital economy and level of new-type urbanization in 31 provinces from 2011–2021 and estimates the impact. The conclusions are: The digital economy exerts a promoting effect, being in the order of Central > Northeast > Western. Since the development of eastern provinces has entered the middle and late stages, the promoting effect has transformed into an inhibitory effect. The digital economy propels the new-type urbanization by facilitating the upgrading of the industrial structure or enhancing technological innovation. There is a threshold effect, when R&D intensity surpasses the second threshold, the promoting effect is remarkably strengthened.

While this study focuses on China, its findings offer valuable insights for other developing economies undergoing rapid digital transformation and are critical for achieving people-oriented urbanization globally. Considering these conclusions, these countermeasures are put forward. Firstly, promote digital technology and innovate applications to drive new-type urbanization. The digital economy indeed has a remarkable promoting effect, yet it exhibits distinct characteristics across regions. For the eastern provinces, they should capitalize on the advantages of abundant production factors, including a large pool of talent and ample capital. Continuously drive the iterative innovation of digital technologies, aiming to become the vanguard of digital technology development in China. By creating new application scenarios, they can boost the new urban areas and inject a continuous stream of impetus into the growth of the national digital economy. Moreover, the Eastern region could focus on policies to manage the digital transition and enhance urban quality rather than on expansion [46,47]. As for the other regions, because of facilitating the reception of transfer of digital industries from the eastern region, they should leverage their characteristics to achieve innovative development. In this way, they can maximize their role in promoting new-type urbanization. Besides, these regions could be supported through targeted R&D subsidies designed to help firms cross the identified threshold.

Secondly, we need to establish a model of digital-industrial integration and harness the fundamental role of industrial transformation in new-type urbanization, which is quite important and practical. Innovation serves as the driving force for development. Thus, it's essential to continuously promote the research, development, and exploration of information technology. By leveraging intelligent information technology, we can enhance efficiency, reduce the production costs of high-tech products, and facilitate diversification. The digital economy transforms the traditional business development model, actively constructs new industrial incubation platforms, and aligns with the trend of industrial digitization. This enables the intelligent and upgrading of industrial structure and contributes to the creation of a globally integrated industry. Furthermore, through digital technology-enabled collaboration and the sharing of digital resources with neighboring regions, we can strategically transfer certain industries. This helps relieve the pressure of industrial agglomeration in large cities, while driving the industrial prosperity of surrounding small towns and rural areas.

Thirdly, we must refine and optimize the science, technology, and innovation ecosystem to fully capitalize on the marginal incremental effect of R&D intensity once it crosses the threshold. Recognizing the impact of increased R&D intensity on digital economy's promotion of new-type urbanization, it's crucial to actively steer and inspire digital economy enterprises to boost their R&D investment by strengthening the science and technology innovation framework. We should enhance the capital market to further expand the financing channels available to digital economy enterprises. Furthermore, we should promote the integration of government-led industrial guidance funds and social capital. This will encourage digital economy enterprises to develop innovative application scenarios that drive new-type urbanization. Continuously improve the public service system for intellectual property rights. By implementing the

guiding principle, we can reinforce the confidence and expectations of digital economy enterprises regarding increased R&D intensity.

7.2. Research Limitations and Future Directions

This study has also has some limitations: First, the scope is confined to provincial-level data from 2011 to 2021, which neglects the heterogeneous impacts at the city and county levels; Second, the measurement of the digital economy and new-type urbanization relies on a comprehensive index system constructed with the entropy weight method, yet it does not fully incorporate micro-level indicators such as household digital adoption behavior and community-level urbanization quality. As well, some measurement of the variables are not that proper, such as the innovation level (mediating variable) and the level of infrastructure (control varible); Third, this study identifies industrial structure upgrading and innovation level as mediation paths but it does not explore the potential interactive effects between these paths, nor does it consider the regulatory role of informal institutional factors in the transmission mechanism.

For future research, several directions can be pursued to address the above limitations and deepen the analysis. First, the researchers can extend the study to city and county-level data to uncover the detailed spatial spillover and hierarchical transmission effects, and further explore the heterogeneous performance; Second, the index systems for core variables can be optimized, to more accurately capture the real development level and welfare effects; Third, subsequent studies can introduce cross-term models and moderated mediation models to examine the interactive mechanisms, and explore how different factors regulate the threshold effect of R&D intensity. Additionally, future research can also conduct comparative analysis with other countries' cases, to provide international reference and enrich the theoretical system of the digital economy and urban sustainable development.

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Author Contributions

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Ethics Statement

Not applicable.

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Not applicable.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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