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Urban Digital Transformation, E-Commerce and Rural Revitalization

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Abstract: Urban digital transformation has become important to promote social progress and economic growth. At present, rural development is seriously lagging, and it is of great significance to explore the impact of urban digital transformation on rural revitalization to promote the coordinated development of urban and rural areas and rural revitalization. This study empirically investigates the impact of urban digital transformation on rural revitalization based on municipal panel data from 2009-2021. The study shows that urban digital transformation significantly drives rural revitalization, and e-commerce plays a mediating role in it. The improvement of green economy efficiency, industrial agglomeration, and human capital level will enhance the impact of urban digital transformation on rural revitalization. From the results of heterogeneity analysis, the effect is more obvious in the eastern region. This study also proposes policy suggestions from three perspectives: to promote urban digital transformation, to focus on key elements such as e-commerce, and to develop regional synergies, which provide a reference for promoting rural revitalization in the context of urban digital transformation.

Keywords: urban digital transformation, rural revitalization, e-commerce.

1. Introduction

In the last few decades, China has undergone rapid industrialization and urbanization, leading to a significant migration of people from rural areas to cities. However, while urban economies thrived, the gap between urban and rural areas widened, and rural development fell behind. In order to address the "three rural issues", promote integration between urban and rural areas, and ensure sustainable development in the countryside, the rural revitalization strategy was implemented.

Since the promotion of the rural revitalization strategy, some regions have achieved certain development results through such channels as rural tourism drive, innovation and entrepreneurship clusters, and promotion of traditional culture, but overall there are still significant problems. Examples include increased agricultural pollution, lack of competitiveness of agricultural products, low sense of well-being of the people, backwardness of public services in the countryside, shortage of resources, insufficient labor force, brain drain, and aging of the knowledge structure.

At the same time, new technologies and new forms of business are constantly emerging, driving deep changes in the global economic landscape and industrial forms. The digital transformation of cities is a powerful driver for advancing high-quality economic and social development. By the end

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of 2023, about 400 prefectural and county-level cities had issued relevant policy documents, and the people's sense of gain, happiness, and security continued to improve.

In sum, the advancement of the urban digital transformation process provides new opportunities for rural revitalization. It can promote the digital transformation of rural industries, open up trading space, improve public services, raise the level of governance, protect the ecological environment, and improve the quality of life of residents, thereby promoting the comprehensive development of the countryside from the perspectives of industry, ecology, rural customs, governance, and life.

However, the relevant construction is still in the initial exploration stage. Therefore, this study aims to focus on the e-commerce perspective, investigate the effects of urban digital transformation on rural revitalization, and analyze its internal mechanism, to propose reasonable suggestions.

The potential marginal contributions of this study are outlined below. This study introduces a novel research perspective, focusing on the impact of urban digital transformation on rural revitalization through e-commerce, filling a gap in quantitative analysis while most existing studies analyze it from the perspectives of industry, education, and governance. This study refines the analysis to the municipal level to capture more detailed local characteristics, differences, and development trends. By aligning with the digital economy era, this study provides strategic insights that are in line with the current context, enhancing its relevance and realism.

The remaining parts of this study are structured as follows. Section 2 reviews existing studies on the influence of urban digital transformation on rural revitalization. Section 3 analyzes the mechanism of the impact. Section 4 introduces the variables and the model. Section 5 performs an empirical study on the effect of urban digital transformation on rural revitalization and examines the mechanism of the effect. The last section includes the conclusion and policy suggestions.

2. Literature Review

The concept of urban digital transformation has expanded to various dimensions such as digital government, digital economy, and digital society [3]. It’s a process of urban development direction and physical form transformation driven by digital technology elements [13]. The rural revitalization strategy is an initiative to address the "three rural areas" issue, with the general requirements of industrial prosperity, ecological livability, civilized rural culture, effective governance, and rich life. An E-commerce transaction is a purchase of goods or services for sale realized through a computer network. GIIC emphasizes that all kinds of market participants are free to engage in a wide variety of economic activities through it.

Recently, theoretical discussions and empirical tests on the impact of urban digital transformation on rural revitalization have been carried out. At the theoretical level, Zhong Yu [14] suggests that the digital economy's high permeability and regional homogeneity can help address the shortage of production factors and the disconnect between supply and demand in traditional production processes, promoting the coordinated development of rural economies. Additionally, existing studies concluded that urban digital transformation could promote the improvement of farmers' incomes, governance service, activation of rural cultural values [8], and so on. At the empirical level, digitalization significantly impacts rural revitalization with regional variations [12], promotes industrial integration, and optimizes market resource allocation [7]. Furthermore, Yang Yujing [10] found that industrial prosperity is a key obstacle factor in the coupling relationship between the two.

From recent research, scholars have been expanding the scope of study on urban digital transformation, rural revitalization, and their interconnection. However, the quantitative empirical research is insufficient, and the research on the internal mechanism is not comprehensive enough, mostly from the dimensions of industry, education, and governance. In addition, the rural situation in different regions of China has significant differences and particularities, but the existing researches are mostly conducted at the national or provincial level. So this study conducts an in-depth

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investigation on the impact of urban digital transformation on rural revitalization and its functioning mechanism from the municipal level, to support the promotion of rural revitalization and the coordinated development of urban and rural areas.

3. Mechanism Analysis

3.1. Urban digital transformation, E-Commerce, and Rural Revitalization

Urban digital transformation provides a good basic condition and external environment for the development of e-commerce and further promotes rural revitalization.

Urban digital transformation enhances e-commerce by improving logistics, payment systems, and transaction opportunities [2], boosting consumer satisfaction and quality of life. It also connects urban consumers with rural agricultural products, stimulating rural economic growth. Additionally, urban digital transformation fosters industrial prosperity by enhancing information exchange and transaction efficiency in e-commerce platforms. This benefits rural areas by facilitating cross-border capital flow and technology transfer, leading to industry integration and innovation, creating more jobs, and advancing rural revitalization [4]. Moreover, urban digital transformation supports effective governance by revitalizing rural organizations and improving the regulatory framework for e-commerce. It promotes the growth of the e-commerce sector and modernizes village governance through digital platforms, enhancing transparency, simplifying processes, and improving service quality and efficiency, ultimately driving rural development.

Accordingly, we propose:

Hypothesis 1: Urban digital transformation has a significant positive impact on rural revitalization.

Hypothesis 2: Urban digital transformation will further contribute to rural revitalization by facilitating e-commerce.

3.2. Urban digital transformation, Green Economy Efficiency, and Rural Revitalization

Green economic growth is an effective strategy to facilitate the economy's transition to high-quality development. Digital platforms offer business opportunities for the sale of agricultural products, while the promotion of the green economy implies increased demand for these products. The dual role of channel security and demand enhancement promotes e-commerce development, leading to increased sales of agricultural products and improved income for farmers. What’s more, the increased efficiency of the green economy fosters energy-saving behaviors, reduces resource dependency, and optimizes rural industries, boosting employment and sustainable growth [5]. Concurrently, consumer awareness drives green consumption, reducing carbon footprints and improving rural infrastructure and residents' quality of life. This synergy between the digital and green economies fosters rural revitalization.

Accordingly, we propose Hypothesis 3: Green economy efficiency plays a moderating role in the impact of urban digital transformation on rural revitalization.

3.3. Urban digital transformation, Industrial Agglomeration, and Rural Revitalization

China's digital development varies by region, leading to uneven expansion and uneven distribution of firms. Firms tend to cluster around information hubs, reinforcing resource concentration and attracting investment. Urban digital transformation fosters information sharing and innovation, reducing e-commerce costs and enhancing platform efficiency and security. Industrial agglomeration enriches product supply, and digital transformation secures channels for product transactions. The synergy optimizes resource utilization, promotes industrial growth in agglomerations [6], and facilitates economic growth. Consequently, urban and rural areas develop together, aided by

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improved factor flow and resource sharing. This fosters a more balanced urban-rural development, narrowing the urban-rural gap.

Accordingly, we propose Hypothesis 4: Industrial agglomeration plays a moderating role in the process of urban digital transformation's impact on rural revitalization.

3.4. Urban digital transformation, Human Capital, and Rural Revitalization

Human capital encompasses the various values of the workforce, including knowledge, skills, and labor capacity [1]. Low levels of human capital would limit access to technological learning, knowledge acquisition, and industrial upgrading in rural areas. Human capital deepens e-commerce's digital integration. Relevant talent can develop digital tools that are more applicable to rural areas, optimize transaction and marketing models, and strengthen rural economic innovation. It also reshapes rural industry, fostering knowledge-driven growth and efficiency [11]. Talent mobility bridges urban-rural divides, optimizing resource allocation and rural revitalization. Efficient e-commerce driven by human capital modernizes the rural economy and promotes sustainable growth.

Accordingly, we propose Hypothesis 5: Human capital plays a moderating role in the impact of urban digital transformation on rural revitalization.

4. Methodology

4.1. Variables

4.1.1. Dependent Variable, Independent Variable, and Mediator

The Rural Revitalization Development Index (Rural_Rev) is the dependent variable. This study constructs the evaluation system refers to existing studies, taking industrial prosperity, ecological livability, civilized rural culture, effective governance, and rich life as the second-level indexes, and filtering out the 16 third-level indexes and 30 fourth-level indicators. Urban digital transformation Level Index (Urban_Digit) is the independent variable. This study refers to the construction system of existing studies, as shown in Table 1. The E-Commerce Development Level Index (EC) is the mediating variable and the evaluation system is shown in Table 1. Then use the entropy weighting method to get the above three indexes.

Table 1: Evaluation system.

Variable	2-grade indexes	3-grade indexes
Urban Digital Transformation Level Index	digital economy	Number of wholesale and retail trade enterprises above the quota (number)
		Total telecommunication services per capita (ten thousand yuan)
		Digital Inclusive Finance Index
		Percentage of employees in information transmission, computer services and software (%)
	digital society	Long-haul fiber optic cable line density
		Internet broadband access ports per capita
		Cell phone penetration rate
		Internet penetration
	digital government	Digital Economy Search Index
		Government Digital Focus

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Table 1: (continued).

E-Commerce Development Level Index	Size of employment	Number of wholesale and retail trade enterprises above the quota (number)
		Number of employees in the transportation, storage, post and telecommunications industry (persons)
	Business Scale	Revenue from telecommunication services (in millions of dollars)
		Total merchandise sales of wholesale and retail trade above the limit (million yuan)
		Total postal operations (in millions of dollars)
	user scale	Number of cell phone subscribers at the end of the year (million)
		Number of Internet broadband access subscribers (10,000)

4.1.2. Moderators

Green economy efficiency (Gee). This study refers to existing studies to measure the green economic efficiency of each city using the non-radial and non-angular super-efficient SBM model and construct the green economic efficiency index system from the three perspectives of resource inputs, and desired outputs.

Industrial agglomeration (Ind). This study refers to existing studies to selects the geographic concentration to measure the industrial agglomeration of the city, which is calculated by the following formula:

$$Ind_{it} = \frac{ind_{it}/\sum_{i=1}^{N} ind_{it}}{A_{it}/\sum_{i=1}^{N} A_{it}}$$

where A denotes the area of the administrative area of each city, ind denotes the regional non-agricultural output value at the end of the year.

Human capital stock (HC). This study refers to existing studies to introduce the accumulation effect, which is calculated as follows:

$$HC = \gamma \sum_{i=1}^{3} HE_i e^{\lambda_i h_i}$$

where γ is the share of urban employed population in each region in the overall urban employed population in the sample; HE_i is the percentage of the proportion of the employed population with the ith educational level; λ is the return to education for the ith educational level; h_i is the number of years of education for the ith educational level: $h_1 = 6$, $h_2 = 10.5$, and $h_3 = 16.67$; the qualifications represented are general primary, general secondary, and general tertiary education, respectively. The return to education draws on the return to education by level measured by Psacharopoulos & Pstrinos: $\lambda_1 = 0.180$, $\lambda_2 = 0.134$, and $\lambda_3 = 0.151$.

4.1.3. Control Variables

This study also introduces a series of control variables in the regression model.

GDP_per_cap reflects the overall economic level of the region. The share of the secondary industry in the regional GDP (Second_Ind_Share) reflects the characteristics of the region's industrial structure. Rural_Population reflects the size of the rural population in the region. The urbanization rate reflects the degree of urbanization in the region.

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4.1.4. Data Sources

Relevant data are from the 2009-2021 statistical yearbooks of cities and autonomous regions, the China Rural Statistical Yearbook, the China Statistical Yearbook, and the CSMAR database. Some missing data were filled in using interpolation.

4.2. Model

To test Hypothesis 1, we apply a model:

$$Rural\_Rev_{it} = \alpha + \beta Urban\_Digit_{it} + \theta \sum Controls_{it} + \mu_i + \gamma_t + \varepsilon_{it}$$

where $Rural\_Rev_{it}$ denotes the rural revitalization development index of the city i in year t, $Rural\_Rev_{it}$ denotes the urban digital transformation index, and $Controls$ denotes control variables, including per capita gross regional product (GDP_per_cap), the share of secondary industry in GDP (Second_Ind_Share), rural population (Rural_Population), urbanization rate (Urbanization). μ_i, γ_t, ε_{it} refer to province fixed effects, year fixed effects, and random errors separately.

5. Results Analysis

5.1. Descriptive Statistics

Table 2 reports the main descriptive statistics of dependent variable, independent variable, and control variables. It shows that the mean, minimum, and maximum values of the rural revitalization development index are 3.351, 0.341, and 9.416, respectively. The mean, minimum, and maximum values of the urban digital transformation development index are 0.160, 0.014, and 0.737, respectively. It indicates that there are certain municipal differences between different regions.

Table 2: Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max.
Rural_Rev	3324	3.351	1.493	0.341	9.416
Urban_Digit	3324	0.160	0.106	0.014	0.737
GDP_per_cap	3324	0.508	0.342	0.001	4.677
Second_Ind_Share	3324	0.462	0.113	0.000	0.898
Rural_Population	3324	0.191	0.133	0.000	1.384
Urbanization	3324	0.547	0.154	0.151	1

5.2. Baseline Estimate Analysis

A baseline estimate is conducted, and the results are shown in Table 3. According to the results, the coefficient of urban digital transformation is significantly positive at the 1% level, so urban digital transformation has a significant positive impact on rural revitalization, and this finding is still robust after adding a series of control variables and fixed effects. Hypothesis 1 is verified.

We further study the effect of urban digital transformation on the five connotations of rural revitalization, and the results are shown in Table 4. As in column (3), the effect on civilized countryside is larger, implying that urban digital transformation can effectively improve the level of education, Internet communication construction, etc. in the countryside. As in columns (4) and (5), the effect on effective governance and rich life is smaller, implying that administrative governance and public services in rural areas are promoted to a lesser extent.

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Table 3: Baseline estimate analysis.

	(1) Rural_Rev	(2) Rural_Rev	(3) Rural_Rev	(4) Rural_Rev
Urban_Digit	4.081***	1.781***	3.602***	1.508***
	(0.200)	(0.253)	(0.521)	(0.220)
GDP_per_cap		0.749***	0.590***	0.395***
		(0.098)	(0.100)	(0.045)
Second_Ind_Share		-2.621***	-2.251***	-0.664***
		(0.210)	(0.224)	(0.109)
Rural_Population		1.304***	1.247***	0.751***
		(0.166)	(0.169)	(0.092)
Urbanization		0.988***	0.820***	0.231**
		(0.206)	(0.210)	(0.093)
_cons	2.930***	3.346***	2.892***	6.078***
	(0.038)	(0.150)	(0.169)	(0.166)
N	3324	3324	3324	3324
r2	0.102	0.184	0.198	0.873
Year	No	No	Yes	Yes
Province	No	No	No	Yes

Standard errors in parentheses
* p < 0.1,** p < 0.05,*** p < 0.01

Table 4: Impact of urban digital transformation on the five connotations of rural revitalization.

	(1) IND	(2) ECO	(3) CUL	(4) GOV	(5) LIV
Urban_Digit	0.143***	0.144***	0.149***	0.140***	0.139***
	(0.022)	(0.021)	(0.021)	(0.022)	(0.021)
_cons	0.562***	0.577***	0.586***	0.578***	0.603***
	(0.016)	(0.016)	(0.016)	(0.017)	(0.016)
N	3324	3324	3324	3324	3324
r2	0.859	0.870	0.871	0.859	0.875
Control	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
* p < 0.1,** p < 0.05,*** p < 0.01

5.3. Mediation Analysis

Then test the mediating role of e-commerce in the process of urban digital transformation affecting rural revitalization. Columns (1)-(4) of Table 5 show the impact of urban digital transformation on the scale of e-commerce employment, the scale of business, the scale of users, and the comprehensive development level, respectively. The regression coefficients are all significant at the 1% level as evidence, indicating that e-commerce development plays a mediating role in urban digital transformation to promote rural revitalization. Hypothesis 2 is verified.

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Table 5: Mediated effects test.

	(1) EC_employment	(2) EC_business	(3) EC_users	(4) EC
Urban_Digit	0.152***	0.083***	0.135***	0.175***
	(0.015)	(0.010)	(0.013)	(0.015)
_cons	0.372***	0.317***	0.156***	0.393***
	(0.010)	(0.007)	(0.010)	(0.010)
N	2790	2790	3324	2790
r2	0.841	0.797	0.698	0.845
Control	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes

Standard errors in parentheses
* p < 0.1,** p < 0.05,*** p < 0.01

To ensure the robustness of the results, this study also applies Sobel-Goodman to test the mediating effect of the level of e-commerce development. The z-values of Sobel, Aroian, and Goodman are 9.795, 9.784, and 9.806, respectively, and all of them are significant at the 1% level. The conclusion is robust and Hypothesis 2 is established.

5.4. Moderation Analysis

As shown in Table 6, the coefficients of the interaction terms of the urban digital transformation index with green economic efficiency, industrial agglomeration, and human capital level are all significantly positive at the 1% level. This indicates that with the improvement of green economic efficiency, industrial agglomeration, and human capital level, the promotion of urban digital transformation on rural revitalization is increasing. Hypothesis 3, 4, and 5 are verified.

Table 6: Moderating effects test.

	(1) Rural_Rev	(2) Rural_Rev	(3) Rural_Rev	(4) Rural_Rev	(5) Rural_Rev	(6) Rural_Rev
Urban_Digit	1.158***	0.811***	0.732***	0.577**	0.433***	0.588***
	(0.165)	(0.223)	(0.164)	(0.224)	(0.166)	(0.225)
Gee	0.398***	0.290***				
	(0.032)	(0.039)				
Urban_Digit×Gee	5.005***	5.591***				
	(0.335)	(0.473)				
Ind			0.030***	0.019***		
			(0.003)	(0.004)		
Urban_Digit×Ind			0.146***	0.190***		
			(0.019)	(0.023)		
HC					32.366***	17.552***
					(1.977)	(2.940)
Urban_Digit×HC					133.558***	169.311***
					(16.116)	(20.143)
_cons	5.997***	5.129***	5.320***	4.585***	5.459***	5.057***
	(0.140)	(0.161)	(0.145)	(0.171)	(0.140)	(0.165)
N	3324	3324	3324	3324	3324	3324

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Table 6: (continued).

r2	0.874	0.885	0.881	0.887	0.883	0.886
Control	No	Yes	No	Yes	No	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
* p < 0.1,** p < 0.05,*** p < 0.01

5.5. Robustness Test

Replace the original evaluation system with the evaluation system of Xu Weixiang et al. [9] to re-test the impact of urban digital transformation level on rural revitalization. According to column (1) of Table 7, the regression coefficient is significantly positive at the 1% level, and the conclusion of Hypothesis 1 is robust.

Exclude the sample data from the four leading developing cities of Beijing, Shanghai, Guangzhou, and Shenzhen and then conduct the regression. As shown in column (2) of Table 7, the regression coefficient is still significantly positive at the 1% level, and Hypothesis 1 is robust.

Considering that the rural revitalization strategy was proposed on October 18, 2017, and the global new crown epidemic broke out in 2020, exclude the 2018 and 2020 data and then conduct the regression. As shown in column (3) of Table 7, the regression coefficients remain significantly positive at the 1% level, and Hypothesis 1 remains robust.

5.6. Heterogeneity Analysis

Considering the significant differences between different regions in terms of economic development level, resource endowment, industrial structure, infrastructure construction, etc., the impact of urban digital transformation on rural revitalization may show regional heterogeneity. This study divides the data into the eastern region and central and western regions for regression. As shown in column (1) of Table 7, the impact in the eastern region is significantly positive at the 1% level, with a regression coefficient of 2.441, and as shown in column (2) of Table 7, the impact in the central and western regions is significantly positive at the 1% level, with a regression coefficient of 0.657. It can be seen that the effect of urban digital transformation on rural revitalization in the eastern region is stronger than that in the central and western regions. The possible reason is that the eastern region has a better foundation and investment in green technology innovation, industrial structure improvement, and human capital cultivation, while the central and western regions have not invested enough in relevant fields, resulting in a lower degree of digitalization.

Table 7: Robustness test and heterogeneity analysis.

	(1) Rural0	(2) Rural_Rev	(3) Rural_Rev	(4) Rural_E	(5) Rural_CW
Urban_Digit	0.123***	0.771***	1.398***	2.441***	0.657***
	(0.018)	(0.194)	(0.224)	(0.437)	(0.247)
_cons	0.533***	-0.078	5.900***	6.151***	-0.014
	(0.014)	(0.075)	(0.167)	(0.254)	(0.089)
N	3324	3324	3324	1027	2297
r2	0.875	0.888	0.872	0.649	0.895
Control	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
* p < 0.1,** p < 0.05,*** p < 0.01

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6. Conclusions and Policy Suggestions

This study takes prefecture-level cities in China from 2009 to 2021 as the research object to empirically test the impact and mechanism of urban digital transformation on rural revitalization. The following conclusions can be drawn: (1) Urban digital transformation has a significant positive effect on promoting rural revitalization. (2) Urban digital transformation can enhance rural revitalization by improving the development of e-commerce, and green economic efficiency, industrial agglomeration, and human capital level play a positive moderating role in the influence process, which can effectively enhance the role of urban digital transformation on rural revitalization. (3) The effect of urban digital transformation to improve rural revitalization is more obvious in the eastern region.

Based on the above conclusions, the following policy suggestions are made:

Firstly, accelerate urban digital transformation. The government should invest in digital infrastructure, offer support for digital transformation, and build a digital government to improve service delivery. This will drive the integration of information technology with traditional industries, promoting digital upgrades for urban development.

Secondly, the Government should focus on key areas of development to enhance urban digital transformation and promote rural revitalization. It involves enhancing e-commerce, advancing green technologies, supporting high-tech industries, improving human capital, and promoting the commercialization of scientific research results.

Finally, the Government needs to formulate construction plans and development strategies according to the characteristics of each region. In the eastern region, the focus is on advancing IoT technology, promoting digital applications, and enhancing digital literacy. In the central and western regions, policy guidance and financial support should be stepped up while making use of external resources to improve digitalization. In addition, implement a coordinated regional development strategy to optimize resource allocation and promote synergistic development.

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