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County-Level Urban–Rural Integration in China from an Urban–Rural Territorial System Perspective: Spatial Differentiation and Influencing Factors

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Abstract

Urban–rural integration is an important pathway for promoting coordinated territorial development and reducing urban–rural disparities. However, its spatial differentiation and regionally heterogeneous pathways at the county level remain insufficiently understood. This study aims to systematically measure county-level urban–rural integration, reveal its spatial differentiation, and examine the spatial effects and regional heterogeneity of factors associated with its development. Drawing on urban–rural territorial system theory, this study develops a four-dimensional evaluation framework and measures urban–rural integration across1863 county-level units in China in 2020 using a combined weighting method. Based on cross-sectional data for 2020, spatial autocorrelation analysis and spatial econometric models, particularly the Spatial Durbin Model (SDM), are employed to examine its spatial patterns and influencing factors. The results show pronounced spatial differentiation, with high-value areas concentrated in eastern coastal regions and around regional central cities, and low-value areas in less-developed western regions. Integration is positively associated with population urbanization, but higher urbanization does not necessarily correspond to higher integration. Economic development and digital development are strongly associated with urban–rural integration, while spatial connectivity primarily exhibits local effects and public services show heterogeneous spatial effects. Moreover, the factors associated with urban–rural integration vary significantly across regions. These findings suggest strengthening county-level economic capacity, leveraging digital technologies, optimizing urban–rural public resource allocation, and enhancing inter-county collaboration to advance urban–rural integration from intra-county coordination toward broader regional coordination.

Keywords: county-level urban–rural integration; urban–rural territorial system; spatial differentiation; spatial spillovers; spatial Durbin model

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1. Introduction

Urban–rural relations are undergoing profound transformations worldwide under the combined influence of rapid urbanization, economic restructuring, and technological change [1,2]. Over the past several decades, urbanization has reshaped the spatial distribution of population, industries, and economic activities, while rural areas have experienced substantial changes in demographic structure, economic functions, and land use [3]. At the same time, urban–rural linkages have intensified, with population, capital, land, infrastructure, information, and public services increasingly exchanged between urban and

rural areas. These changes have blurred conventional spatial and functional boundaries, challenging the view of urban and rural areas as separate and functionally independent systems. Instead, they are increasingly understood as interconnected components of a broader urban–rural territorial system [4–6].

However, stronger urban–rural linkages do not necessarily lead to coordinated development. Substantial disparities persist between urban and rural areas in income, employment opportunities, public services, and infrastructure in many regions worldwide [7]. Meanwhile, rural decline and persistent population loss may further concentrate population, capital, and other resources in urban areas, adding complexity to the transformation of urban–rural relations [8,9]. Against this background, promoting stronger linkages and more coordinated development between urban and rural areas has become an important challenge for regional development.

Urban–rural integration has emerged as an important perspective for understanding and responding to these transformations. Rather than focusing solely on reducing urban–rural disparities, it emphasizes stronger interaction and coordinated development through factor flows, functional linkages, infrastructure connectivity, and more equitable access to public services [10]. From this perspective, urban–rural integration can be understood as a dynamic territorial process in which urban and rural subsystems maintain their respective development foundations while achieving greater coordination through factor exchange, functional complementarity, and structural adjustment [11]. This perspective moves beyond the conventional urban–rural dualism by emphasizing the relational and systemic nature of urban–rural transformation. It also implies that urban–rural integration should be assessed from multiple complementary dimensions rather than solely by the magnitude of urban–rural disparities, including the development of both subsystems, their interactions, and the coordination of their development.

China provides an important context for examining this transformation. Since the launch of reform and opening up, rapid industrialization and urbanization have substantially promoted economic development and strengthened the capacity of urban areas to accommodate population and economic activities, while profoundly reshaping the spatial distribution of population, industries, and settlements [12]. At the same time, the long-standing urban–rural dual structure has contributed to persistent disparities in income, infrastructure, and access to public services. Imbalanced urban–rural development and inadequate rural development have consequently remained important challenges [13]. As China has entered a new stage of development, policy priorities have gradually shifted from a predominantly city-oriented growth model and a relatively segmented urban–rural development pattern toward greater urban–rural coordination [14]. Since the 19th National Congress of the Communist Party of China, urban–rural integration has increasingly been positioned as a national development strategy. In this context, promoting urban–rural integration has become an important means of coordinating urbanization with rural revitalization, facilitating multidimensional factor flows, and reshaping urban–rural spatial relations.

Within China's territorial system, the county provides a particularly appropriate spatial scale for examining urban–rural integration. As a fundamental unit of administrative governance, counties are numerous, cover extensive areas, and accommodate a large share of the population, particularly the rural population [15]. More importantly, counties link urban and rural areas within a common territorial space and encompass diverse settlement types, including county seats, towns, and villages. They therefore provide a spatial context in which urban–rural factor flows and functional linkages take place. China's 14th Five-Year Plan explicitly identified counties as a basic spatial unit for advancing urban–rural integration. Examining integration at the county level can reveal finer-scale spatial

differentiation and provide insights into interactions between urban and rural subsystems within specific territorial contexts. Moreover, counties vary substantially in resource endowments, locational conditions, industrial foundations, and stages of development, which may generate pronounced spatial heterogeneity in urban–rural integration. A systematic assessment at the county level is therefore important for identifying spatial patterns and examining the factors underlying these differences.

Research on urban–rural integration has developed increasingly diversified approaches to measurement. Early studies primarily relied on single indicators, such as urban–rural income or consumption gaps, to characterize urban–rural relations [16,17]. Subsequent research developed multidimensional evaluation systems incorporating economic, demographic, social, spatial, and ecological dimensions [18–21]. More recent studies have further introduced indicators of population mobility, transportation connectivity, and information networks to capture the interactive dimension of urban–rural relations [22,23]. These frameworks have been applied at multiple spatial scales, including national, provincial, and prefecture-level scales [24–27]. Existing findings generally reveal pronounced spatial differentiation, with higher levels of urban-rural integration concentrated in the eastern coast regions and major urban agglomerations, while lower levels are more prevalent in inland areas of central and western China, as well as border, mountainous, and less-developed regions [18,21].

A related body of research has examined the factors influencing urban–rural integration and generally identified the combined effects of natural conditions, economic development, institutional arrangements, infrastructure, and factor mobility. Economic development, industrial upgrading, and fiscal support for agriculture can strengthen the economic foundation of integration [28,29]. Institutional reforms, including household registration reform, land system innovation, and fiscal transfer policies, can facilitate factor mobility and promote more equitable access to public services [30,31]. Transport infrastructure and information networks can further strengthen spatial linkages between urban and rural areas [32]. Population migration, human capital, and capital mobility may have mixed effects: while they can enhance urban–rural interaction, they may also contribute to talent loss and resource outflows from some rural areas [33]. Natural geographical conditions and locational characteristics can also shape the spatial differentiation of urban–rural integration [34,35].

Despite these advances, three important gaps remain. First, although an increasing number of studies have examined urban–rural integration at the county level, relatively limited attention has been paid to its spatial differentiation and spatial dependence across a large number of counties at the national scale. Existing county-level studies have mainly focused on measuring the level of urban–rural integration and examining its spatial characteristics within specific regions or selected county samples. This limits a systematic understanding of the fine-scale spatial patterns of urban–rural integration across Chinese counties. Second, in terms of measuring urban–rural integration, existing studies have commonly constructed evaluation systems from multiple dimensions, including population, economic, social, spatial, and ecological dimensions. However, these indicators tend to place greater emphasis on urban–rural disparities while paying relatively less attention to the interaction and coordination between urban and rural areas [36]. This may limit the ability of existing measurement frameworks to simultaneously capture the development of urban and rural subsystems, the interactions between them, and the coordination of urban–rural relations. Third, with respect to influencing factors, existing studies have largely examined the average effects of individual factors, while paying relatively less attention to their spatial spillovers and regional heterogeneity. Given substantial differences among counties in development stages, resource endowments, and territorial conditions, the ef-

fects of individual factors may vary across regions and may extend beyond administrative boundaries through spatial spillovers. A spatial analysis is therefore needed to distinguish local effects from cross-county spillovers and to identify regionally differentiated pathways of urban–rural integration.

To address these gaps, this study adopts a territorial systems perspective to examine county-level urban–rural integration across 1863 county-level units in China in 2020. Building on this perspective, an evaluation framework is developed along four dimensions: urban development, rural development, urban–rural interaction, and urban–rural disparities. Exploratory spatial data analysis (ESDA) and spatial econometric models, particularly the Spatial Durbin Model (SDM), are employed to examine the spatial differentiation, spatial dependence, and influencing factors of county-level urban–rural integration. Specifically, this study addresses three questions: (1) How can county-level urban–rural integration be measured in a systematic and theoretically grounded manner? (2) What spatial differentiation and clustering patterns characterize urban–rural integration across Chinese counties? (3) What factors influence county-level urban–rural integration, and how do their effects vary across regions?

This study makes three main contributions. First, it extends the national-scale empirical examination of urban–rural integration to a comprehensive set of county-level units, providing systematic evidence on its fine-scale spatial differentiation and spatial dependence across China. Second, it develops a multidimensional measurement framework grounded in the urban–rural territorial systems perspective, conceptualizing urban–rural integration as a process involving the development of urban and rural subsystems, their interaction, and the coordination of urban–rural relations, rather than simply as a process of narrowing development disparities. Third, by incorporating spatial spillovers and regional heterogeneity into the analytical framework, this study distinguishes local effects from cross-county effects and identifies differentiated spatial pathways through which various factors are associated with county-level urban–rural integration.

2. Conceptual Framework

2.1. Urban–Rural Territorial Systems and the Conceptualization of Urban–Rural Integration

Urban–rural relations constitute a fundamental dimension of territorial development. Early theories primarily focused on structural differences between urban and rural areas. From the perspective of factor mobility, Lewis's (1954) dual-sector theory explained the transfer of labor from the traditional agricultural sector to the modern industrial sector in urban areas [37], highlighting the role of population mobility in transforming urban–rural structures during industrialization and urbanization. As urban–rural linkages have intensified, research has gradually shifted from emphasizing structural differences to examining the interconnections and exchanges between urban and rural areas. Tacoli highlighted extensive economic, social, and spatial linkages manifested through flows of people, goods, capital, and information [1]. Douglass further conceptualized urban–rural linkages as multidimensional exchanges involving population, production, goods, capital, and information [38]. Meanwhile, Howard's Garden City theory [39], McGee's Desakota model [40], and studies of in situ urbanization highlighted the blurring of urban–rural spatial boundaries and the increasing integration of urban and rural functions [41]. Together, these perspectives suggest that urban and rural areas are increasingly connected through population mobility, factor flows, industrial linkages, infrastructure connectivity, and information exchange, challenging the conventional view off them as spatially separate and functionally independent units [42].

Systems theory provides a broader framework for understanding these changing relationships [43]. In geography, the human–land relationship territorial systems perspective

further conceptualizes territorial systems as complex systems formed through interactions among natural, economic, social, and other elements within a specific geographical space [12,44]. From this perspective, urban and rural areas can be understood as distinct but interconnected territorial subsystems with different functions and development characteristics [45]. Through the flows of population, capital, land, industrial activities, information, infrastructure, and public services, these subsystems establish functional linkages and continuously adjust through interaction, jointly forming an urban–rural territorial system [46]. The development of one subsystem can therefore influence the development conditions and functional relationships of the other, making urban–rural relations a dynamic process of interaction and adjustment rather than a simple comparison between two spatial categories.

Within this framework, urban–rural integration extends beyond the convergence of urban and rural development levels or the reduction in urban–rural disparities. It refers to a dynamic process through which urban and rural territorial subsystems maintain their respective development foundations while becoming increasingly interconnected and coordinated through factor flows, functional linkages, and mutual interaction. The development capacity of both subsystems provides the foundation for sustained interaction, while the circulation of population, capital, land, information, technology, and other factors strengthens functional connections in employment, industry, infrastructure, and public services. At the same time, excessive urban–rural disparities may constrain two-way factor flows and limit the sharing of development opportunities. Reducing such disparities is therefore an important aspect of urban–rural integration, but not its sole objective. Rather, integration emphasizes the strengthening of connections between urban and rural subsystems and enhancing their capacity to interact, complementone another, and develop in a more coordinated manner while maintaining appropriate differentiation.

Thus, from the perspective of the urban–rural territorial system, urban–rural integration should be understood as an interactive and co-evolutionary process involving both the development of urban and rural territorial subsystems and the relationships established between them (Figure 1). Stronger development capacity can create conditions for more sustained interaction, while intensified interaction and functional linkages can in turn reshape the development trajectories of both subsystems. The coordination of urban–rural relations is therefore not a static outcome, but an evolving process shaped by the reciprocal adjustment of the two subsystems. This conceptualization provides the theoretical basis for examining county-level urban–rural integration and for translating its core conceptual content into specific dimensions for empirical measurement in the following section.

2.2. Dimensions of County-Level Urban–Rural Integration

Building on the territorial systems perspective developed above, the county provides a suitable spatial context for examining urban–rural integration because it encompasses urban and rural areas within a common territorial unit, including county seats, towns, and villages. This spatial scale allows the development and interactions of urban and rural subsystems to be examined within a unified framework. Accordingly, county-level urban–rural integration is conceptualized and measured along four interrelated dimensions: urban development, rural development, urban–rural interaction, and urban–rural disparities (Figure 1). These four dimensions do not represent independent aspects of urban–rural integration; rather, they capture different but interconnected components of the urban–rural territorial system.

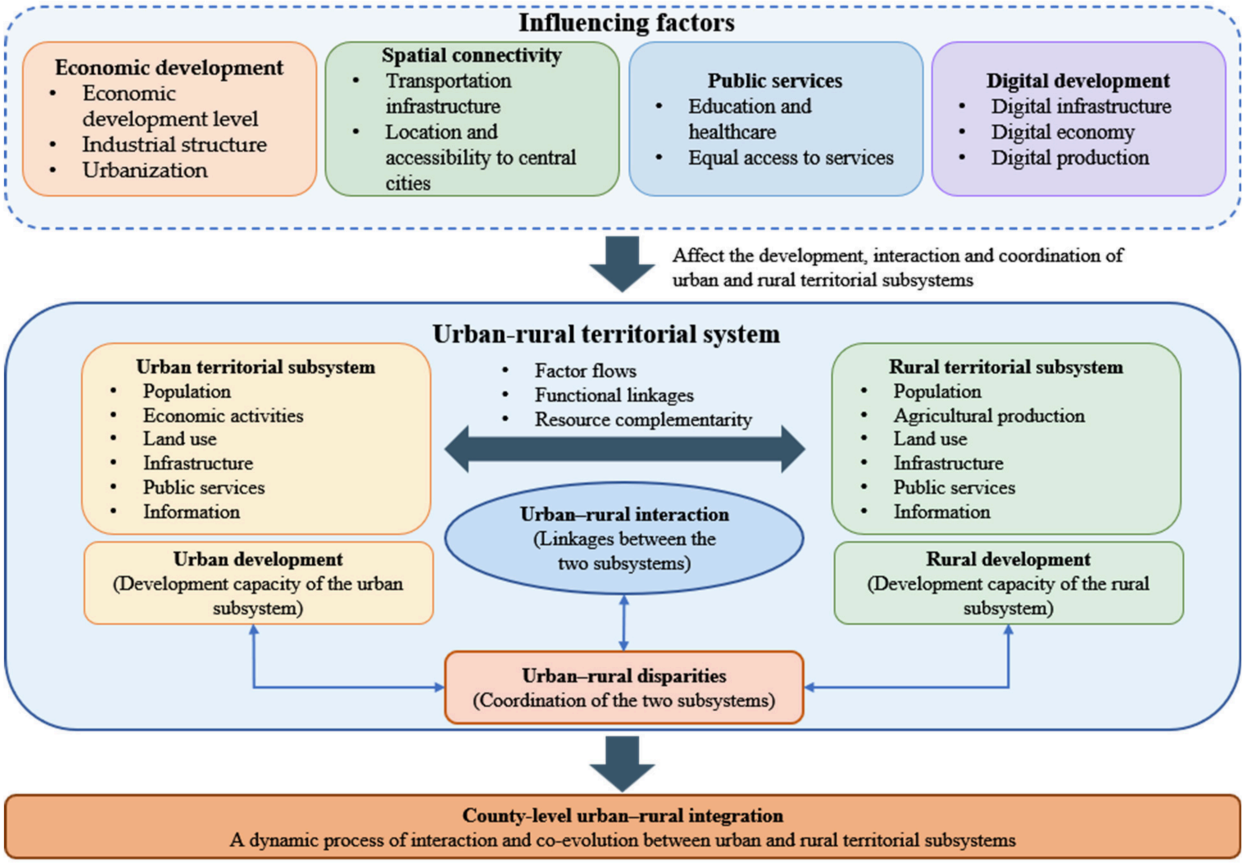


Figure 1. Conceptual framework of county-level urban–rural integration from the urban-rural territorial system perspective.

(1) Urban development: The urban subsystem includes county seats, central towns, and other towns, which generally serve as important centers of economic activity, employment, public services, and factor agglomeration. A higher level of urban development can strengthen the capacity of urban areas to absorb population and economic activities and create opportunities for linkages with surrounding rural areas. Urban development therefore constitutes an important foundation for urban–rural integration.

(2) Rural development: The rural subsystem performs important economic, social, ecological, and residential functions. A higher level of rural development can strengthen the economic and social capacity of rural areas and their ability to participate in urban–rural factor exchange and functional specialization, thereby supporting more stable and complementary urban–rural linkages. Conversely, weak rural development may reinforce the concentration of population and resources in urban areas and increase urban–rural imbalances. Rural development is therefore an essential component of the coordinated development of the urban–rural territorial system.

(3) Urban–rural interaction: Urban–rural integration depends not only on the development of the two subsystems but also on the intensity of their interactions and the functional linkages between them. The flows of population, capital, land, industrial activities, information, and technology constitute important forms of multidimensional factor flows and functional linkages in urban–rural interaction [38]. These flows are not necessarily independent; population mobility, for example, may be accompanied by changes in employment, capital allocation, information exchange, technology diffusion, and consumption demand. The intensity of population mobility can therefore provide an observable indication of the broader intensity of factor ex-

change within a territorial system, although it does not comprehensively capture all forms of urban–rural flows. Effective interaction can reduce spatial and transaction costs, improve resource allocation and functional complementarity, and strengthen connections between urban and rural areas. It can also facilitate the transformation of the urban–rural territorial system from relatively segmented relations toward more interconnected and networked linkages. Urban–rural interaction thus represents a key process through which integration develops.

(4) Urban–rural disparities: Urban–rural integration does not require complete convergence in development levels. Rather, urban and rural areas may retain distinct development characteristics while sharing development opportunities and maintaining appropriate differentiation. Excessive disparities in income, public services, and infrastructure may reinforce urban–rural separation, constrain factor flows and functional linkages, and weaken functional complementarity. Reducing excessive or unreasonable disparities while preserving the distinctive functions of urban and rural areas is therefore an important manifestation of coordinated development. Urban–rural disparities thus provide an important indication of the degree of coordination within the urban–rural territorial system, while not fully defining urban–rural integration.

The four dimensions are therefore complementary rather than strictly sequential. Urban development and rural development describe the development capacity of the two territorial subsystems, respectively, and provide the foundation for their sustained interaction. Urban–rural interaction captures the flows of factors and functional linkages through which the two subsystems are connected and influence one another. Urban–rural disparities reflect the degree of coordination between the two subsystems and may both result from and constrain their interaction and development. These dimensions are thus linked through dynamic feedback: stronger development capacity can facilitate interaction, greater interaction can reshape the development of both subsystems, and changes in their relative development levels may alter the extent of urban–rural disparities and the conditions for further interaction. Taken together, the four dimensions provide a comprehensive framework for understanding county-level urban–rural integration as a dynamic process of interaction and coordination within the urban–rural territorial system.

2.3. Factors Influencing County-Level Urban–Rural Integration

Building on the conceptualization of urban–rural integration as a dynamic process within an urban–rural territorial system, the factors influencing integration can be understood in terms of how they shape the development capacity of the two territorial subsystems, the interactions between them, and the conditions for their coordinated evolution (Figure 1). Accordingly, this study considers four groups of factors: economic development, spatial connectivity, public services, and digital development [32,47]. These factors do not operate independently; rather, they may influence urban–rural integration through resource agglomeration and diffusion, factor flows, functional linkages, public service provision, and information connectivity. From the perspective of the urban–rural territorial system, they may therefore affect not only the development conditions of individual urban and rural subsystems but also the intensity of interactions and the degree of coordination between them. This provides the theoretical basis for examining the factors associated with county-level urban–rural integration.

Economic development provides a fundamental basis for strengthening the development capacity of urban and rural territorial subsystems. A higher level of economic development can enhance a county's fiscal and investment capacity, thereby supporting infrastructure, public services, and industrial development [28]. It can also expand

opportunities for residents to participate in economic activities and share the benefits of development. Industrial restructuring further affects the allocation of labor, capital, and other factors by reshaping employment opportunities and the spatial distribution of industries. In particular, the transition toward a more service-oriented and advanced industrial structure can expand non-agricultural employment opportunities and strengthen the division of labor and collaboration between urban and rural industries [29]. Population urbanization may further reshape urban–rural linkages by promoting the concentration of population and economic activities, improving resource allocation, and extending urban functions to surrounding rural areas. Through these pathways, economic development may strengthen the development capacity of the two territorial subsystems and enhance their functional linkages, while also generating spillovers to neighboring counties through industrial linkages and factor flows.

Spatial connectivity determines the accessibility and efficiency of interactions within the urban–rural territorial system. Transport infrastructure reduces the time and economic costs of moving people and goods and facilitates the circulation of capital and information, thereby promoting resource exchange and functional complementarity between urban and rural areas [35]. The locational relationship between a county and regional central cities also affect its access to external resources, industrial opportunities, and public services. Favorable locational conditions can strengthen a county's access to central-city spillovers and transmit external development opportunities through industrial linkages, population mobility, and infrastructure networks [48]. Spatial connectivity therefore influences not only the efficiency of interactions between urban and rural areas within counties but also the extent to which counties can access and benefit from external development opportunities.

Public services provide an important basis for sharing development opportunities and strengthening coordination within the urban–rural territorial system. Basic services such as education and healthcare directly affect residents' quality of life and can enhance their participation in economic activities through human capital accumulation and improved health [21,49]. More equitable public service provision can reduce disparities in development opportunities between urban and rural residents and support a more balanced distribution of population, employment, and public resources. Conversely, excessive concentration of high-quality educational and healthcare resources in county seats or higher-level towns may widen urban–rural disparities and weaken the development capacity of rural areas. Public service provision may therefore affect urban–rural integration not simply through its aggregate level, but through its spatial distribution, accessibility, and capacity to be shared across urban and rural areas.

Digital technologies are reshaping the spatial organization of information exchange, resource allocation, and economic activities within the urban–rural territorial system, creating new opportunities to overcome geographical distance [50]. Digital infrastructure improves information accessibility and network connectivity, facilitating the circulation of knowledge, technology, capital, and other resources across space. Digital inclusive finance can broaden access to financial services among rural residents and businesses by lowering access barriers and transaction costs. Digitalized production can also strengthen urban–rural industrial linkages and value-chain coordination by transforming agricultural production, industrial organization, and market transactions [47,51]. Unlike conventional infrastructure, digital technologies exhibit strong network effects and cross-regional connectivity, allowing their influence to extend beyond administrative boundaries and potentially generate spatial spillovers across counties. Digital development can therefore affect both the development capacity of urban and rural subsystems and the linkages between them, while also strengthening connections between counties within the broader urban–rural territorial system.

Importantly, these factors may operate through both local and spatially connected pathways because counties are embedded in broader regional networks. Economic development, infrastructure connectivity, public service provision, factor flows, industrial linkages, and digital connections may extend beyond administrative boundaries, generating positive or negative spatial spillovers across neighboring counties. The spatial reach of these effects may differ across factors and regions. Accordingly, the analysis of county-level urban–rural integration needs to consider not only the effects of factors within individual counties but also their potential cross-county spatial effects. This spatially embedded perspective provides the theoretical basis for subsequently examining the direct and indirect effects of the factors influencing county-level urban–rural integration and their regional heterogeneity.

3. Materials and Methods

3.1. Study Area and Data Sources

This study examines 1863 county-level units across 28 provinces, autonomous regions, and municipalities in China. Beijing, Shanghai, and Tianjin are excluded because they do not contain county-level administrative units, while Hong Kong, Macao, and Taiwan are excluded due to the lack of relevant data. In addition, county-level units with substantial missing data are excluded to ensure the completeness and comparability of the empirical analysis. The final sample comprises counties, county-level cities, autonomous counties, banners, autonomous banners, special districts, and forest districts. The year 2020 was selected because it coincides with the Seventh National Population Census and provides relatively comprehensive and consistent population and socioeconomic data at the county level.

Data on urban and rural residents' income were primarily obtained from the China County Statistical Yearbook (https://www.stats.gov.cn/zs/tjwh/tjkw/tjzl/202302/t20230215_1908004.html, accessed on 15 October 2025) and, for a small number of counties, from their 2020 Statistical Communiqués on National Economic and Social Development. Where county-level income data were unavailable, the corresponding urban and rural income data of the prefecture-level city were used to supplement the dataset. Data on the intra-county mobile population were derived from the Tabulation of the 2020 Population Census of China by County (https://www.stats.gov.cn/zs/tjwh/tjkw/tjzl/202302/t20230220_1913738.html, accessed on 20 October 2025).

Data for the explanatory variables were mainly obtained from the China County Statistical Yearbook (https://www.stats.gov.cn/zs/tjwh/tjkw/tjzl/202302/t20230215_1908004.html, accessed on 15 October 2025). Average years of schooling were derived from the county-level tabulations of the Seventh National Population Census, which report the average years of schooling among the population aged 15 years and above (https://www.stats.gov.cn/zs/tjwh/tjkw/tjzl/202302/t20230220_1913738.html, accessed on 20 October 2025). The Digital Inclusive Finance Index was obtained from the Peking University Digital Financial Inclusion Index developed by the Institute of Digital Finance at Peking University [52]. The indices of digital information infrastructure and digitalized production were obtained from the Research Report on the County-Level Digital Village Index (2020) compiled by Peking University (https://ccap.pku.edu.cn/nrdi/xmycg/yjxm/50162ncyjzx363361.htm, accessed on 10 October 2025).

3.2. Measurement of County-Level Urban–Rural Integration

3.2.1. Indicator System

Given the nationwide coverage of the study and the limited availability of county-level statistical data, representative indicators were selected to balance conceptual comprehensiveness and data availability (Table 1). Urban and rural development are measured by

the per capita disposable income of urban and rural residents, respectively, while the urban–rural income ratio is used to capture the degree of urban–rural disparity. A value closer to 1 indicates a smaller income gap and greater urban–rural coordination.

Table 1. Indicator system and weights for measuring county-level urban–rural integration.

Dimension	Indicator	Definition	Entropy Method Weight	Subjective Weight	Composite Weight
Urban development	Urban residents' income	Per capita disposable income of urban residents at the county level (CNY)	0.252	0.250	0.251
Rural development	Rural residents' income	Per capita disposable income of rural residents at the county level (CNY)	0.248	0.250	0.249
Urban–rural disparities	Urban–rural income ratio	Per capita disposable income of urban residents/per capita disposable income of rural residents	0.252	0.250	0.251
Urban–rural interaction	Intra-county population mobility rate	Intra-county mobile population/county resident population	0.248	0.250	0.249

For urban–rural interaction, capital, industrial activities, information, and technology constitute important forms of factor flows. However, comparable measures of these flows are difficult to obtain consistently at the county level across China. Population mobility is often accompanied by the movement and reallocation of other factors, such as capital, information, and technology. Therefore, the intensity of population mobility can, to some extent, provide an observable indication of the broader intensity of factor exchange within a territorial system. Accordingly, this study uses the intra-county population mobility rate as a proxy for the intensity of population mobility and, more broadly, the intensity of factor exchange.

It should be noted that population mobility includes rural-rural, rural-urban, urban-rural, and urban–urban movements. Among these, rural-urban and urban-rural mobility is particularly relevant to urban–rural interaction, and these two types of movement account for more than half of the total mobile population according to the 2020 Population Census data. From this perspective, the intra-county population mobility rate can also provide a reasonable approximation of the intensity of population movement between urban and rural areas within counties.

3.2.2. Data Standardization

To eliminate differences in measurement units and scales, all indicators were standardized before aggregation. For positive indicators, including urban residents' income, rural residents' income, and the intra-county population mobility rate, min–max normalization was applied as follows [53]:

$$Z_{ij} = X_{ij} - Min(X_j)/Max(X_j) - Min(X_j) \quad (1)$$

where Z_{ij} denotes the standardized indicator value, X_{ij} denotes the original indicator value, and $Min(X_j)$ and $Max(X_j)$ denote the minimum and maximum values of indicator, respectively.

The urban–rural income ratio was treated as a target-value indicator, with 1 representing the ideal state. A value closer to 1 indicates a smaller urban–rural income gap and greater coordination. The deviation of the observed income ratio from the target value was therefore first transformed into a measure of closeness to the ideal state:

$$d_i = 1 - |X_i - 1| \quad (2)$$

where X_i denotes the original urban–rural income ratio for county i, and d_i denotes its closeness to the target value of 1. The resulting indicator was then normalized using the min–max method.

3.2.3. Indicator Weighting and Composite Index

To reduce the potential bias associated with a single weighting method, the entropy weighting method was combined with subjective weighting. The entropy method assigns objective weights according to the degree of variation across counties and thus reflects the relative information content of each indicator [54]. Subjective weighting incorporates the theoretical meaning of urban–rural integration and the relative importance of the indicators. The two sets of weights were then averaged to obtain the composite weights.

(1) Calculation of the proportion for county i under indicator j

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{n} Z_{ij}} \tag{3}$$

where P_{ij} denotes the proportion of county i in indicator j, Z_{ij} denotes the standardized indicator value, and n denotes the number of counties.

(2) Calculation of the entropy value

$$E_j = -k\sum_{i=1}^{n} P_{ij} ln(P_{ij}) \tag{4}$$

where E_j denotes the entropy value of indicator j, and $k = 1/lnn$ is a scaling constant.

(3) Calculation of the degree of information utility

$$D_j = 1 - E_j \tag{5}$$

where D_j denotes the degree of information diversification of indicator j.

(4) Calculation of the objective weight

$$W1_j = \frac{D_j}{\sum_{j=1}^{m} D_j} \tag{6}$$

where $W1_j$ denotes the objective weight of indicator j obtained using the entropy method, and m denotes the total number of indicators.

(5) Calculation of the composite weight

$$W_j = \frac{W1_j + W2_j}{2} \tag{7}$$

where $W2_j$ denotes the subjective weight of indicator j. Because the four dimensions were considered theoretically complementary and of approximately equal importance in characterizing urban–rural integration, an equal subjective weight of 0.25 was assigned to each dimension. The subjective and entropy-based weights were then averaged to obtain the final composite weights (Table 1).

(6) Construction of the county-level urban–rural integration index

The county-level urban–rural integration index was calculated using a linear weighted sum:

$$URI_i = \sum_{j=1}^{m} W_j Z_{ij} \tag{8}$$

where URI_i denotes the urban–rural integration index of county i, W_j denotes the composite weight of indicator j, and Z_{ij} denotes its standardized value. A higher URI_i indicates a higher level of county-level urban–rural integration.

After calculating the county-level urban–rural integration index, this study further classifies the 1863 county-level units according to their integration index relative to the national mean. The national mean integration index is used as a common benchmark for cross-county comparison. Specifically, each county's integration index is expressed as a percentage of the national mean, and the counties are classified into six categories: low integration (<50%), relatively low integration (50–75%), medium-low integration (75–100%), medium-high integration (100–125%), relatively high integration (125–150%), and high integration (≥150%).

3.3. Spatial Autocorrelation Analysis

To examine the spatial dependence and clustering patterns of county-level urban–rural integration, both global and local spatial autocorrelation analyses were conducted. Global Moran's I was first used to assess the overall spatial autocorrelation of urban–rural integration, followed by Local Moran's I to identify spatial association patterns, including high–high (HH), high–low (HL), low–high (LH), and low–low (LL) clusters [55]. The corresponding statistics are calculated as follows [56]:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(X_i - \overline{X}\right)\left(X_j - \overline{X}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{9}$$

$$I_i = \frac{X_i - \overline{X}}{S^2}\sum_{j}^{n} W_{ij}\left(X_i - \overline{X}\right) \tag{10}$$

where n denotes the number of county-level units, X_i and X_j denote the levels of urban–rural integration in counties i and j, respectively; $\overline{X}$ denotes the sample mean; W_{ij} denotes the spatial weight matrix, with $W_{ij} = 1$ when counties i and j are adjacent and $W_{ij} = 0$ otherwise; and S^2 denotes the variance of county-level urban–rural integration.

Global Moran's I ranges from -1 to 1. A positive value indicates positive spatial autocorrelation, meaning that counties with similar levels of urban–rural integration tend to cluster spatially, whereas a negative value indicates spatial dispersion. A value close to zero suggests an approximately random spatial distribution. When the corresponding Z-statistic exceeds the critical value, statistically significant spatial autocorrelation is indicated [56].

3.4. Spatial Econometric Model

3.4.1. Spatial Weight Matrix

Because county-level urban-rural integration may be influenced by both local conditions and the development of neighboring counties, conventional OLS models may not adequately capture spatial dependence. Spatial econometric models were therefore employed to examine the factors associated with county-level urban–rural integration.

Spatial linkages between counties are shaped not only by geographic proximity but also by similarities in economic development [57]. An economic-geographic distance-based spatial weight matrix was therefore constructed by jointly considering geographic distance and differences in economic development [58].

$$W_{ij} = \frac{1}{\left|PGDP_i - PGDP_j\right| d_{ij}} \tag{11}$$

$$d_{ij} = R \cdot arccos\left(sin\beta_i sin\beta_j + cos\beta_i cos\beta_j cos\left(\alpha_i - \alpha_j\right)\right) \tag{12}$$

where W_{ij} denotes the economic–geographic distance-based spatial weight between counties i and j; d_{ij} denotes the geographic distance between the two counties; α_i and α_j denote the longitudes of counties i and j, respectively, while β_i and β_j denote their corresponding

latitudes; R denotes the mean radius of the Earth; and $PGDP_i$ and $PGDP_j$ denote the per capita gross regional product of counties i and j, respectively. A shorter geographic distance and a smaller difference in economic development imply stronger spatial linkages and, consequently, a larger spatial weight.

3.4.2. Explanatory Variables and Model Specification

Based on the driving mechanisms discussed in Section 2.3, explanatory variables were selected from four dimensions: economic development, spatial connectivity, public services, and digital development. These variables represent the principal economic, spatial, social, and technological conditions that may influence county-level urban–rural integration.

Economic development. Per capita GDP (*P-gdp*) is used to measure the overall level of economic development. The shares of the secondary (*Sec*) and tertiary (*Ter*) industries in GDP are included to characterize industrial structure, while the urbanization rate (*Urb*) captures the degree of population concentration in urban areas.

Spatial connectivity. Road network density (*Road*) is used to measure transportation infrastructure and accessibility, while distance to the prefecture-level city (*Distance*) captures the locational relationship between a county and its higher-level urban center. Together, these indicators reflect transportation accessibility and access to external urban resources and spillovers.

Public services. Education level (*Edu*) and healthcare level (*Hospital*) are used to characterize the provision of basic public services. Education level is measured by average years of schooling among the population aged 15 years and above, while healthcare level is measured by the number of hospital beds per 10,000 people.

Digital development. Three indicators are used to capture complementary aspects of digital development: information infrastructure (*Info*), digital inclusive finance (*DigiFin*), and digitalized production (*DigiPro*). Info reflects digital information infrastructure, including 5G networks, fiber-optic broadband, and data centers; *DigiFin* measures the development of digital financial services; and *DigiPro* captures the application of digital technologies in agricultural production and industrial activities.

The definitions and measurements of all explanatory variables are summarized in Table 2.

Table 2. Dimensions and explanatory variables of county-level urban–rural integration.

Dimension	Influencing Factor	Definition	Variable
Economic development	GDP per capita	Per capita GDP in 2020 (10,000 CNY)	*P_gdp*
	Share of secondary industry	Share of the value added of the secondary industry in GDP in 2020 (%)	*Sec*
	Share of tertiary industry	Share of the value added of the tertiary industry in GDP in 2020 (%)	*Ter*
	Urbanization rate	Percentage of urban population in 2020 (%)	*Urb*
Spatial connectivity	Road network density	Total length of transportation infrastructure divided by county area in 2020 (km/km^2)	*Road*
	Distance to prefecture-level city	Distance from the county government to the prefecture-level city government in 2020 (km)	*Distance*
Public services	Education level	Average years of schooling among the population aged 15 years and above in 2020 (years)	*Edu*
	Healthcare level	Number of hospital beds per 10,000 people in 2020	*Hospital*
Digital development	Information infrastructure	Digital information infrastructure index in 2020	*Info*
	Digital inclusive finance	Digital inclusive finance index in 2020	*DigiFin*
	Digital production	Digitalized production index in 2020	*DigiPro*

Based on the spatial dependence framework, four econometric specifications were considered: ordinary least squares (OLS) model, spatial lag model (SLM), spatial Durbin model (SDM), and spatial error model (SEM) [59]. The appropriate specification was determined using LM tests, robust LM tests, and LR tests.

The OLS model is specified as:

$$y = \beta x + \varepsilon \tag{13}$$

where y denotes the level of urban–rural integration, x denotes the vector of explanatory variables, β denotes the vector of parameters to be estimated, and ε denotes the random error term.

The spatial lag model (SLM) is specified as:

$$y = \rho W y + \beta x + \varepsilon \tag{14}$$

where ρ denotes the spatial autoregressive coefficient, capturing the spatial dependence of county-level urban–rural integration and the influence of neighboring counties' integration levels on the focal county.

The spatial Durbin model (SDM) is specified as:

$$y = \rho W y + \beta x + \theta W x + \varepsilon \tag{15}$$

where θ denotes the vector of coefficients associated with the spatially lagged explanatory variables, capturing the influence of explanatory variables in neighboring counties on urban–rural integration in the focal county.

The spatial error model (SEM) is specified as:

$$y = \beta x + \mu \tag{16}$$

$$\mu = \lambda W \mu + \varepsilon \tag{17}$$

where λ denotes the spatial error coefficient and μ denotes the spatially autocorrelated error term.

3.4.3. Model Selection and Effect Decomposition

Before estimating the spatial econometric models, multicollinearity among the explanatory variables was assessed using the variance inflation factor (VIF). The results are reported in Table 3. Most explanatory variables have VIF values below 5, with a maximum value of 5.966, and none exceeds the commonly used threshold of 10 [60]. Overall, the results suggest that multicollinearity is not sufficiently severe to pose a serious concern for the subsequent spatial econometric analysis.

Table 3. VIF diagnostics for the regression models at the national and regional levels.

Variable	National	Eastern	Central	Western	Northeastern
P_gdp	2.635	3.946	2.890	2.999	1.587
Sec	2.711	3.162	5.966	3.183	1.297
Ter	1.891	2.192	4.108	2.376	1.233
Urb	2.573	2.477	2.305	2.743	4.664
Road	1.379	1.339	1.250	1.349	1.370
Distance	1.168	1.119	1.125	1.182	1.430
Edu	2.008	1.748	1.702	2.452	5.546
Hospital	1.100	1.153	1.092	1.163	1.192
Info	1.474	1.893	1.595	1.359	1.666
DigiFin	2.774	3.135	1.950	2.546	4.099
DigiPro	1.255	1.418	1.093	1.047	1.092

The appropriate spatial specification was then determined using a series of spatial dependence tests. As reported in Table 4, the LM test for the spatial lag and spatial error, together with their robust counterparts, were all statistically significant at the 1% level, providing evidence of significant spatial dependence in county-level urban–rural

integration and indicating that the conventional OLS may not adequately capture the spatial structure of the data.

Table 4. Tests for the selection of the spatial econometric model.

Test Statistic	Value	Test Statistic	Value	Test Statistic	Value
LM spatial error	659.308 ***	Robust LM spatial error	82.798 ***	LR spatial lag	48.950 ***
LM spatial lag	671.706 ***	Robust LM spatial lag	95.195 ***	LR spatial error	80.345 ***

Note: *** denote significance at the 1% level.

The suitability of the SDM relative to the SLM and SEM was further assessed using LR tests. Both the LR spatial lag and LR spatial error tests were statistically significant at the 1% level, rejecting the null hypotheses that the SDM can be reduced to the SLM and SEM, respectively [61]. These results indicate that the spatial effects of the explanatory variables cannot be adequately captured by spatial dependence in the dependent variable or spatially correlated errors alone. The SDM was therefore selected as the baseline model.

Because the SDM incorporates both the spatial dependence of the dependent variable and spatially lagged explanatory variables, its estimated coefficients cannot be directly interpreted as marginal effects in the presence of spatial feedback effects [62]. Following the partial derivative approach proposed by LeSage and Pace [62] and Selhorst [63], the effects of the explanatory variables were decomposed into direct, indirect, and total effects. The direct effect captures the effect of a change in an explanatory variable within a county on its own level of urban–rural integration while accounting for spatial feedback. The indirect effect, or spatial spillover effect, captures the effect transmitted to other counties through spatial linkages. The total effect is the sum of the direct and indirect effects and represents the overall effect within the spatial system. This decomposition distinguishes local effects from cross-county spillovers and provides an appropriate basis for interpreting the spatial effects of the explanatory variables.

4. Results

4.1. Spatial Differentiation and Clustering of County-Level Urban–Rural Integration

4.1.1. Overall Distribution and Regional Differences

In 2020, the mean level of county-level urban-rural integration across the 1863 county-level units was 0.426. Among these units, 891 (47.83%) recorded integration levels above the national mean, while 972 (52.17%) fell below it. Integration levels varied substantially across counties, ranging from 0.165 in Tangyuan County, Heilongjiang Province, to 0.768 in Zhuji, Zhejiang Province. The highest value was approximately 4.65 times the lowest, indicating pronounced spatial disparities in county-level urban–rural integration.

According to the classification of the 1863 county-level units by their level of urban–rural integration (Table 5), the distribution exhibited a spindle-shaped pattern, with counties concentrated in the middle categories and relatively few at the two extremes. The medium-low and medium-high integration categories accounted for 45.36% and 39.02% of all counties, respectively, together representing 84.38% of the sample. By comparison, only 3 counties (0.16%) were classified as having low integration, while 32 counties (1.72%) fell into the high-integration category. Overall, most counties had integration levels between 0.320 and 0.533, indicating that county-level urban–rural integration in China was predominantly at medium-low to medium-high levels, with relatively few counties at either the low or high end of the distribution.

Table 5. Classification of county-level urban–rural integration in China in 2020.

Category	Level of Urban–Rural Integration	Number	Proportion (%)
Low integration	<0.213	3	0.16
Relatively low integration	0.213 ≤ URI < 0.320	124	6.66
Medium-low integration	0.320 ≤ URI < 0.426	845	45.36
Medium-high integration	0.426 ≤ URI < 0.533	727	39.02
Relatively high integration	0.533 ≤ URI < 0.640	132	7.09
High integration	≥0.640	32	1.72
Total		1863	100.00

At the regional level, county-level urban–rural integration varied substantially across the four regions. Eastern China recorded the highest mean integration level (0.485), substantially exceeding those of the northeastern (0.435), central (0.431), and western regions (0.392). This regional variation is further reflected in the spatial distribution shown in Figure 2.

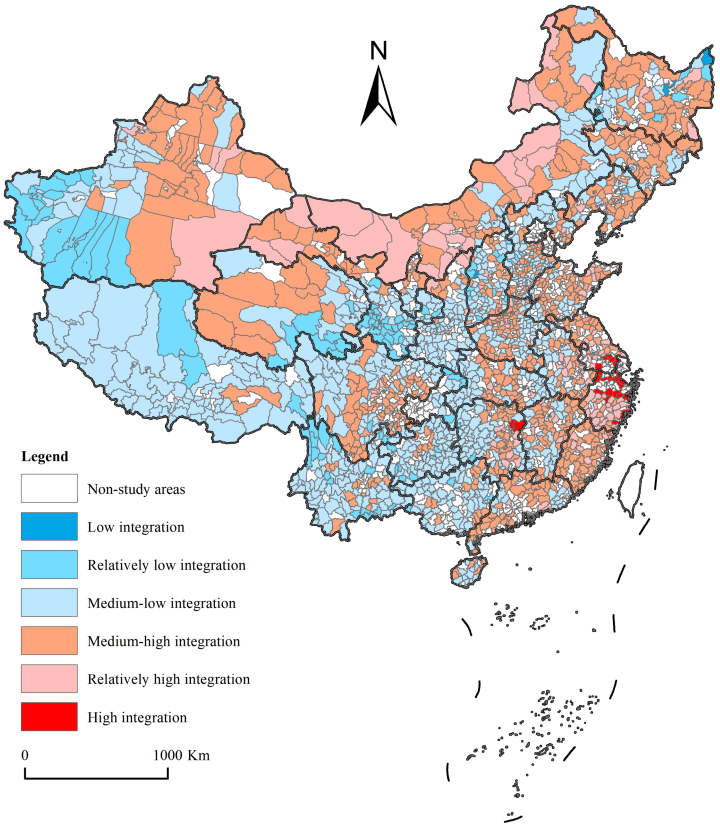


Figure 2. Spatial distribution of county-level urban–rural integration in China in 2020.

The spatial pattern was characterized by a concentration of higher integration levels in eastern and coastal China and lower levels in western and inland areas. Counties southeast of the Hu Line [64], where population and economic activities are relatively concentrated, generally exhibited higher levels of urban–rural integration. Relatively continuous high-value clusters were observed in the Yangtze River Delta, Pearl River Delta, Beijing–Tianjin–Hebei region, and Shandong Peninsula. Zhejiang Province had the largest concentration of high-integration counties, accounting for 24 of the 32 high-integration counties nationwide. Zhuji (0.768), Yiwu (0.742), and Xinchang (0.712) recorded the three highest integration levels. In central and western China, relatively high-integration counties were more dispersed and were mainly located around major urban agglomerations and regional

centers, including Wuhan, Zhengzhou, Changsha, and Chengdu. Several border and resource-based areas also exhibited localized high-value clusters.

By contrast, counties northwest of the Hu Line generally exhibited lower integration levels, with relatively low-integration counties concentrated primarily in western China and parts of northeastern China. The three counties with the lowest integration levels nationwide were Tangyuan County (0.165), Fuyuan City (0.170), and Fangshan County (0.211). Relatively low-integration counties were widely distributed along the eastern margin of the Qinghai–Tibet Plateau, in the oasis areas of southern Xinjiang, in the karst regions of southwestern China, and in mountainous areas along several provincial boundaries. These areas constituted the main spatial concentration of low-value counties.

4.1.2. Spatial Autocorrelation and Clustering

The Global Moran's I was 0.424 ($p < 0.01$), indicating significant positive spatial autocorrelation in county-level urban–rural integration. Counties with relatively high integration levels tended to be spatially associated with other high-integration counties, whereas counties with relatively low levels tended to cluster with other low-integration counties.

The local spatial association results further identified distinct clustering patterns (Figure 3). A total of 423 counties exhibited a high-high (HH) pattern, mainly concentrated in eastern coastal China and selected areas in the northwest, forming relatively distinct high-value clusters. In contrast, 554 counties exhibited a low-low (LL) pattern, predominantly distributed in western China and forming the main low-value clusters. The substantial numbers of HH and LL counties indicate that spatial clustering of both high- and low-integration counties was a prominent feature of county-level urban-rural integration.

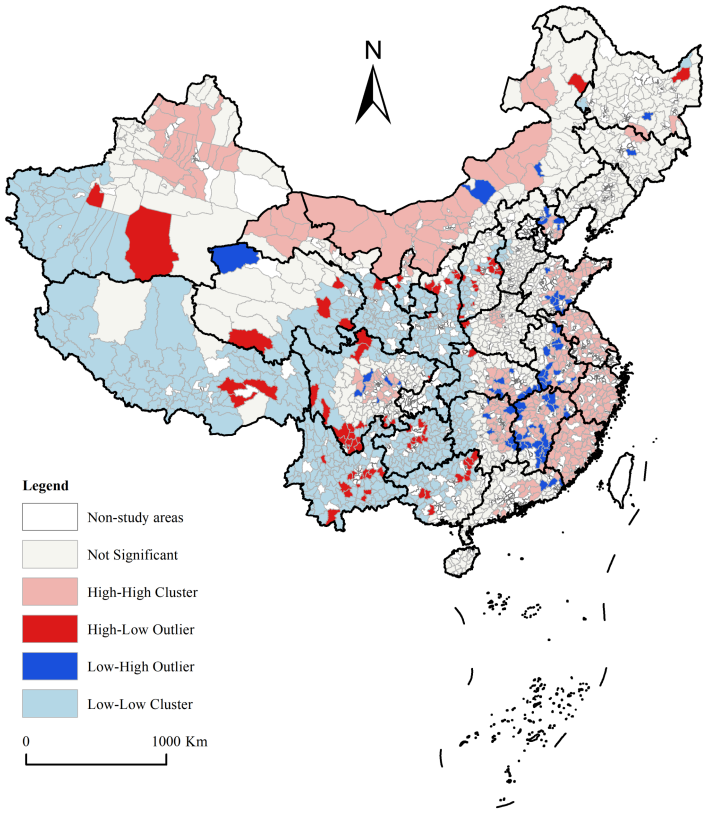


Figure 3. LISA map of county-level urban–rural integration in China in 2020.

In addition to these clusters, 88 counties exhibited a high-low (HL) pattern, indicating relatively high integration levels surrounded by counties with lower levels. These counties were mainly scattered within or around low-value areas, representing localized high-

value areas embedded in predominantly low-integration surroundings. A further 83 counties exhibited a low–high (LH) pattern, representing relatively low integration levels surrounded by counties with higher levels. These counties were mainly located around high-value clusters, indicating localized spatial discontinuities within otherwise high-integration areas.

4.2. Urbanization and County-Level Urban–Rural Integration

Figure 4 illustrates a clear positive association between county-level urban–rural integration and the population urbanization rate in 2020. In general, counties with higher urbanization rates tended to exhibit higher levels of urban–rural integration. However, considerable variation remained among counties with similar urbanization rates, indicating that urbanization and urban–rural integration did not always develop in parallel. To examine this relationship across different stages of urbanization, the sampled counties were classified according to Northam's urbanization curve [65,66] (Table 6).

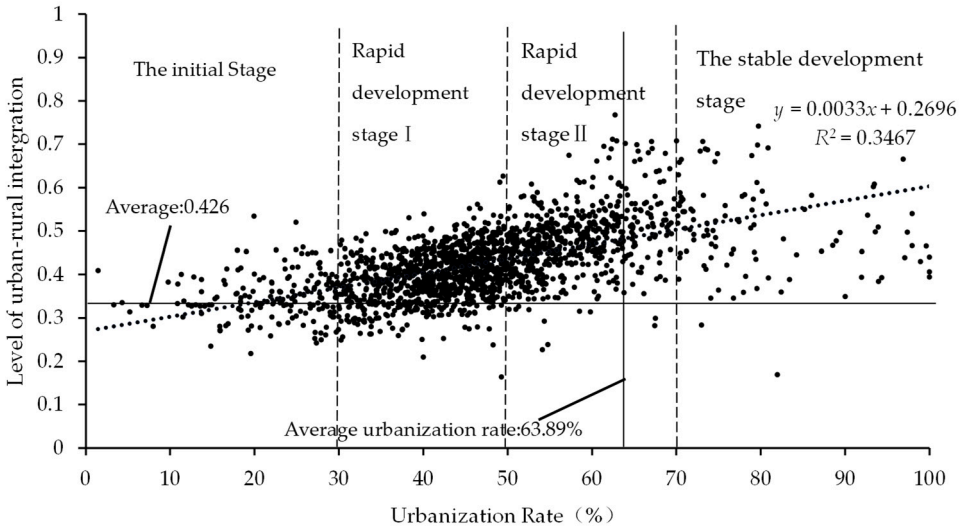


Figure 4. Relationship between county-level urban–rural integration and population urbanization rate in China in 2020.

Table 6. County-Level urban–rural integration across different urbanization stages in China in 2020.

Urbanization Stage	Number of Counties	Above National Mean, n	Above National Mean, (%)	Below National Mean, n	Below National Mean, (%)	Mean Level of County-Level Urban–Rural Integration
Initial stage (<30%)	176	14	7.95	162	92.05	0.349
Rapid development stage I (30–50%)	977	324	33.16	653	66.84	0.400
Rapid development stage II (50–70%)	606	470	77.56	136	22.44	0.478
Stable development stage (>70%)	104	83	79.81	21	20.19	0.507

The counties were divided into four stages: the initial stage (<30%), rapid development stage I (30–50%), rapid development stage II (50–70%), and stable development stage (>70%). The mean level of urban–rural integration increased progressively across these stages. Among the 176 counties in the initial stage, the mean integration level was 0.349, and only 14 counties (7.95%) exceeded the national mean of 0.426, while 162 counties (92.05%) remained below it.

In rapid development stage I, comprising 977 counties, the mean integration level increased to 0.400. The number of counties above the national mean rose to 324 (33.16%), although the majority, 653 counties (66.84%), remained below the national mean. Compared with the initial stage, this stage was characterized by a higher overall level of urban–rural integration, but integration levels above the national mean were still relatively uncommon.

A more pronounced increase was observed in rapid development stage II. Among the 606 counties in this stage, the mean integration level reached 0.478, exceeding the national mean. Moreover, 470 counties (77.56%) had integration levels above the national mean, more than twice the proportion observed in rapid development stage I. This stage therefore marked a substantial increase in both the average level of urban–rural integration and the proportion of counties reaching above-average levels.

In the stable development stage, the mean integration level further increased to 0.507, the highest among the four stages. Of the 104 counties in this stage, 83 (79.81%) were above the national mean, while only 21 (20.19%) were below it. Thus, above-average levels of urban–rural integration were predominant among counties with urbanization rates exceeding 70%.

The results indicate a clear stage-wise increase in county-level urban–rural integration as population urbanization advanced, with the mean integration level rising from 0.349 in the initial stage to 0.507 in the stable development stage. The most substantial increase occurred between rapid development stage I and stage II, when the mean integration level increased from 0.400 to 0.478 and the proportion of counties above the national mean rose from 33.16% to 77.56%. Nevertheless, the dispersion of observations in Figure 4 indicates that a higher urbanization rate did not necessarily correspond to a proportionally higher level of urban–rural integration. Some counties exhibited relatively high urbanization but comparatively low integration, while others achieved relatively high integration at lower levels of urbanization, suggesting a degree of spatial mismatch between urbanization and urban–rural integration.

4.3. Spatial Effects of the Drivers of County-Level Urban–Rural Integration

Based on the model selection tests, the Spatial Durbin Model (SDM) was selected as the baseline specification. Table 7 reports the direct, indirect, and total effects of the factors associated with county-level urban–rural integration. The decomposition of spatial effects makes it possible to distinguish between effects operating within individual counties and spillover effects extending to neighboring counties. The results reveal substantial heterogeneity across the explanatory variables, with some factors showing predominantly local effects, some exhibiting significant spatial spillovers, and others displaying contrasting direct and indirect effects.

Table 7. Spatial effect decomposition results of the spatial Durbin model.

Variable	Direct		Indirect		Total	
	Coefficient	Z-Value	Coefficient	Z-Value	Coefficient	Z-Value
P_gdp	0.208 ***	11.44	0.132 **	2.40	0.339 ***	6.06
Sec	−0.036 ***	−2.97	0.034	0.94	−0.003	−0.07
Ter	−0.024 **	−2.07	0.005	0.13	−0.020	−0.52
Urb	0.109 ***	8.22	0.058	1.34	0.167 ***	3.61
Road	0.045 ***	3.34	−0.009	−0.28	0.035	1.05
Distance	−0.009	−0.94	0.015	0.51	0.007	0.22
Edu	−0.013	−0.67	0.027	0.72	0.013	0.39
Hospital	−0.046 ***	−3.44	−0.036	−0.76	−0.082	−1.58
Info	0.013 *	1.79	−0.058 ***	−3.40	−0.045 ***	−2.64

Table 7. *Cont.*

Variable	Direct		Indirect		Total	
	Coefficient	Z-Value	Coefficient	Z-Value	Coefficient	Z-Value
DigiFin	0.066 ***	3.97	0.015	0.42	0.081 **	2.28
DigiPro	0.042 ***	4.08	0.149 ***	3.64	0.191 ***	4.29
R^2	0.710					
LogL	3136.556					
AIC	−6223.112					
N	1863					

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

4.3.1. Economic Development

Economic development was strongly associated with county-level urban–rural integration, although the estimated spatial effects varied across indicators. Per capita GDP (*P_gdp*) exhibited significant positive direct and indirect effects, resulting in the largest positive total effect among all explanatory variables. Its significant direct effect indicates a strong positive association between local economic development and urban–rural integration within the same county, while the significant indirect effect indicates a positive spatial association between economic development in a county and urban–rural integration in neighboring counties. The coexistence of significant local and indirect effects suggests that counties with higher levels of economic development tend to be located within spatial contexts characterized by higher levels of urban–rural integration, potentially reflecting regional economic linkages and factor flows across county boundaries.

Urbanization (*Urb*) also exhibited a significant positive local effect. Its direct effect was 0.109 ($p < 0.01$), and its total effect reached 0.167 ($p < 0.01$), whereas the indirect effect was not statistically significant. Thus, the positive association between urbanization and urban–rural integration was concentrated primarily within individual counties, with no statistically significant evidence of systematic spatial association with urban-rural integration in neighboring counties. This pattern may indicate that the relationship between urbanization and urban–rural integration is more closely related to the internal integration of population, employment, and urban–rural linkages within counties than to cross-county spatial diffusion.

Industrial structure showed predominantly local and negative effects. The shares of both the secondary and tertiary industries had significant negative direct effects, while their indirect and total effects were not statistically significant. This indicates that industrial structure was more closely associated with the internal configuration of the county-level urban–rural system than with cross-county spatial diffusion. The negative direct effects further suggest that a greater industrial share does not necessarily correspond to higher urban–rural integration, potentially depending on how industrial development is connected with employment, factor mobility, and rural areas [67].

4.3.2. Spatial Connectivity

The effects of spatial connectivity were primarily local. Road network density (*Road*) had a significant positive direct effect (0.045, $p < 0.01$), whereas its indirect and total effects were not statistically significant. This result indicates that better transport connectivity was positively associated with urban–rural integration within the county, potentially by facilitating population mobility, market access, and interactions between urban and rural areas. However, no statistically significant spatial spillover effect was detected for neighboring counties.

In contrast, the distance between the county government and the prefecture-level city government (*Distance*) showed no statistically significant direct, indirect, or total

effect. Thus, the measured proximity to the prefecture-level administrative center was not significantly associated with county-level urban–rural integration. Taken together, the results suggest that internal transport accessibility may be more closely related to county-level urban–rural integration than simple administrative proximity to a higher-level urban center.

4.3.3. Public Services

Public service indicators exhibited relatively limited and heterogeneous spatial effects. Average years of schooling (*Edu*) had no statistically significant direct, indirect, or total effect, indicating that educational attainment alone was not significantly associated with county-level urban–rural integration in 2020. Healthcare provision showed a significant negative local association. Hospital beds per 10,000 people (*Hospital*) had a significant negative direct effect (-0.046, $p < 0.01$), whereas its indirect and total effects were not statistically significant. This result suggests that a higher level of healthcare provision, as measured by hospital beds, was not necessarily associated with stronger urban–rural integration within counties. The negative local association may partly reflect the uneven distribution of healthcare resources within counties and persistent differences in service accessibility between urban and rural areas.

4.3.4. Digital Development

Digital development exhibited the most differentiated spatial effects among the four groups of explanatory variables. Information infrastructure (*Info*) had a significant positive direct effect (0.013, $p < 0.10$) but a significant negative indirect effect (-0.058, $p < 0.01$), resulting in a significant negative total effect (-0.045, $p < 0.01$). This contrasting pattern indicates that information infrastructure was positively associated with urban–rural integration within individual counties but negatively associated with urban–rural integration in neighboring counties through the estimated spatial spillover effect. This result suggests that the spatial association between information infrastructure and urban–rural integration may differ between focal counties and their surrounding areas.

Digital inclusive finance (*DigiFin*) exhibited a significant positive direct effect (0.066, $p < 0.01$), while its indirect effect was not statistically significant. Its total effect was also positive and statistically significant (0.081, $p < 0.05$), indicating that digital inclusive finance was primarily associated with higher urban–rural integration through local effects, with limited evidence of spatial associations with neighboring counties.

Digitalized production (*DigiPro*) showed the strongest spatial spillover effect among the digital development variables. Both its direct effect (0.042, $p < 0.01$) and indirect effect (0.149, $p < 0.01$) were positive and statistically significant, with the indirect effect substantially larger than the direct effect. Its total effect was also strongly positive (0.191, $p < 0.01$). This finding indicates that the positive association between digitalized production and urban–rural integration was not confined to individual counties and was also evident in neighboring counties.

4.4. Regional Heterogeneity in the Spatial Effects of Drivers of County-Level Urban–Rural Integration

Given substantial regional differences in natural resource endowments, economic foundations, and stages of urban–rural development, the factors associated with county-level urban–rural integration may vary considerably across China. To examine this heterogeneity, separate Spatial Durbin Models (SDMs) were estimated for the eastern, central, western, and northeastern regions, with direct and indirect effects decomposed accordingly (Table 8). The results indicate substantial regional variation not only in the factors associated with

county-level urban–rural integration but also in the spatial pathways through which these factors operate.

Table 8. Regression results by region.

Variable	Eastern		Central		Western		Northeastern	
	Direct	**Indirect**	**Direct**	**Indirect**	**Direct**	**Indirect**	**Direct**	**Indirect**
P_gdp	0.148 ***	−0.174	0.426 ***	−0.022	0.130 ***	0.277 ***	0.109	−0.069
	(4.22)	(−1.53)	(11.45)	(−0.29)	(5.76)	(4.63)	(1.10)	(−0.36)
Sec	0.012	0.091	−0.103 ***	−0.039	−0.079 ***	−0.076 *	0.046	−0.110
	(0.47)	(1.21)	(−3.08)	(−0.60)	(−4.96)	(−1.84)	(0.79)	(−1.26)
Ter	0.013	0.011	−0.031	−0.076	−0.093 ***	−0.096 ***	0.107 **	−0.028
	(0.51)	(0.17)	(−0.98)	(−1.25)	(−6.06)	(−2.64)	(2.28)	(−0.40)
Urb	0.144 ***	0.013	0.253 ***	0.110	0.087 ***	0.101 **	−0.079	−0.169
	(5.28)	(0.16)	(7.90)	(1.64)	(5.03)	(2.39)	(−1.11)	(−1.34)
Road	0.004	0.019	0.023	0.092**	0.086 ***	0.045	0.090	0.126
	(0.24)	(0.55)	(0.77)	(2.10)	(2.69)	(0.71)	(0.47)	(0.38)
Distance	0.063 **	0.072	−0.055 **	0.013	0.004	0.037	0.049	−0.106
	(2.36)	(1.05)	(−2.33)	(0.29)	(0.33)	(1.44)	(0.98)	(−1.53)
Edu	0.102 **	0.021	−0.093 **	−0.034	0.043 **	−0.101 **	−0.134	−0.053
	(2.28)	(0.19)	(−2.38)	(−0.51)	(1.98)	(−2.59)	(−0.63)	(−0.17)
Hospital	0.024	−0.013	−0.101 ***	−0.049	−0.017	−0.059	0.037	0.250 **
	(0.75)	(−0.13)	(−4.12)	(−0.98)	(−1.09)	(−1.34)	(0.55)	(2.21)
Info	0.037 **	0.004	0.047 **	−0.051	0.009	−0.040 **	−0.003	−0.095
	(2.21)	(0.10)	(2.34)	(−1.50)	(1.13)	(−2.47)	(−0.07)	(−1.53)
DigiFin	0.113 ***	0.231 ***	0.038	−0.006	0.061 ***	−0.011	0.228 **	0.283
	(3.67)	(3.68)	(1.15)	(−0.09)	(3.03)	(−0.22)	(2.19)	(1.46)
DigiPro	0.012	−0.015	0.002	−0.017	0.036	0.097	0.034	0.153
	(0.96)	(−0.36)	(0.11)	(−0.31)	(1.44)	(1.17)	(0.45)	(1.02)
R^2	0.842		0.667		0.701		0.202	
LogL	797.258		866.804		1463.937		199.966	
AIC	−1544.515		−1683.608		−2877.874		−349.932	
N	417		479		820		147	

Note: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively; values in parentheses are Z-statistics.

4.4.1. Eastern China

County-level urban-rural integration in eastern China was associated with a relatively diverse set of factors, with urbanization, human capital, and digital finance showing particularly pronounced effects. The population urbanization rate and average years of schooling both exhibited significant positive direct effects, indicating that population agglomeration and human capital accumulation were positively associated with higher levels of urban-rural integration within counties. Digital inclusive finance showed a broader spatial effect, with both direct and indirect effects being significantly positive, suggesting that the development of digital financial services was associated not only with higher local integration but also with positive spillovers to neighboring counties. Per capita GDP and information infrastructure also exhibited significant positive direct effects, suggesting positive local associations between economic capacity, digital connectivity, and urban-rural integration. An additional finding was the significant positive direct effect of distance to the prefecture-level city. This result indicates that, in eastern China, greater administrative distance from prefecture-level centers was not necessarily associated with lower levels of urban–rural integration.

4.4.2. Central China

In central China, county-level urban-rural integration was primarily associated with economic development and urbanization. Per capita GDP and the population urbanization

rate both showed significant positive direct effects, indicating that stronger economic capacity and higher levels of urbanization were positively associated with local urban–rural integration. Road network density exhibited a significant positive indirect effect, suggesting a positive spatial association between transport connectivity and urban–rural integration in neighboring counties.

In contrast, the shares of the secondary industry, average years of schooling, and hospital beds per 10,000 people all exhibited significant negative direct effects. These results indicate that, during the study period, higher levels of these indicators were not necessarily associated with stronger county-level urban–rural integration in central China. Notably, except for information infrastructure, which exhibited a significant positive direct effect, none of the other digital development variables showed statistically significant direct or indirect effects, suggesting that the statistical association between digital development and county-level urban–rural integration was not evident at the regional level.

4.4.3. Western China

In western China, county-level urban–rural integration was significantly associated with economic development, urbanization, and transport infrastructure. Per capita GDP, the population urbanization rate, and road network density all exhibited significant positive direct effects. Per capita GDP also showed a significant positive indirect effect, with its magnitude substantially exceeding the direct effect. This pattern suggests that economic development was associated not only with higher levels of local urban–rural integration but also with pronounced positive spillovers to neighboring counties.

The industrial structure variables exhibited a contrasting pattern. Both the secondary and tertiary industry shares had significant negative direct and indirect effects. These findings suggest that higher shares of the secondary and tertiary industries were associated with lower levels of urban–rural integration both within western counties and in neighboring counties, indicating that these negative associations extended beyond individual counties. Average years of schooling exhibited a significant positive direct effect but a significant negative indirect effect, indicating a contrasting local and spatial pattern. Information infrastructure likewise showed a significant negative indirect effect, suggesting a negative association with urban–rural integration in neighboring counties. By contrast, digital inclusive finance exhibited a significant positive direct effect, indicating a positive local association between digital inclusive finance and county-level urban–rural integration in western China.

4.4.4. Northeastern China

The northeastern region exhibited a more limited set of statistically significant factors than the other three regions. Per capita GDP, urbanization, road network density, education, and information infrastructure did not show statistically significant direct or indirect effects, indicating that these conventional economic, urbanization, infrastructure, and human-capital indicators had limited explanatory power for county-level urban–rural integration in the region. In contrast, the tertiary industry share and digital inclusive finance exhibited significant positive direct effects, suggesting positive local associations between service-sector development, digital financial inclusion, and local integration.

Hospital beds per 10,000 people also exhibited a significant positive indirect effect, indicating a positive spatial association between healthcare provision and urban–rural integration across neighboring counties. This pattern may reflect inter-county service sharing and population mobility, although the cross-sectional estimates do not establish a causal mechanism. Overall, the northeastern region showed a more selective pattern of

significant associations, with the tertiary industry, digital inclusive finance, and healthcare-related spatial spillovers standing out relative to the other factors examined.

5. Discussion

5.1. Beyond Narrowing Urban–Rural Disparities: Coordination Within the Urban–Rural Territorial System

This study extends the interpretation of established theories of rural–urban interaction by situating their emphasis on flows, linkages, and spatial hybridization within a broader territorial-systems framework. Tacoli and Douglass emphasize the flows and linkages connecting urban and rural areas [1,38], while McGee's desakota framework highlights the spatial and functional hybridization associated with intensified urban–rural interaction [40]. While these perspectives highlight the increasing interdependence of urban and rural areas, the territorial-systems perspective further conceptualizes them as distinct but interconnected territorial subsystems embedded within a common territorial context. From this perspective, factor flows, functional linkages, and spatial transformations are interconnected with the development and coordination of both subsystems. The territorial-systems perspective therefore complements rather than replaces established theories by providing a broader framework for understanding urban–rural integration, particularly at the county level, where urban and rural areas share a common territorial context and closely interconnected development trajectories.

Building on this theoretical perspective, urban–rural integration can be understood as more than the narrowing of urban–rural development disparities. Existing studies have often conceptualized urban–rural integration primarily in terms of reducing disparities in income, public services, and other development conditions [19,24]. While this approach is useful for capturing the extent and evolution of urban–rural imbalances, the findings of this study suggest that a reduction in disparities alone does not necessarily indicate a higher level of urban–rural integration. A smaller urban–rural gap may result from changes in either the urban or rural subsystem without corresponding improvements in their interaction and functional linkages. Conversely, substantial differences in development levels may persist alongside increasingly intensive factor flows and functional connections. Urban–rural integration should therefore be understood not simply as a process of convergence, but as a broader process of coordination and interaction between interconnected urban and rural territorial subsystems.

This broader conceptualization highlights the need to consider the development of urban and rural areas, their interactions, and their disparities jointly. Urban and rural areas have distinct development foundations and functional characteristics, but they are continuously connected through population mobility, capital flows, industrial linkages, infrastructure, public services, and employment, production, and consumption relationships. These dimensions represent different but interrelated aspects of the urban–rural territorial system. Accordingly, the coexistence of development disparities and intensive urban–rural interactions does not necessarily indicate a contradiction. Rather, it suggests that integration does not require the elimination of urban–rural distinctions, but involves strengthening interactions and functional complementarity while maintaining the development capacity and distinctive functions of both subsystems. In this sense, urban–rural integration reflects not only how similar urban and rural areas are in their development levels, but also how effectively they interact and complement each other within a shared territorial system.

This understanding also provides a theoretical rationale for the multidimensional measurement framework adopted in this study. Counties with relatively small urban–rural income disparities may nevertheless have relatively weak urban and rural development

foundations or limited population mobility and functional linkages. Conversely, strong population mobility alone does not necessarily imply comparable access to development opportunities between urban and rural residents. The four-dimensional framework adopted in this study—urban development, rural development, urban–rural interaction, and urban–rural disparities—therefore provides a more comprehensive basis for interpreting the transformation of urban–rural relations. Rather than treating the narrowing of disparities as the sole manifestation of integration, this framework considers the development of both territorial subsystems, the interactions between them, and the extent to which their development remains coordinated within a shared territorial context.

5.2. Urbanization and the Stage-Specific Evolution of County-Level Urban–Rural Integration

The results show a generally positive association between population urbanization and county-level urban–rural integration, but also reveal substantial variation among counties with similar levels of urbanization. This suggests that urbanization provides an important foundation for urban–rural integration but does not automatically translate into stronger integration. Existing research has emphasized that urbanization reshapes urban–rural relations through the spatial redistribution of population and economic activities, while the agglomeration of population and firms in urban areas can generate both concentration effects and diffusion effects across urban–rural space [68,69]. However, urbanization may also generate social costs and inequalities, highlighting the need to balance agglomeration and dispersion to achieve more inclusive urban–rural development [70]. Building on these perspectives, the findings of this study suggest that the contribution of urbanization to urban–rural integration depends not only on the extent of urban agglomeration, but also on whether the benefits of agglomeration are translated into stronger urban–rural linkages and functional complementarity.

From a territorial-systems perspective, urbanization may have dual implications for urban–rural integration. On the one hand, the concentration of population and economic activities in county seats and central towns can generate economies of scale, improve labor allocation, expand public service provision, and strengthen market and service functions. These processes may create favorable conditions for interactions between urban and rural areas. On the other hand, if agglomeration is accompanied by the excessive concentration of population, capital, industries, and high-quality public services in urban areas, it may reinforce the relative development advantage of county seats and central towns without generating corresponding improvements in rural development capacity. In this case, urbanization may be associated with stronger urban development while leaving urban–rural functional linkages relatively weak. This dual possibility helps explain why counties with similar urbanization levels may exhibit substantially different levels of urban–rural integration. The key issue is therefore not simply the degree of urbanization, but whether urban agglomeration is accompanied by diffusion, interaction, and functional complementarity across the urban–rural territorial system. This interpretation is also consistent with county-level evidence showing that the relationship between urbanization and rural development outcomes varies across different stages and spatial contexts rather than following a uniform pattern [71].

The stage-specific pattern identified in this study provides further evidence for this interpretation. At relatively low levels of urbanization, both urban and rural development foundations remain comparatively limited, so strengthening the basic development capacity of the two subsystems may be particularly important. During intermediate stages of urbanization, when population and economic activities are reorganized more rapidly, the role of population mobility, factor flows, infrastructure, and functional linkages may become increasingly important. Recent county-level evidence further demonstrates that

labor, capital, and land mobility can generate differentiated local and spatial spillover effects on urban–rural integration, highlighting the importance of factor flows in linking urban and rural territorial subsystems [72]. At higher levels of urbanization, continued population concentration may contribute less to further improvements in urban–rural integration, while the sharing of development opportunities and the sustainable development capacity of rural areas may become more important. This stage-specific interpretation is also consistent with research emphasizing that the spatial strategies required for rural development may change as urbanization advances, with greater attention needed to balancing agglomeration benefits and rural development [70].

These findings therefore add a territorial dimension to the conventional interpretation of urbanization. Rather than treating urbanization and urban–rural integration as synonymous processes, the results suggest that urbanization should be understood as a process that reorganizes the spatial distribution of population and economic activities, while urban–rural integration concerns how these reorganized resources, functions, and opportunities are connected and coordinated across the two territorial subsystems. The central challenge is thus to transform the agglomeration advantages associated with urbanization into broader urban–rural linkages, functional complementarity, and shared development opportunities. In this sense, the relationship between urbanization and urban–rural integration is better understood as stage-specific and place-dependent rather than as a simple linear process.

5.3. From Local Effects to Cross-County Spatial Spillovers

The spatial effects identified in this study indicate that county-level urban–rural integration is embedded in a broader regional system rather than confined to individual administrative units. The factors examined exhibit distinct spatial pathways, with some primarily associated with local integration and others generating significant cross-county spillovers. This heterogeneity suggests that the spatial dimension of urban–rural integration depends not only on the internal development capacity of individual counties but also on the extent to which economic, industrial, technological, and factor linkages extend beyond administrative boundaries.

Economic development exhibits both strong local and spillover effects, indicating that economic capacity operates through multiple spatial channels. Stronger economic foundations can improve local industrial development, fiscal capacity, infrastructure, and public services while also strengthening inter-county market interactions, industrial linkages, and capital flows [28,29]. The relatively strong spillover effect observed in western China further suggests that, where county-level development foundations are comparatively weak, economic expansion may generate effects that extend beyond individual counties through regional economic networks. By contrast, population urbanization is more strongly associated with local integration at the national level, with no significant cross-county spillover. This pattern suggests that the effects of urbanization are primarily realized through population agglomeration and resource reallocation within individual counties. However, population concentration does not necessarily generate benefits for neighboring counties [70], particularly where inter-county industrial specialization and functional collaboration remain limited. Urbanization can therefore provide an important foundation for county-level urban–rural integration, but its broader spatial effects depend on whether agglomeration advantages can be transmitted through cross-county linkages.

Industrial structure shows a negative local association with urban–rural integration at the national level. A higher share of secondary or tertiary industry does not necessarily imply stronger urban–rural linkages, because industrial activities may remain concentrated in county seats and generate limited employment, value-chain linkages, or factor flows to

rural areas. Recent county-level research suggests that industrial development contributes to urban–rural integration mainly when it is accompanied by industrial linkages, employment coordination, and technology transfer [73]. Thus, the composition of industrial activity alone may be insufficient to improve urban–rural integration; the extent to which industries are connected with rural areas and facilitate factor flows may be more important.

Transportation connectivity represents a more localized spatial pathway. Road network density has a significant positive local effect but no significant cross-county spillover, suggesting that improved transport connectivity primarily facilitates population mobility, market access, and the circulation of goods and services within counties by reducing travel and transaction costs [74]. Existing studies similarly show that transport infrastructure can improve access to employment and markets and facilitate rural labor mobility, thereby strengthening urban–rural linkages [75]. The insignificant effect of distance to prefecture-level cities provides a different perspective. Although previous studies have found that accessibility to higher-level urban centers can facilitate county-level urban–rural integration [76], our results suggest that physical proximity alone may not be sufficient. The effects of central cities may depend more on actual functional linkages and resource flows than on geographical distance.

The effects of public services suggest that their contribution depends not only on aggregate provision but also on spatial distribution, accessibility, and local demand. The insignificant effect of education may reflect the difficulty of translating human capital into local economic and rural development, particularly in counties experiencing population outmigration [77]. The negative association between healthcare provision and urban–rural integration may have two possible explanations. First, hospital beds may be concentrated in county seats, limiting rural residents' access to healthcare services. Previous studies have also documented substantial spatial disparities and clustering in the distribution of hospital beds across Chinese counties [78]. Second, this association may partly reflect reverse selection: counties with greater healthcare needs or weaker development conditions may provide more hospital beds while still having relatively low levels of urban–rural integration. Overall, these findings highlight the importance of the spatial allocation and accessibility of public services, rather than simply expanding their aggregate provision.

Digital development exhibits particularly complex spatial effects. Information infrastructure is positively associated with local integration but negatively associated with neighboring counties, suggesting that its benefits may be unevenly distributed across space. This siphoning effect is more likely to dominate when digital infrastructure, skilled labor, firms, and innovation resources are highly concentrated in relatively developed counties, while surrounding counties have weaker economic and absorptive capacities and limited cross-county cooperation mechanisms [79]. Under such conditions, better-equipped counties may attract scarce resources from neighboring areas rather than generate sufficient diffusion effects. By contrast, digital inclusive finance shows a predominantly local association, consistent with its potential role in reducing barriers to financial services and improving access to financial resources for rural residents, micro and small enterprises, and new agricultural business entities. Digitalized production exhibits the strongest positive spatial spillover, which may reflect its closer links with industrial chains, technology diffusion, production networks, and regional markets [66].

Taken together, the findings show that county-level urban–rural integration is shaped by multiple spatial pathways rather than a single process of development diffusion. Positive spillovers depend on functional channels through which economic, industrial, technological, and factor linkages can effectively cross administrative boundaries. Advancing county-level urban–rural integration therefore requires both stronger development capacity within individual counties and closer inter-county collaboration in industry, factor flows,

and functional linkages. In this sense, county-level urban–rural integration is both an internal process of coordination between urban and rural territorial subsystems and a spatially embedded process within broader regional networks.

5.4. Context-Dependent Pathways of County-Level Urban–Rural Integration

The regional heterogeneity results indicate that the pathways toward county-level urban–rural integration are strongly context-dependent. The same factor may exhibit different directions, magnitudes, or spatial effects across regions, reflecting differences in economic foundations, industrial structures, urbanization levels, resource endowments, and regional linkages. Eastern China exhibited the most diversified pattern, with urbanization, human capital, digital inclusive finance, economic development, and information infrastructure showing predominantly positive local effects, while digital inclusive finance also generated significant spatial spillovers. Central China relied more strongly on economic development and urbanization, with emerging spillover effects associated with transport connectivity. Western China remained more dependent on economic development, urbanization, and infrastructure, with per capita GDP showing particularly strong positive spatial spillovers. In northeastern China, conventional growth factors were generally less prominent, whereas the tertiary industry, digital inclusive finance, and healthcare provision showed more distinct positive associations.

These regional differences suggest that the effectiveness of individual factors depends on the development context in which they operate. Regions with stronger economic foundations and more developed urban–rural linkages may have greater capacity to translate urbanization, human capital, and digital development into positive integration outcomes. In less-developed regions, by contrast, economic development, urbanization, and infrastructure may remain more fundamental to strengthening the conditions for integration. Thus, the mechanisms underlying urban–rural integration vary across regions and cannot be readily generalized from the experience of one region to another.

An important finding is that digitalized production exhibits a significant positive effect in the national model but does not reach statistical significance in any of the four regional sub models. This difference suggests that the spatial effects of digitalized production may extend beyond the conventional regional boundaries used in the sub-sample analysis. Unlike factors that are more closely tied to local conditions, digitalized production can operate through technology diffusion, industrial collaboration, production networks, and market linkages that connect counties across provincial and regional boundaries [80]. When the national sample is divided into broad eastern, central, western, and northeastern regions, some of these cross-regional linkages are excluded from the sub-sample estimation, which may weaken the identification of its spatial effects. This result suggests that the spatial influence of emerging digital factors may not align with conventional geographic divisions. Therefore, regional sub-sample analysis should be interpreted with caution, as broad administrative or geographical divisions may obscure spatial relationships that operate through cross-regional networks.

These findings imply that advancing county-level urban–rural integration requires differentiated strategies that are adapted to regional development conditions rather than a uniform set of interventions. At the same time, regional differentiation should not lead to fragmented development. Strengthening the development capacity of individual counties should be accompanied by greater inter-county industrial collaboration, factor flows, and functional linkages, so that locally grounded integration can be connected to broader regional networks. Such an approach can help move county-level urban–rural integration beyond isolated improvements within individual counties toward more coordinated regional development.

5.5. Limitations and Future Research

Several limitations should be acknowledged. First, each theoretical dimension of urban–rural integration is represented by a single observable indicator, mainly because of the limited availability of comparable county-level data at the national scale. Although the four indicators correspond to the conceptual framework, a single indicator may not fully represent the multidimensional nature of each construct. Future research could integrate population, economic, land-use, industrial, digital, and public-service data from multiple sources to develop more comprehensive measurement systems and assess the robustness of alternative indicator specifications.

Second, the measurement of urban–rural interaction is constrained by the availability and comparability of county-level data. The intra-county population mobility rate used in this study captures an important aspect of population mobility but does not directly measure other forms of urban–rural linkages, such as capital, land, industrial, information, technology, and public service flows. Future research could incorporate more comprehensive and multidimensional measures of these linkages as more disaggregated data become available.

Third, this study relies primarily on cross-sectional data for 2020. Although the data provide relatively detailed information for examining the spatial differentiation and regional heterogeneity of county-level urban–rural integration, they cannot capture its temporal evolution or establish causal relationships. In particular, the cross-sectional Spatial Durbin Model identifies conditional spatial associations but cannot fully rule out reverse causality or unobserved factors. Future research could construct multi-year county-level panel datasets and employ longitudinal spatial econometric models and appropriate causal identification strategies to examine temporal dynamics and underlying mechanisms.

Finally, the spatial effects identified in this study may depend on the specification of spatial relationships and regional boundaries. The spatial weight matrix used in the analysis captures a particular form of inter-county connectivity, while conventional eastern, central, western, and northeastern divisions may not fully reflect network-based linkages, particularly for emerging factors such as digitalized production. Future research could employ alternative spatial weight matrices based on transportation, economic, industrial, or digital connectivity, and explore more flexible spatial or network-based regional divisions to better capture cross-county and cross-regional interactions.

6. Conclusions and Implications

6.1. Conclusions

Urban–rural integration is an important pathway for narrowing the urban–rural divide, promoting coordinated urban–rural development, and advancing common prosperity. As key territorial units connecting urban and rural areas, counties provide an appropriate spatial scale for examining the transformation of urban–rural relations. From the perspective of the urban–rural territorial system, this study develops an evaluation framework comprising four dimensions: urban development, rural development, urban–rural interaction, and urban–rural disparities. Using a combined objective–subjective weighting approach, the study evaluates county-level urban–rural integration across 1863 county-level units in China in 2020 and examines its spatial patterns, clustering characteristics, and associated factors using spatial autocorrelation analysis and spatial econometric models. The main findings are summarized as follows.

First, county-level urban–rural integration exhibits pronounced spatial differentiation and clustering. Most counties are concentrated at medium-low to medium-high levels, while relatively few reach the highest or lowest levels, resulting in a distinct spindle-shaped distribution. Spatially, integration generally follows an east–west gradient, with

higher levels concentrated in eastern and coastal China and lower levels in western and inland areas. Significant positive spatial autocorrelation further indicates that counties with similar levels of urban–rural integration tend to cluster geographically rather than develop independently.

Second, population urbanization is positively associated with county-level urban–rural integration, but higher urbanization does not necessarily correspond to higher integration. Integration generally increases with the population urbanization rate and exhibits clear stage-specific characteristics. This finding indicates that urbanization provides an important foundation for urban–rural integration, but its contribution is not automatic or uniformly proportional to the level of urbanization. Where population, capital, and industries become concentrated in urban areas without corresponding improvements in urban–rural linkages and factor flows, higher urbanization may not translate into greater integration.

Third, the factors associated with county-level urban–rural integration exhibit differentiated spatial effects. Economic development and digitalized production show both significant local effects and positive spatial spillovers, with digitalized production exhibiting a particularly strong spillover effect. Population urbanization, road network density, and digital inclusive finance primarily show positive local effects, whereas information infrastructure, industrial structure, and public services exhibit more heterogeneous effects. These findings indicate that county-level urban–rural integration is shaped not only by conditions within individual counties but also by spatial linkages and interactions across county boundaries.

Fourth, the pathways of county-level urban–rural integration vary substantially across regions. The eastern region exhibits a relatively diversified set of associated factors, whereas the central and western regions rely more strongly on economic development and urbanization. The northeastern region shows a more selective pattern, with several service- and digital-related factors exhibiting distinct effects. These differences indicate that the factors and spatial pathways associated with urban–rural integration are strongly context-dependent and cannot be readily generalized across regions. Accordingly, strategies for advancing county-level urban–rural integration should be adapted to regional development stages, resource endowments, and the characteristics of urban–rural relations.

6.2. Implications

First, strengthen county-level development capacity and translate urban agglomeration into urban–rural integration. Development strategies need to reflect the resource endowments and development foundations of individual counties, with a particular focus on strengthening industrial and overall development capacity. Greater coordination among modern agriculture, manufacturing, and services can help extend industrial value chains and employment opportunities into rural areas. At the same time, closer industrial linkages, better infrastructure connectivity, and more efficient factor flows between county seats and rural areas can help transform the agglomeration advantages associated with urbanization into broader urban–rural linkages and integration.

Second, leverage digital technologies and improve public service sharing to promote more equitable development opportunities between urban and rural areas. Digital technologies can be more deeply integrated into agricultural production and county-level industries, while improvements in digital inclusive finance can expand access to financial resources for rural residents, micro and small enterprises, and new agricultural business entities. Greater connectivity of digital infrastructure and data resources across counties can also facilitate the diffusion of digital technologies and associated spatial spillovers. Meanwhile, the allocation of public service resources, particularly in education and healthcare, should be optimized to extend high-quality services to townships and rural areas, reduce excessive

concentration in county seats, and improve the accessibility and sharing of basic public services across urban and rural areas.

Third, account for regional differences and extend urban–rural integration from intra-county coordination to broader regional coordination. Given the substantial regional variation in the factors and spatial pathways associated with urban–rural integration, a uniform policy approach is unlikely to be appropriate. Instead, policy strategies need to reflect differences in regional development stages, resource endowments, and urban–rural relations. Greater emphasis should be placed on inter-county industrial collaboration and functional complementarity. This would facilitate the cross-county diffusion of the effects associated with factors that exhibit significant spatial spillovers, particularly economic development and digitalized production, thereby extending urban–rural integration beyond individual counties and supporting more coordinated regional development.

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