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The current situation and driving factors of urban–rural integration in the Yangtze River Delta region

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Abstract

This study examines the degree of urban–rural integrated development (URID) and its determinants across 41 cities within the YRDR during the period spanning from 2012 to 2021 by employing the entropy weighting method and geodetic detector model. The results reveal the following. First, the overall URID in the Yangtze River Delta region (YRDR) accelerated. Cities in the central and eastern parts exhibit a greater URID, which decreases toward the west, north, and south, highlighting prominent developmental imbalances between cities. Second, integrated economic development between urban and rural areas (URAs) has consistently demonstrated superior performance. Social integration in URA has exhibited a steady upward trajectory, whereas the integration and improvement of urban and rural residents' quality of life have advanced at a comparatively modest pace. Third, the factors that significantly influence the URID within the YRDR include per capita GDP, postal and telecommunication services per capita, and the proportion of private car ownership. Conversely, the impact of governmental intervention and agricultural security appears to be comparatively diminished. Moreover, the combined influence of interacting dual factors surpasses that of individual elements, with the influence gradually stabilizing over time. Ultimately, this study provides policy suggestions to foster integrated urban and rural development in the Yangtze River Delta (YRD) with a focus on regional collaboration and development strategies.

1. Introduction

The report of the twentieth CPC National Congress advocates for a comprehensive rural revitalization strategy, highlighting the primacy of agricultural and rural advancement. As the powerhouse of China's economy, the YRD contributes nearly a quarter of the nation's GDP despite occupying just 1/26 of its landmass and hosting approximately 1/6 of its population. With the ongoing implementation of the integrated development strategy in the YRD, the region is poised to play an even more pivotal role in national modernization efforts and global competitiveness. Evaluating the state of URID in the YRD and identifying key influencing factors are crucial steps toward fostering greater integration and advancing Chinese-style modernization. The marginal contributions of this study may have the following two points: (1) conducting quantitative exploration of the level of integrated urban-rural development at the regional level from the urban dimension to enrich the research perspective on integrated urban-rural development; (2) the empirical analysis evaluated how the interplay of dual driving factors influences urban-rural integration, revealing their significant positive effect, complementing the research on the integrated development of urban and rural areas.

Engels initially introduced the concept of urban–rural integration in his work "Principles of Communism," marking integration as the culmination of the evolution of urban–rural relations. The essence of urban–rural integrated development does not entail eradicating urban–rural boundaries or merging their functions and landscapes, nor does it require absolute parity in their development. Rather, integrated development strives for the equitable distribution of development opportunities and spatial resources in URAs, ensuring comparable developmental outcomes for both urban and rural residents (Liu & Li,2017). URID underscores the principle of "equitable importance with differentiation" in urban–rural development (Wei et al.,2022), aiming to facilitate optimal resource allocation through bidirectional flows of urban–rural factors. This shared goal fosters comprehensive integration and coordinated advancement across economic, social, ecological, and spatial dimensions, ultimately fostering multitier urban–rural equilibrium and similar living standards for residents in both settings (Liu et al.,2015). The attainment of mature urban–rural integration is a notable hallmark of a nation's modernization (Liu et al.,2023). In the contemporary era, promoting integrated urban and rural development hinges on forging symbiotic ties between cities and villages and fostering a unified entity. Facilitating balanced resource allocation and unimpeded factor mobility between urban and rural domains departs from prior biases toward urban development, steering toward a path where urban and rural realms progress in tandem, culminating in holistic socioeconomic advancement (Yang et al.,2021).

Assessing urban–rural integrated development entails considering economic, social, ecological, demographic, and spatial dimensions (Kai & Jiahao,2015;Wu & Cui,2016). China's urban–rural integration and development have steadily advanced every year (Minjuan & Qian,2023). This progress is evidenced by various achievements, including democratizing the agricultural population, reforming rural land policies, enhancing urban and rural infrastructure, improving basic public services, and triumphing over poverty (Yang & Jin,2023). However, overall levels of integrated development exhibit fluctuations and geographical disparities (Wang et al.,2023), characterized by a gradual weakening in economic, demographic, and social aspects (Zheng & Long,2023). Moreover, the efficiency of urban–rural integration development has declined (Muga et al.,2023), and disparities persist between urban and rural development, with rural areas facing inadequacies (Liu, Y,2018; Liu Y & Long H et al.,2016). Regions with high urban–rural integration, such as the Pearl River Delta, Shandong Peninsula, and Jiangsu, Zhejiang, and Shanghai areas, contrast with those west of the "Hu Huanyong Line," where integration levels are lower (Zheng & Long,2023). The YRDR's integration and development display a fluctuating growth trend, evolving from severe dysfunction to moderate and then mild dysfunction, illustrating a zigzagging progression (Zhao & Jiang,2022).

Urban–rural integrated development is the outcome of various driving forces, including regional growth dynamics, market forces, and governmental regulations, operating within a framework of coordinated development (Yang et al.,2020). Factors such as the rise of the platform economy (Zhang,2023), the expansion of tourism (Tan et al.,2023), and the advancement of digital finance (Yunping et al.,2023) exert substantial and positive influences on the process of urban–rural integration. Moreover, the size of the labor force significantly shapes the extent of URID (Sun et al.,2023). Despite the positive impact of land use transformation on this integration, challenges such as disparities in urban–rural development, distortions in land markets, and obstacles to social integration may impede its benefits (Chen et al.,2020). Behavior of power is also a major factor affecting urban and rural development (Labbe & Musil,2013;Bittne & Sofer,2013). Significant spatial heterogeneity exists in urban–rural integration and development (Zeng & Chen,2023), wherein the influence of multiple interacting factors is greater than that of single factors; this heterogeneity emerges as a result of a combination of drivers (Liu et al.,2023). To further advance integrated urban and rural development, comprehensive planning and the coordinated implementation of strategies for new urbanization and rural revitalization are imperative. It is essential to focus on addressing specific challenges in rural areas while adhering to the development concept of supporting cities, synchronizing urban and rural development, prioritizing rural development, and creating innovative models and pathways for integrated urbanization and rural revitalization (Zhan et al.,2023). Simultaneously, strong support for the overall leadership of the Party, the removal of barriers to urban–rural integration between regions, the promotion of interregional exchanges and cooperation (Wang,2023), increased investment in urban and rural infrastructure, and the equitable development of public service facilities in both urban and rural settings are essential to enhancing the quality of life of residents across regions (Sun & Yang,2022). Moreover, advancing reforms in rural property rights, enhancing agricultural and rural modernization efforts, improving the consumption environment, and optimizing the income distribution model are essential steps toward achieving common prosperity and comprehensive progress (Qin et al.,2022).

Although extensive research on URID has produced valuable insights, there remains a lack of quantitative analysis concerning the extent of URID and its determinants in the YRDR from an urban-centric standpoint. This study examines 41 cities within the YRDR using panel data from 2012 to 2021 to create a comprehensive evaluation framework for measuring the level of URID across economic, social, and lifestyle dimensions. Furthermore, it explores the primary influences on URID, including economic aggregates, urban–rural exchanges, the industrial structure and governmental biases. These findings are intended to inform government policy formulation regarding the promotion of URID.

2. Methods and Data Sources

2.1 Literature Review

2.1.1 The Entropy Method

The methodology chosen for this research involves utilizing the entropy weight method to allocate weights to the various indicators and assess the level of URID across 41 cities in the YRDR while also determining the scores for each dimension of the indicators. The procedural framework for the entropy weight method is outlined below:

(i) Normalization of indicators: Acknowledging the diverse units in which indicators are presented, a crucial step is standardizing the data for each indicator. In cases of positive indicators, the standardization process unfolds as follows:

$$Z_{ij}=\frac{X_{ij}-Min\{X_{1j},X_{2j},...X_{nj}\}}{Max\{X_{1j},X_{2j},...X_{nj}\}-Min\{X_{1j},X_{2j},...X_{nj}\}},i=1,...n,\ j=1,...k \qquad (1)$$

For negative indicators, normalization is performed as follows:

$$Z_{ij} = \frac{Max\{X_{1j}, X_{2j},...X_{nj}\} - X_{ij}}{Max\{X_{1j}, X_{2j},...X_{nj}\} - Min\{X_{1j}, X_{2j},...X_{nj}\}}, i = 1,...n, j = 1,...k \quad (2)$$

where Z_{ij} is the standardized indicator value of indicator j in city i, X_{ij} is the original value of indicator j in city i, $Min\{X_{1j}, X_{2j}, \cdots\cdots, X_{nj}\}$ is the minimum value of the original value of indicator j in all cities, and $Max\{X_{1j}, X_{2j}, \cdots\cdots, X_{nj}\}$ is the maximum value of the original value of indicator j in all cities. When $X_{ij} = Max(X_{ij})$ or $X_{ij} = Min(X_{ij})$, Z_{ij} is zero, and the formula cannot be used; therefore, when Z_{ij} is zero, the formula is processed as follows:

$$Z_{ij} = X_{ij} \times 0.99 + 0.01 \quad (3)$$

(ii) Determine the weights of the indicators. The weight of each indicator is calculated after standardization P_{ij}:

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{n} Z_{ij}}, i = 1,...n, j = 1,...k \quad (4)$$

The information entropy of the indicator E_j is calculated:

$$E_j = -\frac{1}{\ln n} \sum_{i=1}^{n} P_{ij} \ln P_{ij}, j = 1,...k \quad (5)$$

The information entropy redundancy D_j is calculated:

$$D_j = 1 - E_j, j = 1,...k \quad (6)$$

The weights of the indicators W_j are calculated:

$$W_j = \frac{D_j}{\sum_{j=1}^{k} D_j}, j = 1,...k \quad (7)$$

(iii) Calculate the composite score and each dimension score. The formula for calculating the composite score is as follows:

$$T_i = \sum_{j=1}^{k} W_j Z_{ij}, i = 1,...n, j = 1,...k \quad (8)$$

When calculating the indicator scores for each dimension, it is sufficient to weight and sum the secondary indicators belonging to each dimension according to Equation (8).

2.1.2 Geographical Detector Model

The spatial algorithm Geodetector, initially introduced by Wang and Xu (Wang & Xu,2017) in 2010, functions based on the fundamental principle of exploiting spatial heterogeneity to uncover the factors (independent variables) impacting the dependent variable. The fundamental idea is that when an independent variable exerts a substantial influence on a dependent variable, their spatial patterns exhibit resemblance (Wang J F, Li et al.,2010;Wang J F & Hu,2012). Geodetectors offer two key benefits: first, they can detect both numerical and qualitative data; second, they can identify interactions between two factors affecting the dependent variable. Initially applied in human health risk assessment, geoprobes are now extensively employed across research domains encompassing the natural, social, and environmental sciences.

The geodetector comprises four primary detectors: detection of divergence and factors, detection of interactions, detection of risk zones, and detection of ecological factors. Our focus in this study is primarily on utilizing the factor detector to ascertain the spatial variance of the dependent variable Y. This process involves assessing the degree to which the independent variable X elucidates the spatial differentiation of Y, measured through a q-value. Additionally, we utilize the interaction detector to evaluate whether the explanatory capacity of the dependent variable Y is strengthened or weakened when both factors operate jointly or if their impacts on Y are mutually independent.

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^{\,2}}{N\sigma^2} \tag{9}$$

$h = 1, \cdots, L$ is the stratification, which involves the classification or partitioning of variable Y or factor X; N_h and N represent the number of units in layer h and the entire area, respectively; and $\sigma_h^{\,2}$ and σ^2 denote the variances of the y-values for layer h and the entire region, respectively.

2.2 Data Sources

The primary information used for this study is derived from various datasets, including but not limited to the statistical yearbooks of prefecture-level cities within the YRDR in preceding years, the Statistical Yearbook of Chinese Cities, the Shanghai Statistical Yearbook, the EPS database and government websites. Missing data are interpolated to fill gaps.

3. Spatiotemporal Analysis

3.1 Index system construction

Urban–rural integration represents an advanced model of urban–rural development, marking the final stage in their progression. The goal of integrated development is to achieve mutual prosperity and overall progress in URAs. Thus, it is important to include comparative indicators reflecting the reduction in the urban–rural gap and status indicators reflecting the shared prosperity of URAs in the system used to evaluate integrated urban–rural development. To scientifically assess the URID in the YRDR from 2012 to 2021, this study engages in an in-depth analysis of the connotations of urban–rural integrated development while drawing on existing research results (Tao et al.,2022). Following the principles of systematicity, scientific rigor, comprehensiveness, and accessibility, this study considers urban–rural disparity and the factor of common prosperity. It constructs a system for evaluating the level of urban–rural integrated development in terms of economic, social, and quality-of-life dimensions. Urban–rural income disparity is gauged by the ratio of the average per capita urban and rural income, while shared prosperity is evaluated using urban and rural GDP per capita.

Table 1. Evaluation system for the URID level.

Core layer	Indicator layer	Causality	Weight
Integration of urban and rural economies	Gross Regional Product (GRP) per capita in urban and rural areas	+	0.352
	Binary comparison coefficient	+	0.241
Social integration of urban and rural areas	Pupil-teacher ratio in urban and rural general secondary schools	-	0.022
	Beds per 10,000 population	+	0.272
Integration of people's lives in urban and rural areas	Ratio of per capita income of urban and rural residents	-	0.081
	Ratio of per capita consumption of urban and rural households	-	0.032

3.2 Analysis of results

To investigate the URID level in the YRDR and its spatiotemporal pattern, the entropy method was employed to allocate URID indicators to 41 cities in the YRDR and calculate the URID level in the YRDR from 2012 to 2021. The specific results are presented in Table 2 and Figure 1.

3.2.1 Temporal Evolution

3.2.1.1 Overall evaluation

Table 2. Level of URID and the score of the first-level indicator.

Year	Level of URID	Economies integration of URAs	Social integration of URAs	Integration of quality of life in URAs
2012	0.2853	0.1438	0.0781	0.0634
2013	0.3107	0.1530	0.0882	0.0695
2014	0.3434	0.1649	0.0973	0.0812
2015	0.3570	0.1692	0.1073	0.0805
2016	0.3740	0.1813	0.1111	0.0816
2017	0.3749	0.1943	0.0974	0.0832
2018	0.3956	0.2060	0.1059	0.0837
2019	0.4175	0.2186	0.1140	0.0849
2020	0.4624	0.2498	0.1250	0.0876
2021	0.4855	0.2691	0.1268	0.0896

As illustrated in Table 2, the URID in the YRDR increased from 0.2853 to 0.4855 between 2012 and 2021, indicating significant and accelerated progress. Specifically, the urban–rural economic integration score increased from 0.1438 to 0.2691, reflecting an average annual growth rate of 7.2%. Concurrently, the urban–rural social integration score increased from 0.0781 to 0.1268, with an average annual growth rate of 5.5%. Moreover, the integration score of urban and rural quality of life increased from 0.0634 to 0.0896, reflecting an average annual growth rate of 3.9%. Figure 1 clearly shows that the overall URID has consistently increased. Notably, the development trend of urban–rural economic integration has consistently maintained its prominence, underscoring economic development as the primary catalyst for enhancing URID. However, the progression of people's quality of life in urban and rural areas, while showing an upward trajectory, has been relatively sluggish. Additionally, the integrated social development of rural and urban areas experienced a marginal decline during 2016-2017 but exhibited an overall upward trend.

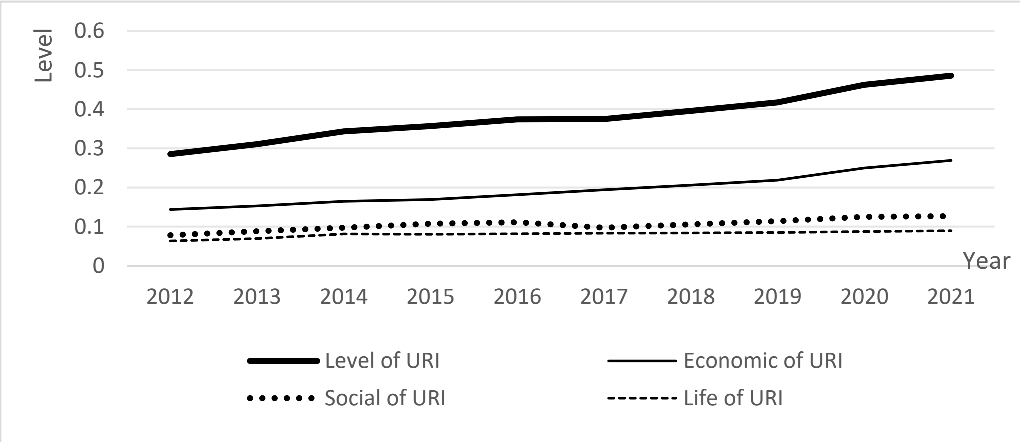

Figure 1. *Trends in the level of URID.*

3.2.1.2 Comparison of different cities

To comprehensively analyze the URID of cities, we calculated the average score and ranking of the URID in 41 cities, as shown in Table 3.

Table 3. URID levels and average scores and rankings of the 3 dimensions from 2012 to 2021.

City	Level of URID	Rank	Economies integration of URAs	Rank	Social integration of URAs	Rank	Integration of quality of life in URAs	Rank
Suzhou	0.6678	1	0.3647	2	0.2131	3	0.0900	14
Ningbo	0.6457	2	0.4157	1	0.1321	9	0.0979	7
Wuxi	0.6320	3	0.3493	4	0.1871	4	0.0956	9
Hangzhou	0.6203	4	0.2934	6	0.2321	2	0.0948	10
Zhoushan	0.5915	5	0.3558	3	0.1313	10	0.1044	2
Shanghai	0.5626	6	0.2585	9	0.2350	1	0.0691	30
Nanjing	0.5394	7	0.2941	5	0.1768	5	0.0685	31
Changzhou	0.5140	8	0.2804	7	0.1411	8	0.0925	11
Jiaxing	0.5064	9	0.2510	13	0.1496	7	0.1058	1
Huzhou	0.4826	10	0.2578	10	0.1220	13	0.1028	5
Shaoxing	0.4633	11	0.2527	12	0.1125	14	0.0981	6
Zhenjiang	0.4565	12	0.2686	8	0.0974	20	0.0905	13
Hefei	0.4316	13	0.2054	17	0.1520	6	0.0742	27
Yangzhou	0.4232	14	0.2547	11	0.0767	29	0.0918	12
Nantong	0.4179	15	0.2325	14	0.1027	16	0.0827	20
Yancheng	0.3846	16	0.2069	16	0.0748	31	0.1029	4
Taizhou	0.3816	17	0.2147	15	0.0814	28	0.0855	19

Taizhou	0.3736	18	0.2044	18	0.0826	27	0.0866	17
Wuhu	0.3642	19	0.1724	21	0.1038	15	0.0880	15
Xuzhou	0.3613	20	0.1812	19	0.0834	25	0.0967	8
Jinhua	0.3592	21	0.1518	26	0.1284	11	0.0790	23
Tongling	0.3431	22	0.1617	22	0.1224	12	0.0590	37
Huaian	0.3329	23	0.1791	20	0.0720	32	0.0818	22
Suqian	0.3295	24	0.1379	27	0.0881	23	0.1035	3
Wenzhou	0.3227	25	0.1529	25	0.0874	24	0.0824	21
Quzhou	0.3103	26	0.1275	31	0.0963	21	0.0865	18
Lianyungang	0.3080	27	0.1605	23	0.0603	36	0.0872	16
Lishui	0.3040	28	0.1371	29	0.0923	22	0.0746	26
Ma,anshan	0.2974	29	0.1531	24	0.0719	33	0.0724	29
Huangshan	0.2895	30	0.1128	34	0.0987	19	0.0780	24
Xuancheng	0.2875	31	0.1374	28	0.0759	30	0.0742	28
Bengbu	0.2787	32	0.1163	33	0.0993	17	0.0631	33
Huainan	0.2653	33	0.1255	32	0.0832	26	0.0566	38
Chizhou	0.2593	34	0.1101	35	0.0714	34	0.0778	25
Chuzhou	0.2590	35	0.1280	30	0.0639	35	0.0671	32
Huaibei	0.2388	36	0.0852	41	0.0987	18	0.0549	39
Anqing	0.2189	37	0.1011	38	0.0564	37	0.0614	34
Suzhou	0.2011	38	0.1053	36	0.0422	39	0.0536	40
Fuyang	0.1976	39	0.1018	37	0.0482	38	0.0476	41
Lu'an	0.1951	40	0.0980	39	0.0368	40	0.0603	36
Bozhou	0.1866	41	0.0975	40	0.0281	41	0.0610	35

Table 3 presents data indicating distinct levels of urban–rural integration development across various cities. Notably, Suzhou, Ningbo, Wuxi, Hangzhou, and Zhoushan emerge as the leading cities in this regard, while Anqing, Fuyang, Lu'an, and Bozhou lag behind. With respect to urban–rural economic integration, Ningbo, Suzhou, Zhoushan, Wuxi, and Nanjing stand out, whereas Fuyang, Anqing, Lu'an, Bozhou, and Huaibei are at the bottom of the spectrum. Shanghai, Hangzhou, Suzhou, Wuxi, and Nanjing excel in urban–rural social integration, whereas Anqing, Fuyang, Lu'an, and Bozhou struggle in this respect. With respect to the integration of urban and rural lifestyles, Jiaxing, Zhoushan, Suqian, Yancheng, and Huzhou lead the pack, while Tongling, Huainan, Huaibei, Suzhou, and Fuyang face challenges. The analysis underscores that highly ranked cities typically benefit from strategic locations and robust economic development, while those at the bottom exhibit lower economic growth and inadequate infrastructure.

In terms of development speed, the cities that exhibited the most rapid increases in URID during the study period were Lu'an, Fuyang, Lishui, Anqing, and Wuhu, while the slowest progress was observed in Huai'an, Suzhou, Wuxi, Huainan, and Tongling. Huaibei, Lu'an, Lishui, Xuancheng, and Anqing experienced the swiftest advancements in urban–rural economic integration, while Wuxi, Suzhou, Suzhou, Tongling, and Huainan demonstrated slower development, with Huainan even experiencing negative growth. Bozhou, Suqian, Fuyang, Ma'anshan, and Anqing emerged as the top-performing cities in terms of integrated urban–rural social development, while Xuzhou, Huaibei, Huaian, Huainan, and Tongling lagged behind, with both Huainan and Tongling exhibiting negative growth. Fuyang, Bozhou, Hefei, Lishui, and Anqing were the frontrunners in integrating urban and rural residents' lives, whereas Nantong, Suqian, Changzhou, Wuxi, and Suzhou demonstrated slower progress in this respect.

From Table 3, it is evident that Bozhou, Lu'an, Fuyang, and Anqing exhibited notable development speeds, notwithstanding their lower rankings in the level of URID. This finding suggests a narrowing of the gap in URID across cities in the YRDR and a consistent increase in integration. Further examination reveals negative growth in certain dimensions for Huainan and Tongling, underscoring the persistent issue of imbalanced interregional development and inadequate rural development.

3.2.2 Spatial Distribution

The level of URID was classified into four stages—high level (≥0.55), medium-high level (≥0.4 and <0.55), medium level (≥0.25 and <0.4), and low level (<0.25)—based on scores from each city in 2012, 2016, and 2021. A spatial distribution map illustrating these categories is presented in Figure 2.

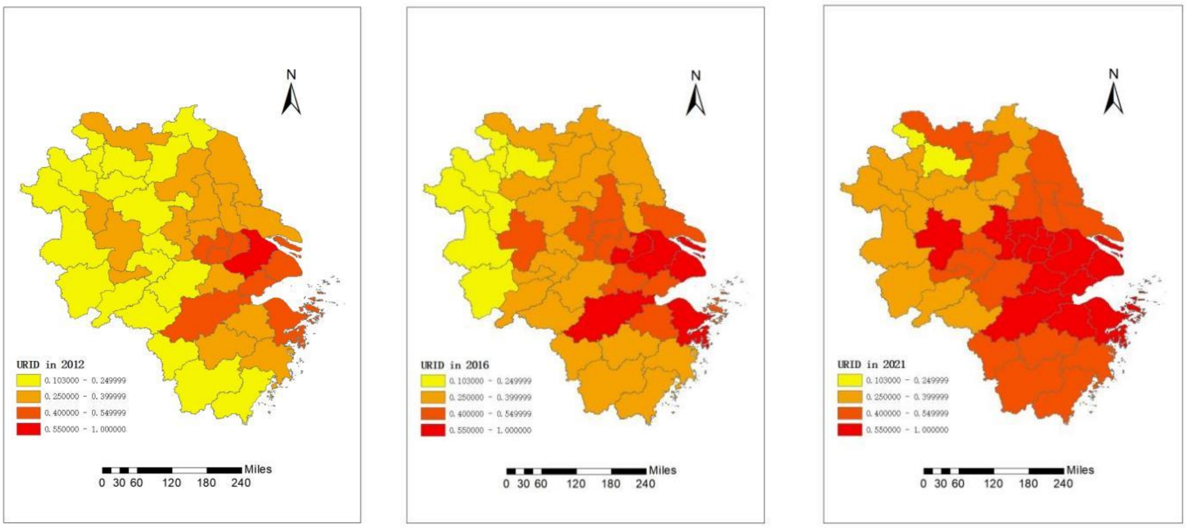

Figure 2. *Spatial distribution of the level of URID.*

In 2012, the level of URID in 18 cities was notably low, decreasing to 7 cities in 2016, with only 1 city exhibiting a low level in 2021. Eight cities were in the high and medium-high stages in 2012, increasing to 15 cities in 2016 and 28 cities in 2021. The overall level of URID has shown an upward trend over time, and the YRDR has gradually formed a high-level "Z-shaped" urban agglomeration with Shanghai as the core. Zhejiang Province has developed from only 3 medium-high level cities in 2012 to 11 cities in 2021, all of which have reached medium-high level and above. Lianyungang city and Huai'an city in Jiangsu Province have experienced a decade of constant struggle to develop from a low level to a medium level, but their levels remain significantly lower than those of other cities in the province. In Anhui Province, only the provincial capital has achieved a high level of URID, underscoring the prevailing low levels of integration and development across the region.

According to the spatial distribution of the URID level of each city and considering the unique characteristics of each city, cities are classified into four sequential levels as follows: consistently at the medium-high and above level, consistently at the medium and above level, low level in the early period transitioning to the high level in the late period, and those that have not yet attained the medium-high level, as detailed in Table 4.

Table 4. Spatial distribution of the level of URID by city in a typical year.

Level of URID	2012	2016	2021
Advanced stage （≥0.55）	Suzhou	Shanghai, Suzhou, Wuxi, Hangzhou, Ningbo	Shanghai, Suzhou, Wuxi, Nanjing, Changzhou, Zhenjiang, Hangzhou, Ningbo, Huzhou, Jiaxing, Shaoxing, Zhoushan, Hefei
Medium-high level stage （≥0.4， and<0.55）	Shanghai, Wuxi, Changzhou, Hangzhou, Ningbo, Jiaxing, Zhoushan	Nanjing, Changzhou, Hefei, Yangzhou, Zhenjiang, Nantong, Huzhou, Jiaxing, Shaoxing, Zhoushan	Yancheng, Taizhou, Yangzhou, Nantong, Wenzhou, Jinhua, Taizhou, Maanshan, Wuhu, Tongling, Xuancheng, Xuzhou, Suqian, Lishui, Quzhou
Intermediate level stage（≥0.25，and<0.4）	Nanjing, Hefei, Zhenjiang, Huzhou, Tongling, Yangzhou, Taizhou, Nantong, Shaoxing, Huainan, Yancheng, Jinhua, Xuzhou, Huaian, Taizhou	Yancheng, Taizhou, Taizhou, Wenzhou, Jinhua, Maanshan, Wuhu, Tongling, Chuzhou, Chizhou, Xuancheng, Xuzhou, Lianyungang, Huaian, Suqian, Lishui, Quzhou, Bengbu and Huangshan.	Chuzhou, Anqing, Chizhou, Lianyungang, Huaian, Bozhou, Huainan, Huaibei, Fuyang, Bengbu, Lu'an, Huangshan
Low level stage （<0.25）	Wenzhou, Maanshan, Wuhu, Chuzhou, Anqing, Chizhou, Xuancheng, Lianyungang, Suqian, Lishui, Quzhou, Bozhou, Suzhou, Huaibei, Fuyang, Bengbu, Lu'an, Huangshan	Anqing, Bozhou, Suzhou, Huainan, Huaibei, Fuyang, Lu'an	Suzhou

As revealed in Table 4, the first level comprises eight cities, including Shanghai, Suzhou, and Wuxi, which demonstrate outstanding economic development coupled with robust urban and rural infrastructure, exerting a significant radiation-driven effect on neighboring villages. The second level encompasses 14 cities, including Nanjing, Hefei, and Zhenjiang, characterized by greater economic development, superior transportation networks, and heightened agricultural development and exerting a certain driving effect on the surrounding villages. The third level comprises seven cities, including Wenzhou, Maanshan, and Wuhu, which have achieved remarkable progress in urban–rural integration and development. These cities exhibit a balanced flow of urban and rural elements, a steadily improving public service system, increasingly closely integrated urban–rural relations, and substantial developmental potential. The fourth level encompasses 11 cities, including Chuzhou, Anqing, and Chizhou, characterized by insufficiently smooth factor flows, delayed urban and rural infrastructure construction, notable disparities between urban and rural residents' incomes and consumption levels, and a weak spillover effect on neighboring villages. Consequently, a substantial gap persists between these cities and the advanced stage of URID.

In summary, it can be concluded that areas showcasing heightened urban–rural amalgamation and progress primarily dot the central and eastern sectors of the YRDR, with Suzhou, Ningbo, Wuxi, Shanghai, Zhoushan and other cities forming the core, while progress gradually diminishes in the west, north, and south directions. After nearly a decade of continuous progress in URID in Zhejiang Province, an overarching high-level urban–rural integration prevails. The URID in Jiangsu Province exhibits a "high-middle-high" structure, where the URID in the central part of Jiangsu Province is relatively low but gradually increases toward the east and west. Conversely, the western precincts of the YRD exhibit areas characterized by subdued URID, comprising mainly Bozhou, Fuyang, Suzhou, and Anqing in Anhui Province, where the overall economic aggregate of these cities is low, and the two-way rational flow of urban and rural factors is not smooth, resulting in insufficiently developed rural areas.

4. Driving Forces

To explore the core influencing factors that generate heterogeneity in the level of URID in the YRDR, we employed the geodetector model to examine the influencing factors through single-factor and two-factor tests in a typical year.

4.1 Variable Selection

The level of URID is affected by a variety of factors. In accordance with a previous study [4], the following aspects are considered in the context of the actual situation:

(1) Total economy. The advancement of the economy has coincided with increased technological innovation and talent accumulation. These factors have accelerated the improvement and modernization of industries and strengthened the link between urban and rural market demand, promoting cohesive urban and rural development. This factor is expressed as GDP per capita (in $/person, X1).

(2) Urban–rural mobility. Urban–rural exchanges primarily manifest in transportation and communication, and the closer these exchanges are, the more beneficial they are for promoting urban–rural integration. This factor is quantified by measuring the ratio of private car ownership (cars per 10,000 people, X2), transportation accessibility (kilometers/square kilometer, X3), and the total amount of postal and telecommunication services per capita (in yuan per person, X4).

(3) Industrial structure. Enhancing the industrial structure through optimization is a central catalyst for advancing URID. This factor serves to rectify the disparity in resource allocation between urban and rural domains. Facilitating the reciprocal movement of resources between urban and rural areas via thorough industrial structure optimization is as a pivotal avenue for achieving integrated urban–rural development. The coefficient of industrial structure upgrading (denoted as isup, X5) and the rationalization of industrial structure (represented by isr, X6) are

chosen to be expressed by the following formulas:

$$\text{isup} = \sum_{i=1}^{3} X_i \times \text{i} = X_1 \times 1 + X_2 \times 2 + X_3 \times 3 \tag{10}$$

where: the proportion of the output value of the first industry, which is directly proportional to the level of optimization and upgrading of the industrial structure;

$$\text{isr} = \sum_{i=1}^{n} \left(\frac{Y_i}{Y}\right) \ln\left(\frac{Y_i}{L_\text{i}} / \frac{Y}{L}\right) \tag{11}$$

where the output value of each of the three industries and the total output value of the three industries are the number of people employed in each of the three industries and the total number of people employed in the three industries, respectively; both variables are inversely proportional to the degree of industrial rationalization.

(4) Policy bias. Government-led mechanisms play a positive role in promoting urban–rural integration. These mechanisms harness the potential of cities to drive rural development through the implementation of policies such as new urbanization and rural revitalization. Simultaneously, the decisions made by local governments regarding fiscal expenditures and financial subsidies directly contribute to the development of a given region. Focused inputs, such as ensuring financial security in agriculture and allocating funding for education, provide substantial support for the relevant areas. These interventions are denoted as X7 for government intervention, X8 for agricultural security, and X9 for educational support.

4.2 Analysis of results

To investigate the changes in the core factors that generate heterogeneity in the level of URID in the YRDR, we employed geodetectors to test the influential factors in 2012, 2016, and 2021. The results are presented in Tables 5 and 6. Table 5 shows that the q-value ranking of GDP per capita, private car ownership ratio, total postal and telecommunication services per capita, and rationalization of industrial structure, which ranked in the top 4 in at least two typical years. This finding indicates that these four variables constitute the core factors contributing to the spatial differentiation of the URID level in the YRDR.

Table 5. Detection results of factors affecting the level of URID.

Code	Impact factor	2012		2016		2021	
		q	Rank	q	Rank	q	Rank
X_1	Per capita GDP	0.7618	1	0.8444	1	0.7982	2
X_2	Private car ownership ratio	0.6071	4	0.6442	4	0.7352	3
X_3	Traffic accessibility	0.2878	9	0.1043	9	0.1118	9
X_4	Total postal and telecommunications services per capita	0.6765	2	0.7971	2	0.8187	1
X_5	Industrial structure upgrading coefficient	0.5301	6	0.5532	5	0.4367	5
X_6	Rationalization of industrial structure	0.6764	3	0.6826	3	0.3159	7
X_7	Government intervention	0.3770	7	0.4569	7	0.3054	8
X_8	Agricultural security	0.3453	8	0.3803	8	0.4726	4
X_9	Educational support	0.5826	5	0.5222	6	0.4210	6

Considering the changes in q-values of the core factors, the q-value of GDP per capita consistently remained above 0.7 throughout the study years, consistently ranking among the top 2, indicating this factor's robust explanatory power for the spatial differentiation of the URID in the YRD. The importance of this factor could be attributed to the higher economic aggregate, providing local governments with the ability to increase financial resources to mitigate the issue of unbalanced development between urban and rural areas, thus facilitating smooth socioeconomic development. Moreover, the thriving development of township and village enterprises contributes significantly to the enhancement of economic development levels in the YRDR, thereby fostering URID. The q-value of rational industrial structure increased marginally from 0.6764 in 2012 to 0.6826 in 2016 but subsequently plummeted to 0.3159 in 2021, suggesting a notable decrease in its impact on the level of URID. This decline may be attributed to the significant challenges currently confronting the rural economy, characterized by large but weak industries and numerous but mediocre products. Furthermore, the objective of integrating urban and rural areas has shifted toward the comprehensive development of three industries to prevent division and conflict. The q-value of total postal and telecommunication services per capita consistently increased, from 0.6765 in 2012 to 0.8187 in 2021, securing the top ranking, thereby suggesting a growing explanatory power of this factor for the level of URID. The q-value of the ratio of private car ownership continued to increase from 0.6071 in 2012 to 0.7352 in 2021, indicating a gradual increase in the spatial explanatory power of this factor. Therefore, it remains imperative to advance rural infrastructure development in areas such as postal and telecommunications and transportation while further bolstering information exchange between urban and rural economies.

During the study period, the two impact factors of transportation accessibility and the coefficient of industrial structure upgrading in 2021 did not achieve statistical significance at the 5% level. However, the remaining influencing factors exhibited varying degrees of influence on the level of URID in the YRD. The q-value for education support decreased from 0.5826 in 2012 to 0.4210 in 2021, indicating a decline in the degree to which investment in education influences the level of URID. Government interventions in q exhibited an "inverted U" trend, initially increasing and then decreasing. This finding suggests that after local fiscal expenditures reach a certain threshold, the impact on urban–rural integration does not continue to increase but, rather, decreases. The q-value for agricultural security increased from 0.3453 in 2012 to 0.4726 in 2021, suggesting that in the YRDR, increased investment in agriculture, forestry, and water services can promote agricultural development and increase farmers' incomes. This, in turn, affects the level of URID.

As shown in Table 6, the explanatory power of the interaction between any two factors surpasses that of any individual factor. This interaction results in a two-factor enhancement, characterized by minor fluctuations in its explanatory strength over the three typical years and gradual stabilization. In 2021, the q-value for the interaction between per capita postal and telecommunication operations and agricultural security and education support exceeded 0.95. This indicates a high degree of consistency between the two interactions and the level of URID. Some interaction factors, such as the ratio of GDP per capita to private automobile ownership and the number of postal and telecommunications services per capita, attained q-values of 0.90 or higher. Moreover, the results strongly explain the influencing factors contributing to spatial heterogeneity in regional URID. Hence, effectively combining influencing factors is beneficial for enhancing the level of URID in the YRDR.

Table 6. Interactive detection results for the factors influencing URID.

Interaction factor	Interaction contribution rate（$X_i \cap X_j$）			Comparison of interaction values
	2012	2016	2021	
$X_1 \cap X_2$	0.8425	0.9357	0.9115	＞maxq（X_1，X_2）
$X_1 \cap X_4$	0.8753	0.9191	0.9307	＞maxq（X_1，X_4）
$X_1 \cap X_5$	0.8616	0.9255	0.8840	＞maxq（X_1，X_5）
$X_1 \cap X_6$	0.9239	0.9004	0.8869	＞maxq（X_1，X_6）
$X_1 \cap X_7$	0.8712	0.8811	0.8786	＞maxq（X_1，X_7）
$X_1 \cap X_8$	0.8257	0.9024	0.8958	＞maxq（X_1，X_8）
$X_1 \cap X_9$	0.8322	0.8670	0.8703	＞maxq（X_1，X_9）
$X_2 \cap X_4$	0.7551	0.8989	0.8530	＞maxq（X_2，X_4）
$X_2 \cap X_5$	0.6508	0.7217	0.8357	＞maxq（X_2，X_5）
$X_2 \cap X_6$	0.8941	0.8493	0.8733	＞maxq（X_2，X_6）
$X_2 \cap X_7$	0.6941	0.8198	0.8790	＞maxq（X_2，X_7）
$X_2 \cap X_8$	0.8437	0.8532	0.9109	＞maxq（X_2，X_8）
$X_2 \cap X_9$	0.8666	0.8874	0.9268	＞maxq（X_2，X_9）
$X_4 \cap X_5$	0.7303	0.8832	0.8921	＞maxq（X_4，X_5）
$X_4 \cap X_6$	0.8565	0.8884	0.8706	＞maxq（X_4，X_6）
$X_4 \cap X_7$	0.7841	0.9184	0.9083	＞maxq（X_4，X_7）
$X_4 \cap X_8$	0.8549	0.8261	0.9504	＞maxq（X_4，X_8）
$X_4 \cap X_9$	0.8817	0.8484	0.9576	＞maxq（X_4，X_9）
$X_5 \cap X_6$	0.8945	0.8557	0.7745	＞maxq（X_5，X_6）
$X_5 \cap X_7$	0.6715	0.8478	0.7117	＞maxq（X_5，X_7）
$X_5 \cap X_8$	0.8102	0.7894	0.5916	＞maxq（X_5，X_8）
$X_5 \cap X_9$	0.8493	0.8017	0.7909	＞maxq（X_5，X_9）
$X_6 \cap X_7$	0.8354	0.8607	0.6242	＞maxq（X_6，X_7）
$X_6 \cap X_8$	0.8320	0.8616	0.7962	＞maxq（X_6，X_8）
$X_6 \cap X_9$	0.9373	0.9078	0.6629	＞maxq（X_6，X_9）
$X_7 \cap X_8$	0.7370	0.8126	0.6711	＞maxq（X_7，X_8）
$X_7 \cap X_9$	0.6947	0.7165	0.7249	＞maxq（X_7，X_9）
$X_8 \cap X_9$	0.7633	0.6801	0.8090	＞maxq（X_8，X_9）

5. Conclusions and Implications

5.1 Conclusions

Based on panel data from 2012 to 2021 for 41 cities in the YRD, a system of indicators is constructed to evaluate URID across three dimensions: economy, society, and quality of life. The entropy power method is employed for analyzing the spatiotemporal pattern of integrated urban–rural development. Additionally, the geodetector model is utilized to investigate the influencing factors of URID in the YRDR, leading to the following conclusions:

(1) Over the period from 2012 to 2021, the level of URID in the YRDR has been consistently increasing, demonstrating an accelerated development trend. Overall, the three dimensions of urban–rural integration, including economic, livelihood, and social aspects, have exhibited a gradual upward trend. Notably, urban–rural economic integration has consistently led the way,

while the integration of urban and rural livelihoods has progressed at a slower pace, highlighting a persistent issue of imbalance.

(2) The disparity in URID among cities in the YRDR is progressively diminishing, accompanied by a steady rise in the level of URID. Nevertheless, Huainan and Tongling have experienced negative growth rates in certain dimensions of development, exacerbating the issue of imbalanced interregional development, which remains salient. Areas with elevated URID levels predominantly lie in the central and eastern sectors of the YRD, centered on Suzhou, Wuxi, and Shanghai, while the levels taper off in the west, north, and south. Zhejiang Province exhibits a high overall URID, which contrasts with the relatively lower URID in central Jiangsu Province, while the level gradually increases toward the east and west. Conversely, the western segment of the YRDR constitutes an area characterized by a lower degree of URID, notably encompassing Bozhou, Fuyang, Suzhou, and Anqing in Anhui Province. These urban areas demonstrate subdued economic performance overall, with an imbalanced distribution of urban and rural elements and insufficient progress in rural development.

(3) GDP per capita, postal and telecommunications services per capita, and the ratio of private car ownership exert the greatest influence on the URID level in the YRDR, whereas government intervention and agricultural supports have limited explanatory power. The explanatory power of any two factors exceeds that of any single factor, indicating that their interaction leads to an enhancement in explanatory capability equivalent to that of two factors.

5.2 Implications

First, to promote balanced regional development, it is imperative to strengthen the leading role of urban-rural economic integration and address existing developmental gaps. Leveraging the economic advantages of the Yangtze River Delta region, we should facilitate coordinated urban-rural industrial development, encourage the flow of urban capital and technological resources into rural areas, and stimulate rural economic vitality. Furthermore, accelerating the integration of social and people's lives between urban and rural areas is crucial. This requires increased investment in rural infrastructure and public services, with a particular focus on narrowing disparities in education, healthcare, and elderly care. Additionally, improving the rural social security system and raising farmers' income levels are essential steps toward achieving equitable and sustainable development.

Second, enhancing intraregional collaboration is crucial, requiring targeted strategies to address specific deficiencies. A cross-provincial specialized coordination platform for urban-rural integration should be established, prioritizing the diffusion of resources from core cities (e.g., Shanghai, Suzhou, and Wuxi) to neighboring regions (e.g., central Jiangsu and western Anhui). This can be achieved through mechanisms such as industrial chain gradient transfer and the "flying land" economy, thereby reducing developmental disparities between eastern and western areas. For underdeveloped regions like Bozhou and Fuyang in Anhui Province, increased fiscal transfers from central and provincial governments are essential. Additionally, priority should be given to transportation and digital infrastructure projects to eliminate barriers to factor mobility and foster equitable regional development.

Third, a multifaceted development strategy should be devised. The interaction detection results show that the interaction of the two most influential factors has stronger explanatory power than any single factor. Therefore, the various key factors affecting urban–rural development should be integrated in the YRDR. For example, the YRDR should vigorously develop its economy, increase the total volume of the economy, invest in rural transportation, postal and telecommunications infrastructure, and simultaneously upgrade rural education, health care, and other public services. These efforts will facilitate the integration of urban and rural areas in all aspects of the economy, society, and quality of life.

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