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Overall Urban–Rural Coordination Measures—A Case Study in Sichuan Province, China

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Abstract: Focusing on urban–rural development issues, this paper analyzes the necessity of coordinated development between the narrowing gap and integral development. An overall urban–rural development dynamic model aimed at two major objectives is pointed out. A principal component analysis (PCA)—Grey Entropy measurement model is proposed to evaluate urban–rural coordination from economic development, social security, public services, and environmental quality perspectives. In this model, principal component analysis (PCA) was used to extract the components that explained overall urban–rural coordination. This model was then combined with Grey Entropy to measure the level of urban–rural development coordination. By establishing a scientific measurement model, the coordination value of the rural and urban areas was effectively calculated from a comprehensive perspective, including subsystems and static and dynamic coordination values. Finally, the model was applied to Sichuan Province as an example to show its effectiveness in measuring urban–rural coordination.

Keywords: overall urban–rural coordination; principal component analysis; Grey Entropy; measurement model

1. Introduction

Urban–rural dual economic structure and urban–rural differences should be mentioned when discussing urban–rural development. Urban–rural dual economic structure refers to the economic structure that coexists with social production as the main characteristics of the city economy and small production as the main characteristics of the rural economy. The economic segmentation [1] formed reflects the disparities between urban and rural living standards, such as medical conditions and educational opportunities. Through statistical study, Baade found that the medical treatment of rural Australian residents was obviously lower than urban residents, and this difference will continue to exist [2]. Similar urban–rural differences [3,4] have also existed in other regions, and the urban–rural dual economic structures in India and China have been the most common research foci [5–7]. Liu and others pointed out that the imbalance between urban and rural development in China meant strategic challenges. Policy and institutional structure, economic growth, and urbanization were the main driving factors causing unbalanced urban–rural development [8].

Therefore, overall urban–rural development was aimed at changing the dual urban–rural economic structure. As urban populations and industrial development have increased, there have been improvements in local public services and living conditions. Efforts have been made to stimulate self-sufficiency in the rural economy in order to narrow the urban–rural gap, and to achieve regional common development.

Studies on the urban–rural areas are not a few. This paper tries to carry out the research of overall urban–rural development from a coordinated development perspective, looking at both the urban–rural gap and integral development. Whether overall urban–rural development is coordinated with [9] regional development can detect the coordinated development of rural areas and cities, and give effective feedback to the strategic implementation of urban–rural development.

2. Literature Review

2.1. Researches on Overall Urban–Rural Development

From the theoretical research process of urban–rural issues and urban and rural co-ordination, the literature is summarized as the following three aspects.

(1) Studies on urban–rural related concepts and economic phenomena. Urbanization and urban–rural dual economic structure were formulated earlier than the overall urban–rural coordination. The interactions relationships and networks had revealed the back ground and basic situation overall urban–rural [10–15]. Urban and rural differences were different in different regions. However, the first performance tested was income inequality between urban and rural residents, and was thus accompanied by unequal treatments on other services. Overall urban–rural development was affected by multiple factors. Fertner studied three migration models of ex-urbanization, displaced urbanization, and anti-urbanization, and found that displaced urbanization was the most susceptible to be impacted by general development [16]. Based on the current situation of the imbalanced urban–rural development in Bucharest, Zamfir discussed the process of structural evolution, and finally put forward sustainable development interventions [17]. Jong-Sup showed that urban social development expenditures on urban and rural integration tended to have a positive impact on regional economic development, which was greater than economic development spending and administrative expenditure. Social development expenditure was a significant investment to promote urban–rural integration [18]. Zhao found that financial development improved access to urban finance, and farmers became the providers of capital, further increasing the urban–rural divide [19]. Berdegué found that small and medium-sized cities were more capable of promoting economic development and narrowing the gap between the rich and the poor [20]. Van found a similar result [21].

(2) Explore the problems and improvement of urban–rural development subsystems. That is, focusing on refinement aspects involved in urban and rural development, such as issues about employment equity, social security, medical services, education resources, and environmental pollution [22–26]. Gu used a social security Gini coefficient and a modified Gini coefficient to analyze the vigilance of old-age security and health care in both urban and rural environments, and found that the social security system in China was unable to effectively regulate the income gap between urban and rural areas [27]. Mushtaq and others found that residents generally do not have a strong awareness of tuberculosis (TB), especially in rural areas. It was recommended that the information dissemination channels to consider more in-depth transmission of TB prevention information [28]. Singh analyzed the 15 years of panel data for 6 regions in India, and found that urban and rural differences and gender differences in immunization had declined, but rural children and female children were still at disadvantaged status. Regular medical assessment and coordination of multiple-health work services include strong immunization systems, broad health systems, and other primary health care delivery programs were required for increasing immunization coverage [29]. Zeng divided the urban and rural areas, and built a core-edge model made up of urban–rural labor migration and environmental pollution [30]. Soffer took the case of Moshavas an example, and the identity of the farmers became diversified due to changes in the agricultural structure, and non-agricultural income had become the main source of narrowing the income gap between urban and rural areas [31]. Angelescu pointed out that narrowing the gap between urban and rural regions was conducted by the motivation and design of strategies. With Rome as the individual case, improving education level to ensure the basic skills could increase the employment rate [32]. Clarke thought that serious public library service

inequality caused by economic inequality in China, which can only be evidently reduced by state intervention [33].

(3) Measure and cause analysis on development level of overall urban–rural development. Following studies focused on causes, using a variety of technical methods which have provided an empirical basis for further strategic adjustment and correlation analyses, and urban–rural evaluation systems were developed to evaluate overall regional development [34,35]. The urban–rural income gap has been identified as an important indicator when seeking to measure the overall situation. Sun built an urban–rural income gap suitability evaluation system based on economic growth, resource allocation efficiency, social stability, and the equitable distribution of income [36]. Ding constructed a harmonization index system to describe the urban–rural development stage characteristics with farmland transfers, labor migration, and urbanization interaction [37]. Cao used land quantity control, landform compactness, and land use efficiency as the evaluation bases to measure the level of smart land use [38]. Afrakhteh assessed the land use planning in urban–rural areas of Falavarjan Township, using a variety of modeling methods for analysis. He suggested that the land surface temperature factor could be applied in future land use planning [39]. Wang suggested that initial measurements could be implemented with objective indicators rather than index systems. The support vector machine method is a learning theory of Vapnik-Chervonenkis Dimension, an indicator about the speed and generalization of uniform convergence, and structural risk minimization principle on the basis of statistics, to find the best compromise according to the limited sample information in model complexity (i.e., learning accuracy of specific training samples) and learning ability (i.e., error free to identify any samples). Based on SVM, an urban–rural development integration level measurement and classification model was developed, and validity and reliability were verified [40].

2.2. Summary on Previous Results and Research Innovation

In the overall urban–rural research system, we found several deficiencies.

(1) There was a limited understanding about overall urban–rural issues. Most scholars focused alone on absolute improvement in the living standard of rural areas, or on narrowing the gap between urban and rural areas to evaluate the implementation effect of overall urban–rural work, ignoring the overall effectiveness of integral regional development. China has entered the middle stage of industrialization, and agriculture is no longer the economy-leading industry. The economic environment requires harmonious development between industry and agriculture, city and rural, to ensure nurturing relationships. The best overall urban–rural status is common prosperity and common development within the acceptable urban–rural gap [9]. This highly coordinated condition exists in each aspect, which means that the urban–rural gap and integral development are highly consistent in pace, which conducts sustainable social development, and then leads to the concept of coordinated development. Narrowing the urban–rural gap and coordinating integral development are prerequisites to regional sustainable development, which requires a joint consideration of the economic, societal, and environmental situations.

(2) A single technological approach failed to study urban and rural issues scientifically. Traditional evaluation methods were unable to fully reflect the interval differences between the measurement values. For example, the analytic hierarchy (AHP) method didn't explain regional factors and internal relationships among factors. Results were obtained by calculating the score of urban–rural factors and their weights given by experts, which had certain subjectivity and fuzziness. However, due to the differences of the research objects, a single technical method was not applicable to all scenarios, and even led to misleading results, and it was difficult to accurately determine the true level of development of urban and rural planning.

(3) The research dimension was too single. Research levels were diverse, but most were limited to a certain dimension, such as unbalanced education development, urban–rural integral

development, or the level of the economic gap. This is especially evident for results presented as a static evaluation, which reflected the overall urban–rural situation at a certain point of time or in a period of time, while dynamic studies were few. Consequently, it was difficult to judge the level and trend of overall urban–rural development.

With this in mind, this paper presents empirical research on the coordination between the two main urban–rural development objectives in Sichuan province. We establish an urban–rural development coordination measurement model, and the coordination of urban and rural areas will be reflected by calculating coordination value to provide a reference for the balanced development of the regional economy. Accordingly, the innovations of this paper are presented from the following three aspects.

(1) Classify indicators from dimensions, urban–rural gap, and integral development. Urban–rural gap refers to the gap between rural residents and urban residents in income level, education level, public services, and other aspects, reflecting the inequality between urban and rural areas. Integral development responds to the overall development situation of the region, including urban and rural areas at the same time. Overall urban–rural development aims to reduce the gap between urban and rural areas and achieve the coordinated development of urban and rural areas. As the index system is large, accurately distinguishing the corresponding indicators for integral development to narrow the urban–rural gap is necessary to ensure that measurement results are scientific and rational.
The same attribute ratios for both urban and rural areas were chosen as the key indicators to reflect the urban–rural gap; the urban–rural resident income difference coefficient, the primary industry to GDP ratio, and the agricultural production utility. Industrial added value, urbanization rate/speed of industrialization, and basic public services growth rate/urban population growth rate, (such per capita income, and integration indicators) were used to measure integral development. Two indicator system sets were selected, based on the above classification criteria.
(2) Comprehensive technical methods were fit to study the scene to ensure the objectivity and impartiality of the research results. This paper proposed a principal component analysis (PCA)-Grey Entropy measurement model. First, PCA was used to extract the main components and the variable contribution rates from the urban–rural gap system and the integral development system. Then, these were processed using normalized standardization, after that, the model was used to calculate the grey correlation coefficients between the principal integral development system and urban–rural gap system components. A Grey correlation coefficient matrix was then constructed, and the entropy method was used to determine the weights for the principal components of integral development system. After multiplying the weights by the coefficients and summing these up, the single principal component coordination values were obtained. Finally, the overall coordination values in the system were determined by applying the mean method to process the data.
(3) Results of the research showed that the coordination degrees of the subsystems and the static and dynamic coordination degrees and demonstrated the overall urban–rural development and evolution law. The overall situation of urban–rural development and weaknesses were demonstrated. Each subsystem's coordination degree reflects the coordinated development of urban and rural areas in relative economic development, social security, public services, and environmental quality. Resident quality of life subsystem and the environmental quality subsystem continued to fluctuate and developed slower than economic development, which resulted in a large environment maintenance cost. The static coordination degree reflects the development of overall urban–rural coordination, while the dynamic coordination degree represents the fluctuation range of overall coordination each year. The cyclical fluctuations of dynamic coordination degree mean the necessary consolidation of work.

3. Overall Urban–Rural Cooperation Model Analysis of Regional Sustainable Development

3.1. Overall Urban–Rural Dynamic Factor Analysis

Urban–rural integration and urbanization both refer to the development of a dual economic structure. The ultimate goal of urban–rural development strategies is urbanization and urban–rural integration [41]. By allocating and sharing economic, societal, and environmental resources and balancing the public service provisions to improve the quality of people's lives, the gap between the urban and rural areas can be reduced. Along with the urbanization, the phenomenon such as transfer of labor force, improvement of living standards, and the technology introduction have occurred. Especially in developing countries, to seek better social security conditions, a large number of rural children have transferred into urban schools, resulted in the emergence of urbanization. Urbanization has become an important feature of developing countries to catch up with industry or the entire economic development [42], although the city has serious pollution and other economic problems [43]. The reduction in the economic gap and whole development will achieve urban–rural integration. Overall urban–rural development, which involves a combination of factors and shows systematic features, is vital to sustainable development.

First, overall urban–rural development arises organically from economic and social development. Initially, the desire for domestic economic development in China led to an excessive emphasis on industrial development, enlarging the urban–rural divide because of many differences between household registration systems, financial mechanisms, and available public services. In 2011, 30 Chinese provinces were found to have marked differences in their urban–rural integration levels, and economically "from east to west, the level gradually reduces, with the three northeastern provinces interspersed between them" [44]. The dual economic structure needs to be developed into a monist centralized social production model. Giving full play to the edge of the urban economy and solving the "Three Rural Issues", overall urban–rural development has become more economically and socially important.

Second, overall urban–rural development seeks to balance the "city" and the "countryside". As the excessive pursuit of heavy industry development has become past, urban–rural development strategies state that industry needs to promote agriculture, and urban areas need to assist in rural development, so as to narrow the gap between the urban and rural areas. Rural cooperatives and contracting systems can stimulate the primary industry output value and enhance the added value of primary industry. Furthermore, emerging city enterprises need to be encouraged to achieve scientific and technological innovations to enhance regional competitiveness. With these coordinated efforts, the region can realize balanced economic development.

Third, overall urban–rural development is based on resource sharing. As the first of "five overall arrangements", overall urban–rural development is an important means to achieve regional development coordination. Industrial zone transformations and intermediary links to small towns have led to the development of innovative urban technological methods that provide human resources to rural areas, and have opened up resource channels to increase entrepreneurial opportunities. Therefore, the rural economic and social development foundations are being reinforced, and resulted in stable economic and social development in the cities nurtured by social and economic growth the rural areas.

Overall urban–rural development is a systematic project that encompasses economic development, social security, public services, and environmental construction, and is closely related with industrial structural development and new urbanization. Demographic factors, economic factors, institutional factors, resource factors, environmental factors, and industrial factors, however, can limit urban and rural development. Therefore, a rational analysis of these dynamic factors and scientific planning of the internal and external operating systems can reduce the urban–rural gap and achieve overall economic development.

3.2. Overall Urban–Rural Development Cooperation Model

Based on the above analysis, this paper builds a cooperation model to promote overall urban–rural sustainable development, as shown in Figure 1.

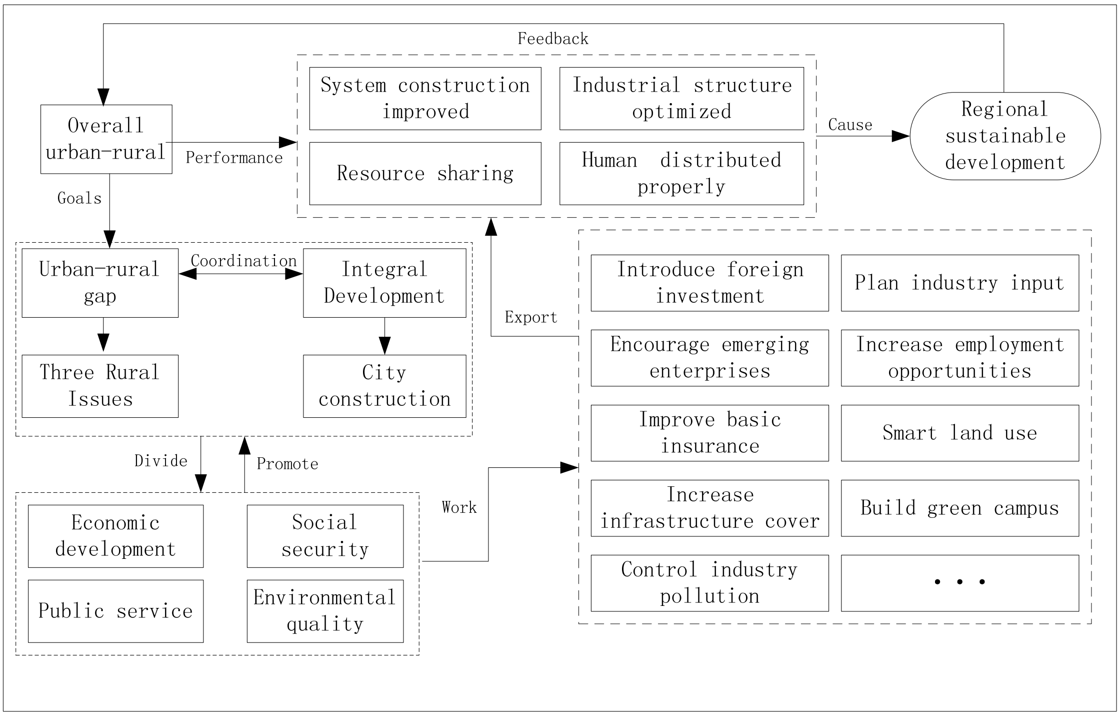

Figure 1. Overall urban–rural development cooperation model.

With overall urban–rural development, the whole economic society can be transformed, ensuring the integrative development of the urban–rural economy. Economic opportunities for rural development can be increased through resource sharing g, such as attracting foreign investment to the city and economic innovation. At the same time, the government can build and improve basic rural support facilities to increase public welfare so as to provide strong backing for city's economic development. Overall urban–rural development strives to achieve a balance within the system of all aspects of the economic-societal system, within which the economy, welfare, and sustainable living environments are accounted for. To achieve industrial optimization and economic mutual promotion, resource sharing, manpower deployment, and system construction are required. Once harmony in the urban–rural development is achieved, organizational development can be remarkable, meaning that the region has a good capacity for sustainable development.

4. Overall Urban–Rural Coordination Measurement Index System

To evaluate the overall urban–rural related content, previous researches have considered elements such as economic development, infrastructure, living conditions, and environmental quality [45]. Whether the policy brings the interests of the masses, in addition to direct economic data, the people's welfares are also very important, such as consumption level, medical conditions, entertainment, and leisure. With protecting of the people's interests and considering the sustainable development, ecological protection is an important index that must be included when masses promote the development. Based on theoretical research and dynamic models, in this paper, an index system for urban and rural coordination measurements was constructed, based on scientific, comprehensive, feasible, stable, and pertinence principles, as shown in Table 1.

Table 1. Index system.

Target Layer	First Level Indicators	Secondary Indicators	Tertiary Indicators
Overall urban–rural coordination	Urban–rural gap	Economic development A1	Primary industry to GDP ratio A11
			Urban–rural Engle's coefficient ratio A12
			Agricultural mechanization level A13
			Per capita agricultural production utility A14
			Urban–rural residents income difference coefficient A15
			Ratio of agricultural and non-agricultural production efficiency A16
		Social security A2	Rural deposit balance A21
			Ratio of urban–rural employed persons A22
			Ratio of urban–rural medical security benefits A23
			Ratio of per capita urban–rural consumption to expenditure A24
			Ratio of urban–rural residents under basic provision protection A25
		Public services A3	Popularization rate of latrines A31
			Ratio of urban–rural telephone users A32
			Rural primary school cultural penetration A33
			Ratio of urban–rural basic medical expenses A34
			Rate of population which benefits from tap water A35
			Ratio of urban–rural entertainment consumption expenditure A36
			Decrease in cultivated land area/Increase in built-up district area A37
		Environmental quality A4	Area of urban green built districts A41
			New sales for forest development in current year A42
			Green covered area as percentage of built districts A43
	Integral development	Economic development B1	Per capita GDP B11
			GDP growth ratio B12
			Industrial added value B13
			Total investment in fixed assets B14
			Urbanization rate/speed of industrialization B15
		Social security B2	Unemployment rate in urban area B21
			Per capita total retail sales for consumer goods B22
			Special fund to support agriculture in finance ratio B23
			Expenditure for social safety net and employment effort B24
			Urbanization ratio B25
		Public services B3	Doctors per 10,000 people B31
			Per 100 capita cultivated land area B32
			Full-time teachers per 10,000 students B33
			Public service expenditure to GDP ratio B34
			Per capital living floor space of rural residents B35
			Per capital living floor space of urban residents B36
			Basic public services growth /urban population growth rate B37
			Per capita business volume of post and telecommunication services B38
		Environmental quality B4	Forest-coverage rateB41
			Per capita public green space B42
			Industrial pollution production utility B43
			Total investment in environmental pollution to GDP ratio B44

The index system is composed of an urban–rural gap system and an integral development system. These dimensions are then divided into economic development, social security, public services, and environmental quality as secondary indicators. The main selection principle is indicators chosen by specific metrics with rural characteristics for the urban–rural gap and regional metrics with micro meaning about specific refinement indicators on education, healthcare, and economic rather than general indicators are followed for an integral development system.

Economic development level indicators measure regional economic strength, which is the material basis for overall urban–rural development. When the economic level happens advanced, with the convergence of occupation structure, income level, and education changes, rural residents' life satisfaction will increase even more than urban residents' life satisfaction [43]. The indicators of this part are selected based on industry tendency affects economic development. For example, the per capita agricultural production utility and the ratio of agricultural and non-agricultural production efficiency reflect the three main value-added industries, while urbanization rate/speed of industrialization reflects coordination between industrial development and population urbanization, and indicates whether the urban economy is harmonious.

The social security level indicators primarily explain the situation and governmental investment in employment and basic living standards. The ratio of the urban to rural residents under basic protection provisions, the ratio of urban to rural employment, and the ratio of urban to rural medical security benefits rate reveal social security uniformity degree for the urban–rural gap. In addition, unemployment rate in urban areas shows the stability of residents' work. With a stable job, basic living needs can be guaranteed. Expenditure for social safety net and employment efforts can reflect government support.

Public service level indicators such as entertainment, communication, water supply, and housing indicate the level of public services is available, and measure people's quality of life. Decreases in cultivated land area and increases in built-up districts reflect the land conversion efficiency to ensure smart land use. Compared with urban–rural gap, doctors per 10,000 people, per 100 capita cultivated land area, and full-time teachers per 10,000 students can give expression to the public resources, the whole region owned, and the coverage level. Other indicators also abide by the same principle.

The environmental quality indicators indicate the level of coordination among economic development, the green production environment, and the living environment, as sustainable industrial development requires a good ecological environment. Area of urban green built districts and new sales for forest development in the current year can reflect whether green space degree of urban is narrowing. Total investment in environmental pollution to the GDP ratio explains the level of government investment required to maintain a sustainable industrial environment. The industrial pollution production utility refers to the economic output lost through pollution, which means an environmental cost for economic development.

Tertiary indicators measure the differences between the urban industrial areas and the rural agricultural areas. The overall urban–rural coordination measurement model provides the decision-making basis for this study. In the research process, each subsystem was individually analyzed.

Figure 2 illustrates the relationships among overall urban–rural coordination and four dimensions. Economic development, social security, public services, and environmental quality give a comprehensive picture of regional development and the mutual influences among the subsystems. For example, industrial development can improve economic growth, but worsen environmental pollution, and sound public services can stimulate consumer demand. In combination with the measurement methods, single subsystem coordination values were first calculated. After data processing, a recombination and division based on the four dimensions was required. Finally, the various subsystems, which coordinate overall urban–rural development, were identified.

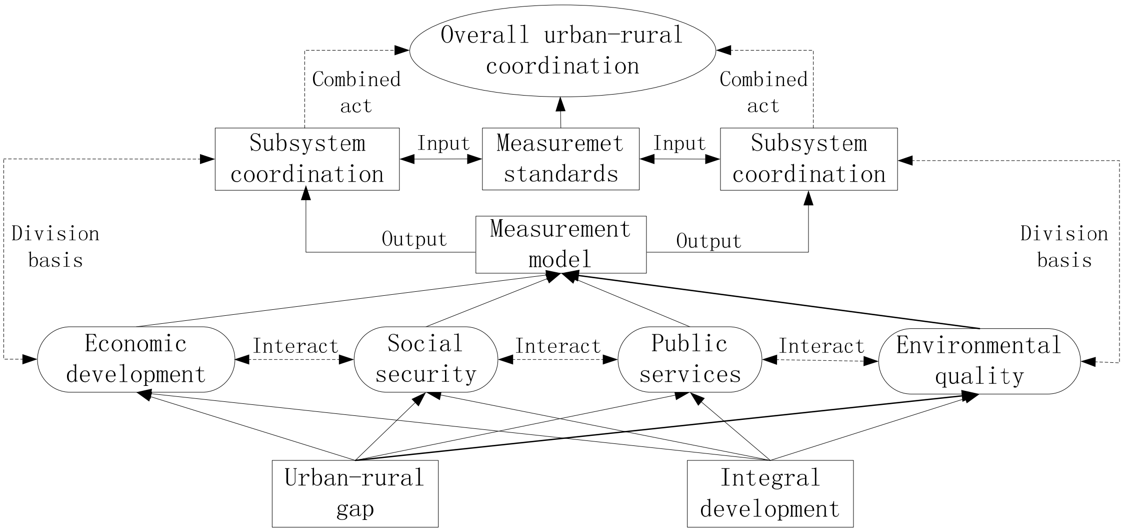

Figure 2. Index support diagram.

5. Overall Urban–Rural Coordination Measurement Method

5.1. Measurement Model

Principal component analysis (PCA) was applied to the data preprocessing to extract the initial effective indexes, and using the dimension reduction principle to restructure the data into several comprehensive indexes. To simplify the calculation process and improve processing efficiency, the data were concentrated to ensure that complete urban–rural information was retained. The main components and the variance contribution rates of each system were then determined.

Then, grey correlation analysis was used to calculate the correlation coefficients among the principal components based on principal components sum matrices and grey correlation coefficient matrices, which were built to measure the final overall urban–rural development coordination. The grey correlation analysis can reflect both the static and dynamic coordination, thereby improving the PCA.

The entropy weight method was introduced to determine the weight for each principal component of the integral development system, after that, the final measurement values for the principal components in the systems were determined. Combined with the evaluation standards, this paper measured overall urban–rural coordination using the overall urban–rural coordination measurement model shown in Figure 3.

Figure 3 shows the principles behind the building of this measurement model. After the model selected the indicators and processed the data, the measurement was analyzed based on the two overall urban–rural coordination goals. Due to relative independence of two systems and complicated index data, the principal components extracted by the PCA then replaced the original information system. Grey correlation analysis was used for the correlation coefficient calculation. These coefficients enhance the rationality of the measurement results, as the entropy weight—rather than the variance contribution rate—can improve the objectivity of the numerical analysis, ensuring the independence of two systems and making the final measurement results more credible.

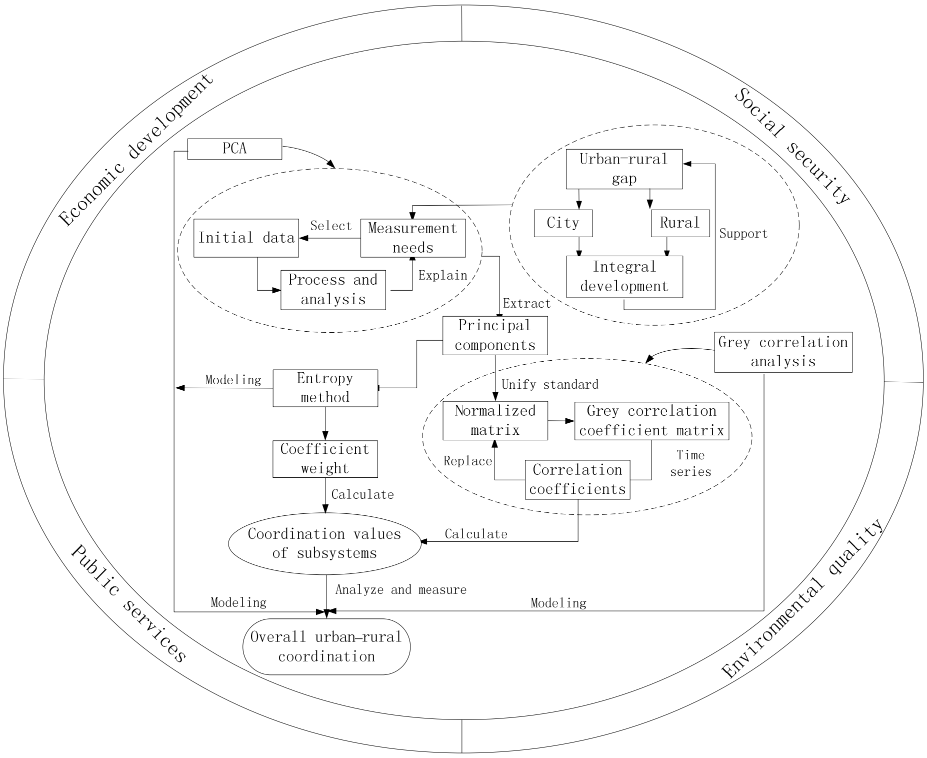

Figure 3. Measurement Model. PCA: principal component analysis.

5.2. Measurement Steps

The technological roadmap used in this paper is shown in Figure 4. The specific analytical steps are as follows:

(1) Data preprocessing. First, the indicator properties were distinguished, and statistics with the same trends were dealt with. The inverse indexes and the moderate indexes were converted to positive indicators, allowing for comparability. Then, the mean value processing was used to eliminate the differences in the dimensions and magnitudes. The conversion functions used were as follows:

$$f = -x_i \tag{1}$$

$$f = -|x_i - u_0| \tag{2}$$

(2) Determine the principal components sum matrices, $F_{jt}(l \times a)$ and $G_{tk}(l \times p)$. PCA was employed to extract the main indicators affecting the coordination of overall urban–rural development, after which the characteristic values, variance contribution rates, and cumulative variance contribution rates were identified. A cumulative variance contribution rate of more than 85% for the j-th component was determined to be main component. The PCA mathematical model was as follows:

$$\begin{cases} F_1 = a_{11}x_1 + a_{21}x_2 + a_{31}x_3 + \cdots + a_{i1}x_i \\ F_2 = a_{12}x_1 + a_{22}x_2 + a_{32}x_3 + \cdots + a_{i2}x_i \\ F_3 = a_{13}x_1 + a_{23}x_2 + a_{33}x_3 + \cdots + a_{i3}x_i \\ \vdots \\ F_j = a_{1j}x_1 + a_{2j}x_2 + a_{3j}x_3 + \cdots + a_{ij}x_i \end{cases} \tag{3}$$

Formula (3) only reflects the F_{jt} value at a certain time point t.

(3) Build the grey correlation coefficient matrices $R_j(l \times p)$. The principal components $F_{tj}(l \times a)$ for urban–rural gap and $G_{tk}(l \times p)$ for the integral development system were normalized, and the grey correlation coefficients between each group with F_{tj} were used as reference sequences, such as $F_{t1} - G_{t1}, G_{t1}, \cdots, G_{tk}$, and were calculated for each year.

$$r_{lp} = \frac{\min_{l} \min_{p} \Delta_l(p) + \rho \max_{l} \max_{p} \Delta_l(p)}{\Delta_l(p) + \rho \max_{l} \max_{p} \Delta_l(p)} \tag{4}$$

In the formula, ρ is the distinguishing coefficient, the general value for which is 0.5.

$$a = 1, 2, \cdots, j; l = 1, 2, \cdots, t; p = 1, 2, \cdots, k.$$

And j is the number of principal components of the urban–rural gap system, while k represents the number for the integral development system. Thus, the number of grey correlation coefficient matrices will be j.

(4) Calculate the coordinated value $C_{tj}(l \times 1)$ for the j-th subsystem. Entropy weights w_p were determined, and correlation coefficients r_{lp} of matrix $R_j(l \times p)$ were multiplied by weight separately, after which they were summed.

$$e_p = -\frac{1}{\ln t}\left(\sum_{l=1}^{t} f_{lp} \ln f_{lp}\right) \tag{5}$$

$$f_{lp} = \frac{1 + b_{lp}}{\sum_{l=1}^{t}\left(1 + b_{lp}\right)} \tag{6}$$

$$w_p = \frac{1 - e_p}{\sum_{p=1}^{k}(1 - e_p)} \tag{7}$$

$$C_{tj} = \sum_{p=1} w_p R\left(r_{lp}\right)_j \tag{8}$$

In the formula, b_{lp} is the principal component standardization matrix.

(5) Determine the static C_{st} and dynamic C_{dt} coordination values. The formulas used were as follows:

$$C_{st} = \frac{1}{j}\sum_{a=1}^{j} C_{ta} \tag{9}$$

$$C_{dt} = C_{st} - C_{st-1} \tag{10}$$

After the calculations from the steps above, the final analysis results would be composed of C_{tj}, C_{st}, and C_{dt}.

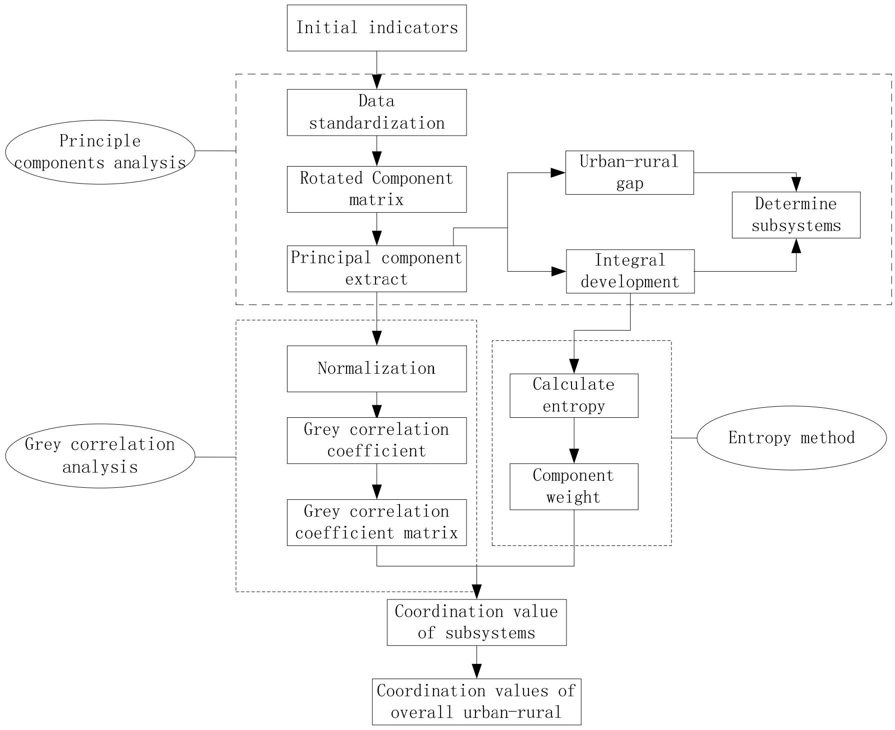

Figure 4. Technological roadmap.

6. Case Analysis

Based on the index system requirements, ten-year statistics taken from the "Sichuan statistical yearbook" [46–55], the "Sichuan rural yearbook" [56–64], the "Chinese population & employment statistics yearbook" [65–73], and the "China health statistics yearbook" [74–81] were extracted and analyzed to develop the initial index system with the conversion formulas.

Index preprocessing and the PCA were completed using SPSS software (22.0, IBM Corporation, New York, NY, USA); the results for which are shown below:

Three principal components in Table 2 were extracted from the urban–rural gap system and restructured into an economic development subsystem (F1), a residents' living quality subsystem (F2), and an environmental quality subsystem (F3). Four principal components in Table 3 were extracted from the integral development system with no recombination. And principal component sum matrix was showed in Table 4.

The grey correlation coefficient matrix for the main components and the static and dynamic coordination values for the overall urban–rural coordination were calculated using Equations (4)–(10). The following calculations were completed in Matlab software (R2012a, Mathworks Corporation, Natick City, MA, USA) and main data results were shown in Tables 5 and 6.

Table 2. Urban–rural gap—Interpretation of total variance.

Ingredients	Initial Eigenvalue			Extracting the Square and Load		
	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %
1	15.932	75.865	75.865	15.932	75.865	75.865
2	2.247	10.701	86.566	2.247	10.701	86.566
3	1.018	4.850	91.415	1.018	4.850	91.415
4	0.867	4.127	95.543			
L	L	L	L			
21	-1.611×10^{-15}	-7.67×10^{-15}	100.000			

Table 3. Integral development—Interpretation of total variance.

Ingredients	Initial Eigenvalue			Extracting the Square and Load		
	Total	**Variance %**	**Cumulative %**	**Total**	**Variance %**	**Cumulative %**
1	14.617	66.441	66.441	14.617	66.441	66.441
2	2.557	11.621	78.062	2.557	11.621	78.062
3	1.597	7.259	85.321	1.597	7.259	85.321
4	1.126	5.120	90.441	1.126	5.120	90.441
5	0.905	4.114	94.555			
L	L	L	L			
22	-9.649×10^{-16}	-4.386×10^{-15}	100.000			

Table 4. Principal component sum matrix.

Year	Urban–Rural Gap			Integral Development			
	F1	**F2**	**F3**	**G1**	**G2**	**G3**	**G4**
2005	−1.06	1.99	−1.56	−1.26	0.26	−1.20	0.18
2006	−1.18	0.62	1.18	−1.17	−0.12	−1.30	−0.13
2007	−1.08	−0.51	0.95	−0.94	0.49	0.29	−0.19
2008	−0.77	−1.11	0.42	−0.71	1.02	1.90	0.76
2009	−0.17	−0.70	−0.30	−0.22	−0.34	0.81	−0.36
2010	0.10	−0.84	−0.66	0.24	−1.70	0.94	−0.87
2011	0.61	−0.55	−1.01	0.53	−1.41	−0.21	0.90
2012	0.88	−0.54	−0.78	0.91	−0.36	−0.64	−0.23
2013	1.25	0.65	0.44	1.21	1.38	−0.23	−1.85
2014	1.41	0.98	1.32	1.41	0.79	−0.34	1.78

Table 5. Grey correlation coefficient matrix.

Year	F1				F2				F3			
	G1	**G2**	**G3**	**G4**	**G1**	**G2**	**G3**	**G4**	**G1**	**G2**	**G3**	**G4**
2005	0.8857	0.5401	0.9172	0.5556	0.3333	0.4844	0.3375	0.4731	0.8052	0.4052	0.775	0.4161
2006	0.9936	0.5939	0.9281	0.5962	0.4758	0.6871	0.4584	0.6842	0.3454	0.4882	0.3333	0.4863
2007	0.9172	0.4968	0.5308	0.6352	0.7908	0.619	0.6701	0.8355	0.3962	0.7294	0.6526	0.521
2008	0.9627	0.4641	0.3673	0.5032	0.8025	0.4328	0.3506	0.4649	0.5232	0.6739	0.4559	0.7848
2009	0.9688	0.9012	0.6126	0.8908	0.772	0.8186	0.5183	0.827	0.9394	0.9688	0.5277	0.9538
2010	0.9172	0.4627	0.6485	0.6151	0.6007	0.6539	0.4772	0.9819	0.5794	0.5439	0.4366	0.8552
2011	0.9509	0.4342	0.654	0.8424	0.6007	0.6539	0.827	0.5285	0.446	0.7561	0.6078	0.3937
2012	0.981	0.5556	0.5049	0.5827	0.5285	0.9003	0.942	0.8398	0.5566	0.8147	0.6881	0.8908
2013	0.9748	0.9226	0.5116	0.3333	0.7437	0.69	0.6487	0.3939	0.6169	0.5688	0.6492	0.3513
2014	1	0.7143	0.4697	0.8073	0.7908	0.8953	0.5518	0.6701	0.9323	0.7006	0.4276	0.7294

Table 6. Coordination values.

Year	C1	C2	C3	Cs	Cd
2005	0.7216	0.4083	0.5973	0.5757	
2006	0.7751	0.5782	0.4146	0.5893	0.0136
2007	0.6444	0.7286	0.5754	0.6495	0.0602
2008	0.5744	0.5128	0.6113	0.5662	−0.0833
2009	0.8452	0.7361	0.8504	0.8106	0.2444
2010	0.6592	0.6803	0.605	0.6482	−0.1624
2011	0.7188	0.6512	0.5517	0.6406	−0.0076
2012	0.6558	0.8028	0.7389	0.7325	0.0919
2013	0.6873	0.6188	0.5456	0.6172	−0.1153
2014	0.7492	0.7291	0.6991	0.7258	0.1086

7. Results Analysis

Table 7 shows the classification criteria for the overall urban–rural coordinated development.

Table 7. Coordination Classification criteria.

Coordination Value	Coordination Level
$0 < C_i \leq 0.4$	Seriouslyuncoordinated
$0.4 < C_i \leq 0.5$	Moderately uncoordinated
$0.5 < C_i \leq 0.6$	Mildly uncoordinated
$0.6 < C_i \leq 0.7$	Mildly coordinated
$0.7 < C_i \leq 0.8$	Moderately coordinated
$0.8 < C_i \leq 0.9$	Well coordinated
$C_i > 0.9$	Highly coordinated

The evaluation criteria were only applied to the static coordination values. The dynamic coordination was judged directly from the data for two adjacent years.

For a more subjective observation of the coordination values in the various subsystems and the overall urban–rural development, urban–rural coordination value variations were generated using the data in Table 6, as shown in Figure 5.

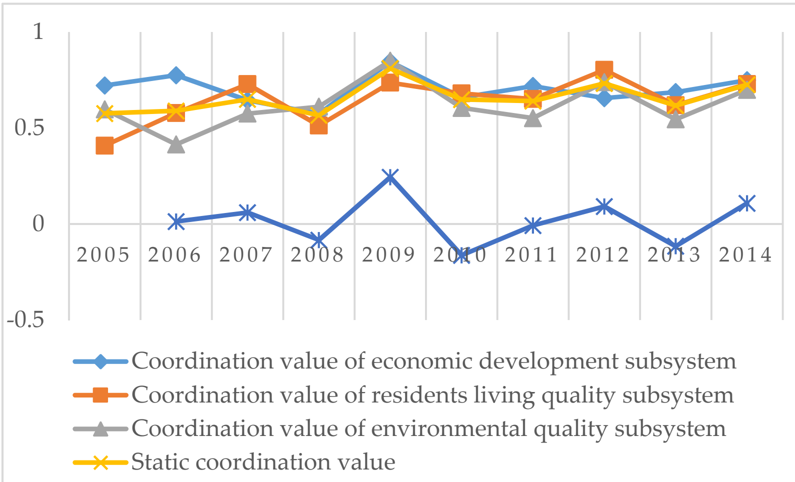

Figure 5. Coordination values variation diagram.

After analyzing the data in Tables 6 and 7 and in Figure 5, the following conclusions can be drawn:

(1) Overall static urban–rural coordination was steady. Before 2008, the subsystem values differed significantly. After 2008, the overall urban–rural coordination values ranged from 0.5 to 0.8, and followed the same trend as the subsystems, indicating that the region had emerged from a relatively uncoordinated situation. In June 2007, the Chengdu-Chongqing region was classified as an experimental urban–rural reform zone. Since that time, Sichuan province has focused on supporting a series of urban–rural projects, and the government has refocused their attention from economic development to social life and environmental construction, leading to an increase in these values in 2009. Agricultural support has been changed to focus more on resource sharing. The overall coordination value reached a peak of 0.7325 in 2012; however, due to national policy changes, the value declined marginally over the subsequent two years. Before 2007, large differences existed among the coordination values of three subsystems. Economic development subsystem coordination value was the highest, followed by living quality and the environmental quality, which reflected the previous emphasis on economic development and the neglect of the environment. Excessive economic development had consumed environmental resources. Both of them restrict and stimulate each other [82].

(2) The economic development subsystem was basically coordinated. Compared with other subsystems, more attention had been paid to the economy. From the minimum value in 2008,

the economic development subsystem coordination values have fluctuated between 0.6 and 0.84.The government has attached great importance to the regional economy, rural labor transfers, and the development of township enterprises, which has led to basically coordinated economic development in Sichuan province. While the urban–rural income ratio dropped from 3.11 to 2.76, the income gap was still large, but there was an obvious shrinking trend; however, the ratio did not influence the fluctuations in the economic development coordination subsystem.

(3) The resident quality of life subsystem and the environmental quality subsystem continued to fluctuate. The resident quality of life subsystem implies a basic livelihood and public service provision guarantee. However, as can be seen, the value was only 0.4083 in 2005, and the system was on the verge of being seriously uncoordinated, indicating that the quality of life was low and there was a lack of rural infrastructure. By 2012, the value had risen significantly to 0.8028; however, the actual rural medical insurance reimbursement rate was low, and the public service and social security systems needed to be improved. The environmental quality subsystem was mildly to moderately uncoordinated, which improved to mildly coordinated in 2014, and was the most volatile subsystem. Agricultural and non-agricultural production can both cause environmental pollution, so if agricultural production efficiency is less than the environmental pollution effectiveness, the urban–rural gap could enlarge, and urban–rural coordination would decline. With mature pollution treatment technologies, regional industrial structures can influence the utility of the agricultural and non-agricultural production, causing large fluctuations in coordination in the environmental quality subsystem. As economic strategies in China and globally constantly change, the internal subsystems are becoming increasingly complex. It is necessary to improve the quality of life of the residents and to ensure environmental protection requirements. The government should pay attention to coordinating development to enhance quality of life investments and take environmental protection measures to ensure the future sustainable development of the regional economy. Therefore, industrial development needs to focus on green production and strengthening environmental governance.

(4) The overall dynamic of urban–rural coordination had cyclical fluctuations. From Figure 5, it can be seen that the dynamic coordination annual fluctuation value remained static at 0.1, indicating that urban–rural coordination development was unstable and had poor ineffective feedback. Although the overall urban–rural development so far has improved the urban–rural coordination, the varying focus on different urban–rural development factors has led to large fluctuations. The Sichuan provincial government needs to analyze the weaknesses in their work plans and continue to strengthen their top-level systems design. As stable overall urban–rural development and sustainable economic and social development are required, there needs to be a focus on long-term urban and rural development convergence.

(5) Large space of overall urban–rural development. The analysis results from the various subsystems showed that Sichuan Province has maintained a basically coordinated economic development. With the activation of the 13th Five Year Plan and the attention on the Three Rural Issues, as the economic center of the southwest, Sichuan Province still has room for development. The guiding principles of the 13th Five Year Plan, including balance in promoting economic development, political construction, cultural construction, social construction, ecological civilization construction, and Party building need to be considered to ensure that the well-off society is built on schedule. Agricultural modernization shall have significant progress made in people's living standards, and quality of life shall have been improved generally. The rural poor population in China under the current standard and in poor counties shall have been lifted out of poverty. Regional overall poverty will have been solved. Therefore, the rural areas as the focus of government work to achieve modernization and reduce poverty. Overall urban–rural development will remain as an important strategy, combined with targeted poverty alleviation, to achieve a better development of urban and rural areas.

8. Conclusions

In this paper, statistics from 2006 to 2015 from the "Sichuan statistical yearbook" [46–55], the "Sichuan rural yearbook" [56–64], the "China population & employment statistics yearbook" [64–73], and the "China health statistics yearbook" [74–81] were extracted to establish a coordination index system to judge overall urban–rural development. Then, economic development, social security, public services, and environmental quality were examined to assess Sichuan Province's urban–rural gap and integral development. Using a combination of PCA, grey correlation analysis, and entropy, the principle indicators were quantitatively researched, from which multi-dimensional coordination values for Sichuan Province were determined. The analysis in this study about the overall urban–rural coordination came to the following inspirations:

(1) Coordination research can scientifically reflect the systematic characteristics of overall urban–rural systems scientifically. The coordination value of the urban–rural gap and integral development is the evaluation criteria of overall urban–rural work, rather than measuring the urban–rural gap or integral development alone. The higher coordination degree means the pace of narrowing the gap and integral development in urban and rural areas tends to be consistent, and the overall urban–rural coordination has reached a high level.
(2) Comprehensive method can scientifically obtain data results. Based on the PCA dimension reduction principle, the large and cumbersome index system is replaced with a few principal components to explain the information, thus simplifying the calculation and reducing the interference of irrelevant information. The urban–rural gap and integral development PCA-Grey Entropy measurement model includes subsystem measurements and data analyses, meaning that the various subsystem and overall urban–rural coordination measurement results are more objective.
(3) The situation of overall urban–rural development is comprehensively reflected from multi-dimensional perspectives, including subsystems, static and dynamic aspects, and provides evaluation ideas for development work. When we are addressing urban and rural issues, in addition to the overall situation, the internal structure and the dynamic changes should also be analyzed. It helps to grasp the study area in order to carry out the distribution of work in economic, public service, environmental protection and so on. The changes from the coordination subsystems can reflect which section of the overall urban–rural development is relatively weak, and, combined with the regional background, well-directed suggestions for future development planning can be put forward.

There were a few limitations to this research. Subsystem division was from the macro level, and the final results were also the coordination values of the subsystems, and were still comprehensive values based on tertiary indicators. Therefore, it was not directly comparable until the final coordination values of subsystems were drawn out. Apart from this, this paper considered a wide range of factors when establishing the comprehensive index system, but not all factors that might affect urban–rural coordination were included. Further, the dynamic effects mechanisms of the subsystems were not fully researched or analyzed.

Therefore, future research work will focus on the measures needed to improve this evaluation system through an in-depth study of the internal logic between the indicators and the influences on the urban–rural coordination mechanism, as well as the extension of coordination study to the more detailed urban–rural issues.

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