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Dynamic Characteristics and Evolution Analysis of China's Rural Population Migration Networks from 2000 to 2020 Based on the Perspective of Regional Differences

Yihu Zhou [1] and Tingting Fang [2,*]

[1] College of Public Administration, Nanjing Agricultural University, Nanjing 210095, China; 2016209024@njau.edu.cn
[2] Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing 210008, China
* Correspondence: ttfang@niglas.ac.cn

Abstract: The large-scale cross-regional migration of rural migrants is a significant feature of the current social system in China, affecting the sustainability of social and economic development. Using China National Census data and socio-economic panel data, we applied the complex network analysis method to construct a rural population migration network and analyze its characteristics, evolution, and mechanisms of network formation and changes. The research findings are as follows: (1) From 2000 to 2020, the rural population migration network developed rapidly, the network scope expanded continuously, regional participation gradually grew, and the inter-regional rural population migration relationship became increasingly complex. The overall network gradually evolved from an early segmented and loose structure to a monolithic and solid structure. (2) The in-degree centralization of the network remained higher than the out-degree centralization. The inbound migration pattern of the rural population was more compact than the outbound migration pattern, and the internal network displayed aggregated inbound population migration and dispersed outbound population migration flow characteristics. (3) The network had a distinctive "core–edge" character, with the core areas and the main migration flows in the network demonstrating high similarity across different periods. The overall network gradually developed around the core areas where the rural population moved in and out. (4) The influence mechanism between the later migration network and the geographical differences was more complex than in the early period. Differences in the regional development levels and geographical factors continued to influence the mobility choices of the rural population, whereas differences in income levels, cost of living, employment opportunities, and education funding only affected the rural migration network during specific periods. Based on these findings, reasonable migration policies should be formulated to ensure sustainable urban and rural development.

Keywords: rural migrants; migration network; complex network analysis; QAP analysis; regional differences

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1. Introduction

Since 1978, with the reform and opening up of China, along with the implementation of the Household Contract Responsibility System, rural surplus laborers have been liberated by degrees and have started working in cities, giving rise to the pattern of rural–urban population migration. Starting in the 21stcentury, with the expansion of the scope of the reform and rapid industrialization, secondary and tertiary industries have generated a strong demand for human resources. The phenomenon of the "migrant labor wave" has emerged as a unique feature of this era, with working away from their hometowns becoming an important way for farmers to increase their income [1–4]. In 2021, the total number of migrant workers in China reached 172 million. Rural migrants, including migrant workers and their accompanying relatives, have become the main component of China's mobile population, and are a crucial factor affecting sustainable social and economic

development [5–9]. Against the background of uneven regional economic development and industrial layout, the long-term presence of large numbers of rural migrants will continue to be an important feature of the social system in China [10–13].

The Chinese government pays close attention to the orderly flow of rural migrants, viewing them as an important component of the new urbanization and rural revitalization strategies, with many policy documents emphasizing their importance. In this context, analyzing the migration of rural populations is necessary to improve coordinated regional development, promoting urban–rural integration, and ensuring the successful implementation of the new urbanization and rural revitalization strategies [14,15].

Academics have conducted various studies on the subject of rural population migration, primarily focusing on micro-individuals and employing theories of management and economics. They have utilized methods such as logistic models, probit models, and structural equation models to analyze the migration behavior, driving factors, and willingness of rural migrants to become urban residents. It is generally believed that the price disparity between industry and agriculture [16–18], the rising opportunity cost due to farming [19], and changes in the relative economic status of rural households are important reasons for rural labor migration [20]. However, the high cost of living in cities [21,22], the rural–urban split household registration system [23–25], and the related employment and social security systems are factors that hinder rural migrants from settling in cities [26–33], resulting in them moving between regions [34–36] and exhibiting characteristics of incomplete integration [37–39]. Fewer studies have analyzed the phenomenon of rural population migration from a macro perspective, and many scholars have taken the migrant population as the object of study without classifying it further into sub-groups. However, rural migrants form a subset of the migrant population, and due to the rural–urban dual system and the household registration system, rural migrants and urban migrants differ in terms of resources, mobility purpose, employment opportunities, and welfare security. Therefore, the study of these groups should not be generalized. Existing macroscopic studies on rural migrants have mainly been based on theories of geography, applying methods such as autocorrelation analysis, hotspot analysis, and spatial lag/error models to analyze the group size, geographical distribution, and agglomeration pattern of rural migrants. These studies have found that the total number of rural migrants has been increasing [40]. The main agglomeration area for rural migrants is the eastern coastal region [41–43], with their distribution in the city overlapping with the industrial layout to a large extent [44–46]. The distance factor is an obstacle to the migration of the rural population [47].

These macro and micro studies are important for analyzing the characteristics of Chinese rural migrants and promoting their integration as residents into urban areas. However, due to the large scale of rural migration and the spatial trajectory formed by each migrant from their place of origin to their destination, rural migration in general presents a significant network structure. This structure possesses explicit spatial pattern characteristics and potential internal structural characteristics. Previous microscopic studies have mostly used local research data, which are limited by coverage and sample size. This approach cannot construct a comprehensive rural population migration network. At the same time, analyzing migration from a macroscopic perspective is challenging due to the limitations of macroscopic studies, which prioritize the surface spatial pattern rather than the internal structure and migration path of the rural population migration network. Moreover, previous studies have predominantly used raw attribute data for analysis, and have ignored the differences and connections between regions, resulting in information loss in the data analysis process [48].

To overcome these limitations, this study proposes the use of complex network analysis tools to construct a rural population migration network incorporating directional information based on relationship data between regions. We analyze key features such as the core regions, migration paths, and network structure, and explain the evolutionary process and driving mechanisms of the network. The aim is to provide references for the formulation of relevant urbanization and rural revitalization policies.

The structure of the paper is as follows: Section 1 contains the research background; Section 2 is an introduction to the research ideas, methods, and data sources; Section 3 discusses the construction of the migration network, analyzing its characteristics and evolution; Section 4 provides an analysis of the factors affecting the formation and changes in the migration network; a discussion of the research results is found in Sections 5 and 6 comprises the conclusion and suggestions.

2. Research Methods and Data Sources

2.1. Research Ideas and Methods

In this paper, the term "rural migrants" refers to the rural household population whose current place of residence is different from their registered residence. First, we extract the rural migrant data from the China National Census data, and then use the complex network analysis method to construct the rural population migration network for 2000, 2010, and 2020 based on the migration relationship between regions. Next, we examine the structural characteristics and developmental evolution of the migration network in different periods. Then, based on theoretical analysis and previous research experience, we select the socio-economic indicators that may influence the migration network from the perspective of regional differences, and construct a matrix of the relationship among the differences for each indicator across regions. Next, we use the QAP (Quadratic Assignment Procedure) analysis approach, which is adept at handling "relationship" data, to define the influence of regional differences on the migration network and identify the driving mechanism.

2.1.1. Complex Network Analysis Method

The concept of the complex network matured in the late 1990s, developing from topology theory, which primarily manifests in a strong diversity of network nodes and connections, a complex network structure, and an evident cluster effect [49].The analysis of complex networks mainly focuses on the network structure characteristics and the discovery of key nodes [50]. In recent years, the theory of complex networks has developed rapidly and has been widely used in research into trade networks [51–53], transportation networks [54,55], and virtual resource trading networks with good results [56–58]. Rural migrants embody the population mobility relationship between different regions, and this is an appropriate topic for the application of complex network analysis.

In the analysis of network structure characteristics, the network density, node association degree, node hierarchy degree, global efficiency, and global centralization are important indicators that reflect the network structure [59]. Among them, the network density is determined by the difference between the actual rural population migration network and the theoretical star-shaped network, and the more similar they are, the higher the network density and the tighter the overall structure. The node association degree is ascertained by the degree of direct connections between regions in the network. When most regions need to be connected by the core region, the node association degree decreases and the overall structure of the network lacks robustness. The node hierarchy degree is established via the status gap between regions in the network. The larger the status gap between the core and peripheral regions, the higher the node level difference and the clearer the hierarchical relationship in the network. The global efficiency is determined by the distance of the shortest path between the regions in the network. The longer the distance, the more regions are included in the path, and the lower the efficiency, but the participation of the regions in the network is higher. The global centralization reflects the network dependency on the core region. The higher the value, the more the network relies on certain core regions to form and develop. The identity of key nodes is mainly reflected by the weighted centrality of each region, which can be further divided into weighted in-degree centrality and weighted out-degree centrality in the migration network based on the incoming and outgoing population relationship. The higher the weighted in-degree(out-degree) centrality of a region, the more central it is in attracting (moving out) the rural population.

2.1.2. Quadratic Assignment Procedure

The data used in analyzing the driving mechanism of the migration network are relational matrix data, which have the property of "linkage", and therefore directly violate the principle of "multicollinearity", so cannot be analyzed by traditional econometric models [59]. The quadratic assignment procedure method provides an effective tool to solve this problem. It uses several relational matrices in the form of N × N as variables, compares the data trends in different matrices, tests the relational data by random nonparametric permutation, and finally gives the econometric analysis results from among the variables to help interpret the relationship between the "relationships" [60].At the same time, this method does not assume that the variables are independent of each other. Thus, it is possible to integrate the theoretical factors affecting rural migrants into the econometric model in the empirical analysis, which enhances the scope of the model and its explanatory power. Previous studies have shown that this method has high reliability and advantages in analyzing relational data [61].

2.2. Data Sources

The data used in this research were obtained from the fifth, sixth, and seventh China National Censuses in 2000, 2010, and 2020. By filtering the current residence, registered residence, and the nature of household registration, the rural population migration data were extracted to construct a directional rural population migration matrix among 31 provinces of the Chinese mainland. Various socio-economic indicator data were obtained from the China Statistical Yearbook and the database of the National Bureau of Statistics in the corresponding years.

3. Characteristics and Evolution of the Rural Population Migration Networks

Since rural migration behavior varies widely among the various regions of China, including all migration behaviors in the analysis may lead to a dilution of the characteristics of the migration networks, and their evolutionary processes may not be fully revealed. Therefore, this study draws on the experience of previous studies and defines only large-scale rural migration flows of more than 10,000 people as effective migration relationships between regions [48]. Based on the data of the 2000, 2010, and 2020 censuses, the rural population migration network corresponding to "current residence" and "registered residence" was constructed (Figure 1), and the characteristics and evolution process of the network in each period were analyzed.

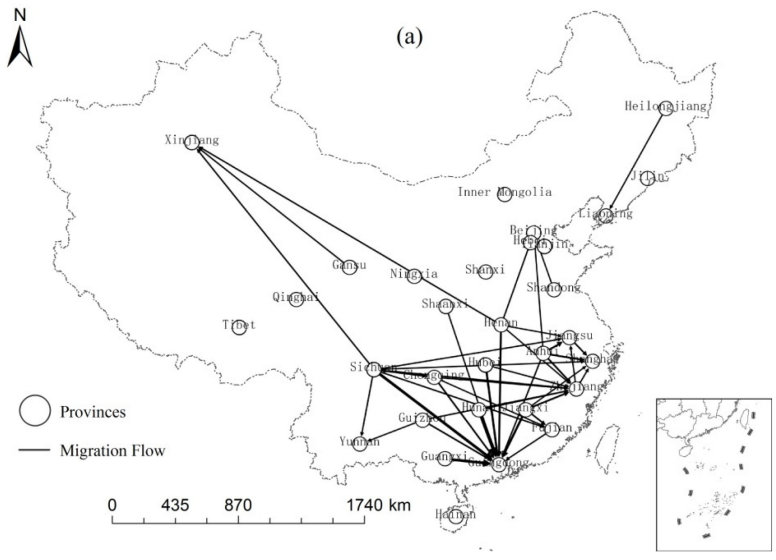

Figure 1. *Cont.*

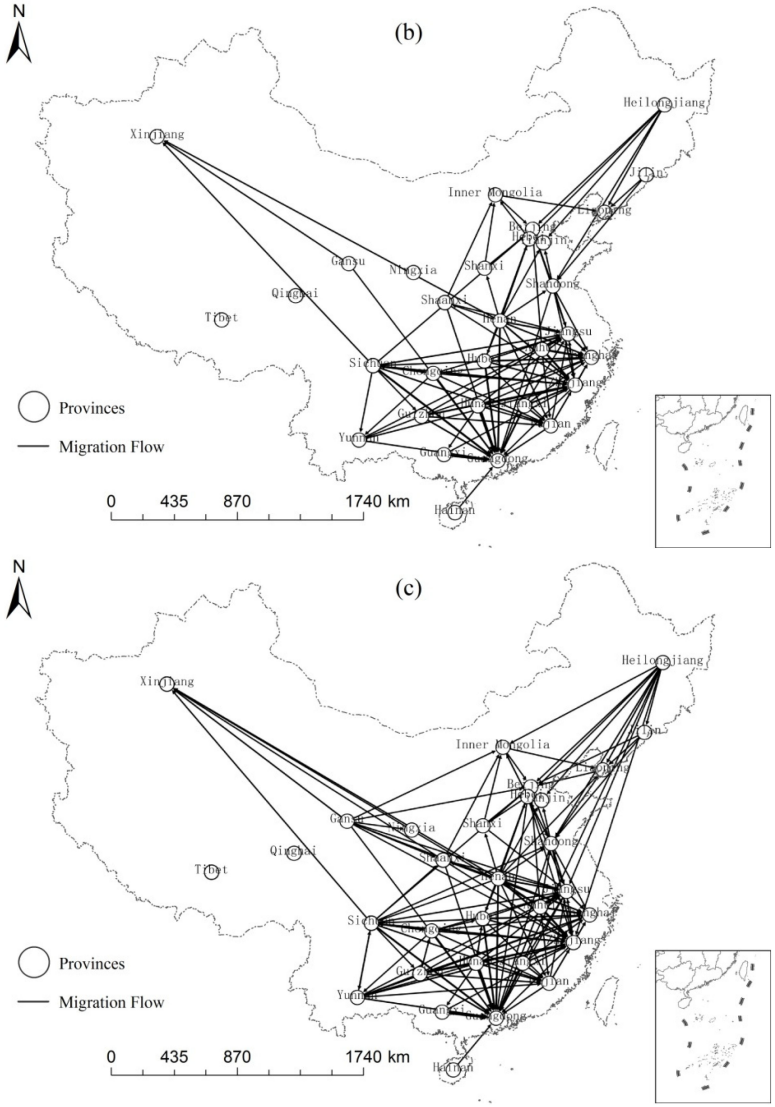

Figure 1. (**a**) Rural population migration network in 2000. (**b**) Rural population migration network in 2010. (**c**) Rural population migration network in 2020.

3.1. Evolution of the Network Structure Characteristics

From Figure 1 and Table 1, it can be seen that China's rural population migration network continued to be in a state of development during the 2000–2020 period, with the number of migration flows in the network increasing period by period, and the overall network undergoing an evolutionary process from simple to complex. There were still eight regions nationwide that did not have large-scale rural migration of more than 10,000 people in 2000, and these regions were mainly frontier provinces that were isolated from the overall network. The entire network contained only 43 effective rural migration flows, most of which were directed to the southeastern coastal provinces. Some of these were not connected to the overall network, leaving the migration network in a fragmented state with a loose overall structure, in which most regions had only one-way rural migration relationships.

By 2010, the total number of rural migrants between regions had increased by 149.87%, the number of effective migration flows had increased to 101, and all migration flows were connected to the overall network. Thus, the rural migration network was integrated, with the rural population starting to migrate in both directions between regions, and only three isolated regions left.

Table 1. Structural characteristics of rural migration networks.

Indicator	2000	2010	2020
Node characteristics			
Total number of nodes	31	31	31
Number of unidirectional nodes	18	14	10
Number of isolated nodes	8	3	2
Migration flow			
Total number of migration flows	923	929	930
Number of flows with over 10,000 people	43	101	146
Total migration (people)	2,589,987	6,471,562	9,470,739
Incremental migration (people)	–	3,881,575	2,999,177
Network structure			
Network density	0.046	0.109	0.157
Degree of node association	0.454	0.813	0.873
Degree of node hierarchy	0.982	0.985	0.814
Global efficiency	0.890	0.795	0.714
Network centrality			
In-degree centralization	13.942%	13.883%	14.067%
Out-degree centralization	3.932%	5.060%	4.613%

Note: Network structure indices were calculated in UCINET v6.560 (Analytic Technologies Company, Lexington, KY, USA) based on migration flows with over 10,000 people.

By 2020, the total migration flows had further increased by 46.34% compared with the previous period, and the network contained 146 effective rural migration flows, with the eastern and southern provinces being closely related to each other. The migration flows to the central and western provinces also increased significantly, leaving only two regions, Qinghai and Tibet, absent from the migration network.

Overall, China's rural population migration network has evolved rapidly over the past 20 years, with the network gradually expanding in scope and the rural migration relationship between regions becoming increasingly complex. Although the overall migration direction remains west to east, a reverse rural population migration trend in the later stages of the network has emerged, with the central and western regions increasing their ability to attract the rural population.

The internal structure of the migration network also changed. As shown in Table 1, the network density and degree of node association increased period by period, from 0.046 and 0.454 in 2000 to 0.157 and 0.873 in 2020, respectively. The increase was 241.30% and 92.29%, respectively, over20 years. This reflects the development process in that the number of migration flows in the network is gradually increasing and the regions are getting progressively closer. Meanwhile, the degree of node hierarchy and global efficiency gradually decreased from 0.982 and 0.890 in 2000 to 0.814 and 0.714 in 2020, decreasing by 17.11% and 19.78%, respectively. This is a manifestation of the increase in the two-way rural migration relationship in the network, the gradual decrease in the hierarchical relationship between regions, and the increasing participation in rural migration. Taken together, the internal structure of the rural population migration network has undergone an evolutionary process from sparse to tight and from fragile to solid.

The overall centrality of the network has also undergone some changes, but the relative patterns of inbound and outbound migration are more convergent. In the temporal dimension, the in-degree centralization of the network shows a trajectory of change that first declined and then increased. That is, compared with 2000, the status of the core areas absorbing the rural population declined in the network in 2010; the rural population had more destination choices when migrating; and the pattern of inbound migration tended to be dispersed. By 2020, however, the in-degree centralization returned to a higher level; a small number of core regions attracted a large proportion of the rural population; and the immigration patterns shifted to a more clustered state. In contrast, the network's out-degree centralization showed an increasing and then declining trajectory.

In the 2000–2010 period, the out-degree centralization of the network improved greatly, reflecting that the clustering of the outgoing population was increasing, with most of the rural population in the network moving out from a few core areas. By 2020, the out-degree centralization of the network decreased slightly; the number of areas with the rural population moving out increased comparatively; and the pattern of emigration tended to be dispersed.

In addition, from the perspective of inbound migration compared with outbound migration, the out-degree centralization was significantly lower than the in-degree centralization in all periods, indicating that the number of areas with the rural population moving out exceeded those with the rural population moving in. The inbound migration pattern of the rural population was more compact than the outbound migration pattern.

3.2. Evolution of the Network Node Characteristics

By observing the evolution of each node, we found that the role of each region in the migration network did not change over time, and the overall network showed a more distinctive "core–edge" character. As shown in Figure 2, from 2000 to 2020, Beijing, the capital city; Jiangsu, Zhejiang and Shanghai in the Yangtze River Delta; and Guangdong and Fujian in the southeastern coastal region all maintained a high-weighted in-degree centrality and were the key areas attracting the rural population. In contrast, Anhui, Jiangxi, Henan, Hubei, and Hunan provinces in the central inland region and Guangxi, Chongqing, and Guizhou provinces in the southwest region had a high-weighted out-degree centrality and were the main areas from which the rural population emigrated. The role and relative position of each region in the network were comparatively similar in different periods. The regions with a higher rural population moving out (or moving in) in the initial network still had a large proportion of the rural population moving out (or moving in) in the later network.

Figure 1 and Table 2 show that the main migration flows in the networks in different periods were also convergent, that the migration flows with higher flows in the initial network were repeated in the later network, and that the flows continued to grow. The rural population migration range was also somewhat similar between the periods, with Beijing attracting rural populations from the whole north and northeastern China, while Jiangsu, Zhejiang, and Shanghai mainly attracted rural populations from provinces in eastern and central China. Most of the rural populations from provinces in southern China migrated to Guangdong and Fujian. Xinjiang was the core area attracting rural populations in the northwest region.

In general, although the migration flow and volume in the rural population migration network continued to grow and the structure became increasingly complex, the areas at the core of the incoming or outgoing population did not change. The peripheral areas participated in rural migration around these core areas, and the overall network was built and developed by the core areas. The later environmental changes did not disrupt the development direction determined by the earlier network. Massey's migration network theory provides a basis for explaining this phenomenon [62]. The formation of a migration network is accompanied by the formation of an information dissemination network, consisting of social relations such as relatives, hometowns, and friends, which is the main source of reference information for non-migrants when making migration decisions. This mechanism allows the latecomers in the migration network to effectively avoid migration risks, and encourages them to follow the migration paths of their predecessors, thus strengthening and developing the original migration network and revealing a significant cumulative effect.

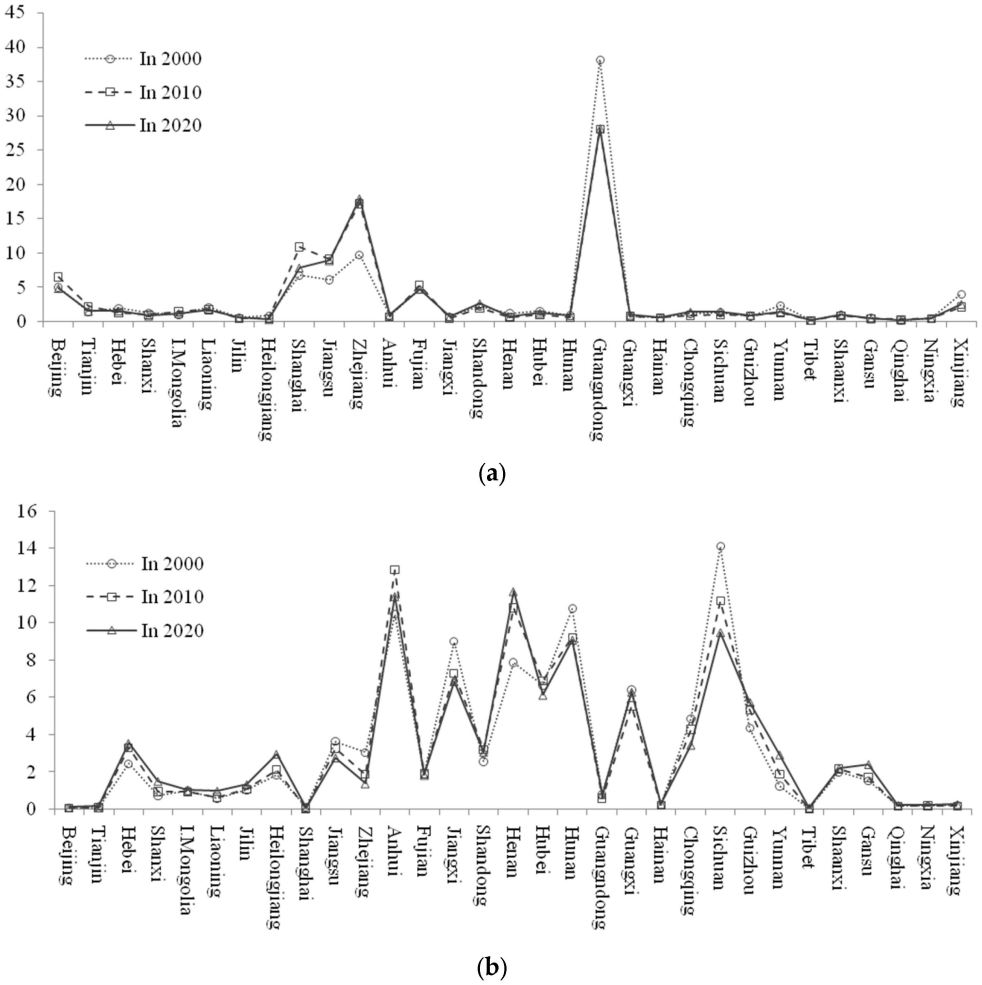

Figure 2. (**a**) Weighted in-degree centrality by region. (**b**) Weighted out-degree centrality by region.

Table 2. Main migration flows for various periods.

Order	2000			2010			2020		
	Migrate from	**Migrate to**	**Flow**	**Migrate from**	**Migrate to**	**Flow**	**Migrate from**	**Migrate to**	**Flow**
1	Hunan	Guangdong	220,668	Hunan	Guangdong	399,745	Hunan	Guangdong	583,388
2	Sichuan	Guangdong	159,606	Guangxi	Guangdong	314,276	Guangxi	Guangdong	520,621
3	Guangxi	Guangdong	150,391	Anhui	Shanghai	228,326	Anhui	Zhejiang	345,253
4	Jiangxi	Guangdong	104,861	Sichuan	Guangdong	225,261	Anhui	Jiangsu	296,749
5	Hubei	Guangdong	93,870	Anhui	Zhejiang	222,928	Sichuan	Guangdong	270,912
6	Henan	Guangdong	72,954	Anhui	Jiangsu	218,305	Hubei	Guangdong	260,387
7	Anhui	Jiangsu	69,776	Hubei	Guangdong	192,292	Jiangxi	Guangdong	233,822
8	Anhui	Shanghai	63,325	Henan	Guangdong	153,986	Henan	Zhejiang	233,415
9	Jiangxi	Zhejiang	57,380	Jiangxi	Guangdong	153,322	Guizhou	Zhejiang	223,692
10	Anhui	Zhejiang	53,274	Jiangxi	Zhejiang	144,976	Anhui	Shanghai	215,201

4. Analysis of Network Evolution Drivers Based on the Perspective of Regional Differences

4.1. Analysis of Related Theories

Migration flows are the basic components of migration networks. Thus, various socio-economic factors that influence migration behavior also affect the formation and evolution of migration networks. Furthermore, in a migration network, each migration flow contains two endpoints: the incoming and the outgoing, and the socio-economic

characteristics of each region do not affect the migration behavior in isolation, but include the effects of inter-regional differences. Therefore, a search for the drivers of the evolution of rural population migration networks should also be conducted from the perspective of regional differences.

In terms of theoretical basis, Ravenstein, the earliest researcher of the phenomenon of migration, pointed out in his Laws of Migration theory that the main direction of migration is always to cities with developed secondary and tertiary industries, and that the rural population is more willing to migrate than the urban population [63]. The "push–pull" theory proposed by Bogue suggests that socio-economic differences are the main reason for this phenomenon, and that people from disadvantaged areas are attracted to areas with higher income levels, more job opportunities, and more developed economic construction in an attempt to improve their living conditions, leading to cross-regional migration behavior [62]. Lee agreed with this idea, believing that the size of the differences will determine the scale of population migration between regions [64]. In Lee's Migration Theory, he proposed a third factor that affects population movement besides the push and pull aspect, namely intermediate factors that hinder population movement, such as the spatial distance and cost of living. This addition of the third factor has perfected the relevant theory. At the same time, since the desire for a higher quality of life is an important driving force for migration, the level of regional welfare security related to the quality of life also significantly influences the choice of migration location for the mobile population. In his model of local public goods supply, Tiebout pointed out that, in the case of economic and geographic convergence, migrants tend to move to areas with better welfare security, along with services such as higher education, good medical facilities, and better infrastructure [65].

4.2. Model Setting and Variable Selection

Based on the above theoretical analysis, in this research, a "relationship–relationship"-type analysis model was constructed with the rural population migration network as the explained variable, and the relationship matrix of the regional differences in terms of regional development level, income and consumption level, industrial structure, employment opportunities, public services, and spatial factors as the explanatory variables. The model contains a total of 20 variables, all of which are in the form of 31×31 relational matrices. It ignores the auto-correlated diagonal grid values, and each matrix has 930 observations. Among them, the grid value of the inter-regional rural migration volume matrix is the actual number of rural population movements between regions; the grid value of the regional adjacency matrix is assigned a value of 0 or 1; the grid value of the regional spatial distance matrix is the actual straight-line distance between the geographical centers of each region; and the grid value of the socio-economic difference matrix is the difference between the corresponding data of each region. Since all variables are relational data, the differences in the data units do not affect the analysis process.

It is worth noting that, in some of the previous studies [66–68], the early-stage network was included as an explanatory variable in the model to explain its impact on the late-stage network. We originally did the same in this research, but the adjusted R^2 in the model results reached over 0.900. As population migration is a complex phenomenon influenced by multiple factors, theoretically, the adjusted R^2 of the model should not be too high. The reason for this phenomenon may be that the late-stage migration network developed on the basis of the early-stage migration network; thus, there is a strong correlation and similarity between them. When using an early-stage network to explain a late-stage network, the similarity between the two may lead to a very high level of adjusted R^2 in the model. This is the result of "using oneself to explain oneself", and may lead to the role of other variables in the model being masked, bringing risks to the reliability of the model results. Therefore, that setting may not be appropriate for this research, and we did not include the early-stage network in the variables.

The specific variable settings and descriptions are shown in Table 3.

Table 3. Model variable settings and descriptions.

Variables	Description
Explained variable	
Rural population migration network	Inter-regional rural migration volume matrix (persons)
Explanatory variables	
Development level	
Total GDP	Matrix of differences in total GDP between regions (billion CNY)
Urbanization level	Inter-regional urbanization level difference matrix (%)
GDP per capita	Inter-regional GDP per capita difference matrix (CNY)
Fixed-asset investment per capita	Inter-regional per capita fixed-asset investment difference matrix (CNY)
Local fiscal revenue per capita	Difference matrix of local fiscal revenue per capita between regions (CNY)
Income level	
Urban per capita income	Inter-regional urban residents' annual per capita income difference matrix (CNY)
Rural per capita income	Inter-regional rural residents' per capita annual income difference matrix (CNY)
Average wage level	Inter-regional average annual wage differential matrix (CNY)
Cost of living	
Urban per capita consumption	Inter-regional urban residents per capita annual consumption difference matrix (CNY)
Rural per capita consumption	Inter-regional rural residents per capita annual consumption difference matrix (CNY)
Industrial structure	
Proportion of secondary industry	Inter-regional secondary industry proportion difference matrix (%)
Proportion of tertiary industry	Inter-regional tertiary industry proportion difference matrix (%)
Employment opportunities	
Unemployment rate	Unemployment rate difference matrix (%)
Proportion of employment in non-agricultural industries	Matrix of differences in the proportion of employment in non-agricultural industries between regions (%)
Public services	
Local fiscal expenditure per capita	Matrix of differences in local fiscal expenditures per capita between regions (CNY)
Education funds per capita	Inter-regional differential matrix of education funds per capita (CNY)
Number of health personnel per capita	Difference matrix of the number of health personnel per capita between regions (persons per 10,000)
Spatial factors	
Regional adjacency	Adjacent = 1; otherwise = 0
Regional spatial distance	Straight-line distance between geographical center points of each region (km)

4.3. QAP Correlation Analysis

Correlation analysis was used to verify the relationship between each regional difference variable and the rural population migration network, and to screen the variables with significant relationships to the network. The results in Table 4 indicate that, among the factors influencing rural migration, the variables reflecting regional development level, income level, and employment opportunities were more consistent with the theoretical expectations. The difference variables such as per capita and total GDP, urbanization level, urban and rural per capita income, wage level, and proportion of employment in non-agricultural industries all had a continuous and significant negative relationship with the rural population migration network in different periods. That is, the more disadvantaged the place being migrated from was compared with the place being migrated to, the more the rural population moved from the former to the latter.

The variables reflecting spatial factors were also consistent with theoretical expectations that migration is likely to be greater between regions with contiguous relationships and decreases as the spatial distance between the regions lengthens.

The urban and rural per capita consumption expenditure variables, which reflect the cost of living, were not the same as theoretically expected, indicating that the rural population did not rule out migration to areas with high consumption levels. The reason for this may be that there is generally a high homogeneity between consumption levels and income levels. The consumption level of a region tends to follow the increase in income accordingly. Some scholars have pointed out that, by consciously reducing living consumption expenditures, rural migrants can instead obtain higher economic benefits in economically developed areas with high consumption levels compared with less developed areas [69].

The variables reflecting industrial structure, such as the proportion of secondary and tertiary industries, as well as the variables reflecting public service level, such as the per capita local fiscal expenditure and the per capita number of health personnel, do not form a consistent and significant correlation with the rural population migration network.

Table 4. Results of the QAP correlation analysis of the rural migration network for each factor.

Variables	2000	2010	2020
Development level			
Total GDP	−0.167 *	−0.192 *	−0.197 **
Urbanization level	−0.180 *	−0.241 ***	−0.206 **
GDP per capita	−0.165 *	−0.243 ***	−0.203 **
Fixed-asset investment per capita	−0.168 *	−0.068	0.048
Local fiscal revenue per capita	−0.172	−0.217 **	−0.198 *
Income level			
Urban per capita income	−0.223 **	−0.274 ***	−0.232 **
Rural per capita income	−0.183 *	−0.235 **	−0.219 **
Average wage level	−0.214 **	−0.206 *	−0.192 *
Cost of living			
Urban per capita consumption	−0.228 ***	−0.281 ***	−0.262 ***
Rural per capita consumption	−0.180 *	−0.248 **	−0.207 **
Industrial structure			
Proportion of secondary industry	−0.091	0.059	0.021
Proportion of tertiary industry	−0.101	−0.191 *	−0.145
Employment opportunities			
Unemployment rate	0.103	0.174 *	0.08
Proportion of employment in non-agricultural industries	−0.150 *	−0.223 **	−0.216 ***
Public services			
Local fiscal expenditure per capita	−0.154	−0.123	−0.068
Education funds per capita	−0.139	−0.220 **	−0.155 *
Number of health personnel per capita	−0.098	−0.111	−0.036
Spatial factors			
Regional adjacency	0.193 ***	0.182 ***	0.200 ***
Regional spatial distance	−0.167 ***	−0.195 ***	−0.194 ***

Note: The table results were calculated using the "QAP correlation" algorithm in UCINET v6.560; ***, **, and * indicate that the *p*-value of the coefficient is less than 0.001, 0.01, and 0.05, respectively.

4.4. QAP Regression Analysis

According to the results of the QAP correlation analysis, the variables with insignificant relationships in each period were excluded, and the remaining variables were subjected to QAP multiple regression analysis with the rural population migration network. The regression results for each period are shown in Table 5.

From the regression results, it can be seen that the significant factors affecting the rural population migration network varied in different periods. Three variables, namely urbanization level, total GDP, and per capita GDP, which represent the degree of regional development, and two variables, namely regional spatial distance and regional adjacency, which represent spatial factors, had significant effects on the rural population migration network in the regression models for different periods.

The variable of local fiscal revenue per capita was significant only in the regression model in 2010, and the sign of the standardized regression coefficient was not consistent with expectations. The variables reflecting income level, cost of living, industrial structure, and employment opportunities mostly lacked a consistent and significant regression relationship with the rural population migration network, with only urban and rural per capita income (2010), urban per capita consumption (2020), and the proportion of non-agricultural employment (2010) being significant in some periods of the regression model. Among the variables reflecting public services, only the per capita education funds variable was significant in the regression models for 2010 and 2020.

In contrast, variables such as per capita fixed-asset investment, average wage level, rural per capita consumption, and unemployment rate did not significantly affect the rural population migration network in each period.

Overall, the mechanism of the influence between regional differences and the rural population migration network in the early stage was relatively simple, with only five variables being significant in the regression model. Regional economic level was the main

pull attracting the rural population, and the spatial distance factor was the main obstacle to rural population migration. By 2010, the interaction mechanism between the regional differences and migration networks had become more complex, with 10significant variables. The differences in the income levels and employment opportunities between regions began to influence rural population migration. By 2020, the number of significant variables in the model had decreased to seven. In addition to economic and spatial factors, cost of urban living and education funds were the main factors influencing the migration of the rural population in this period. Thus, it can be seen that the rural population migration network and the regional differences were related, not only in the spatial dimension, but also in the temporal dimension. While the migration network evolved, the driving relationship between it and the regional differences also evolved over time.

Table 5. Results of the QAP regression analysis of the rural migration network with each factor.

Variables	2000	2010	2020
Development level			
Total GDP	−0.213 *	−0.223 **	−0.254 ***
Urbanization level	−0.486 **	−0.837 ***	−0.522 ***
GDP per capita	−0.592 *	−0.384 *	−0.519 ***
Fixed-asset investment per capita	−0.198	–	–
Local fiscal revenue per capita	–	0.548 **	0.153
Income level			
Urban per capita income	−0.296	−0.626 **	−0.274
Rural per capita income	0.001	0.443*	0.094
Average wage level	−0.143	−0.037	0.275
Cost of living			
Urban per capita consumption	0.051	0.084	−0.341 *
Rural per capita consumption	0.179	−0.066	0.058
Industrial structure			
Proportion of secondary industry	–	–	–
Proportion of tertiary industry	–	0.028	–
Employment opportunities			
Unemployment rate	–	−0.002	–
Proportion of employment in non-agricultural industries	0.130	0.262*	0.119
Public services			
Local fiscal expenditure per capita	–	–	–
Education funds per capita	–	−0.469 **	−0.435 ***
Number of health personnel per capita	–	–	–
Spatial factors			
Regional adjacency	0.148 ***	0.120 **	0.142 ***
Regional spatial distance	−0.102 **	−0.142 ***	−0.132 **
R^2	0.137	0.189	0.184
Adjust R^2	0.126	0.176	0.173
p-value	0.000	0.000	0.000

Note: The table results were calculated using the "MR-QAP linear regression" algorithm in UCINET v6.560; ***, **, and * indicate that the *p*-value of the coefficient is less than 0.001, 0.01, and 0.05, respectively.

5. Discussion

The current migration status of China's rural population is the result of a combination of macro, micro, individual, and environmental factors. This research explored the characteristics, evolution, and driving mechanisms of rural population migration networks from the perspective of macro-geographical differences, yielding four main contributions. First, this study extracted rural migrants from the floating population, which refined the research object. Second, rural migrants were analyzed from a macro perspective, rather than from a micro/individual perspective, as in previous studies. Third, the internal structure of the rural migrant network was analyzed using network tools, rather than simply focusing on the superficial migration pattern. Finally, this study concentrated on regional differences,

not just on the situation in each region itself. These contributions effectively complement previous studies and improve the whole research system.

In addition, due to the differences in research perspectives, time scales, and geographical scopes, findings on rural population migration vary from study to study. This study found that, from a macro perspective, the total amount of rural migration is increasing and continues to gather pace in the eastern region, which is consistent with the findings of Liu [70] and Lin [71]. This confirms the view that China's coastal areas have a strong population-siphoning capacity. However, although the overall rural population continues to follow the west-to-east migration direction, the scale of reverse migration gradually expanded between 2010 and 2020, which is consistent with the findings of Wu [36] and Yang [72]. This indicates that, since the implementation of China's industrial transfer strategy, with the gradual transfer of industries from the eastern region to the inland region, the attractiveness of the central and western regions to the rural population is increasing, and a population return trend has emerged. In terms of driving factors, economic development differences, urbanization differences, spatial distance, and neighboring relationships significantly influenced the migration relationship between regions for the whole period, consistent with the findings of Luo [73] and Gao [74]. This shows that the rural population migrated to neighboring regions with higher levels of economic development and urbanization as much as was possible under the constraints of spatial factors. Generally, developed areas offer more job opportunities and higher incomes, and are more attractive to the extraterritorial population. However, due to the uncertainty of migration results and the influence of factors such as transportation, culture, and nostalgia, the rural population is more inclined to migrate to neighboring, relatively developed areas after considering the spatial distance and economic aspirations, thus reducing the migration risk and cost of leaving home. The education factor also significantly influences the migration behavior of the rural population, consistent with the findings of Chen [75]. This suggests that, over time, the rural population not only considers economic and distance factors in their migration choices, but also gradually incorporates their own, or their fellow migrants', educational development opportunity potential into their migration decision.

In contrast, unlike the results of some micro studies, differences in the income level, cost of living, industrial structure, and employment opportunities between regions, although having a consistent and significant correlation with rural population migration networks, lack a stable regression relationship, as observed in the studies of Qi [43] and Wang [76]. The reasons for this may be as follows. First, as mentioned above, distance and cultural factors prevent migration from occurring. For example, although there is a large gap between the northwestern provinces and Guangdong Province in terms of income and employment, the actual scale of migration is small, resulting in an unclear regression relationship between the relevant factors. Second, the complexity of rural population migration networks is increasing, and migration directions are gradually diversifying, which is itself an entropy-increasing process. Therefore, in the macroscopic analysis, the role of some factors may be obscured or diluted, resulting in insignificant regression relationships with the explained variable.

Finally, it is worth noting that the ongoing trade frictions between China and the United States have led to changes in China's industrial development policies, which will inevitably have an impact on the migration patterns of rural populations, and further research related to this issue remains to be conducted.

6. Conclusions and Suggestions

In this study, we used complex network analysis to construct rural population migration networks for different periods based on the fifth, sixth, and seventh China National Census data, analyzing the network characteristics and evolution process. We then used regional difference data and QAP analysis to reveal the key factors affecting the formation and evolution of the networks. The main research findings were as follows.

(1) During the 2000–2020 period, China's rural population migration network developed rapidly, with the network scope expanding, regional participation gradually increasing, total rural migration and large-scale migration flows between regions growing, the one-way inflow or outflow of the rural population gradually decreasing, and inter-regional rural migration relationships becoming increasingly complex. The overall network gradually evolved from the early segmented and loose structure to a monolithic and solid structure.

(2) In all periods, the in-degree centralization of the network was significantly higher than the out-degree centralization. The inbound pattern was more compact than the outbound pattern, with the network showing the aggregation flow characteristics of the inbound population and the dispersion of the outbound population. The in-degree centralization first decreased and then increased, and the concentration of the inbound pattern was more significant in the later period than in the earlier period. In contrast, the out-degree centralization first increased and then decreased, and the migration pattern was more dispersed in the early period than in the later period.

(3) The rural population migration network showed a distinctive "core–edge" character, and the role of each region in the network did not change over time. Regions with a high inbound (outbound) rural population migration in the initial network continued to have high inbound (outbound) rural population migration in the later network. There was also a high degree of similarity in the main migration flows in the network across time, with higher migration flows in the initial network recurring in the later network and gradually increasing. The overall network gradually developed around the core regions of the inbound and outbound rural population, such as Guangdong and Zhejiang or Anhui and Sichuan, showing a significant cumulative effect.

(4) The significant factors influencing the migration network varied from one period to another. The mechanism of influence between the migration network and the geographical difference factors was more complicated in the later period than in the early period. The level of regional development and geographical factors continued to have a significant impact on the mobility choices of the rural population, whereas factors such as income level, cost of living, employment opportunities, and education funds only had an influential role in the rural population migration network in some periods.

Since the labor force is one of the most important drivers of productivity, and is an indispensable resource for promoting regional development, under the policy background of "people-oriented" new urbanization and rural revitalization strategies in China, scientifically and reasonably guiding rural population migration will be an important measure for promoting urban–rural integration and regional coordinated development. However, new urbanization needs to guide capable and willing rural migrants to settle down in cities, while rural revitalization also requires capable and resourceful rural migrants to return to their hometowns to work and to drive rural development. There is a potential competition for rural talent resources between the two strategies. In this situation, the Chinese government could try to change its past development strategy centered around large cities and instead make small towns a key focus for future development. As an administrative unit connecting cities and rural areas, small towns cannot only effectively undertake the transfer of urban industries and resources, they also have a strong radiating and driving effect on the development of the surrounding rural areas. Moreover, from the perspective of rural migrants, the risk brought by urbanization and the cost of settling down in nearby small towns will be lower [77]. In this process, industries and the employment opportunities they provide remain the primary factors that attract rural migrants [78], so the population distribution adjustment needs to be based on the industrial distribution adjustment. For coordinated regional development, the relatively disadvantaged central and western regions of China should actively undertake the transferal of industries from the developed eastern regions, and set up these industries in small towns to create more jobs and raise wage levels. This would enable the rural migrants who find it difficult to settle in the eastern regions to return to their hometowns for employment and settlement, thus

promoting the development of disadvantaged areas, and achieving coordinated regional development and urbanization growth. For urban–rural integration, local governments should appropriately transfer city-based industries to surrounding small towns, and allocate more funds, land development rights, and other resources to them. This would effectively promote the construction of infrastructure in these small towns, improve their welfare security, guarantee the level of housing, education and medical care, and enhance their population-siphoning capacity. Attracting rural migrants to work or set up businesses nearby and to eventually become citizens would drive the socio-economic development of the surrounding villages and achieve the goal of rural revitalization.

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