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Spatial and Temporal Measurement of the Interaction between the County Economy and Rural Transformation in Xinjiang, China

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Abstract: Given the background of urbanization and rural revitalization in the new era, it is important to explore the synergy between regional macroeconomics and rural transformation, as a balanced and coordinated urban–rural relationship must be built to promote regional sustainable development and rural revitalization. This paper used the spatial econometric model to study the spatiotemporal synergy and interaction between Xinjiang's county economy and rural transformation from 2007 to 2017. The conclusions were as follows. A clear spatial difference exists between the county economy and the rural transformation level, and regional bulk agricultural products lack competitiveness. The synergy between the county economy and rural transformation is weak, as the county economy is lagging while rural transformation progresses without collaboration, indicating different types of non-equivalence. The county economy has a stronger spatial dependence on rural transformation and insufficient spillover, a stagnating effect, mainly negative driving effects, and unstable interaction effects; while the unstable changes in rural transformation affect the county economy. The urbanization rate, urban wage level, rural employment structure, and planting area per capita were the main influencing factors. It is necessary to deepen rural transformation, consolidate and enhance its stability, cultivate regional growth poles, promote overall development, and promote regional coordination.

Keywords: rural transformation; spatial measurement; interaction effects; Xinjiang

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Citation: Tan, B.; Wang, H.; Ma, C.; Wang, X.; Zhou, J. Spatial and Temporal Measurement of the Interaction between the County Economy and Rural Transformation in Xinjiang, China. *Sustainability* **2021**, *13*, 5318. https://doi.org/10.3390/su13095318

Academic Editor: Joanna A. Kamińska

Received: 16 April 2021
Accepted: 5 May 2021
Published: 10 May 2021

1. Introduction

In recent years, the steady development of regional economic policies has driven changes in the rural economic environment. The influence of talent return, capital and technology input, and rural factor-structure-function reconstruction has changed rural industry, populations, functions, and spatial structure [1], and feedback effects are further affecting regional macroeconomics [2]. Villages have built a new format for the rural economy based on their agricultural structure, planting structure, and the integration of traditional and emerging industries. These new dynamics of rural transformation and development and the coordinated development of regional macroeconomics are playing an important role in narrowing the gap between urban and rural areas, establishing a reasonable relationship between industry and agriculture, realizing broad and deep poverty reduction and achieving rural revitalization [3]. At present, the theory and methods of rural transformation research are gradually maturing. Phan Le conducted an extensive survey of 2150 households in 12 provinces in Vietnam to explain the microeconomic characteristics of the Southeast Asian economic activities involved in rural transformation [4]. Ben Belton verified the characteristics of rural transformation in the arid areas of Myanmar by examining the interaction between land ownership, agricultural mechanization, and population mobility [5]. Rahmalia Rifandin explored the role of egalitarianism, collective activities, and community organizations in rural transformation [6]. Anna Pudianti observed that culture promotes rural transformation by transforming into material power and resolving obstacles and that the related research topics tend to be diverse [7]. The mechanisms of rural transformation are understood as comprising three types, endogenous, exogenous, and endogenous/exogenous comprehensive, which emphasize the influence of rural self-development on rural transformation in urbanization and industrialization [8]. For all types, whether local participants can effectively use social and industrial networks to realize the transformation of resources into profits plays an important role [9]. Regional towns and rural networks are crucial in this process.

The transformation of production function, spatial consumption, and the commercialization of rural space have also become modes of rural transformation [10–12] that produce different results within the spatial transformation of the regional economy [13]. This process has undergone a transition from industrialization to deindustrialization, showing the characteristics of prosperity or decline in different eras [14] as well as changes in time and space with urban life [15]. The social and economic output in the process of rural transformation is released into the market and participates in the development of the regional economy as a new capital element. Such elements affect the regional economic pattern and development efficiency through time accumulation and spatial distribution heterogeneity. Therefore, exploring the relationship and state of rural transformation and regional economy from the perspective of time and space is essential to maintaining regional sustainable development.

Domestic research on rural transformation has focused mainly on the development of theoretical frameworks and the exploration of the paths of rural transformation [16,17], rural spatial transformation, rural organizational transformation, rural land use, and functional transformation [18–21]. The development dynamics and effects of rural transformation in the context of urbanization, rural revitalization, and poverty alleviation have been discussed [2,22–24]. Although there is systematic recognition of the effectiveness of rural transformation elements in the process of urban and rural evolution in southern China [9,13,14], very few studies have examined the northern region. In the current era of globalization, industrialization, and urbanization, China is entering a new era of profound economic and social transformation and accelerated reconstruction of urban–rural relations [25]. Rural transformation and county economies should complement each other and maintain a cooperative relationship. Despite the importance of cooperation, a phenomenon exists in which the county economy is developed but the rural transformation is lagging, or the county economy remains backward within a transforming rural area. Whether the two are synergistic is related to the effectiveness of the implementation of regional economic development with industry to promote agriculture and lead the township; the presence of such synergy also confirms whether the village has the ability to transform and develop itself. Identifying the state and type of the synergy between the two and discussing the evolutionary characteristics of temporal and spatial changes are issues that policy makers and scholars should explore as understanding these elements is of great significance to the promotion of urbanization and the improvement of rural poverty. For the vast underdeveloped regions, revealing the spatial correlation and interactive effects of county economy and rural transformation is an urgent frontier issue that needs to be resolved to accelerate the transformation and development of backward regions, maintain the economic competitiveness of developed regions, and ease regional development differences [25].

This research focuses on the level of rural transformation, the characteristics it exhibits, and the state of coordination with social and economic development, as well as the interactive process of and theoretical research on regional development and rural transformation. Xinjiang is located in the inland area of Northwest China, and its geographical environment is complex and diverse. As of 2017, the rural population in Xinjiang accounted for 50.62% of the total population. The rural area is vast and covers contiguous impoverished areas in the three prefectures of southern Xinjiang, and the overall development of the regional economy lags behind that of other areas. There is currently no relevant research on the level, characteristics, and coordination of social and economic development comprising Xinjiang's rural transformation and a lack of theoretical research on the interaction between regional development and rural transformation. The main direction of regional development in Xinjiang has been to realize the in-depth development of its rural economy, make full use of the policy advantage offered by "full-scale counterpart assistance to Xinjiang", improve the regional development level [26], and realize the coordinated development of urban and rural areas. Given the lack of research on this area, this article uses Xinjiang as the research area to conduct an empirical analysis of the temporal and spatial synergy of county economic levels and rural transformation, as well as spatial interaction effects, from 2007 to 2017. A quantitative analysis of the relationship between Xinjiang's macroeconomic development and rural transformation is performed, and the state and mechanism of the interaction between rural transformation and county economy is discussed. Revealing the influence and representation of spatiotemporal differences on this interaction provides examples and theoretical references for regulating the dynamic relationship between county economy and rural transformation and development in underdeveloped areas and promotes the coordinated development of urban and rural areas and rural revitalization.

2. Materials and Methods

2.1. Data

The socioeconomic data used in this research come from the *Xinjiang Statistical Yearbook* (2008–2018), *China County Statistical Yearbook* (2008–2018) and the *Xinjiang Local National Economic Development Bulletin*; the research period is from 2007 to 2017. To avoid affecting the integrity of the data system, any counties and regions that changed after 2007 were merged. Due to the large dimensional differences in the selected indicators and differences in the same indicator, dimensionless and non-negative treatment was needed [27].

2.2. Method

2.2.1. Comprehensive Index Evaluation Method

To accurately assess the county economy and the level of rural transformation and development, when constructing an index system based on similar research [17,21,28], indicators that are commonly used to characterize the regional economic level are selected to reflect the county economic level. Rural transformation takes the rural population composition, rural production conditions, output levels, and rural industrial system as the entry points and selects indicators that reflect the transformation of the rural population structure, the improvement in production conditions, the growth of agricultural output value, the regional agglomeration of rural industry and the evolution of the system. To capture the level of transformation in the constituent elements of rural transformation, an index system and weights are shown in Table 1. To avoid subjective weighting, the entropy weight method is used to determine the index weights [29].

Table 1. Rating index for the time and space coordination system between the county economy and rural transformation in Xinjiang.

Subsystem	Indexes	Definition	Weight
County economy	Real GDP per capita (yuan/per capita)	Regional real GDP per capita	0.055
	Urbanization level (%)	Urban population/total resident population at the end of the year	0.0587
	Urban wage level (yuan/per capita)	Average salary of urban non-private units	0.0597
	Per capita income (yuan/per capita)	Regional fiscal revenue/total regional population	0.0422
	Industrial output value per capita (yuan/per capita)	Gross industrial output value/total regional population	0.043
	Per capita consumption level (yuan/per capita)	Total retail sales of consumer goods/total regional population	0.0495
Rural transformation	Proportion of rural population (%)	Rural population/total regional population	0.0602
	Rural employment level (%)	Rural employed population/total regional population	0.0602
	Rural electricity consumption level (10,000 kWh)	Rural electricity consumption per capita	0.0462
	Labor productivity (10,000 yuan/person)	Gross agricultural production value/ rural employment population	0.0481
	Agricultural modernization level (kW/ha)	Total power of agricultural machinery/total planting area	0.0569
	Plastic film coverage rate (%)	Plastic film coverage/total planting area	0.0592
	Fertilizer application rate (ton/ha)	Fertilizer application rate/sown area	0.0587
	Per capita planting area (hectares/person)	Total crop planting area/total regional population	0.0582
	Agricultural production efficiency (10,000 yuan/ha)	Gross agricultural production value/total crop planting area	0.0573
	Livestock alfalfa possession (tons/head)	Total livestock production/total alfalfa production	0.0362
	Output system structure entropy	Indicates the regional agglomeration of agricultural product output [30]	0.0601
	Output system structure conversion rate	Indicates the comprehensive performance of the agricultural product output system [30]	0.0312

For the index output system structure entropy in Table 1 [30], the calculation formula is:

$$x_1 = -\sum_{i=1}^{n} P_i \times \ln P_i$$

where P_i is the proportion of the i-th agricultural output in the total output. The total output is the sum of per capita food, cotton, oil, vegetables, fruits and melons, and meat per capita, which is the same below. The calculation formula for the output system structure conversion rate [30] is:

$$x_2 = \sqrt{\sum_{i=1}^{n} \frac{(N_i - G)^2 \times K_i}{G}}$$

where N_i and G are, respectively, the average annual growth rate of the i-th agricultural output and total output, and K_i is the proportion of the i-th agricultural output in the total output.

2.2.2. Coupling Model Method

The coupling model is used to measure the coordinated development level and development stage of the county economy and rural transformation [31]. For the numerical calculation of the coupling degree, refer to the research of Liao Chongbin [32]. To avoid the result wherein a high level of coupling is identified for two systems that happen to be at a low level at the same time, resulting in a situation that is inconsistent with reality, the calculation refers to the study of Sheng Yanchao to measure the development of coupling coordination [33]. The degree is calculated as follows:

$$C = \{f(x)g(y)/[\frac{f(x)+g(y)}{2}]^2\}^k, \quad (1)$$

$$D = \sqrt{C \times T}, T = \alpha f(x) + \beta g(y). \quad (2)$$

In the formula, C represents the degree of coupling coordination, and K represents the adjustment coefficient ($K \geq 2$). In this paper, $K = 2$. $C \in [0, 1]$, such that the larger the value of C, the stronger the correlation of the system is, and vice versa; D is the coupling and coordinated development degree of county economy and rural transformation; T is the comprehensive benefit index of county economy and rural transformation; and α and β are undetermined coefficients. In this paper, $\alpha = \beta = 0.5$. According to similar research the coupling types are further divided (Table 2) [31].

Table 2. Coordinated development level of coupling.

Coupling Coordination Degree (D)	0–0.09	0.1–0.19	0.2–0.29	0.3–0.39	0.4–0.49
Type	Extremely dysfunctional	Seriously dysfunctional	Moderately dysfunctional	Mildly dysfunctional	Slightly dysfunctional
Coupling Coordination Degree (D)	0.5–0.59	0.6–0.69	0.7–0.79	0.8–0.89	0.9–1
Type	Slight coordination	Primary coordination	Intermediate coordination	Good coordination	Quality coordination

2.2.3. Spatial Measurement Method

Within a certain geographic space, the county economy and rural transformation in different spatial units are affected not only by capital but also by spillover effects and policies generated by investment activities in other surrounding areas, resulting in significant economic behavior exchange between regions, creating external effects that thereby form regional economic clusters [34]. The investigation of economic clusters is realized through spatial effects. The spatial measurement model examines how to deal with spatial interaction (spatial autocorrelation) and spatial structure (spatial nonuniformity) in the regression models of (cross-sectional data) and (panel data) [35,36]. The spatial measurement method used in this study can effectively interpret the differences in temporal and spatial changes and the synergistic interaction between the county economy and rural transformation, thereby revealing the differences in the overall and local impacts of the two.

(1) Spatial autocorrelation

Spatial autocorrelation is a method used to measure the spatial connection and correlation of different regional attributes [37]. It is mainly used to explore the spatial dependence of regional unit attributes from both the global and local perspectives.

① Global autocorrelation (Moran's I)

Global autocorrelation is applied to explore the spatial dependence of Xinjiang's county economy and rural transformation from a global perspective. This paper uses univariate and bivariate global autocorrelation to test the spatial dependence between the county economy and rural transformation. The formula is as follows [38]:

$$Moran's\ I = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})/s^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \quad (3)$$

where X_i and X_j are the observation values of spatial units i and j, respectively; n is the number of spatial units;$\overline{x}$ and s^2 are the mean and variance of the observation value x; W_{ij} is a spatial weight matrix constructed based on neighboring criteria; and Z_i and Z_j are the standardized values of variance of the observations of spatial units i and j (the same below). *Moran's* $I \in (-1,1)$, where 0 indicates negative correlation, equal to 0 indicates irrelevance, and greater than 0 indicates global positive correlation.

② Local autocorrelation (LISA)

To compensate for the shortcomings of the global autocorrelation assessment, which ignores the potential instability of the spatial process and lacks local variation, the local indicators of spatial connection are used to identify counties with local agglomeration and describe the spatial agglomeration between similar attribute units, revealing local spatial connections and differences in the synergy between county economies and rural transformation. The formula is as follows [38]:

$$LISA\ I_i = Z_i \sum_j w_{ij} z_j, z_i = \frac{x_i - \overline{x}}{\sqrt{\frac{1}{n}\sum(x_i - \overline{x})^2}} \quad (4)$$

where i and j represent the spatial unit; n is the number of spatial units; W_{ij} is the spatial weight matrix when two spatial units are adjacent to 1 (otherwise 0); x is the observation value (i.e., the degree of coupling coordination); $\overline{x}$ is the average value of the observation value.

(2) Spatial lag model

Because of the spatial autocorrelation (spatial dependence) between the rural transformation and the county economy in each time section, the selected factors can be explored through the spatial panel measurement model by incorporating spatial and temporal effects on the basis of the ordinary panel data model. Impact on the changes in the temporal and spatial pattern between the county economy and rural transformation can thus be observed [36,39].

The spatial lag model can effectively explore the spillover effect and test the dynamic interactive feedback relationship between variables [40]. With the spatial lag model, the analysis reveals the strength of the impact of the county economy on rural transformation and vice versa. The formula is as follows [36,40]:

$$\ln ei_{it} = a_{it} + \rho \ln e_{it} + \beta_1 \ln urb_{it} + \beta_2 \ln ind_{it} + \beta_3 \ln fd_{it} + \beta_4 \ln open_{it} + \beta_5 \ln gdp_{it} \cdots + u_1 + \varepsilon_{it}. \quad (5)$$

In the formula, ei_{it} represents the attribute of the i-th spatial subject in year t; i = 1, 2, 3,..., n stands for different spatial subjects; t = 1, 2, 3,... stands for different years;

a_{it} represents the longitudinal intercept; m_i represents random individual differences; β_1, β_2, β_3, β_4, β_5, β_6 indicate the parameter to be estimated; ρ is the spatial autoregressive coefficient; ε_{it} represents the random error term and satisfies the independent and identical distribution such that the expectation is 0, the variance is σ^2, that is, $\varepsilon_{it} \sim N[0, \sigma^2 I_N]$; and i_N is the N-order unit matrix. All variables take the form of natural logarithms, so the estimated coefficients can be interpreted as elasticity.

(3) Spatial error model

The spatial error model supplements the spatial lag model by constructing driving factors and explores the influence of items causing random interference in interactions, such as uncertain factors, difficult-to-measure factors, and measurement errors in system operation. The formula is as follows [36,40]:

$$y = X\beta + \varepsilon, \varepsilon = \lambda W \varepsilon + \mu. \tag{6}$$

In the formula, ε is the random error term vector, λ is the spatial error coefficient of the n*1 order cross-sectional dependent variable vector, and μ is the random error vector of the normal distribution.

(4) Geographically-weighted regression (GWR)

The spatial lag model and spatial error model focus on evaluating the global driving effect, revealing insufficiencies in the local driving effect, evaluating the driving effect of the local area through geographically-weighted regression, and performing local regression on the variable coefficients for the functions capturing the county economy and the level of rural transformation. The estimated coefficients of the variable after regression are used to analyze the spatial variability characteristics [41,42], revealing the local differences and the types of interactions. The formula is as follows [41,43]:

$$y_i = \beta_0(u_i, v_i) + \sum_{j=1}^{\mathrm{k}} \beta_j(u_i, v_i) x_{ij} + \varepsilon_i. \tag{7}$$

In the formula, (u_i, v_i) indicates the geographic coordinates of the sample i spatial unit, and $\beta_j(u_i, v_i)$ is the value of the continuous function $\beta_j(u_i, v_i)$ in the sample i spatial unit, which is a function of geographic location.

3. Results

To a certain extent, rural transformation can be understood as the development of a rural regional system through the accumulation and transformation of rural capital under the influence of progress in rural productivity and production methods and the diversification of group interest needs, all guided by economic benefits. Rural areas have been transformed, and the resulting transformation of rural production systems, labor, and employment, such as the output of surplus labor, non-agricultural employment in rural areas, and diversification of production and management, has promoted the upgrading and innovation of the functional forms of rural regional systems. In the process of rural capital accumulation and transformation in the output of rural labor services and adaptation to market supply and demand, the rural regional system exchanges value and realizes value with a regional economic system dominated by counties, districts, and cities, causing capital components to move between the village and the region. The change in the spatial pattern of flow and the formation of a new pattern of element flow and a new regional interaction structure are the manifestations of rural adaptation to market-oriented development. The spatial pattern of urban–rural capital flow through the feedback process will affect the stability of regional economic growth and the spatial pattern of rural transformation, resulting in the reorganization of the urban–rural regional system.

3.1. The Interactive Process between the County Economy and Rural Transformation

The spatiotemporal synergy of the county economy and rural transformation is a process in which the components and system functions of the two interact in time and space during a dynamic development process (Figure 1).

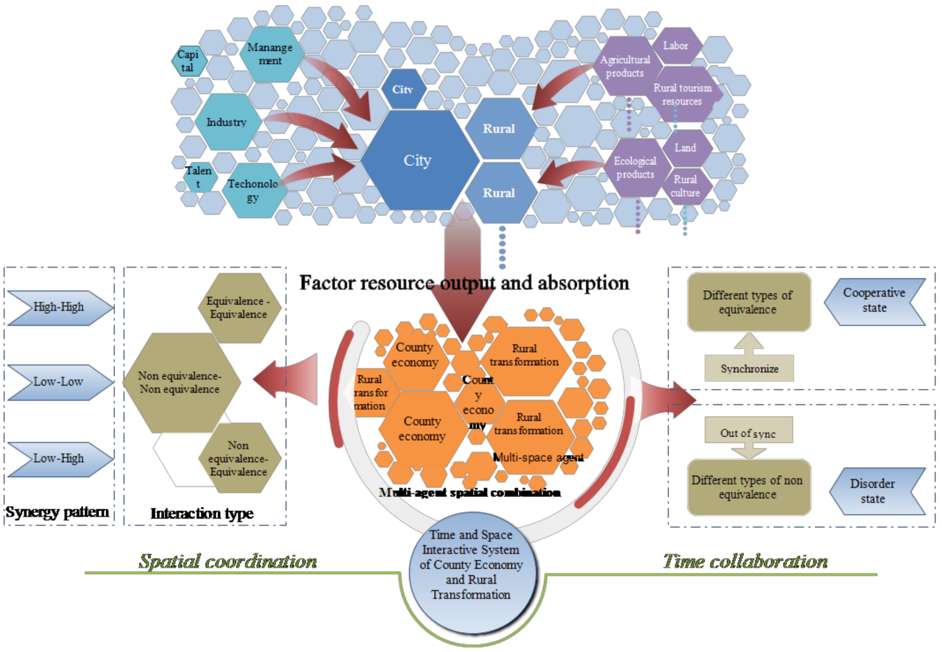

Figure 1. Time–space interaction process between the county economy and rural transformation.

The county economy and rural transformation have different characteristics of spatial and temporal evolution. Based on their respective development patterns, the spatial interactions of subsystems are formed through spatial adjacency, production and consumption links, and potential social, policy, and cultural links to constitute a coordinated system of county economy–rural transformation. The composition of the county economy and rural transformation in the system, the regional relationship, and the environmental background determine the system's integrity and function. The relationships between the components of the county economy–rural transformation coordination system or between the components, the hierarchy, and the system environment are changed and adjusted to ensure that they are coordinated. Thus, the overall county economy–rural transformation coordination system exhibits ideal interactive functions and achieves coordination.

In the county economy–rural transformation synergy system, when a region's county economy and rural transformation are in a state of "different equivalence" [44], that is, when the development levels of the two subsystems are relatively balanced, there is no significant topography. If the energy is poor, the polarization and diffusion effects are in an equal state and the two-way interaction process is balanced and sufficient, the development of the two is synchronized in time, and the region is in an ideal state of synergy. In contrast, an area can be characterized by "different types of non-equivalence", wherein the level of the county economy and rural transformation and development in this area is uneven, and there is a significant difference in potential energy. The chemical effect or the diffusion effect in this context is more prominent. The county economy and rural transformation do not match, and the two are not synchronized in time, eventually leading to the collapse of the coordination system between the county economy and rural transformation.

Between different spatial units, the degree to which "different types of equivalence" or "different types of non-equivalence" characterize the relationship of the county economy and rural transformation will vary, and two adjacent county intervals will produce different degrees of "equivalence–non-equivalence", "equivalence–equivalence" or "non-equivalence–non-equivalence"; these are three states of synergistic combination that correspond to the "high-low", "high-high" and "low-low" spatial coordination patterns. To achieve the spatial coordination of different county-regional economic-rural transformation systems, it is necessary to build a regional development model and solution strategy that focuses on improving the interactive process of the element structures and levels in the system to gradually realize the transformation from unbalanced to balanced regional development and achieve urban, rural, and regional synergy.

3.2. Temporal and Spatial Differentiation of the County Economy and Rural Transformation

From 2007 to 2017, the economic development gap between Xinjiang's counties narrowed, and although there was local volatility, overall development stabilized. The low economic value areas were concentrated in the Kashgar, Ho Tan, Aksu, Ili Kazakh Autonomous Prefecture and Ta Cheng areas. The economic level of the county was high in the east and low in the west, and the economic level of some counties in northern Xinjiang had decreased. The annual average was at a high level, and development was stable.

In 2017, 19 counties (0.14–0.26) had strong rural transformation capabilities, accounting for 22.35% of the total number of samples. They were concentrated on the northern slope of the Tianshan Mountains and the eastern margin of the Tarim Basin, and their concentration was stronger than it had been in 2007. The lagging rural transformation counties were mainly distributed in the three prefectures of southern Xinjiang and the Kazakh Autonomous Prefecture of Ili. There tended to be alpine regions and deserts in these regions, with scarce land resources, slow economic and industrial development, and deep poverty.

In 2017, the average conversion rate of the output system structure was 0.00099, an increase of 90.38% over 2007 (0.00052). With the gradual establishment of Xinjiang's food security reserve base, high-quality cotton production base, characteristic forest and fruit industry base, and modern livestock product base [45], the comprehensive agricultural output capacity of Xinjiang was significantly improved, the production capacity of bulk agricultural products was improved and the output was tending toward stability. This provided a good agricultural economic foundation for rural transformation and development. The average entropy score of the output system in 2007 was 0.0203, while it was 0.0147 in 2017, a decrease of 27.58%. The regional agglomeration of the agricultural output system decreased, reflecting the scattered distribution of bulk agricultural products in Xinjiang, such as grain, cotton, oilseed, and vegetables; the spatial agglomeration of melon cultivation and meat production was reduced, and the region did not hold a competitive advantage. The development of characteristic regional agriculture could deliver obvious advantages for improving the competitiveness of county agricultural output, enhancing rural development and promoting transformation and development.

3.3. Space–Time Synergy Analysis

By calculating the coupling model, the interaction intensity of the county economy and rural transformation from 2007 to 2017 was obtained, and the spatial distribution of its coupling grade was obtained (Figure 2). The main year parameters are shown in Table 3.

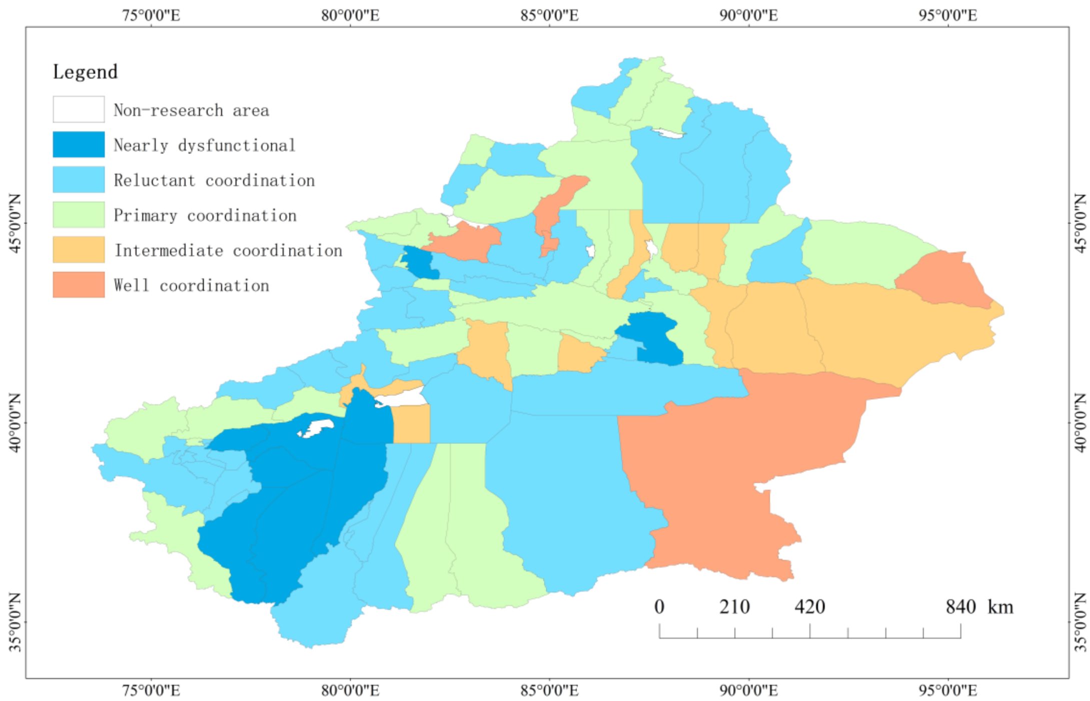

Figure 2. Spatial distribution of the coupling coordination between the county economy and rural transition in 2017.

Table 3. Statistics for the coupling level of the county economy and rural transition in 2007–2017.

Type	2007	2009	2011	2013	2015	2017	Average	Total
Moderately dysfunctional			1					1
Mildly dysfunctional	5	1	4					10
Slightly dysfunctional	19	9	11	4	4	9	8	64
Slight coordination	15	20	21	19	16	35	21	147
Primary coordination	24	20	22	28	38	27	34	193
Intermediate coordination	15	25	14	25	17	9	15	120
Good coordination	5	7	9	9	9	5	6	50
Quality coordination	2	3	3		1		1	10

Table 3 shows that from 2007 to 2017, the coupling of the county economy and rural transformation in Xinjiang was at a medium level, with slight coordination, primary coordination, and intermediate coordination as the most common. In 2017, the coupling of the county economy and rural transformation showed a spatial distribution of high in the east and low in the west (Figure 2). The synergy of counties and districts in southern Xinjiang was at a low level, showing different types of non-equivalence, while in northern Xinjiang, the distribution of high and low was staggered. The five well-coordinated counties and districts were scattered in the north and south, and the spatial connection was weak. The nine counties and districts of Pishan, Awati, Yecheng, Maigaiti, Moyu, Bachu, Jiashi, Yining, and Heshuo were on the verge of imbalance, and all were lagging in the county economy. The transformation was not synchronized in time, and they were in a serious different state of equivalence. The shortcomings in county economic development urgently needed to be addressed.

The coupling univariate spatial autocorrelation test for 2017 showed that the county economy was positively correlated with the rural transformation coupling space, and the global Moran index was 0.2241. The local autocorrelation test (Figure 3) showed that the local area had formed a high-high agglomeration area with Buxel Mongolian Autonomous County–Tori County, Balikun Kazakh Autonomous County–Turpan City–Shanshan County as the core, which were centrally distributed in northern and eastern

Xinjiang. The low-low agglomerations were mainly in the Hotan-Kashi region of southern Xinjiang and Kazakh Autonomous Prefecture of Yili, and the coupling driving factors between counties were strongly correlated, forming contiguous low-level areas. High-low and low-high agglomerations reflected the cross-distribution of counties and districts with significant differences in coupling. The type of interaction and the interaction in space were unidirectional, contradictory, or contained and concentrated in central Xinjiang.

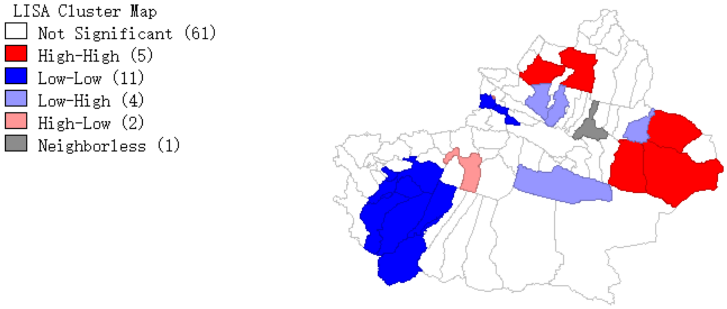

Figure 3. LISA map of the coupling county economy and rural transformation in Xinjiang.

4. Discussion

4.1. Spatial Effects of County Economy and Rural Transformation

The 2017 county economy and rural transformation were tested with univariate and bivariate global spatial autocorrelation to explore the spatial correlation and dependence between the county economy and rural transformation and to reveal their interactive influence and strength.

(1) Global spatial autocorrelation univariate test

In 2017, the overall spatial autocorrelation test results for the county economy and rural transformation Moran's I index were 0.0872 and 0.1735, respectively, which passed the test of significance $p = 0.05$; the distribution of the two was positively correlated. Due to the similar development environment and the small spatial distance between adjacent counties, the interaction effect decreased with spatial distance, resulting in local aggregation.

(2) Global spatial autocorrelation bivariate cross-test

Bivariate cross-tests can test the correlation of two variables in the study area. Cross-check (A) takes the county economy as the independent variable and rural transformation as the dependent variable to reflect the spatial dependence of rural transformation on the county economy. Cross-check (B) takes rural transformation as the independent variable and the county economy as the dependent variable to reflect the spatial dependence of the county economy on rural transformation. Both cross-check (A) and cross-check (B) passed the significance test of 0.05, and the global Moran's I indexes were 0.2204 and 0.2206, respectively. The county economy and rural transformation showed positive spatial autocorrelation, and there was spatial dependence. The size of the Moran's I index showed that the county economy had a stronger spatial dependence on rural transformation, and this dependence was manifested in the fact that in Xinjiang's agricultural-based rural industrial system the rural population was the majority, and the objective reality was that the region had a huge agricultural economy that held a basic role in promoting regional economic development.

(3) Local autocorrelation test

The results of the local autocorrelation test (LISA map) of the county economy and rural transformation in 2017 are shown in Figure 4, in which three counties are high-high clusters and nine counties are low-low clusters. The spatial correlation of low-low clustering of the county economy was more obvious: the two clusters were differentiated from north to south, wherein the north was high, and the south was low. The low-low clustering areas were concentrated in Hotan and Kashgar, and the economic development of these subordinate areas was slow. These areas represented the main poverty-stricken areas in Xinjiang. The partial spatial correlation of rural transformation was stronger than that of the county economy. Among them, eight high-high cluster counties were distributed on the south side of the Tianshan Mountains and the east side of the Tarim Basin. The low-low cluster counties were the four counties of Luopu, Hotan, Atushi, and Yecheng in southern Xinjiang, and the county economy and rural transformation in southern Xinjiang were at a relatively low level.

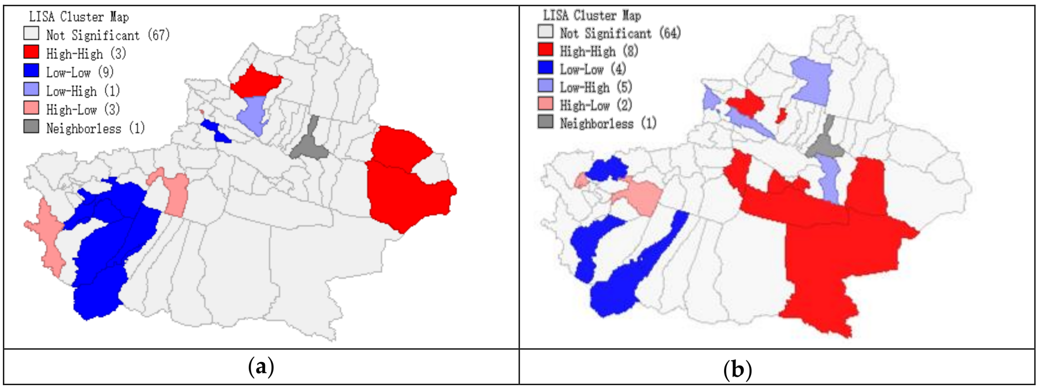

Figure 4. County economy and rural transformation LISA: (**a**) County economy; (**b**) Rural transformation.

4.2. Overall Interactive Driving Effect of the County Economy and Rural Transformation

A previous article found that the county economy and rural transformation have significant spatial dependence, so spatial lag (spatial lag) and spatial error (spatial error) models were used to explore the diffusion and spillover effects between them in space, namely, their interactive drive. In this paper, the spatial weighting matrix of the adjacency relationship was used to test the spatial regression of the county economy and rural transformation in GeoDa, and the measurement parameters proposed by Anselin were used as test criteria (Table 4) to determine the suitability of the model to accurately reflect its spatial interaction [41].

Table 4. Spatial lag and spatial error verification parameters.

Model 1 The Driving Force of the County Economy on Rural Transformation			**Model 2 The Driving Force of Rural Transformation on the County Economy**		
Parameter	**Spatial Lag**	**Spatial Error**	**Parameter**	**Spatial Lag**	**Spatial Error**
C	0.0831 (0.0000) *	0.1304 (0.0000) *	C	0.0792 (0.0000) *	0.9001 (0.0000) *
Coefficient	−0.0281 (0.0774) ***	−0.1065 (0.0270) **	Coefficient	0.0173 (0.0121) ***	−0.0062 (0.0224) *
LAMDBA		0.3860 (0.0032) *	LAMDBA	-	0.1009 (0.0151) **
LogL	165.629	166.0685	LogL	158.087	158.0774
R^2	0.821	0.4701	R^2	0.6179	0.6464
AIC	−325.258	−328.137	AIC	−310.174	−312.155
SC	−317.3	−323.252	SC	−302.846	−307.27
LR	5.0976 (0.0240) ***	5.9701 (0.0145) **	LR	0.2789 (0.5974)	0.2603 (0.0060) **
BP	0.6306 (0.0427)	0.1477 (0.7007)	BP	3.4228 (0.0643)	3.1852 (0.0743)
LM (lag)		0.5635 (0.0183) **	LM (lag)		0.2529 (0.5319)
R-LM (lag)		16.0101 (0.0000) *	R-LM (lag)		10.1065 (0.0014) **
LM (error)		5.0771 (0.0242) **	LM (error)		0.1674 (0.6824)
R-LM (error)		15.5237 (0.0000) *	R-LM (error)		10.0210 (0.0015) **

Note: The values in parentheses are P values, *, **, and *** represent significance at the 1, 5, and 10% confidence levels, respectively.

In the regression test of the driving effect of the county economy on rural transformation in Model 1, LM and R-LM were significant at the levels of 1 and 10%, the statistics were similar, and the constants passed the 1% test. Compared with the spatial lag, spatial error had similar LogL, AIC, and SC values, and the difference in measurement statistics was small, but the fitting degree R2 of the spatial lag model was significantly greater than that of the spatial error. Therefore, the spatial lag model was more suitable for appraisal. The spatial lag regression coefficient was −0.0281, the spillover effect of county economic development had a negative relationship with the driving effect of rural transformation, and the economic spillover effect of county economic development was insufficient.

Model 2 showed the test of the driving effect of rural transformation on the county economy. Both spatial lag and spatial error LM failed the significance test, and R-LM was significant at the 5% level, which was insufficient to determine the choice of specific spatial models. Spatial lag and spatial error had similar R2, LogL, AIC, and SC values. The regression coefficient of rural transformation on the county economy spillover effect was 0.0173, and through a 10% confidence test, rural transformation had a good driving effect on the county economy. The error term of rural transformation was negatively correlated with the economic development of the county; that is, the random error of rural transformation, i.e., unstable changes, had a stagnating effect on the economic development of the county.

Comparing the spatial interaction between the county economy and rural transformation, the county economy negatively drove rural transformation, while rural transformation positively drove the county economy. This showed that the economic development of the county in Xinjiang had a low exogenous drive toward rural transformation, and rural transformation required an endogenous drive and evolution. The promotion of rural functional structure optimization, industrial development and upgrading, rural poverty alleviation, infrastructure improvement, and other rural development trends represents a potential market for county economic development, realizing rural revitalization and driving county economic growth.

4.3. Local Interactive Effects of County Economy and Rural Transformation

Geographically-weighted regression (GWR) through ArcGIS was used to test the local driving effects of the county economy and rural transformation. The GWR test model R2 was 0.7628, the adjusted R2 was 0.7316, the AICc was −331.9280, and the residual sum of squares was 7.7607; the parameter R2 of the local driving test model of rural transformation to the county economy was 0.7883, the adjusted R2 was 0.7153, and the AICc was −3317.4592, the sum of squared residuals was 8.6809, and the model showed a better fit. The test showed that the regression coefficients of the two driving effects were between −0.7109 and 0.4352. According to the statistical characteristics of the regression coefficients, the driving effects were divided into four categories: strong negative drive, weak negative drive, weak positive drive, and strong positive drive. The results are shown in Figure 5.

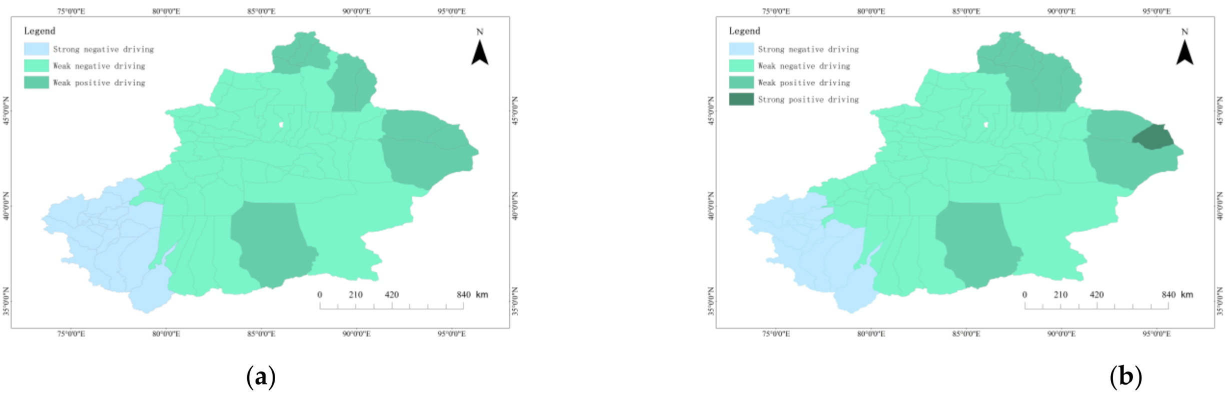

Figure 5. Distribution of the driving effects of the county economy and rural transformation: (**a**) The driving effect of the county economy on rural transformation. (**b**) The driving effect of rural transformation on the county economy.

The results showed that the local driving effect of the county economy and rural transformation was dominated by a negative drive, in which the county economy accounted for 88.09% of the rural negative drive areas, and rural transformation accounted for 85.71% of the county negative economic drive areas. A negative drive indicates that the interaction between the county economy and rural transformation is unstable in the local space, the synergy between county development and rural transformation is low, and the clustering of economic behaviors is weak.

Using the index layer in Table 1 as the hypothetical ideal factor, classical least squares regression (classic OLS) was used to perform attribution analysis on the influencing factors of the local driving effects of the county economy and rural transformation. In the OLS results, the urbanization rate, urban wage level, rural employment structure, and per capita planting area passed the T test, showing that they had a more significant impact on the local driving effect of the county economy and rural transformation. Therefore, improvement in the local driving effect requires the investment of more resources in the optimization of the urban system, rural urbanization, urban–rural industrial upgrading, agricultural modernization, and poverty alleviation in local areas, the cultivation of regional growth poles, and the development of regional industrial clusters with complementary functions. Population, industry, land, and environment are all starting points for building a coordinated urban–rural development system in line with Xinjiang's social, economic, and natural environment to promote regional development.

Rural transformation is a current characteristic of rural development and an inevitable process of rural revitalization. From the perspective of geographic time and space, the process of rural transformation requires accumulation of practice to realize the transformation from quantitative change to qualitative change over time, and to interact with the main body of the county and city in the process of quantitative change to form urban–rural collaboration. The rural transformation that occurs in the rural spatial entity is subject to spatial distribution and spatial distance coercion. The progress and degree of rural transformation are localized in the regional space. There are differences in the spatial synergy of rural transformation, and spatial asynchrony weakens rural area's spatial spillover effect and regional driving capacity of transformation to a certain extent. The process of realizing synergy between rural transformation and the county economy involves multiple subjects on the time and space scale. The time and space differences in multi-subject coordination represent systematic synergy. The empirical results show that Xinjiang's rural transformation and county economy are out of sync. The synergy needs to be further improved. However, both endogenous and external adjustment needs to be carried out to address the spatiotemporal synergy difference between rural transformation and county economic synergy at the regional scale. It is important to pay attention to the self-organizing evolution of the system and to strengthen the external adjustment of other organizations considering the function of the system. Structural and external environmental conditions should be established to begin rural transformation and improve the synergistic effect of the county economy. At the same time, as part of the urban–rural regional system, the functions of rural transformation and the county economy in the system need to be further identified and quantified to promote the synergy between them.

As a major arid area, Xinjiang's social and economic behaviors are restricted by the objective natural environment. While the region has abundant resource reserves, it also has inherent deficiencies, such as a fragile ecological environment and low ecological carrying capacity. The environmental dependence on industrial production and agricultural activities needs to be maintained at a low level, which makes it difficult to upgrade the regional economy. However, the gradual breakthrough in addressing practical problems, such as the cultivation of characteristic rural industries, the transformation of traditional agriculture, ecological protection and restoration, and poverty alleviation, has released the potential for rural development, which has significantly driven the overall development of the region. It is necessary to further expand rural development given the existing conditions, starting by stimulating the transformation of rural labor force, cultivating and optimizing the township industry system, enhancing urban–rural linkages, cultivating growth poles, and improving the quality of agricultural production, to further consolidate and enhance the steady progress of rural transformation and prevent unstable changes from slowing the overall development of the region.

5. Conclusions

This paper analyzes the spatial–temporal changes and interactive effects of the coordinated development between the county economy and rural transformation in the county-level units of Xinjiang from 2007 to 2017 using spatial measurement methods. The results are as follows. (1) There are significant spatial differences in the county economy and rural transformation levels in Xinjiang. The characteristics of a strong north and weak south and a strong east and weak west are obvious, and the three prefectures in southern Xinjiang and Ili Kazakh Autonomous Prefecture are significantly lagging. (2) The synergy between the county economy and the rural transformation level is weak, showing different types of non-equivalence, wherein rural transformation is ahead and the county economy is lagging. (3) There is positive spatial autocorrelation between the county economy and rural transformation, and the county economy has greater spatial dependence on rural transformation. The county economy is dominated by low-low spatial clustering, rural transformation has greater high-to-high agglomeration, and the difference between north and south is significant. The county economy and rural transformation in southern Xinjiang are at a low level, and the social and economic level needs to be improved. (4) The driving effect of county economic development on rural transformation is negative, and the economic spillover effect of county economic development is insufficient. Rural transformation positively drives the county economy, and unstable changes in rural transformation are slowing the development of the county economy. The local driving effect of the county economy on rural transformation is mainly negative, and the effects of local spatial interaction are unstable. The urbanization rate, urban wage level, rural employment structure, and per capita planting area are the main influencing factors.

The ultimate goal of rural transformation and county economic coordination is to achieve regional prosperity, eliminate urban–rural polarization, and break economic and geographic marginalization [46], thereby reducing the gap between urban–rural and regional development. Just as success in life requires the proper combination of material and spirit, realism and idealism, seriousness and playfulness, a modern society requires both cities and rural areas [47]. The result of rural transformation is not the complete urbanization and elimination of the countryside but the optimization and promotion of the countryside, maintaining rural characteristics even in the common development of the city. Although the level of urbanization is high, there are still a large number of people living in rural areas [48], and an increase in urbanization does not directly lead to the improvement of life in rural areas [49]. The spatial imbalance in regional development directly leads to this unequal distribution of capital and benefits and even triggers social conflicts [50]. Although spatial imbalance is a temporal phenomenon, it will decrease with economic development. Nonetheless, in this process, spatial inequality may be harmful to the development process itself [51]. Undifferentiated equalization does not improve the state of spatial imbalance [52]. Based on this situation, rural transformation and the coordinated development of the county economy can release their economic benefits to a certain extent through the externalities of economic behavior, stimulate the free flow and equal exchange of urban and rural capital within the space, and, consequently, narrow the urban–rural development gap. Due to differences in national conditions, we need to further understand the response of rural changes in different regions to regional economic development in the process of globalization, explore the synergistic characteristics of rural and regional transformation at different levels, and reveal the synergistic mechanism of rural and regional transformation in different regions. Focusing on breaking down barriers in social and geographic space, summarizing the rural and regional synergy strategies suitable for most regions, and building a bridge between rural and regional synergy by developing theories, practices, and policies should be the work of future research.

Author Contributions: B.T.: Conceptualization, methodology, software, writing—review and editing. H.W.: Conceptualization, supervision, writing—review and editing, resources. C.M.: Project administration, resources. X.W.: Data curation, software. J.Z.: Data curation. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China (grant numbers 418610370).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We thank the editor and the reviewers for their insightful and valuable suggestions, which greatly improved the quality of this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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