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Study on the Interactions Between Urbanization, Tourism, and the Ecological Environment in Underdeveloped Regions: PVAR Model Analysis Based on Data from 32 Chinese Cities

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Abstract: Clarifying the dynamic relationships between urbanization, tourism development, and the ecological environment in underdeveloped regions can assist local governments in optimizing industrial upgrades and environmental management through effective policy planning, despite resource constraints, thereby promoting high-quality urban development. This study, based on data from 32 cities in northwestern China, constructs a multi-dimensional evaluation system incorporating demographic, economic, social, and environmental indicators. Using a PVAR model, the long-term dynamic interactions between urbanization, tourism, and the ecological environment are explored. The results indicate that, although in the initial stages, the three subsystems can support each other, in the long term, tourism has a positive impact on urbanization and the ecological environment, whereas both urbanization and the ecological environment negatively impact tourism. The interaction effects between urbanization, tourism, and the ecological environment are weak, with contribution rates below 20%, failing to create a synergistic development. The primary reason for this issue is that urbanization development policies lag behind the needs of tourism and ecological environment development. Policy recommendations are provided, including optimizing cross-sector collaboration strategies, enhancing urbanization quality, and prioritizing environmental protection, to foster coordinated development among the three.

Keywords: underdeveloped regions; urbanization; coordinated development; PVAR model

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1. Introduction

Currently, many developing countries, including China, are experiencing a transitional phase of urbanization, with the goal of enhancing the quality of urbanization through industrial optimization and upgrading. Tourism is a significant part of the tertiary industry and is one of the fastest-growing new industries globally, offering new support for urban development and change. This trend is especially noticeable in underdeveloped regions. These areas often have complex ecological conditions that greatly limit the development of their secondary industries, leading to slower urbanization. However, these ecological settings also shape the unique natural environments found in underdeveloped regions, which provide resources that can be used for tourism development.

Achieving a harmonious interaction between tourism, urbanization, and the ecological environment is a crucial factor for sustainable economic and social development in underdeveloped regions. Urbanization is a vital driver of national and regional development, but it is closely associated with industrial growth. The tourism industry, as an emerging comprehensive sector, has gradually become a breakthrough point and a new driving force for urbanization. Conversely, the development of the tourism industry also requires support from urbanization. Enhancing the conditions for tourism through urbanization—by providing a customer base, basic services, skilled personnel, as well as tourism spaces and branding—is essential for ensuring the sustained growth of the tourism industry. In the meantime, both tourism development and urban expansion depend heavily on the ecological environment, which serves as a foundation.

However, the relation between the three is not always positive and significant. Several studies have explored the bilateral relationships between urbanization, tourism, and the ecological environment in developed regions [1,2]. For instance, research on Guangdong provinces, a leading economic province of China, indicates that urbanization, though generally increasing tourism development, does not affect all types of tourism development uniformly. Some of the studies are based on geographical division, combining developed and less developed regions. Such research on 11 provinces along the Chinese Yangtze River Economic Belt indicates that urbanization positively impacts tourism, though tourism's influence on urbanization is less pronounced [3].

Existing research concludes that as tourism grows, the quality of the ecological environment undergoes staged changes. For example, the decline of coral reefs and mangroves along the Persian Gulf and Red Sea coasts [4], the worsening soil salinization along Turkey's Aegean coast [5], the coastal areas in eastern Thailand are vulnerable to climate change-related risks [6], and the water quality of Lijiang Ancient Town has deteriorated sharply with the development of tourism [7]. But in China's Great Nanyue tourism circle, the interaction between tourist sites and their surrounding environments evolves through stages of intrusion, competition, reaction, and regulation. Over time, with the development of tourism resources shifting from extensive to intensive environmental management, the environment will be improved [8].

The relationship between urbanization and the environment is complex. Fang et al. [9] argued that prioritizing environmental protection may impede urbanization, whereas prioritizing urbanization could exacerbate environmental degradation. However, effective policies and technological interventions can mitigate the negative environmental impacts of urbanization. So, the relationship between urbanization and the environment may follow a Kuznets inverted U-curve [10]. Ma et al. [11] confirmed the inverse U-shaped relationship between tourism urbanization and the eco-environment in western China based on the construction method of the interactive stress model. Xu et al. [12] confirmed that land urbanization and economic urbanization displayed a Kuznets curve relationship with carbon emissions.

Some studies have examined the interactions between tourism, urbanization, and the ecological environment in underdeveloped regions. This research largely used provincial or higher-level data [13,14] and focused on the degree of coupling and coordination between the subsystems [15]. Gao et al. [16] and Zhao et al. [17] conducted an empirical study on the coupling coordinative development and types among tourism, urbanization, and ecological systems based on provincial-level data in the Beijing–Tianjin–Hebei region by using the principal component analysis and the coordinated coupling model. Tian et al. [18] also used the coordinated coupling model to find that the coupling coordination degree of the tourism industry, urbanization, and ecological environment has increased from a low level of coordination to a very high level of coordination. Brahmasrene et al. [19] used cointegration tests and panel regression models to find that tourism negatively impacts carbon emissions while industrialization and urbanization directly cause carbon emissions in Southeast Asian countries.

What kind of unique characteristics do the long-term dynamic interactions between urbanization, tourism, and the ecological environment exhibit in underdeveloped regions? The systematic research related to this topic remains limited. Existing studies suggest that interactions among urbanization, tourism, and the ecological environment are complex and vary significantly across regions and time periods. Thus, several areas in this field require further exploration: (1) Research scope. Most studies focus on regions where urbanization and tourism are already well-developed, with limited attention to underdeveloped areas where urbanization is just beginning and tourism is still emerging. This study specifically examines underdeveloped regions to analyze the interactions between urbanization, tourism, and the ecological environment, offering a fresh regional perspective for multi-variable interaction analysis. (2) Research methods. Previous studies primarily employ static analyses, such as coupling models and correlation analyses. However, results from these models do not clarify causal relationships between variables, and correlation analysis does not effectively capture the dynamic changes and underlying influences between variables. This study applies a PVAR model, which better addresses lagged effects and issues of endogeneity between variables, enabling a more precise and thorough analysis of dynamic relationships.

This study focuses on 32 prefecture-level cities in northwestern China to analyze interactions between urbanization, tourism, and the ecological environment. Northwestern China, which encompasses the provinces of Shaanxi, Ningxia, Gansu, Qinghai, and Xinjiang, remains economically underdeveloped but has abundant ecological and cultural tourism resources. This makes tourism a strategic industry for regional development. However, the region is also tasked with major responsibilities in biodiversity conservation, water resource protection, and soil conservation, making ecological management both vast in scale and highly demanding. The long-standing policy of prioritizing environmental governance highlights the tension between resource development and environmental protection. Conversely, the development of the tourism industry also requires support from urbanization. Enhancing the conditions for tourism through urbanization—by providing a customer base, basic services, skilled personnel, as well as tourism spaces and branding—is essential for ensuring the sustained growth of the tourism industry.

By considering data availability and representativeness, a comprehensive and multi-dimensional evaluation index system is established to assess the development levels and evolution trends of urbanization, tourism, and the ecological environment from 2008 to 2017. The dynamic relationships among these three factors are explored, and recommendations for improvement are provided. The findings are expected to offer insights and support for coordinating urbanization, tourism development, and environmental protection in underdeveloped regions globally.

2. Research Methodology

2.1. Data Sources

The data used in this study primarily comes from the China City Statistical Yearbook, China Regional Economic Statistical Yearbook, and provincial statistical yearbooks of Shaanxi, Ningxia, Gansu, Qinghai, and Xinjiang, covering the years 2008 to 2017. Additional sources include national economic and social development bulletins from each city, as well as environmental status reports from certain cities. Due to severe data deficiencies in certain regions, statistics from Qinghai include Xining and Haidong city, while data from Xinjiang includes Urumqi, Karamay, Turpan, and Shihezi city.

The missing cities in the provinces of Qinghai and Xinjiang are primarily from regions with relatively slow development, where progress in various aspects largely relies on the provincial capitals and other major cities. The development paths of these areas are generally similar to those of other major cities. Data from the provincial capitals and key cities in Qinghai and Xinjiang are included, and these cities are representative in terms of population, economic, and social development, thus adequately reflecting the overall situation of these provinces. Consequently, the absence of data from some cities in Qinghai and Xinjiang will not lead to significant bias.

2.2. Indicator Selection and Sample Description

Drawing on the perspectives of scholars such as Yu [20] and Khan [21], this study combines the concepts of urbanization, tourism, and the ecological environment to select evaluation indicators. Urbanization is measured from the perspectives of population urbanization, economic urbanization, social urbanization, and urban-rural integration. Tourism is evaluated based on domestic and inbound tourism as well as industry scale, while the ecological environment is assessed through environmental pressures and management efforts. The selection of these indicators also considered data availability and reliability across various cities in northwestern China. The constructed indicator system is shown in Table 1.

Table 1. Evaluation indicators for the urbanization–tourism–ecological environment system.

Subsystem	Specific Indicators	Min	Max	Mean	Std. Dev.	Attribute
Urbanization (urb)	Urban population ratio (%)	5.30	99.12	45.55	23.94	Positive
	Per capita GDP (yuan)	3602.00	153,084.00	37,161.81	27,222.17	Positive
	Proportion of tertiary sector in GDP (%)	5.84	70.22	37.64	11.73	Positive
	Proportion of tertiary sector employees (%)	20.87	94.82	58.45	14.33	Positive
	Education and science expenditure ratio (%)	5.26	85.75	19.56	6.00	Positive
	Urban-rural per capita disposable income ratio (%)	20.83	69.36	35.59	9.85	Positive
Tourism (tour)	Number of inbound tourists (millions)	0.0001	180.00	7.66	23.18	Positive
	Number of domestic tourists (millions)	24.79	17,918.01	1432.97	2149.02	Positive
	Number of employees in large-scale catering and accommodation industries (persons)	178.00	86,639.00	7181.62	13,537.11	Positive
	Number of star-rated hotels	4.00	118.00	28.13	22.83	Positive
	Foreign exchange earnings from tourism (USD million)	0.02	122,723.00	3761.43	14,774.39	Positive
	Domestic tourism revenue (billion yuan)	2.30	1550.44	96.02	164.49	Positive
Ecological Environment (envir)	Industrial wastewater discharge (million tons)	99.00	25,248.00	2725.15	2895.96	Negative
	Sulfur dioxide emissions (million tons)	0.25	32.11	5.00	5.35	Negative
	Sewage treatment rate (%)	11.79	100.00	77.08	17.59	Positive
	Green space area (hectares)	23.00	30,076.00	3223.71	4950.95	Positive
	Proportion of days with good air quality (%)	37.81	99.80	84.92	11.25	Positive

2.3. Research Methods

2.3.1. Factor Analysis

Factor analysis is a multivariate statistical method primarily used for data dimensionality reduction and exploring underlying relationships among variables. By identifying latent factors, factor analysis combines multiple correlated variables into a few factors, thereby reducing data dimensions, removing redundant information, and enhancing the predictive and explanatory power of subsequent models. In cases of multicollinearity, factor analysis can also merge correlated variables, reducing the impact of multicollinearity on the model. In this study, the subsystems of urbanization, tourism, and the ecological environment are measured through a series of indicators. Therefore, factor analysis is applied to process the indicators for each system, generating scores for each system to facilitate the subsequent regression analysis.

Factor analysis is used to calculate the evaluation scores for the subsystems of urbanization, tourism, and the ecological environment. Since the statistical indicators have different units of measurement, the data are first standardized using the range standardization method. Then, SPSS is used to perform factor analysis on the standardized data, extracting the factor scores and variance contribution rates for each subsystem, and calculating the overall development score for each subsystem.

The formula for data standardization is as follows:

$$X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)}(\text{Positive})X'_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)}(\text{Negative})$$

where X'_{ij} is the standardized value, X_{ij} is the original value, and min (X_j) and max (X_j) are the minimum and maximum values of indicator X_j, respectively.

The formula for calculating the development level of the subsystem is as follows:

$$A_i = \sum_{n=1}^{k} (F_{in} \times V_{in})/V_i$$

where A_i is the development level score of subsystem i, F_{in} and V_{in} are the factor scores and variance contribution rates of factor n in subsystem i, and V_i is the cumulative variance contribution rate of the k extracted factors in subsystem i.

Since the factor scores may contain negative values, a data translation method is used to transform the scores into positive values for easier subsequent analysis:

$$V'_{in} = c + V_{in} \times d$$

$$c = \sum_{n=1}^{y} V_{in} / \sqrt{\sum_{n=1}^{y} (V_{in} - \overline{V}_i)^2}$$

$$d = 1/\sqrt{\sum_{n=1}^{y} (V_{in} - \overline{V}_i)^2}$$

2.3.2. Panel Vector Autoregression (PVAR) Model

The PVAR model is an analytical method that combines panel data with a vector autoregressive model, primarily used to study the dynamic interactions and lagged effects among multiple variables. The PVAR model can address heterogeneity across individual entities in panel data (such as regions, countries, and companies). Compared to traditional VAR models, PVAR allows each entity to have its own unique intercept, capturing differences between entities. This is especially important for analyzing multi-regional data, as economic, social, and environmental conditions vary across regions.

The PVAR model analyzes dynamic interaction relationships among variables through lagged terms, revealing causal relationships and temporal effects between variables. Additionally, the PVAR model does not require predefined causal directions among variables. By using lagged terms, the model can automatically identify dynamic associations between variables, thus avoiding issues related to incorrect causal assumptions.

Therefore, the PVAR model can integrate the variables of urbanization, tourism, and the ecological environment into a unified system to analyze their dynamic relationships. To reduce heteroscedasticity, the data are log-transformed. The final PVAR model is structured as follows:

$$\text{lny}_{i,t} = \alpha_0 + \sum_{j=1}^{k} \alpha_j \, \ln \, y_{i,t-j} + \eta_i + \theta_i + \mu_{i,t}$$

where $y_{i,t}$ = {$\text{lnurb}_{i,t}$, $\text{lntour}_{i,t}$, $\text{lnenvir}_{i,t}$} represents the vector of urbanization, tourism, and the ecological environment for city i in year t. Considering the heterogeneity across different cities and the significant time trend characteristics of the explanatory variables, the model incorporates the variable η_i to represent fixed effects and the variable θ_i to represent time effects. And $\mu_{i,t}$ is the random error term.

3. Temporal Changes in Urbanization, Tourism, and the Ecological Environment in Northwestern China

3.1. Temporal Changes in the Three Subsystems

After standardizing the statistical data for each indicator, the mean values for each year and region were calculated to determine the evaluation scores for northwestern China from 2008 to 2017. By using data translation methods to convert the subsystem scores into positive values, the mean subsystem scores for each year across all cities were used to assess the overall development level. The trends in urbanization, tourism, and the ecological environment in northwestern China from 2008 to 2017 are shown in Figure 1. From Figure 1, it is evident that all three systems showed overall improvement over the 10-year period, with 2017 levels surpassing those of 2008. However, urbanization progressed more rapidly than tourism.

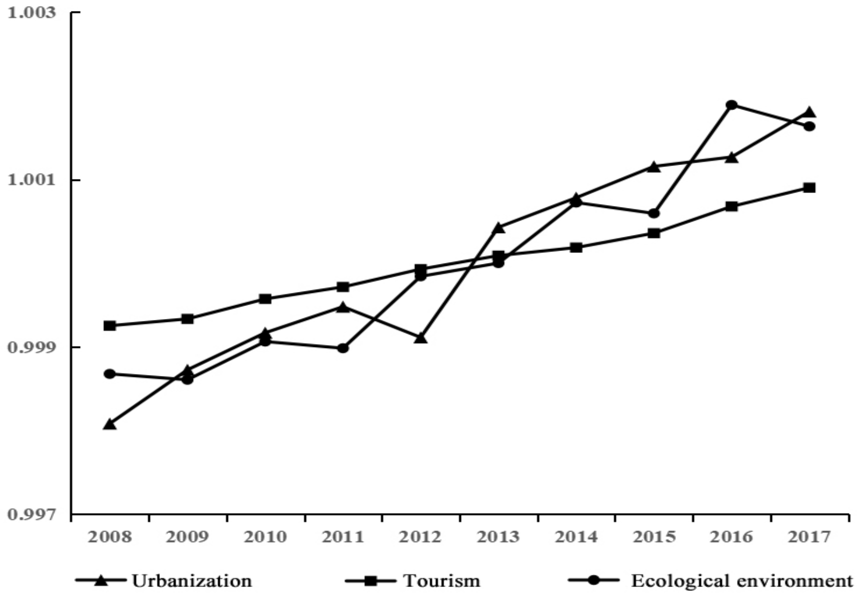

Figure 1. Development trends of the three subsystems from 2008 to 2017.

3.2. Temporal Changes in Urbanization Levels

Figures 2–4 also depict the changes in urbanization, tourism, and the ecological environment systems, respectively.

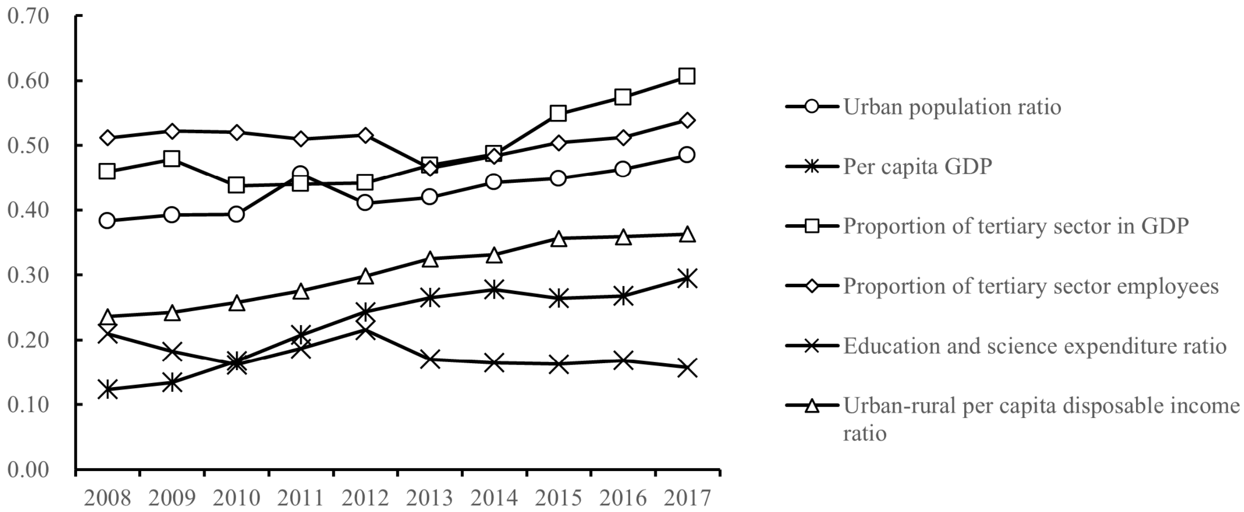

Figure 2. Development trends of urbanization from 2008 to 2017.

Figure 2 demonstrates that urbanization in northwestern China underwent rapid development, making it the fastest-growing subsystem in both speed and growth rate. The score increased from 0.9981 to 1.0018, with an average annual growth rate of 0.041%. The development trends of the urbanization indicators can be divided into three categories. The urban-rural per capita disposable income ratio steadily increased, while the proportion of education and science expenditures in total expenditures showed a gradual decline. Other indicators exhibited fluctuating upward trends. Comparing the overall urbanization trend with individual indicator trends reveals that, before 2013, urbanization closely mirrored changes in the urban population ratio and per capita GDP. Notably, in 2011 and 2012, turning points in the urban population ratio coincided with shifts in overall urbanization levels, with urbanization decreasing to 0.9991 in 2012 before rising to 1.0004 in 2013. From 2013 onwards, urbanization trends aligned more closely with the proportion of the tertiary sector in GDP, indicating that population migration drove urbanization before 2013, whereas the tertiary sector became the primary driver thereafter.

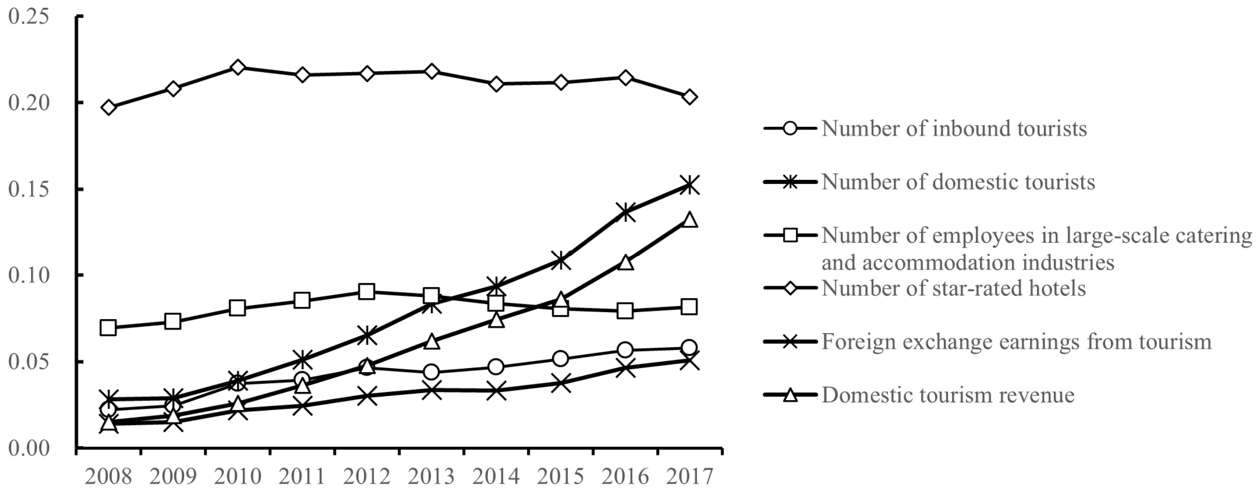

Figure 3. Development trends of tourism from 2008 to 2017.

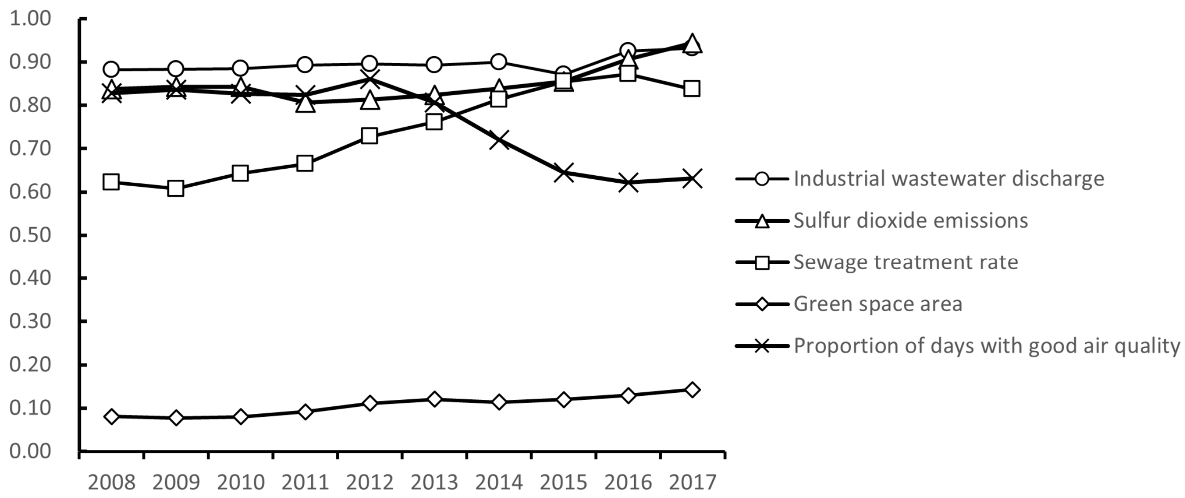

Figure 4. Development trends of the ecological environment from 2008 to 2017.

3.3. Temporal Changes in Tourism Development Levels

Figure 3 illustrates that the development of tourism in northwestern China was relatively stable, albeit slow, with the overall score increasing from 0.9992 to 1.0009, representing an average annual growth rate of only 0.018%. In 2008, the tourism subsystem had a higher development level than urbanization and the ecological environment, but by 2017, it had become the weakest subsystem. The development trends of tourism indicators can also be divided into three categories. Domestic tourist numbers and domestic tourism revenue experienced rapid growth, while the number of star-rated hotels and employees in large-scale catering and accommodation industries declined. Although the number of inbound tourists and foreign exchange earnings from tourism showed modest increases, the overall growth was slow.

3.4. Temporal Changes in Ecological Environment Levels

Figure 4 shows that the ecological environment fluctuated over the study period, with alternating periods of improvement and decline. The overall score increased from 0.9987 to 1.0016, representing an average annual growth rate of 0.032%. The trends of individual ecological indicators varied. Industrial wastewater discharge and sulfur dioxide emissions followed similar patterns, with minor fluctuations between 2008 and 2014, but both improved significantly from 2015 to 2017. Sewage treatment rates steadily increased from 2008 to 2016 but dropped slightly in 2017. The green space area remained relatively unchanged over the 10-year period, with only limited growth. Meanwhile, the proportion of days with good air quality has been declining steadily since 2011.

4. PVAR Model Analysis

4.1. Unit Root and Cointegration Tests

Before estimating the panel data, unit root tests are required to avoid spurious regression issues. Based on the characteristics of the panel data used, this study applies the commonly used Fisher-ADF test, Hadri LM test, and HT test, which is suited for panels with short time dimensions. Among these, the Hadri LM and HT tests assume common unit roots across panels, while the Fisher-ADF assumes heterogeneous roots across panels. As shown in Table 2, while urbanization, tourism, and the ecological environment cannot all be considered stationary in levels, the first differences in the three variables pass the unit root tests, indicating that these variables are all first-order integrated series.

Table 2. Panel unit root test results.

Test Method	Urb	△ Urb	Tour	△ Tour	Envir	△ Envir
Fisher-ADF	98.2748 *** (0.0038)	212.8824 *** (0.0000)	52.0735 (0.8572)	101.3839 *** (0.0020)	121.2813 *** (0.0000)	99.9425 *** (0.0000)
HT	−0.0786 *** (0.0000)	−0.4815 *** (0.0000)	0.0604 *** (0.0000)	−0.3792 *** (0.0000)	0.1046 *** (0.0000)	−0.2362 *** (0.0000)
Hadri LM	1.5619 * (0.0592)	−4.0062 (1.0000)	4.2579 *** (0.0000)	−0.4725 (0.6817)	3.9406 *** (0.0000)	−1.5783 (0.9428)

Note: The Hadri LM test's null hypothesis assumes no unit root, while the other tests assume a unit root. p-value are shown in parentheses, * $p < 0.1$, *** $p < 0.01$.

These results confirm that urbanization, tourism, and the ecological environment are first-order integrated series. Therefore, a cointegration test can be conducted to determine whether there is a long-term equilibrium relationship among the three variables. This study uses the Kao, Westerlund, and Pedroni methods for panel cointegration tests. As shown in Table 3, all three methods reject the null hypothesis, confirming the existence of cointegration among urbanization, tourism, and the ecological environment. The PVAR model can thus be estimated.

Table 3. Panel cointegration test results.

Test Method	Statistic	*p*-Value
Kao	3.8548 ***	0.0001
Pedroni	−7.5955 ***	0.0000
Westerlund	−1.9945 **	0.0230

Note: The null hypothesis assumes no cointegration. ** $p < 0.05$, *** $p < 0.01$.

4.2. Lag Length Selection

Before estimating the PVAR model, it is necessary to select an appropriate lag length. Excessive lag lengths result in the loss of too many observations, while insufficient lags reduce the reliability of the estimates. The Akaike information criterion (AIC), Bayesian information criterion (BIC), and Hannan–Quinn information criterion (HQIC) are used to determine the optimal lag length. As shown in Table 4, all three criteria suggest that a lag of one is optimal.

Table 4. Optimal lag length selection.

Lag Length	AIC	BIC	HQIC
1	−31.7592 *	−30.3051 *	−31.1743 *
2	−31.5998	−29.8635	−30.8989
3	−28.7111	−26.6243	−27.8659

* $p < 0.1$.

4.3. Model Estimation Results

4.3.1. Generalized Method of Moments (GMM) Estimation

As shown in Table 5, each subsystem (urbanization, tourism, and the ecological environment) is primarily influenced by its own previous values, while the interconnections between subsystems are relatively weak. Urbanization and the ecological environment positively influence each other, and urbanization has a positive impact on tourism development. However, tourism negatively affects urbanization, though the impact is not statistically significant. Additionally, tourism negatively affects the ecological environment, while improvements in the ecological environment positively influence tourism development. Although the GMM estimates provide coefficient values, they do not fully capture the dynamic relationships among the variables. Further analysis using impulse response functions and variance decomposition is necessary to explore the long-term interactions and shock contributions [22].

Table 5. GMM estimation results.

Variable	Urb	Tour	Envir
urb (−1)	0.4400 **	0.0047	0.5164
	(0.014)	(0.937)	(0.102)
tour (−1)	−0.0319	0.7764 ***	−0.2010 *
	(0.613)	(0.000)	(0.065)
envir (−1)	0.0522	0.0444 *	0.4912 ***
	(0.267)	(0.061)	(0.000)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.3.2. Impulse Response Analysis

Using Monte Carlo simulations with 500 iterations, impulse response functions were generated for 0–6 periods, showing the effects of one standard deviation shock on the variables. The central trend lines in Figure 5 illustrate the impact of shocks to one variable on itself and the other two variables. The horizontal axis represents the time periods, while the vertical axis represents the response magnitudes. As seen in Figure 5, each subsystem exhibits a peak response to its own shocks in the current period, which then gradually decays to near zero in subsequent periods. The interactions between subsystems remain weak, though they display different characteristics in response to shocks from other systems. In Figure 5, the upper bound line represents the upper 95% percentile of the impulse responses and the lower bound line shows the lower 5% percentile of the impulse responses. The median line shows the median response of all the simulated paths. It reflects the typical or most likely impulse response.

As shown in Figure 5b,c, a one standard deviation shock to urbanization has a positive impact on the ecological environment but a negative impact on tourism. The effect on the ecological environment peaks in the first period before rapidly declining. This suggests that urbanization initially supports environmental protection, but this effect diminishes over time. The effect on tourism is relatively stable but remains below zero, indicating that urbanization may hinder tourism growth.

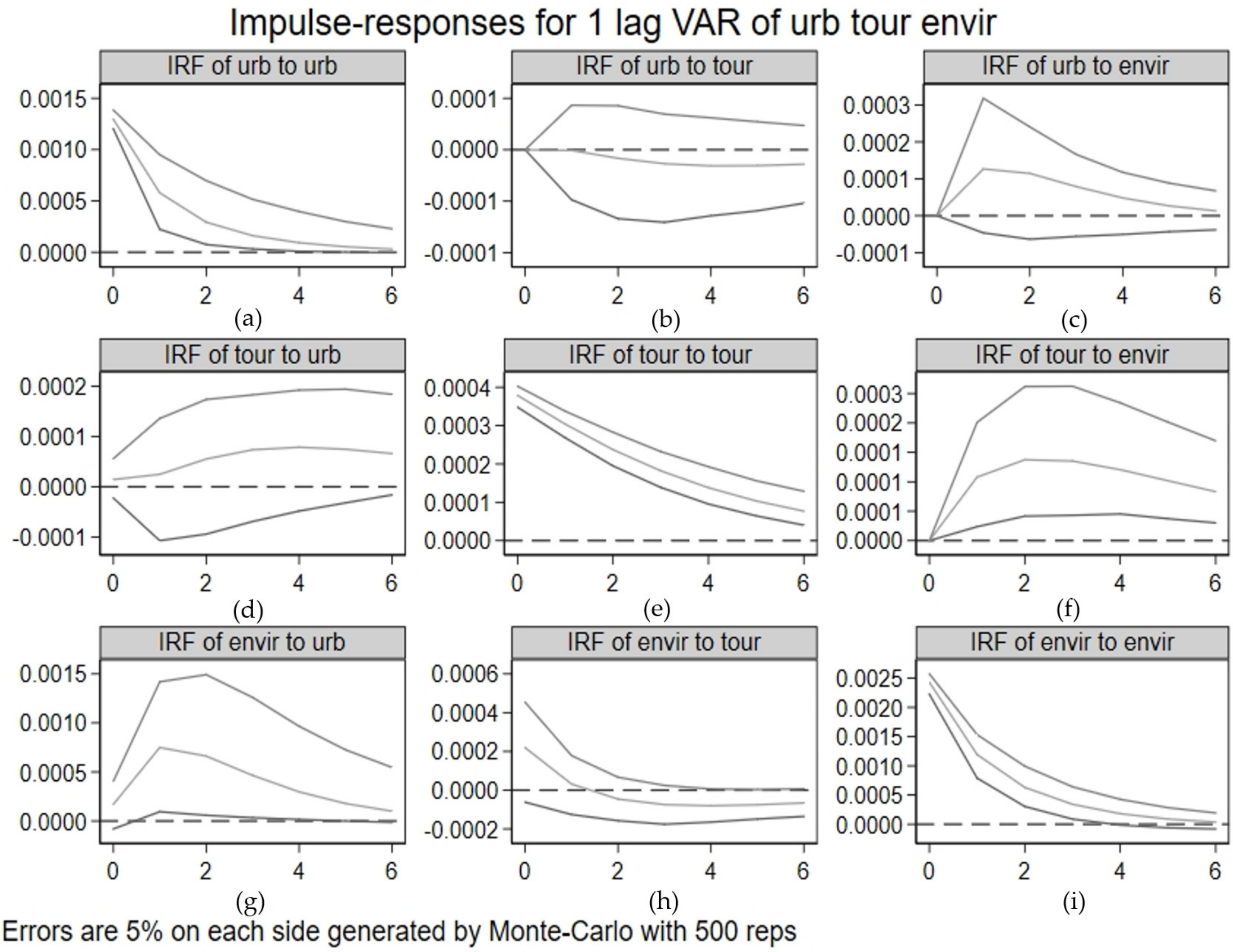

Figure 5. Impulse response function graphs.

Figure 5d,f shows that a one standard deviation shock to tourism positively affects both urbanization and the ecological environment in the long term. While the short-term effect on the ecological environment is positive, the long-term effect is gradually decreasing. Distinct from this, tourism's impact on urbanization became more positive after the first period.

Figure 5g,h illustrates that shocks to the ecological environment positively influence urbanization, with the effects peaking in the first two periods before gradually decreasing. However, the ecological environment will influence tourism negatively after the first period. This indicates a lagged effect of environmental change on both urbanization and tourism. In the long run, these positive impacts diminish as tourism exerts increasing pressure on the environment and urbanization's environmental benefits weaken.

4.3.3. Variance Decomposition

As shown in Table 6, over 10 periods, each subsystem remains primarily influenced by its own developments, though the contributions of urbanization, tourism, and the ecological environment to one another increase slightly over time. For urbanization, the contributions of tourism and the ecological environment increase from 0.1% and 0.5% in the first period to 6.6% and 14.8% in the 10th period, respectively. For tourism, urbanization's contribution remains small, increasing to just 0.1% by the 10th period, while the ecological environment's contribution rises to 0.9%. For the ecological environment, tourism's contribution surpasses that of urbanization, reaching 16.5% in the 10th period. However, none of the inter-subsystem contributions exceed 20%, indicating weak linkages between subsystems.

Table 6. Variance decomposition results (%).

Period	Shock Variable	Variable Shocked		
		Urb	Tour	Envir
1	urb	1.000	0.000	0.000
	tour	0.001	0.999	0.000
	envir	0.005	0.008	0.987
5	urb	0.982	0.000	0.017
	tour	0.037	0.814	0.150
	envir	0.144	0.007	0.849
10	urb	0.982	0.001	0.018
	tour	0.066	0.749	0.183
	envir	0.148	0.009	0.844

5. Discussion

Using data from 32 cities in northwestern China, this study constructed subsystems for urbanization, tourism, and the ecological environment and evaluated their development levels from 2008 to 2017. In the initial stage, the three subsystems can support each other. However, the application of the PVAR model demonstrates that the long-term dynamic relationships between urbanization, tourism, and the environment are weak and complex, with different subsystems exerting varying levels of influence over time.

In northwestern China, urbanization progressed more rapidly, while tourism lagged and the ecological environment exhibited fluctuating development. In the long term, urbanization and tourism have a positive effect on the environment, though it is decreasing. However, both urbanization and the environment exert a negative impact on tourism. The interactions between urbanization, tourism, and the ecological environment remain weak, with urbanization contributing almost nothing to tourism's development.

Based on the analysis, the three subsystems tend to rely more heavily on their own inertial development. Specifically, tourism provides unidirectional support to urbanization, while the feedback effect of urbanization on tourism is relatively weak, aligning with the conclusions of Ma et al. [23]. In terms of the relationship between urbanization, tourism, and the ecological environment, a Kuznets curve with an inverted U-pattern is also observed, consistent with the findings of Ma et al. [11] and Xu et al. [12]. However, in underdeveloped areas, this inverted U-shape exhibits a more leftward peak. In other words, as urbanization and tourism progress, the ecological environment in underdeveloped areas experiences a slight short-term improvement, followed by a long-term gradual and continuous decline. This conclusion has rarely been highlighted in previous research. It is evident that the development of urbanization and tourism in underdeveloped regions is largely based on sacrificing the ecological environment. Consequently, over time, the ecological environment's support for urbanization and tourism gradually decreases and may even have a negative impact.

These results are primarily associated with urbanization development policies in Northwest China. Currently, urbanization efforts in this region remain focused on traditional industries and infrastructure construction, while the development of emerging industries, attraction of high-skilled talent, and improvement of the ecological environment lag behind. Due to a heavy reliance on resource-based industries, urbanization in Northwest China intensifies ecological degradation through resource extraction, further limiting the development of tourism. Additionally, the limited employment opportunities in this region make it difficult to attract a substantial number of highly skilled professionals. The relative scarcity of educational resources also hinders the local cultivation of high-end talent, thereby limiting intellectual support for the growth of emerging industries and the upgrading of traditional industries. As a result, a positive feedback cycle among urbanization, tourism, and the ecological environment has not been established.

Specifically, as tourism develops, it facilitates the shift in the local agricultural population to non-agricultural industries, increasing the proportion of the tertiary sector. For the ecological environment, tourism development initially alleviates environmental pressures while also causing some resource depletion. In the early stages, the ecological environment in Northwest China provides favorable conditions for tourism development, and the benefits tourism brings to the environment outweigh the resource costs. Consequently, the ecological environment initially promotes local tourism development, and tourism, in turn, facilitates rapid environmental improvements.

Similarly, although northwestern China started with a low level of urbanization, significant progress has been made in driving rural-to-urban migration because of the advance of non-agricultural industry and therefore reducing the ecological impact of agricultural production and promoting industrial restructuring, which has improved the region's ecological efficiency. As urbanization reaches higher levels, the pace of population migration and industrial transformation slows, and the positive effects on the environment will slow down. For urbanization, tourism development promotes the growth of the non-agricultural population and brings funding to urban construction. Thus, tourism provides sustained support for urbanization.

Urbanization primarily promotes tourism development by concentrating talent, capital, and technology in cities, which supports the construction of urban infrastructure and the shift toward service-oriented industrial structures. Improvements in urban modernization, consumer standards, external recognition, and hospitality facilities are essential conditions for tourism growth [24]. However, in Northwest China, urbanization efforts are still predominantly focused on the secondary industry. Over time, this approach not only fails to foster tourism development but also creates competition for resources between other industries and tourism, thereby negatively impacting the latter.

In economically advanced regions, tourism often integrates with other high-value-added industries, such as cultural and creative industries and technology sectors, forming unique tourism brands and innovative models. In contrast, in many underdeveloped areas, urban industrial upgrades are mostly concentrated in low-tech industries, which limits tourism's ability to attract specialized talent and technological investment. Due to a lack of high-quality planning and management, tourism resource development and operations tend to be extensive, resulting in a weakly extended tourism industry chain that constrains the utilization of tourism resources and reduces the market potential.

On the other hand, while some environmental improvements have been achieved in recent years, the region still faces significant ecological challenges. The fragile ecosystems and limited governance capacity make sustained environmental improvement uncertain. Although a healthier environment supports both urbanization and tourism, as tourism projects mature and visitor numbers grow, additional pressures are exerted on the ecological environment. Concurrently, urbanization's low resource efficiency and rising pollution have intensified its adverse environmental impacts. With continued ecological degradation, tourism loses its foundational support, and the negative effects of the environment on tourism gradually become evident.

6. Conclusions: Implications for Policy Design and Research

In general, the interactions between tourism, urbanization, and the ecological environment in underdeveloped regions do not follow a linear pattern. They are complex and often non-linear. Delays or weaknesses in one subsystem can hinder the development of others. In northwestern China, the relatively low quality of urbanization has limited its support for tourism, which has resulted in a failure to create effective synergies among urbanization, tourism, and the ecological environment.

The findings offer several important implications for both future research and the design of policy interventions in similar regions. First, policymakers should develop integrated planning strategies that simultaneously address urban development, tourism expansion, and environmental sustainability. Cross-sector collaboration and the creation of policies that align with the goals of these systems are essential for achieving coordinated and sustainable development. Second, the quality of urban development must be prioritized. Governments should focus on promoting new technologies, extending the industrial chain, and adopting smart city solutions to ensure that urban expansion is both sustainable and environmentally friendly. Last, policy planning should pay attention to environmental protection. Given the diverse characteristics of the cities analyzed, policies must be tailored to the specific needs and conditions of each region. For instance, cities with more developed tourism industries may need stricter environmental regulations, while those with rapid urbanization might focus on infrastructure improvements and pollution control.

For future research, this highlights the need for (1) expansion of comparative studies. Future research could extend beyond northwestern China to compare dynamic interactions in other underdeveloped regions globally. Such comparative analyses could help generalize the findings and identify regional specificities in the interactions between urbanization, tourism, and ecological sustainability. (2) Inclusion of new indicators in tourism. The study primarily focused on traditional tourism indicators. Future studies can incorporate more modern, environmentally friendly forms of tourism to assess their potential positive impacts on the environment.

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