Correlation Analysis of Tourism and Urban Economic Development Based on VAR Model: An Empirical Study Taking Beijing as An Example

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Abstract. Under the background of regional coordinated development, Beijing's tourism economy has become an important driving force for promoting high-quality regional development. Therefore, in order to further explore the correlation between economic and tourism development and promote the coordinated development of tourism and urban economy, this paper constructs a VAR model based on the annual data of the number of tourists received, the revenue of tourist areas, and GDP from 2008 to 2023. Finally, the following conclusions are drawn: The short-term pulling effect of economic growth on tourism demand is significant, but there is a lag period of 1-2 years. Meanwhile, the feedback of tourism to the economy is limited (the contribution rate is less than 3%). Based on this, this paper proposes to establish a collaborative mechanism of "tax optimization - industrial upgrading". By adjusting the distribution of cultural and tourism taxes, strengthening the deep integration of the tourism industry with local scientific, technological, and cultural resources, and establishing a data-driven dynamic policy evaluation system, bottlenecks such as the development gap of tourism resources and the insufficient efficiency of consumption conversion can be broken. Provide systematic solutions for the coordinated development of Beijing's urban tourism economy.

Keywords: Tourism Economy, Urban Economy, VAR Model.

1. Introduction

China's tourism industry has become a pillar industry of the national economy, with comprehensive effects of promoting ecological protection, cultural inheritance, employment, and infrastructure construction. As a thousand-year-old ancient capital and an international consumption center, under the framework of coordinated development of the Beijing-Tianjin-Hebei region, the development of tourism and the transformation of the city's economy in Beijing have significant exemplary significance. Based on this, this study aims to reveal the time-delay mechanism and interaction path between tourism and economic growth and provide empirical references for the integration of culture and tourism as well as the optimization of urban policies.

At present, in the empirical research of scholars on the relationship between tourism and economic growth using econometric models, they generally support the conclusion that economic growth can promote the development of tourism. However, regarding the question of whether the development of tourism can promote economic growth, scholars have certain differences in their conclusions based on different samples and analytical models. Early studies mostly relied on cointegration analysis or Granger causality tests, using annual or lower-frequency data [1-3]; Samples tend to focus on tourism-advantageous areas (such as major European destinations and Central and Eastern European countries), ignoring the institutional and structural differences between megacities and underdeveloped regions [4-7]; Meanwhile, the existing literature mostly adopts descriptive statistics in the evaluation of policy effects and lacks the use of panel VAR or structural breakpoint models to quantify the dynamic marginal effects of policy shocks such as tourism subsidies and cultural incentives [8-12].

The existing research has three limitations: First, it is difficult for static methods and short-period data to capture the dynamic interaction laws of travel and travel. Secondly, the samples are concentrated in areas with tourism advantages, lacking comparisons of underdeveloped regions and diverse industrial forms, which weakens the universality of the conclusion. Thirdly, policy evaluation relies on descriptive statistics and fails to quantify the marginal effects of interventions such as cultural and tourism subsidies. In the future, dynamic econometric models (such as VAR) need to be introduced to track the timing mechanism, and policy variables need to be integrated to analyze the regulatory effects of the system.

Inject fresh perspectives and empirical evidence into controversial fields. Previous studies have mostly focused on medium and small cities or specific heritage sites (such as Qufu), while Beijing, as a megacity, has a more complex economic structure and tourism formats. By analyzing the Beijing case through the VAR model, the applicability of the model in complex economic systems can be verified, the nonlinear interaction mechanism between tourism and economic growth in megacities can be dynamically captured, the simplified assumptions of traditional static models for complex economic systems can be overcome, and methodological references can be provided for other large cities. Thirdly, through the variance decomposition and explicit indicators of the VAR model, it provides relevant policy suggestions and inspirations for the subsequent development of tourism by the Beijing government.

2. The basic fundamental of the VAR model

The main measurement methods adopted in this paper are theoretically expounded, including the basic definitions of unit root test, cointegration test, vector autoregressive (VAR) model, and their key analytical tools: Granger causality test, impulse response function, and variance decomposition.

2.1. Unit root test: ADF test

To test the stationarity of the time series, the Augmented Dickey-Fuller (ADF) test is introduced. Its basic form is:

$$\triangle y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{k} \delta_i \triangle y_{t-i} + \varepsilon_t \tag{1}$$

Among them, the y_t for the test sequence, t as time trends, delta $\triangle y_t = y_t - y_{t-1}$ first-order difference, k as the lag order number, and ε_t for the error term. The null hypothesis of the ADF test is that the sequence has a unit root ($H_0{:}\,\gamma = 0$), and the robustness of the sequence is judged by comparing the t-statistic with the critical value to determine whether the null hypothesis is rejected.

2.2. Cointegration test: Johansen test

When multiple variables are all mono-integral sequences of the same order, in order to identify the long-term equilibrium relationship among them, the Johansen cointegration test is adopted. First, write the VAR(p) model as the Vector Error Correction Model (VECM):

$$\triangle Y_t = \mathit{\Pi} Y_{t-1} + \sum_{i=1}^{p-1} \mathit{\Gamma}_i \triangle Y_{t-i} + \varepsilon_t \tag{2}$$

where, Y_t is an n-dimensional variable vector, and Π and Γ_i are matrices of coefficients to be estimated. The rank r of the matrix Π determines the number of cointegration relations: if r=0, there are no cointegration relations; If 0<r<n, there exist r cointegration relations; If r=n, the sequence is stationary. The value of r can be determined by testing the hypothesis through the Trace statistic and the maximum characteristic root statistic, and then the long-term equilibrium direction vector can be obtained.

2.3. Definition and Estimation of the VAR model

The vector autoregressive model (VAR) can handle the dynamic mutual influence of multiple variables simultaneously, and its p-order form is defined as:

$$Y_t = c + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \varepsilon_t \tag{3}$$

Among them, the Y_t to include $n \times 1$ vector of the endogenous variables, such as the ln this paper $\ln tn$, $\ln rt$ and $\ln gdp$; c is the constant term vector $n \times 1$; A_i is the matrix of coefficients of $n \times n$; ε_t is the vector of error terms satisfying $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_t{}') = \Sigma$.

For each equation, the OLS estimation can be used respectively to obtain the estimates of A_i and c. The stability of the model requires the characteristic polynomial of the adjoint matrix.

$$det\left(I_n - A_1 z - A_2 z^2 - \cdots - A_p z^p\right) = 0 \tag{4}$$

All the root z-modulus lengths are less than 1 to ensure that the system shock does not diverge.

2.4. Granger causality test

The Granger causality test is used to determine whether the lag term of one variable can significantly improve the prediction of another variable. Take the Granger causality test of X versus Y as an example, and construct two VAR regressions:

Restricted model:

$$Y_t = c + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \varepsilon_t \tag{5}$$

Unrestricted model:

$$Y_t = c + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{i=1}^{p} \gamma_i X_{t-i} + \varepsilon_t \tag{6}$$

If $H_0: \gamma_1 = \gamma_2 = \cdots = \gamma_p = 0$ is rejected in the combined f-test or the $\mathcal{X}2$ test, then it is said that X Granger causes Y.

2.5. Impulse Response Function (IRF)

The impulse response function describes the dynamic responses of various variables to a certain impulse $\varepsilon_{j,t}$ at a point in time *t* when a unitized impulse occurs. Convert the VAR(p) model into the form of an infinite-order moving average:

$$Y_t = \sum_{S=0}^{\infty} \Phi_S \varepsilon_{t-s} \tag{7}$$

where $\Phi_0 = I_n$, Φ_s can be recursively obtained. The impulse response function Φ_s represents the transmission effect per unit impulse after the *s* period.

2.6. Variance decomposition

Variance Decomposition measures the relative importance of each variable shock to system fluctuations by analyzing the contribution share of the variance of the prediction error among different shock sources. Let the prediction error in period *h* be:

$$e_{t+h} = \sum_{S=0}^{h-1} \Phi_S \varepsilon_{t+h-s} \tag{8}$$

Then the contribution ratio of the JTH shock to the variance of the prediction error of the i-th variable in period *h* is:

where e_i is the selection vector for choosing the i-th variable. This section theoretically clarifies the key methods relied upon in the empirical analysis of this paper, laying the foundation for the subsequent empirical tests and result analyses.

3. Empirical research

3.1. Variable selection, data processing, and model establishment

3.1.1 Variable selection and data processing

The adopted data mainly come from the "China Statistical Yearbook", and the data time range is from 2008 to 2023, providing an empirical basis for identifying the long-term impact of institutional shocks on the tourism economy. Based on the annual data of the number of tourists received in Beijing (recorded as *tn*), the revenue from tourism (recorded as *rt*), and the gross domestic product (recorded as *gdp*), the main object to be examined is the interrelationship between tourism and economic growth.

The relationship between regional tourism and economic growth is studied by establishing a vector autoregressive model for the above variables. To eliminate the possible heteroscedasticity, we conducted logarithmic processing on the original time data. The transformed variables were represented by $\ln tn$, $\ln rt$, and $\ln gdp$, which respectively represent the number of tourists received, the revenue of the tourist area, and the gross domestic product. The data analysis software used for measurement and analysis was EViews.

3.1.2 Model selection

The VAR model, namely the Vector autoregressive model, captures the nonlinear interaction effects and time-delay characteristics among multiple variables through the Granger causality test, impulse response function, and square difference decomposition. It is particularly suitable for verifying the transmission path of "economic growth - tourism demand". This article will analyze the relationship between tourism and regional economic development based on the VAR model.

3.2. Empirical Results and Analysis

3.2.1 Unit root test

The ADF unit root test was conducted on the revenue $\ln rt$, the number of visitors $\ln tn$, and the gross domestic product $\ln gdp$ of the Beijing tourist area in the original time series with the help of the Eviews software. The results show that the t-statistics of $\ln rt$ and $\ln tn$ in the original data are 0.1841 and 0.1995 respectively, both of which have not reached the critical values at each confidence level and belong to non-stationary sequences. The t-statistic of $\ln gdp$ shown in Table 1 is 0.0228, which is lower than the critical value. It can be considered that the original sequence of $\ln gdp$ has stabilized. To ensure the construction of the subsequent VAR model, when taking the first-order difference for $\ln rt$ and $\ln tn$, the P value of the ADF test of the sequence after the first-order difference was significantly lower than 0.05 ($\mathrm{d}\ln rt$: p=0.0017; $\mathrm{d}\ln tn$: p=0.0004), meeting the requirements of stationarity. The specific results are shown in Table 2.

Table 1. The unit root test result of the ADF original data of the variable

Variable	T-statistic	1% critical value	5% critical value	10% critical value	P value
dln gdp	-3.5446	-4.0044	-3.0989	-2.6904	0.0228

Table 2. The ADF first-order difference unit root test result of the variable

Variable	T-statistic	1% critical value	5% critical value	10% critical value	P value
dln rt	-5.8389	-4.7284	-3.7597	-3.3250	0.0017
dln tn	-4.1569	-2.7283	-1.9663	-1.6050	0.0004

3.2.2 Selection of the optimal lag order: lag by 1 order

After the stationarity test is passed, when establishing the VAR model, the lag order is selected based on information criteria such as AIC and SC. The results in the Table 3 show that when the lag order is set to 1, all criteria achieve the optimal or superior performance, thereby determining that the VAR model adopts the first-order lag structure.

Table 3. The selection result of the ADF optimal lag order of the variable

Lag	LogL	LR	FPE	AIC	SC	HQ
0	6.5984	NA	0.0001	-0.4798	-0.3382	-0.4813
1	53.088	68.1849*	8.72e-07*	-5.4784*	-4.9120*	-5.4845*
2	57.664	4.8810	1.91e-06	-4.8885	-3.8973	-4.8991

3.2.3 Granger causality test

To explore the causal relationship between tourism and regional economic growth in the Beijing area, this paper adopts the Granger causality test. The specific results are shown in Table 4.

In empirical testing, significance levels of 1%, 5%, and 10% are typically chosen, corresponding to p-value thresholds of 0.01, 0.05, and 0.10. When the p-value of the test statistic falls below the selected level, the null hypothesis is rejected, indicating the existence of a Granger causal relationship between the variables. The results show that when the change in gross domestic product (GDP) is taken as the dependent variable, neither the tourism revenue (RT) nor the number of visitors (TN) with a lag of one period has a significant impact on GDP (P values are 0.3865 and 0.4086 respectively). When tourism revenue is taken as the dependent variable, the lag period effect of GDP is significant at the 10% significance level (Chi^2=2.9634, P=0.0852), while the effect of TN on RT is not significant. When the number of visitors was taken as the dependent variable, neither GDP nor RT showed a significant causal effect.

Overall, this indicates that regional economic growth has a strong promoting effect on tourism demand and tourism revenue, but the reverse impact is relatively weak. From an economic perspective, the results of the Granger causality study indicate that in the long-term changes, economic growth exhibits a one-way Granger causality effect on the tourism industry. That is, economic growth (GDP) increases residents' disposable income and stimulates tourism consumption (Engel's curve effect), which conforms to the "income-demand" transmission mechanism. Tourism revenue has no significant causal effect on GDP. This may be due to the relatively low proportion of tourism in the economy (such as Beijing, which is dominated by services and technology), or the leakage of tourism revenue (such as the incomplete conversion of consumption by tourists from other places into local investment). The significance close to the 10% level implies potential policy sensitivity. If the integration of tourism with high-value-added industries (such as cultural creativity) is strengthened, its feedback effect on the economy may be enhanced.

Table 4. The result of the Granger causality test

Dependent variable: D(GDP)			
Excluded	Chi-sq	df	Prob.
D(RT)	0.7500	1	0.3865
D(TN)	0.6829	1	0.4086
All	0.7635	2	0.6827
Dependent variable: D(RT)			
Excluded	Chi-sq	df	Prob.
D(GDP)	2.9634	1	0.0852
D(TN)	0.2541	1	0.6142
All	3.0560	2	0.2170
Dependent variable: D(TN)			
Excluded	Chi-sq	df	Prob.
D(GDP)	0.2015	1	0.6535
D(RT)	0.0290	1	0.8648
All	0.2320	2	0.8905

3.2.4 Johansen cointegration test

Cointegration tests are used to explore whether there is a long-term stable relationship between variables. Since at least two of the variables in the revenue $\ln rt$, the number of visitors $\ln tn$ and the gross domestic product $\ln gdp$ of the tourist area in Beijing are first-order simple integration sequences, it meets the prerequisite conditions of the cointegration test. The Johansen eigenspace test method was used to test the cointegration relationship between variables. The result shown in Table 5 indicated that the statistic under the "None" assumption (i.e., there was no cointegration relationship) was 26.5895, which did not reach the critical value of 5% (29.7971). In the case of "at most two cointegration relations", under the assumption of "at most two cointegration relations", the Trace statistic is 3.8109, approaching the 5% critical value (3.8415), indicating that there may be a long-term equilibrium relationship among the variables (P=0.0509). This indicates that there is a long-term and stable equilibrium relationship among the variables, further verifying the intrinsic connection between tourism and economic development within the region.

Table 5. Johansen cointegration test

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.6933	26.5895	29.7971	0.1121
At most 1	0.2858	8.8598	15.4947	0.3785
At most 2	0.2244	3.8109	3.8415	0.0509

3.2.5 Unit circle (AR root graph)

After constructing the VAR model, to test the stability of the model, the unit root graph of the adjoint matrix (i.e., the AR root graph) is drawn to determine whether the system feature roots are all located inside the unit circle (see Figure 1). The figure in Table 6 shows that the moduli of all roots are less than 1, thereby proving that the VAR model is in a stable state as a whole.

Table 6. Accompanying the unit root result of the matrix

Root	0.9500	0.4624-0.4489i	0.4624+0.4489i	-0.4704-0.3348i	-0.4704+0.3348i	-0.0449
Modulus	0.9500	0.6445	0.6445	0.5774	0.5774	0.0449

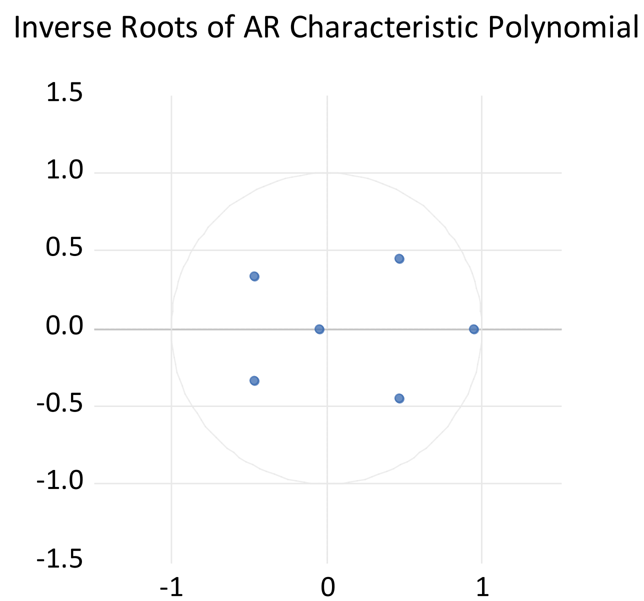

Figure 1. Accompanying the unit root result of the matrix

3.2.6 Impulse response analysis

Impulse response can analyze the dynamic impact on the system when an error term changes, and it can vividly depict the path changes of the interaction between variables. In this paper, based on the VAR model, impulse response analyses of the revenue $\ln rt$, the number of visitors $\ln tn$, and the gross domestic product $\ln gdp$ of the tourism area in Beijing were conducted for 10 and 5 periods respectively.

Impulse response analysis shows that when lntn is subjected to a unit of positive shock, its own response value is 0.15 in the first period (Figure 2), then gradually decreases and turns negative (-0.03) in the fourth period, indicating that the shock effect is short-term. The impact trend on the revenue lnrt of the tourism area in Beijing is similar. However, the response value to lngdp was 0.02

in the first period and then attenuated to 0, indicating that its promoting effect on economic growth is relatively weak.

When the revenue $\ln rt$ of the tourist area is impacted, although its impact on the number of visitors $\ln tn$ of the tourist area gradually increases from the second period, the overall amplitude is relatively small. At the same time, the impacts on both itself and the gross domestic product $\ln gdp$ are relatively weak.

In contrast, after the gross domestic product ($\ln gdp$) was impacted, there was a one-period lag in its impact on the number of visitors ($\ln tn$) and the revenue ($\ln rt$) of tourist areas. From the second period, it gradually strengthened and maintained a positive effect continuously. Meanwhile, the impulse response of $\ln gdp$ to itself shows an initial positive effect and then maintains a steady increase. The high self-explanatory ratio of GDP is in line with the Real Economic Cycle Theory (RBC), emphasizing the dominant role of technological shock and total factor productivity, and is also relatively consistent with the characteristics of actual economic operation (Figure 3).

Overall, the impulse response results show that the pull of GDP on various indicators of the tourism industry is relatively obvious, while the reverse contribution of tourism to GDP still needs to be improved. An increase in the number of visitors can directly boost tourism revenue. However, the growth of tourism revenue takes a longer time to attract more tourists and the effect is relatively weak. At the same time, the relationship between the two is also affected by multiple factors such as industrial structure, consumption level, and seasonality in practice. Therefore, the development model and supporting measures of the tourism industry should be further improved to enhance the positive contribution of tourism to the economy while maintaining the sustainable growth of the tourism market.

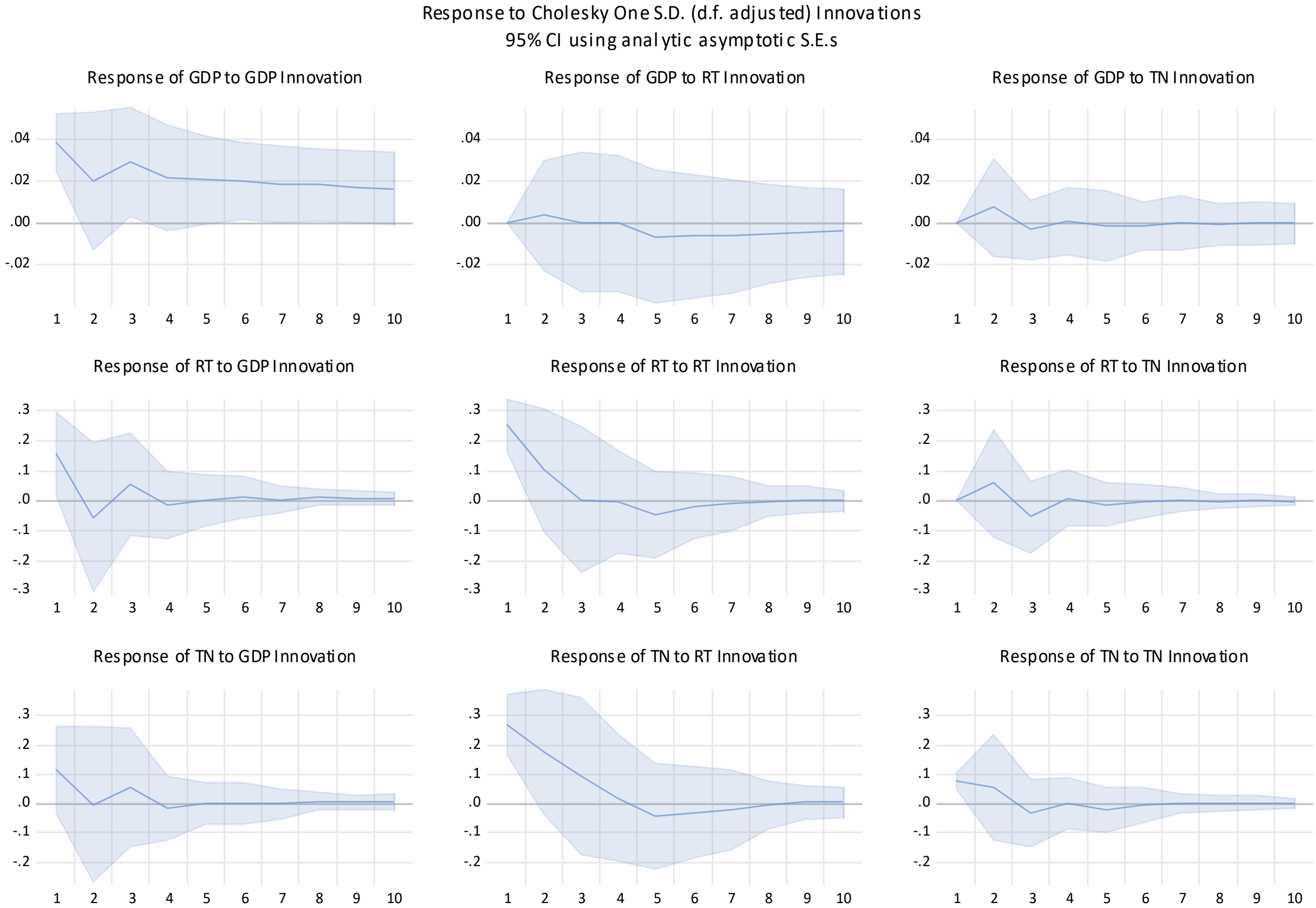

Figure 2. Impulse response Results (10 issues)

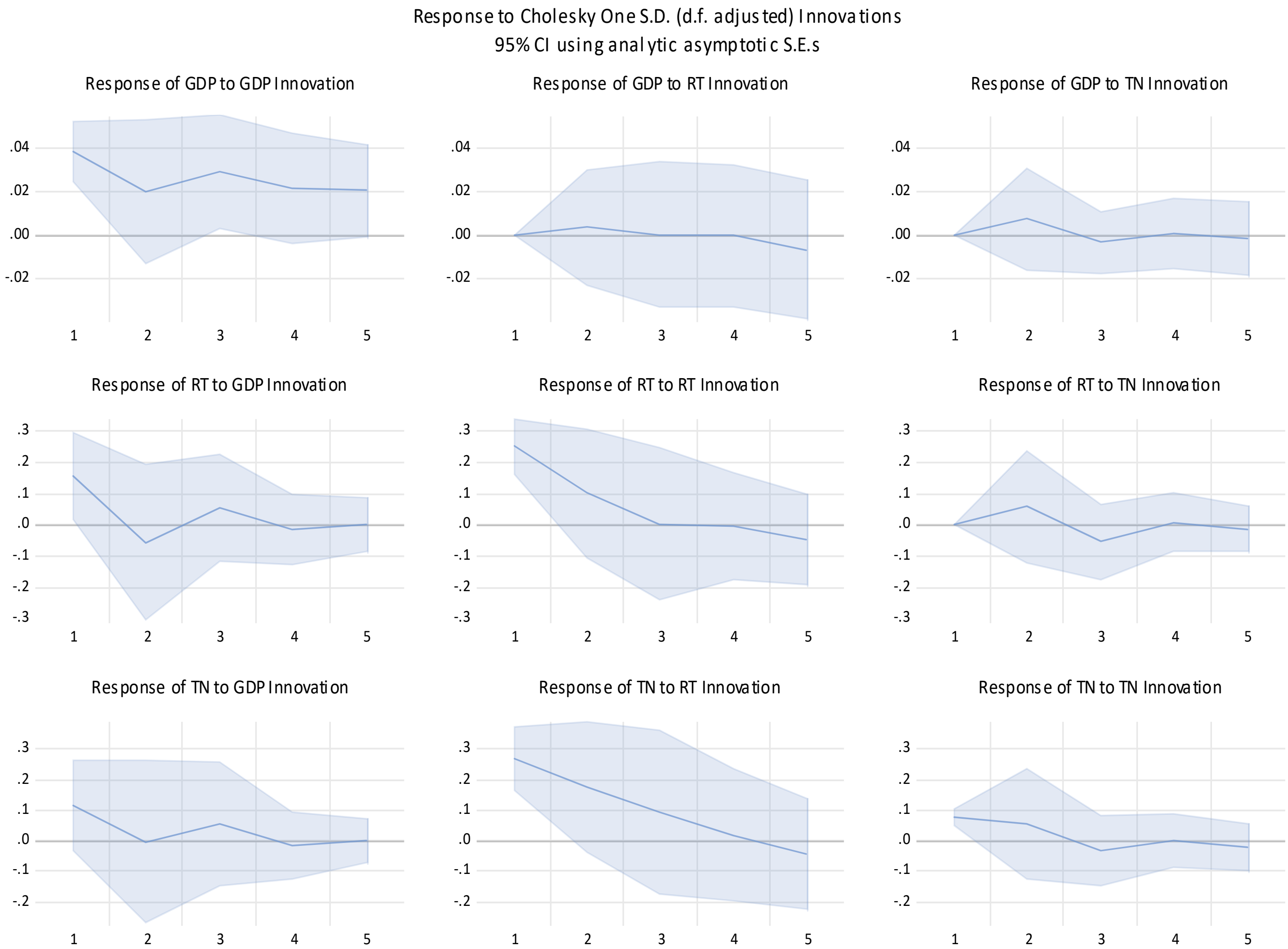

Figure 3. Impulse response Results (5 issues)

3.2.7 Variance decomposition

Variance decomposition is an analytical method that evaluates the influence of different structural shocks by analyzing the contribution of each structural shock to the change of endogenous variables. The author selects 10 periods as the lag period of variance decomposition and conducts variance decomposition for each variable based on the established vector autoregressive VAR model.

Refer to Table 7. For the variance decomposition of $\ln gdp$, its fluctuations are mainly explained by itself (always remaining above 95%), while the contributions of tourism revenue $\ln tn$ and the number of visitors $\ln tn$ to the fluctuations of $\ln gdp$ are negligible (Figure 4).

For the $\ln rt$ of tourism revenue, its fluctuations were mainly explained by itself in the early stage (about 67% - 72%), $\ln gdp$ contributed approximately 27%, and the contribution of the number of visitors was even lower.

For the reception number $\ln tn$, the variance decomposition results show that the variance decomposition results indicate that more than 95% of the $\ln gdp$ fluctuation is explained by its shock (Table 7), while the contribution of $\ln tn$ to the $\ln gdp$ fluctuation is always less than 3% (less than 2% and 0.5% respectively).

The results show that in the Beijing area, economic growth has a high explanatory power for the fluctuations in tourism (especially the number of tourists), fully demonstrating the key role of regional economic development in promoting the growth of tourism. Although there is a certain internal interaction among various variables of the tourism industry, its feedback effect on regional economic fluctuations is limited, suggesting that the multiplier effect of tourism in the regional economy has not been fully exerted.

Table 7. Partial variance decomposition results

Variance Decomposition of D(GDP):				
Period	S.E.	D(GDP)	D(RT)	D(TN)
1	0.0390	100.0000	0.0000	0.0000
2	0.0448	96.1530	0.7912	3.0558
3	0.0536	96.9884	0.5641	2.4475
4	0.0578	97.3832	0.4839	2.1329
5	0.0618	96.5756	1.5160	1.9083
6	0.0654	96.0414	2.2348	1.7237
7	0.0683	95.5626	2.8551	1.5823
8	0.0710	95.3498	3.1820	1.4682
9	0.0732	95.3138	3.3058	1.3804
10	0.0752	95.2984	3.3924	1.3092
Variance Decomposition of D(RT):				
Period	S.E.	D(GDP)	D(RT)	D(TN)
1	0.2975	28.0287	71.9713	0.0000
2	0.3247	26.3003	70.3360	3.3637
3	0.3340	27.7658	66.5007	5.7335
4	0.3343	27.8410	66.3729	5.7861
5	0.3377	27.2919	66.9177	5.7904
6	0.3384	27.3283	66.8981	5.7736
7	0.3386	27.3161	66.8925	5.7914
8	0.3388	27.4320	66.7854	5.7826
9	0.3390	27.4766	66.7411	5.7823
10	0.3391	27.5261	66.6955	5.7784
Variance Decomposition of D(TN):				
Period	S.E.	D(GDP)	D(RT)	D(TN)
1	0.3049	14.0331	79.2367	6.7302
2	0.3569	10.2629	82.4316	7.3055
3	0.3746	11.5842	81.0412	7.3746
4	0.3755	11.7089	80.9477	7.3433
5	0.3786	11.5213	80.9858	7.4929
6	0.3798	11.4450	81.0979	7.4571
7	0.3804	11.4102	81.1528	7.4370
8	0.3805	11.4496	81.1173	7.4331
9	0.3806	11.4649	81.0979	7.4372
10	0.3807	11.4864	81.0790	7.4345
Cholesky Ordering: D(GDP) D(RT) D(TN)				

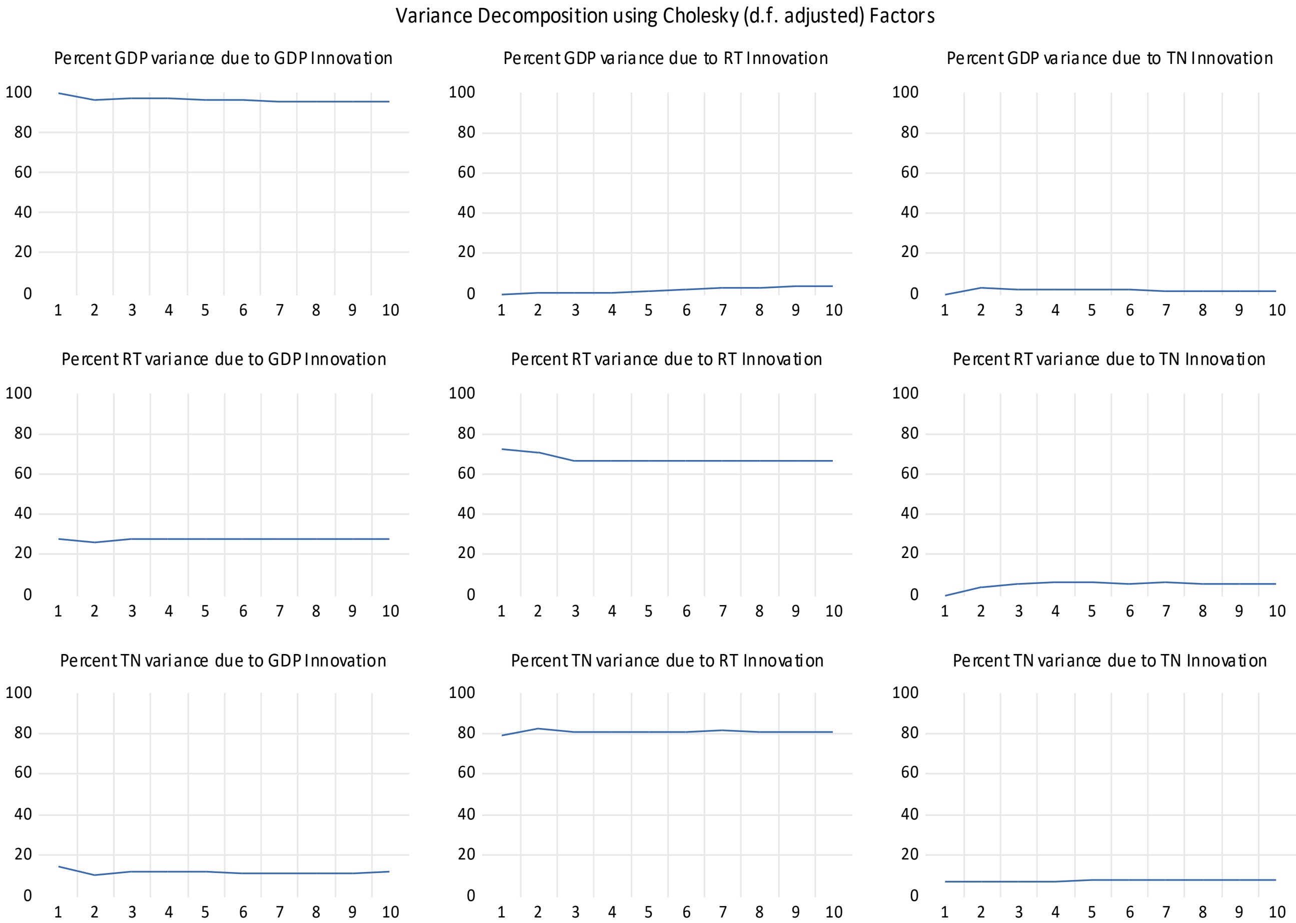

Figure 4. Variance decomposition result

4. Conclusions

Under the background of the coordinated development of the Beijing-Tianjin-Hebei region and the strategic transformation of Beijing, this study constructs a VAR model based on the data of the number of tourists received, tourism revenue, and GDP in Beijing from 2008 to 2023. The dynamic interaction between economic growth and tourism was systematically analyzed by using methods such as the ADF test, Johansen cointegration, Granger causality, impulse response, and variance decomposition. It was found that the pulling effect of GDP on tourism demand was significant and had a lag of 1-2 years, while the feedback contribution of tourism to economic growth was less than 3%.

In light of the above conclusions, this section offers a discussion: first, the significant stimulative effect of GDP on tourism demand and revenue indicates that economic expansion provides a solid foundation for tourism growth, yet the fact that tourism's feedback to the economy is less than 3% reveals that its multiplier effect still needs strengthening—possibly due to an industry structure skewed toward technology and services, a scarcity of high value-added tourism products, and income leakages. Second, seasonal fluctuations and policy changes exert a pronounced influence on tourism dynamics, suggesting that policymakers should pay attention to lag characteristics and sensitive time nodes in order to allocate cultural tourism taxes and creative-industry resources more precisely. Finally, this study's reliance on an annual linear VAR model entails certain limitations; future research could incorporate quarterly or high-frequency panel data, nonlinear or structural-break models, and integrate spatial econometric methods with additional institutional variables to explore the heterogeneous effects of different tourism activities across regions, thereby providing more targeted empirical evidence for optimizing urban tourism policies.

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