

# Study on the Spatio-Temporal Relationship of Tourism Industry in Jiangxi Province Based on Nighttime Light Remote Sensing Data

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**Abstract.** Nighttime light data serves as a vital indicator reflecting urban economic activities and social vitality, extensively utilized in gauging the level of urban economic development and the status of tourism growth. This study zooms in on 11 prefecture-level cities in Jiangxi Province, collecting data on nighttime light intensity and multifaceted tourism metrics spanning from 2010 to 2020. Following data preprocessing, a Panel Vector Autoregression model is employed, integrated with a multi-step statistical testing approach, to delve into the dynamic relationship between nighttime light and the tourism industry. The findings reveal a positive correlation between nighttime light intensity and both domestic tourist arrivals and domestic tourism revenue. Notably, the number of star-rated hotels exerts a marked influence on nighttime light intensity. Further, through the incorporation of Support Vector Machine modeling, this study explores the differentiated impacts of various tourism indicators on light emissions across time and space. It is discerned that all five indicators examined positively correlate with nighttime light data in Jiangxi's prefecture-level cities, with star-rated hotels (coefficient = 4.349) and domestic tourism revenue (coefficient = 3.471) exhibiting the most substantial weights, whereas foreign exchange earnings from international tourism exhibit the least influence (coefficient = 0.193). This research quantifies the specific effects of tourism indicators on nighttime light, offering valuable insights for policymakers and night-time economy planners.

**Keywords:** Nighttime Light; Tourism Industry in Jiangxi Province; Panel Vector Autoregression Model Support Vector Machine Model.

## 1. Introduction

By 2025, the scale of the domestic tourism market needs to grow reasonably, the quality of tourism needs to be further improved, and the nighttime economy as an important part of the urban economy has attracted much attention. Nighttime lighting data can intuitively reflect the city's economic development level, population distribution and infrastructure construction, especially in measuring the level of urban tourism development has an important application value [1]. The relationship between nighttime lighting and tourism in different cities in China has been reported by Zhang Zexin and Xu Shumei [2], who studied nighttime lighting in Harbin. Li Xia [3] conducted a study for Chongqing city, and Leng Qin, Cao Ming studied the effect of nighttime lighting on urban expansion [4]. However, none of the articles studied the relationship between nighttime lighting and tourism development based on individual cities in Jiangxi Province. Therefore, it is important to study the relationship between tourism development and nighttime lighting in Jiangxi province.

Gao Nan, Zhang Xincheng [5] et al. used spatio-temporal characterization in their study of tourism attention in China. Yuling Zhang, Yuting Fang [6] used PVAR model to analyze the red tourism in China, Ouyang Zhi, Zhaoqi Tao et al [7] applied SVM to tourism industry for application, Fangfang Gu, Keshen Jiang [8] used SVM to predict tourists, Ziyu Pan, Shaowei Zhou [9] combined mathematical modeling to conduct tourism research. For this study we proceeded to use PVAR and



support vector machine models, considering each variable as endogenous, analyzing the influence of each variable and its lagged variables on other variables in the model, proving that there is a correlation and interaction between the intensity of urban nighttime lighting and the development of its tourism industry. The SVM can find the optimal decision boundary to make predictions in both spatial and temporal dimensions. Mining gets the relationship between different indicators interacting with each other, and further refines mining variables' influence on night lighting.

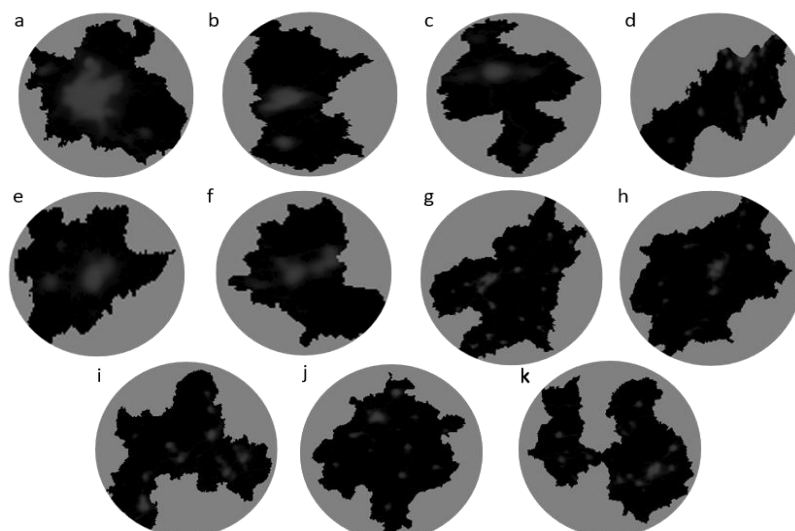
In this study, firstly, the data of indicators are collected from National Bureau of Statistics, Jiangxi Bureau of Statistics, and Harvard database. Z-Scores standardization [10] was adopted for data processing. PVAR model was used to study the relationship between each variable, and GMM estimation [11], Granger causality test [12], impulse response [13], and variance decomposition [14] were used to prove the reasonableness of the data. Finally, the support vector machine was used to test and make predictions, and the relationship between night lighting and tourism indicators was proposed to be obtained.

## 2. Data Source and Description

This study primarily collects and processes data from various prefecture-level cities in Jiangxi Province. The data for this study is sourced from the following websites: [www.stats.gov.cn](http://www.stats.gov.cn); <http://tjj.jiangxi.gov.cn/>; HarvardDataaverse and APIsandDataatHarvardUniversity.

The Chinese-like DMSP-OLS time series data, improved by integrating DMSP-OLS and SNPP-VIIRS, was obtained from Harvard University's database (1992-2023). From this dataset, nighttime satellite remote sensing brightness images (in TIFF format) from 2011 to 2022 were selected. These images were imported into ArcGIS, where histogram equalization and denoising were applied to enhance image quality. The nighttime light data was then clipped to the boundaries of the prefecture-level cities using local boundary data, and the brightness data was extracted using a raster calculator.

This paper aims to study the relationship between urban tourism development and nighttime light intensity, and thus selected relevant data on tourism development and nighttime light intensity for analysis. For the nighttime light intensity data, the total, maximum, minimum, average, and standard deviation of nighttime light intensity were obtained through the aforementioned remote sensing image analysis. To ensure data validity and avoid the impact of regional area on nighttime light intensity, the average and standard deviation data were chosen to measure urban nighttime light intensity. In fact, during the stationarity test of the data using the PVAR model in later sections, the total data did not meet the P-value standard even after two differences, indicating that the total data was not sufficiently stationary, and thus the total nighttime light data was not adopted. The Nighttime light remote sensing data was shown in fig. 1.



**Figure 1.** Nighttime Light Remote Sensing Data

For urban tourism development data, this paper collected data from five perspectives: economy, transportation, catering, accommodation, and culture. Indicators such as the number of domestic tourists, domestic tourism revenue, the number of star-rated hotels, the number of inbound tourists, international tourism foreign exchange revenue, year-end highway mileage, catering, and accommodation profits, and the number of museums were obtained to measure the development of urban tourism.

Descriptive statistics of the obtained data are shown in the Table 1 below:

**Table 1.** Descriptive Statistics of Nighttime Light and Tourism Indicators

Hypothetical Variables	Indicators	N	Minimum	Maximum	Mean	Standard Deviation
y1	Average Nighttime Light Intensity	110	0.77	13.05	3.2059	2.43791
y2	Standard Deviation of Light Intensity	110	3.46	20.18	8.6752	3.51776
x1	Number of Domestic Tourists	110	675.00	9731.96	3993.7205	2354.37461
x2	Domestic Tourism Revenue	110	40.00	1244.15	409.0934	309.39267
x3	Number of Star-rated Hotels	110	4.00	83.00	36.5091	21.55886
x4	Number of Inbound Tourists	110	0.24	37.65	13.8663	9.72686
x5	International Tourism Foreign Exchange Revenue	110	64.12	16710.73	4922.6531	3804.25345

From the descriptive statistics above, it can be observed that there are no missing data for each indicator, and the standard deviations of x1 and x5 are relatively large, mainly due to the significant decline in tourist numbers and tourism revenue in 2020 caused by the pandemic, which led to an increase in standard deviation.

Finally, the data in this paper was standardized using Z-scores. The Z-Score, also known as the standard score, is used to assess the distance of a sample point from the overall mean. Its primary application is to measure how many standard deviations the original data is from the population mean. The formula is as follows:

$$z = \frac{x - \mu}{\sigma / \sqrt{n}} \quad (1)$$

### 3. PVAR Analysis of NightLight Intensity and Tourism Development

To effectively demonstrate the correlation and interaction mechanism between urban nighttime light intensity and tourism development, the Panel Vector Autoregression model was applied to analyze the panel data from 11 prefecture-level cities in Jiangxi Province spanning from 2011 to 2022.

Firstly, modeling with non-stationary data is highly prone to spurious regression phenomena, leading to misleading judgments of relationships, ineffective predictive capabilities, and even compromising the validity of subsequent impulse response models. Therefore, it is imperative to conduct a stationarity test on the panel data beforehand. Stationarity test results are shown in Table 2:

**Table 2.** Stationarity Test Results

Detection Method	Stdy1	Stdy2	Dstdx1	D2stdx2	Dstdx3	Dstdx4	D2stdx5
LLC	0.0008	0.0000	0.6264	0.0000	0.0000	0.0000	0.0805
IPS	0.0311	0.0787	0.3278	0.0717	0.0019	0.4083	0.9251
HT	0.0640	0.3583	0.0128	0.0000	0.2682	0.0000	0.0000

Both the nighttime light intensity data and the prefecture-level tourism data have passed the P-value test. Upon observing the raw data, it is evident that a significant decline in tourism data occurred in 2020, attributed to the immense impact of the COVID-19 pandemic, which emerged at the end of 2019, consequently resulting in unsatisfactory unit root tests for the original data.

Subsequently, to ensure that the model accurately captures the structural patterns within the panel data and avoids both overfitting and underfitting, the optimal lag order was determined, results of optimal lag order determination are shown in Table 3.

**Table 3.** Results of Optimal Lag Order Determination

Lag	AIC	BIC	HQIC
1	5.7549*	9.93515*	7.40672*
2	76.2424	82.6293	78.7122
3	105.589	114.672	108.957
4	116.992	129.372	121.158

Based on the research by Chen Hongling (2021), this study determined the optimal lag order according to the following principles: firstly, using the AIC, BIC, and HQIC criteria to determine the lag order; secondly, to preserve sample freedom, the optimal lag order is generally no more than three. Following these principles and the test results, the optimal lag order was determined to be 1.

Finally, employing the Generalized Method of Moments (GMM) estimation, which assumes that random variables follow specific moment conditions, GMM estimation results are shown in Table 4.

**Table 4.** GMM Estimation Results

Stdy1	Coefficient	P-Value> z
Stdy2	0.8821061	0.000
Dstdx1	-0.262414	0.267
D2stdx2	0.1076546	0.440
Dstdx3	0.404231	0.199
Dstdx4	0.6010161	0.235
D2stdx5	-0.4786726	0.160

The results indicate that the lagged tourism data can significantly alter the current levels of various variables, suggesting a certain degree of path dependence between tourism development and nighttime light intensity in Jiangxi's prefecture-level cities. Notably, among the variables, the number of star-rated hotels and inbound tourist arrivals exert a more pronounced influence on nighttime light intensity.

#### 4. Dynamic Relationship Analysis of Night Lights and Tourism

To further investigate the dynamic relationship between nighttime light intensity and tourism, a Granger causality test was conducted after the previous chapter's determination of the optimal lag order of 1. The results indicate that the lagged tourism data in period 1 significantly alters the current levels of various variables, suggesting a path dependence between tourism development and nighttime light intensity in Jiangxi's prefecture-level cities. Notably, the number of star-rated hotels and inbound tourists, as well as international tourism foreign exchange earnings, exert more pronounced influences on nighttime light intensity, whereas domestic tourist numbers and domestic tourism revenue display statistically insignificant impacts. Granger causality test results are summarized in Table 5:

**Table 5.** Granger Causality Test Results

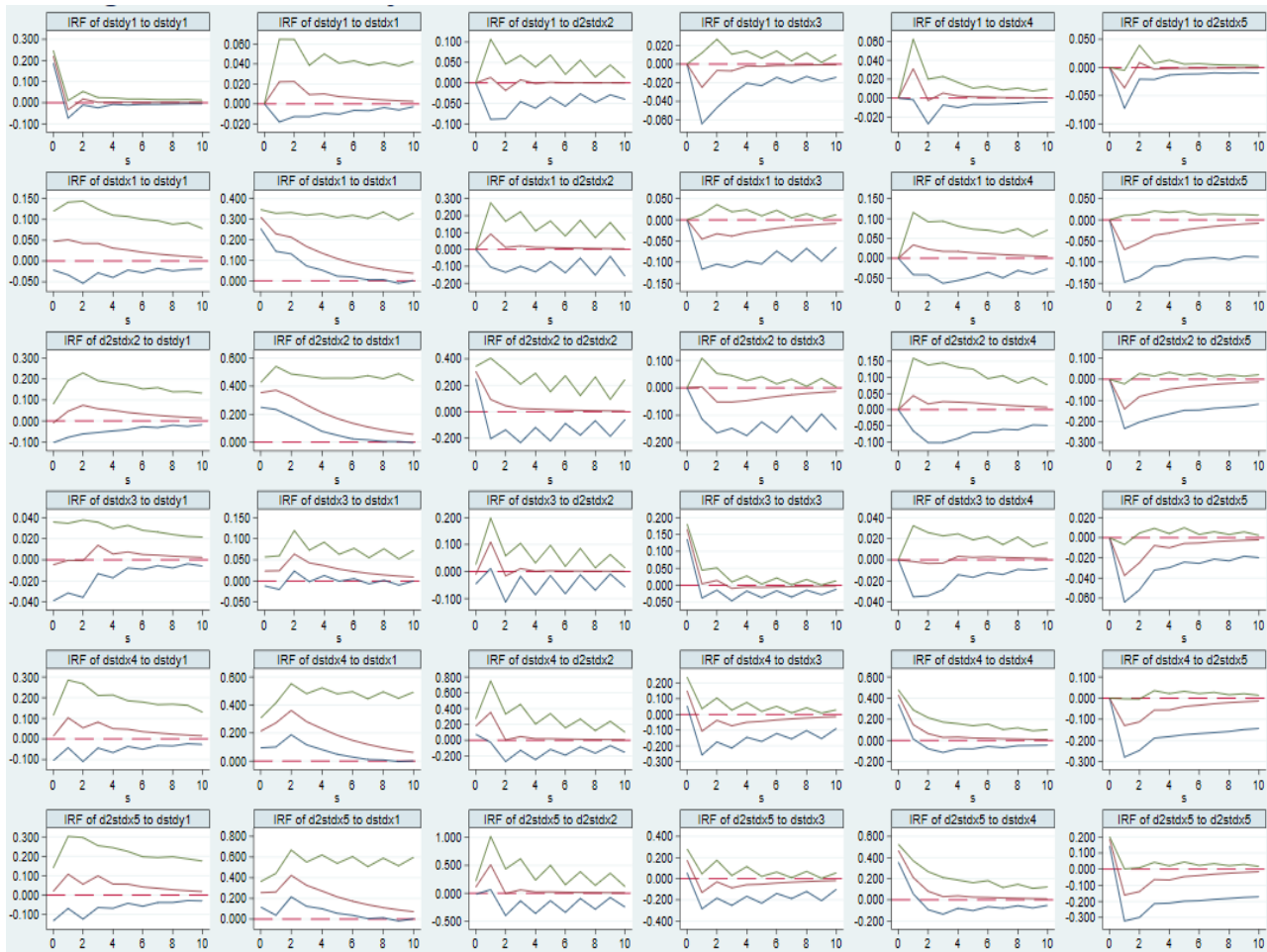
Stdy1	0.191
Dstdx1	0.681
D2stdx2	0.785
Dstdx3	0.085
Dstdx4	0.060
D2stdx5	0.089

According to the significance levels of p-values, variables x3, x4, and x5 (representing star-rated hotels, inbound tourists, and international tourism foreign exchange earnings, respectively) exhibit near-significant impacts on y1 (nighttime light intensity), while x1 and x2 (domestic tourists and domestic tourism revenue) have statistically insignificant effects on y2.

This underscores that international tourism activities, which are more reflective of a city's development level, tend to influence nighttime light intensity more significantly than domestic tourism. Hence, fluctuations in the mean of nighttime light intensity likely signify changes in the international tourism landscape.

The number of star-rated hotels, commonly regarded as a crucial indicator of a city's tourism service level, exhibits a significant impact on urban nighttime light intensity with a p-value of 0.06. This significance underscores the importance of star-rated hotels as a vital factor influencing both the night-time tourism economy and broader urban economic development.

Subsequently, a pulse response analysis was performed, as depicted in Fig. 2.



**Figure 2.** Impulse Response Analysis

In the aforementioned impulse response diagrams, each row represents the impact of the same shock on different variables, while each column represents the impact of different shocks on the same variable. Dstyd1, Dstx1, D2stdx2, Dstdx3, Dstdx4, and D2stdx5 represent the standardized mean of nighttime light intensity, domestic tourist numbers, domestic tourism revenue, the number of star-rated hotels, inbound tourist numbers, and international tourism foreign exchange earnings, respectively.

From the first row of graphs, it can be observed that when nighttime light intensity receives a one-unit standard deviation shock, domestic tourist numbers and domestic tourism revenue initially experience a positive impact in the first period, followed by a negative impact in the second period, albeit minor, eventually stabilizing at the original level. However, the number of star-rated hotels and international tourism foreign exchange earnings receive a positive impact in the first period and a negative impact in the second. Notably, international tourism foreign exchange earnings, influenced by exchange rates and the macroeconomic situation among countries, exhibit a slight increase when the domestic nighttime light intensity is shocked.

The second row of graphs reveals that when domestic tourist numbers experience a one-unit standard deviation shock, nighttime light intensity data shows a sustained downward trend. Concurrently, domestic tourism revenue and inbound tourist numbers also decline from the second period onwards, while the number of star-rated hotels decreases in the first period, indicating a highly responsive hotel industry to domestic tourist numbers. The third row of graphs closely resembles the second, suggesting consistency in the influence of domestic tourist numbers and domestic tourism revenue on other indicators.

The fourth row of graphs demonstrates that when the number of star-rated hotels is shocked by a one-unit impact, nighttime light intensity data initially experiences significant fluctuations, although the mean remains relatively unchanged, indicating a disturbance. Domestic tourism data rises in the first period, whereas international tourism data declines, suggesting a significant role of star-rated hotels in international tourism.

The fifth and sixth rows of graphs exhibit similarity, indicating a consistency in the impact of inbound tourist numbers and international tourism foreign exchange earnings on nighttime light intensity and other tourism data. When these two indicators are shocked by a one-unit standard deviation, nighttime light intensity receives a positive impact in the first period. As international tourism data is influenced by international economic developments, its decline may signify a shock to the international economy. Maintaining one's own pace of development, in comparison, translates to improvement, manifested as an increase in nighttime light intensity. Domestic tourism data also experiences a positive impact, while the number of star-rated hotels suffers a negative impact, consistent with the aforementioned negative impact of star-rated hotels on international tourism data.

Finally, variance decomposition is conducted to explain the contribution of individual endogenous variables to the random disturbance term of the predicted variable, thereby determining the importance of each variable in predicting the disturbance term. With a study period of 10, the variance decomposition results are presented in the Table 6.

**Table 6.** Variance Decomposition Results

Impacted Variable	Period	Shock Variable					
		Dstdy1	Dstdx1	D2stdx2	Dstdx3	Dstdx4	D2stdx5
Dstdy1	1	1.000	0.000	0.000	0.000	0.000	0.000
	5	0.913	0.021	0.010	0.013	0.018	0.025
	10	0.910	0.024	0.010	0.013	0.018	0.025
Dstdx1	1	0.022	0.978	0.000	0.000	0.000	0.000
	5	0.034	0.868	0.033	0.020	0.008	0.037
	10	0.036	0.865	0.030	0.023	0.009	0.037
D2stdx2	1	0.000	0.570	0.429	0.000	0.000	0.000
	5	0.021	0.749	0.163	0.012	0.005	0.051
	10	0.025	0.759	0.145	0.016	0.006	0.050
Dstdx3	1	0.001	0.020	0.004	0.975	0.000	0.000
	5	0.005	0.163	0.243	0.546	0.001	0.043
	10	0.007	0.192	0.233	0.524	0.001	0.042
Dstdx4	1	0.001	0.159	0.112	0.080	0.648	0.000
	5	0.026	0.447	0.186	0.050	0.248	0.042
	10	0.029	0.489	0.167	0.050	0.224	0.042
D2stdx5	1	0.001	0.181	0.032	0.085	0.604	0.098
	5	0.023	0.405	0.228	0.049	0.223	0.073
	10	0.026	0.449	0.205	0.048	0.202	0.070

Based on the results presented in the table above, it can be observed that the nighttime light data and domestic tourist numbers in various prefecture-level cities in Jiangxi Province are consistently less impacted by external shocks and are more significantly influenced by their shocks. In the early stages, domestic tourism revenue, apart from being influenced by its shocks, is also greatly impacted by

domestic tourist numbers. By the tenth period, its self-influence reaches 75.9%. The number of star-rated hotels is heavily influenced by its shocks in the first period, but this declines to 11.2% by the tenth period, with the primary influence coming from inbound tourist numbers, accompanied by impacts from domestic tourist numbers and domestic tourism revenue. Inbound tourist numbers experience a high level of self-influence at 64.8% in the first period, which drops to 22.4% by the tenth period, with domestic tourist numbers having a significant impact. Initially, international tourism foreign exchange earnings are heavily influenced by inbound tourist numbers, but this influence decreases by the tenth period, with domestic tourist numbers and domestic tourism revenue also exerting considerable impacts. As domestic tourism grows and the number of domestic tourists increases, the country's image and reputation may improve, attracting more international tourists and thereby boosting international tourism foreign exchange earnings.

## 5. SVM Application in NightLight and Tourism Prediction

### 5.1. Goodness of Fit Test

This article employs the k-fold cross-validation method to assess the generalization capability of the Support Vector Machine model. By selecting three subsets as the validation set and conducting multiple training and validation processes, the average performance of the model on the validation set is calculated in terms of RMSE (Root Mean Square Error), MSE (Mean Square Error), and MAE (Mean Absolute Error). Additionally, scatter plots of actual data versus predicted data are drawn to determine whether the model is suitable for describing the relationship between nighttime lighting and tourism development. MSE is highly sensitive to large errors and is suitable for scenarios where outliers have a significant impact on model performance; RMSE is consistent with the dimension of the original data, making it easier to interpret; while MAE is not sensitive to outliers and is applicable when the data contains many outliers. Based on the above indicators, validation is performed, and the relevant validation set values are outputted, resulting in Table 7.

**Table 7.** Goodness of Fit Test

Validation Set	Number
RMSE	0.8054
MSE	0.6486
MAE	0.4645

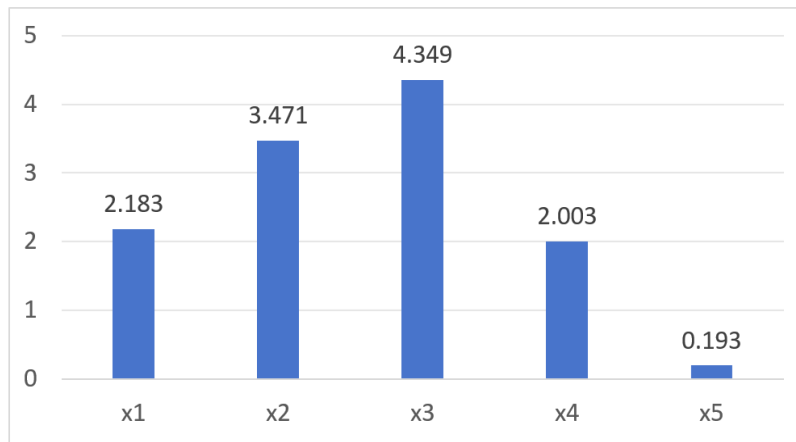
Theoretically, the closer these three indicators are to zero, the higher the predictive accuracy of the model. Based on the results obtained from running the code, we can observe that all three values are very small, ranging from 0 to 1, indicating that the difference between the model's predicted values and the actual values is minimal. This suggests that the model has a good fit, demonstrating a high level of predictive accuracy. It is capable of capturing the relationships and patterns in the data effectively. The fitting effect is satisfactory, and the Support Vector Machine (SVM) model can be applied for predictions between nighttime lighting and various tourism indicators.

### 5.2. Support Vector Machine Model Prediction

This study uses the number of domestic tourists, domestic tourism revenue, the number of star-rated hotels, the number of inbound tourists, and international tourism foreign exchange income as independent variables, and the standard deviation and mean of nighttime lighting as dependent variables. By employing the independent and dependent variables as the training dataset and applying the Support Vector Machine (SVM) model, the relationship between nighttime lighting and the independent variables is determined

Organize the preprocessed data into a tabular format according to the code specifications, and make reasonable use of the aforementioned formulas. Import all tables of independent and dependent variables, and use Python code for machine learning to predict the relationships between various data

on both temporal and spatial dimensions. This will help assess the impact of tourism indicators on nighttime lighting. Based on the conclusions drawn, each city in Jiangxi Province can determine the range of nighttime lighting that can better promote the development of the tourism industry and stimulate the night-time economy. The indicator contribution degree was shown in Fig. 3.



**Figure 3.** Indicator Contribution Degree

Through numerical analysis, it can be concluded that the number of star-rated hotels has the highest relative weight and the greatest impact on nighttime lighting. Following that, the count of star-rated hotels also significantly influences nighttime lighting. The number of domestic and inbound tourists has relatively equal weights, exerting a similar influence on nighttime lighting. International tourism foreign exchange, with a relatively low weight and close to zero, has a minimal effect on the brightness of night lights. In summary, by analyzing the four indicators—number of domestic tourists, domestic tourism revenue, number of star-rated hotels, and number of inbound tourists—we can predict nighttime lighting and thus determine the range within which more efficient promotion of the development of the tourism industry in various cities in Jiangxi can be achieved.

## 6. Conclusion

This paper provides a research approach and framework applicable to the field of regional economics, demonstrating the feasibility of the PVAR and SVM models in this area. Based on the Panel Vector Autoregression (PVAR) model, empirical analyses were conducted on panel data through unit root testing, optimal lag order determination, GMM parameter estimation, Granger causality testing, impulse response analysis, and variance decomposition. Combined with the results of the SVM model, we found that five indicators are positively correlated with nighttime light data across various prefecture-level cities in Jiangxi Province, with the number of star-rated hotels and domestic tourism revenue exhibiting the most significant positive correlations. Furthermore, among the five indicators, the relationships between international tourist numbers and domestic tourism revenue, between international tourist numbers, international tourism revenue, and domestic tourism revenue with the number of star-rated hotels, and between star-rated hotels and both international tourist numbers and international tourism revenue, are particularly noteworthy.

Nighttime light intensity is an important reflection of urban economic development, symbolizing the prosperity and vitality of cities. Urban managers and planners can convey information about urban development through light design and management, promoting economic prosperity and social progress. It is recommended that local governments and tourism operators strengthen the exploration and management of the domestic tourist market, enhance tourism service levels, and develop new tourism products and routes. They should also increase support for the construction and management of star-rated hotels and actively promote international tourism to improve the city's international tourism image and attractiveness, thereby promoting the enhancement of nighttime light intensity and urban economic development.

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