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Research and Simulation on Improving Methods for Optimizing Local Catering Revenue Forecast

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Abstract: Accurately predicting catering income is of great significance for promoting domestic economic development. The traditional cointegration analysis prediction method is difficult to accurately describe the causal relationship between catering income and local economic development, resulting in poor prediction effects. This study proposes a catering income optimization prediction method based on time series. Firstly, it tests the cointegration of catering income and local economic development time series data, constructs a two-variable autoregressive model, and then uses the Granger method to test the causal relationship. Calculate the proportion of the catering industry as a direct influencing factor, and count the correlation effect to form an optimized prediction model. Taking the data of Yan'an City from 2014 to 2023 as an example, simulated by eviews 5.0 software, the results show that this model is superior to the comparison algorithm in prediction accuracy, error rate, stability and time efficiency. The conclusion is that this method can effectively improve the accuracy of catering income prediction and contribute to local economic research and planning.

Keywords: catering income prediction; time series analysis; cointegration and Granger test

1. Introduction

The catering industry is a labor-intensive industry that can provide a large number of employment opportunities. According to the data of the National Bureau of Statistics, in 2019, the number of employees in China's catering industry reached 10.65 million, accounting for 4.3% of the national employment. The development of the catering industry can not only create employment opportunities but also improve the quality and level of employment. With the improvement of people's living standards, the demand for catering services is constantly increasing [1]. The catering industry not only provides basic dietary needs but also offers diversified and personalized catering services, promoting consumption upgrading. At the same time, the development of the catering industry has also driven the development of related industries such as food processing and tableware manufacturing [2]. The catering industry is an important force in driving domestic consumption. With the development of China's economy, people's income levels and consumption levels are constantly rising, and the consumption demand of the catering industry is also constantly increasing [3]. The development of the catering industry can promote the growth of domestic consumption and drive the stable growth of the economy. The catering industry is an important part of the local economy. The catering cultures and special dishes in different regions have attracted a large number of tourists and consumers, promoting the

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development of the local catering industry and cultural industries [4]. At the same time, the development of the catering industry has also driven the development of related industries such as agriculture and fishery. In conclusion, the impact of the catering industry on China's economy is very significant [5]. The development of the catering industry can create employment opportunities, promote consumption upgrading, drive domestic consumption, and promote local economic development, which is of great significance for the stable growth and sustainable development of China's economy [6–8]. Therefore, it is very meaningful to calculate the proportion of the local catering industry and thus judge the factors affecting the local economy.

2. Principles of Prediction

In the process of forecasting local catering industry revenue, we first calculate regional catering revenue and the growth rate of catering revenue. We then obtain the characteristics of catering revenue's promotion on the local economy, describe the change patterns between catering revenue and economic growth, and establish a catering revenue prediction model. The specific steps are detailed as follows:

Assuming that NP represents the value added by the catering industry, CCS represents the connectivity between the catering industry and other industries, and DW represents the elasticity of catering revenue, we use Equations (1) and (2) to calculate regional catering revenue and the growth rate of catering revenue.

$$Q_{jp} = \frac{D_{DS} \times w''}{C_{cs}} \times TES \times N_p DW \tag{1}$$

$$W'' = \frac{D_{DS} \times w''}{C_{cs}} \times \frac{TES \times N_p Q_{JP}}{DW} \tag{2}$$

In this formula, N_p represents the added value of the catering industry, W'' represents the local final demand for catering, and TES represents the income effect of the catering economy. Assuming that X represents the degree of dependence of the catering industry on other industries, we use Equation (3) to obtain the characteristics of how catering income promotes the local economy.

$$\phi'' = \left(Q_{JP} \cdot W^*\right) \frac{\varphi \times \kappa}{\left(H \cdot \chi\right)} \times \beta \tag{3}$$

In this formula, φ represents the equilibrium relationship between restaurant revenue and restaurant growth, κ represents the income effect of the catering industry, H represents factors affecting the development of the catering industry, χ represents the comprehensive employment coefficient of the catering industry on other industries, and β represents the lagged structure between restaurant revenue and economic growth. Using Equation (4), we construct a model for predicting restaurant revenue.

$$NA = \frac{vr \times \phi''}{W^*} \otimes Q_{JP} \cdot DW \tag{4}$$

In this formula, vr represents the pattern of change between restaurant revenue and economic growth.

However, traditional methods cannot accurately describe the causal relationship between restaurant revenue and local economic development, nor can they accurately predict restaurant revenue. A new method for optimizing restaurant revenue prediction based on time series is proposed.

3. A Time Series-Based Method for Optimizing and Predicting Restaurant Revenue

3.1. Vector Autoregression Model of Two Variables: Catering Revenue and Local Economy

During the process of optimizing and predicting restaurant revenue through modeling, obtain time series data on restaurant revenue and local economic growth. Conduct cointegration tests on the time series data for restaurant revenue and economic development. Establish a vector autoregression model for restaurant revenue and economic development variables, and test the causal relationships between the models. The specific steps are detailed as follows:

Before conducting cointegration tests on the time series data for restaurant revenue and economic development, it is necessary to test the stationarity of each time series separately. This step aims to avoid high R^2 values in spurious regressions between the time series variables of restaurant revenue and economic development. Assuming that B represents the standard for judging regional economic growth, use Equation (5) to calculate the level of economic growth in a region with restaurants.

$$p_a(X,A) = \frac{B \cdot \Omega}{\mu_n \cdot R^2} \cdot \frac{\beta^y \times U_n}{M^{\notin}} \tag{5}$$

In the formula, Ω represents total restaurant revenue, μ_n denotes the random disturbance affecting the dynamic system of variables, β^y represents the impact of economic lag variables in the economic region on current variables, U_n represents the availability of variable data, and M indicates the order of integration of the time series data for restaurant revenue and economic growth.

Assuming that the time series of restaurant revenue is first-order integrated, and the time series of economic growth data is second-order differenced, then use Equation (6) to obtain time series data for restaurant revenue and economic development that are stationary.

$$P\left(v/\eta_1\right) = \frac{\xi\left[\sum_{i=1}^{k}\eta_{1i}\right]}{\Gamma\left(\eta_{1i}\right)\ell} \mathrm{Y}_1^{\eta_{1i}-1} \tag{6}$$

In the equation, η_{1i} represents the cointegration relationship between catering revenue and regional GDP, Γ denotes the random disturbance term, Y represents the n-dimensional endogenous variable, and k indicates the lag period of economic growth. Using Equation (7), a vector autoregressive model is constructed for catering revenue and economic development variables.

$$P^L = \frac{u_{1n} - u_{jn}}{t_{ES} \times P\left(\gamma/\eta_1\right)} \cdot pa\left(X,A\right) \tag{7}$$

In the formula, u_{1n} represents the dining consumer’s propensity to consume, u_{jn} represents the scale of consumption, and t_{ES} represents the second-order difference sequence of the economic growth data series.

Assuming that W^* represents the second-order difference sequence of the economic growth data series, it can be determined that the economic growth time series is second-order integrated, expressed by Equation (8).

$$W^* = \frac{\hbar \times \theta^\beta}{P^L \cdot p_a\left(X,A\right)} \tag{8}$$

In the formula, $\hbar$ represents the extension of the autoregressive model, and θ^β denotes the optimal lag period selection for the relationship between catering revenue and economic growth. From Equation (8), it can be concluded that if the orders of integration of the local catering revenue and economic growth time series data differ, then the two variables are not cointegrated. If, however, the two time series are cointegrated, it indicates that there exists a long-term equilibrium relationship between them. The cointegration between the local catering revenue and economic growth time series can be defined as another way of expressing their long-term equilibrium relationship.

Using Equation (9) to test the causality between local catering revenue and economic growth.

$$\gamma_t = \frac{Y_t - \partial_\beta}{W^*} \tag{9}$$

In the formula, Yt represents the logarithm of local economic GDP and total restaurant revenue, δ denotes the stationary time series of the stochastic variable of local restaurant income and economic growth, and β represents heteroscedasticity phenomena in the time series.

3.2. Establishment of an Optimized Restaurant Revenue Prediction Model Based on Correlation Effects

The impact of restaurant revenue is defined as the influence of the restaurant industry on per capita domestic income. Since the expenses incurred by diners at dining destinations directly become the income of local enterprises, and restaurant revenue gradually permeates into the local economic system based on its related industries, it can drive the overall economic improvement of the region. Therefore, the local restaurant effect can be expressed as both direct and indirect impacts of the restaurant industry on the local economy. Based on the causal relationship between local restaurant income and economic growth obtained in Section 3.1, calculate the proportion of the restaurant industry and define the result as the direct influencing factor of the restaurant industry on the local economy. Integrate the industrial correlation effects of local restaurants to establish an optimized restaurant revenue prediction model, with specific steps detailed as follows:

Assume that X_j represents the catering output value of various economic sectors in the catering destination, and Y_j represents the added value of catering. Using γ_t obtained in Section 3.2, calculate the proportion of the catering industry using Equation (10).

$$\vartheta = \frac{\left(X_j \cdot Y_j\right)}{\gamma_t} \cdot \frac{\left(G_j \cdot X_J\right)}{C \cdot A} Y \tag{10}$$

In the formula, A represents the direct input coefficients between industries, G_j represents the final demand for catering services, Y represents the foreign exchange effect generated by the catering industry, and C represents the foreign exchange income from catering. The linkage effect of the catering industry is defined as the complex and inseparable economic ties between the catering industry and other industries. The local catering industry's industrial linkage effect is analyzed from several aspects, including input structure, intermediate input rate, and intermediate demand rate.

(1). Input structure of the catering industry

The input structure of catering is defined as the cost structure that the catering sector incurs when purchasing intermediate products and utilizing production factors from various industrial sectors for production purposes. It reflects the production technology linkages between the catering industry and related departments through the mode of intermediate product inputs. This effect is measured using the direct input coefficients of the catering industry on other production sectors, expressed by Equation (11).

$$a_{ij} = \frac{X_{ij}}{X_j} \times X_j \cdot \vartheta^{\circ} \tag{11}$$

In the formula, X_{ijs} represents the consumption of product i by industry j, and X_j represents the total input of industry j.

(2). Intermediate demand rate for the catering industry

This intermediate demand rate is the ratio of the total intermediate demand for a certain product by per capita domestic economic activity to the total demand for that product by society. A high intermediate demand rate indicates that the industry has a greater nature of providing intermediate products, which can be expressed using Equation (12).

$$h_{ij} = \frac{a_{ij} \cdot \vartheta^{\circ}}{\left(X_j \cdot Y_j\right)} \gamma_t \tag{12}$$

(3). Intermediate input rate in the catering industry

If the intermediate input in the catering industry is low, then the corresponding value-added rate is higher; conversely, if the intermediate input rate in the catering industry is high, the value-added rate is lower. This relationship can be expressed using Equation (13).

$$k_i = \frac{X_{ij}}{N_i + X_{ij}} h_{ij} \tag{13}$$

In the formula, Ni represents the total input into the industry. Based on the aforementioned explanation, use Equation (14) to construct the optimal revenue prediction model for the catering industry.

$$Q^{\otimes} = \frac{k_i \cdot h_{ij}}{h_{ij} \cdot \gamma_t} \times a_{ij} \tag{14}$$

4. Experimental Evidence Demonstrates

To demonstrate the validity of the proposed time-series-based revenue optimization prediction modeling method for the catering industry, an experiment was conducted. The study used Xi'an city's catering revenue data from 2014 to 2023 to empirically examine the relationship between catering revenue and economic growth. The simulation tool employed for this experiment was EViews 5.0 software.

4.1. Comparison of Prediction Accuracy for Restaurant Revenue Optimization Using Different Algorithmic Mossssdels

We constructed restaurant revenue optimization prediction models using the algorithm proposed in this paper and the algorithm from reference [9]. We compared the accuracy of different algorithmic models for restaurant revenue optimization prediction. The comparison results are shown in Figure 1.

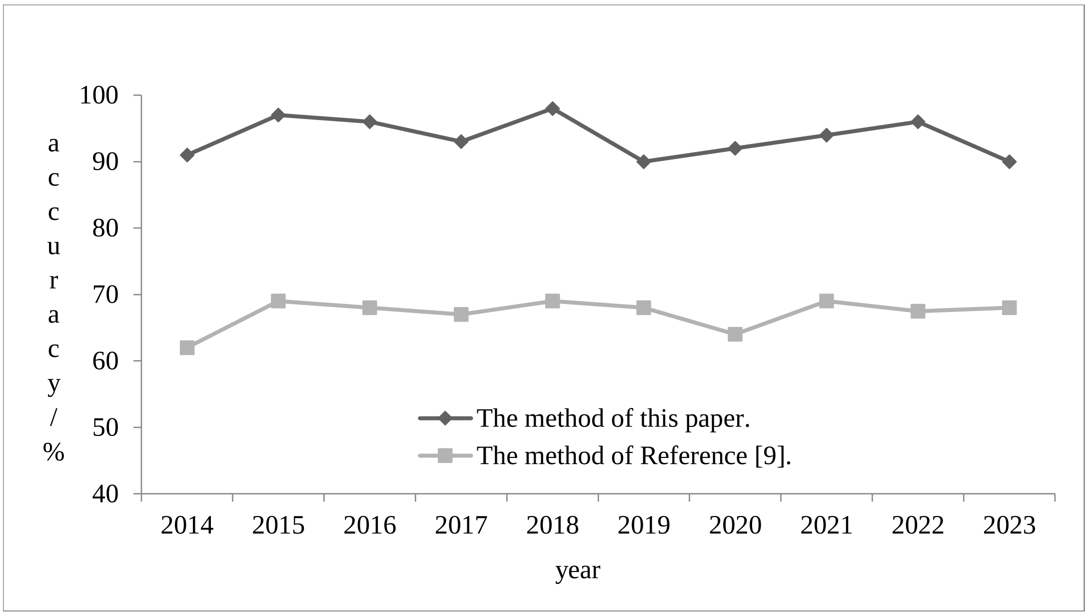

Figure 1. Comparison of accuracy among different models.

Figure 1 presents a clear and distinct comparison that clearly demonstrates the superiority of the precision in optimizing restaurant revenue prediction when using the algorithm model proposed in this paper over that of the time series test conducted with the algorithm model from reference [9]. The underlying reason for this significant disparity can be traced back to the fundamental steps involved in the model construction process. When implementing the algorithm proposed in this paper to establish the model, a crucial initial step is taken. Specifically, comprehensive cointegration tests are meticulously carried out on the time series data of both restaurant revenue and local economic indicators. This process is of utmost importance as it plays a pivotal role in enhancing the reliability and validity of the model.

By performing these cointegration tests, potential spurious relationships between the variables are effectively identified and eliminated. This helps to establish a more solid foundation for the model, ensuring that the relationships captured are genuine and meaningful. As a result, the precision of optimizing restaurant revenue prediction is significantly enhanced, providing more accurate and reliable forecasts. This not only benefits the academic research in this field but also has practical implications for businesses and policymakers who rely on accurate revenue predictions to make informed decisions.

4.2. Comprehensive Effectiveness of Precision Models for Optimizing Restaurant Revenue Forecasting under Different Algorithms

In this research, both the algorithms proposed in this paper and those sourced from reference [9] were systematically employed to construct restaurant revenue optimization prediction models. This dual approach was adopted to comprehensively assess and compare their capabilities in predicting restaurant revenue.

To gain a more profound understanding of their performance, a detailed comparison was made regarding the error rate (%), stability (%), and time efficiency (%) of the two models based on different algorithms. The error rate is a crucial indicator that reflects the deviation between the predicted values and the actual values, directly influencing the reliability of the model. A lower error rate indicates a higher level of accuracy in the prediction. Stability is another vital aspect. A stable model is one that can maintain consistent performance over different data sets and time periods. It ensures that the predictions are not overly sensitive to fluctuations in the input data, providing more reliable and trustworthy results. Time efficiency is also of great significance, especially in practical applications where timely predictions are often required. A model with high time efficiency can quickly process the data and generate predictions, saving valuable time and resources.

Based on the comprehensive comparison of these three key aspects, the comprehensive effectiveness of establishing restaurant revenue optimization prediction models using the two different algorithms was thoroughly evaluated. The detailed results of this evaluation are vividly presented in Figures 2–4, which offer a clear visual representation of the performance differences between the two models, enabling researchers and practitioners to make more informed decisions regarding the selection and application of the most suitable algorithm for restaurant revenue prediction.

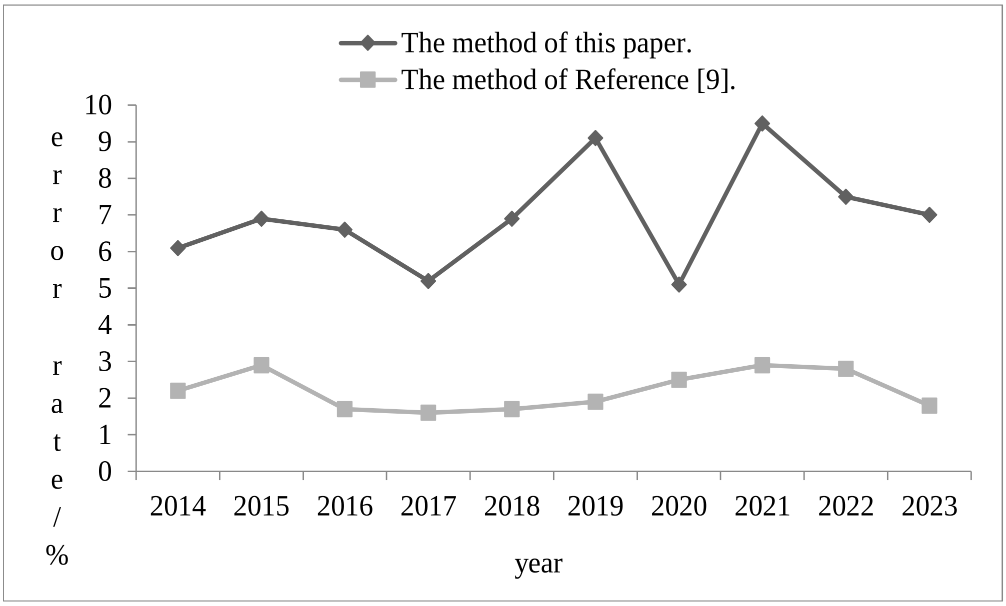

Figure 2. Comparison of modeling error rates for different algorithms.

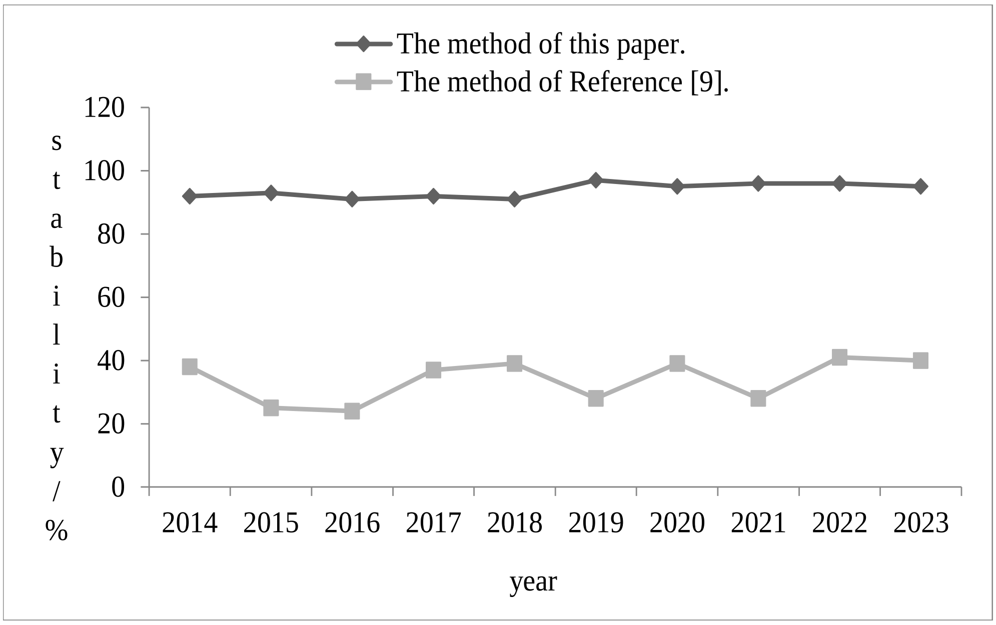

Figure 3. Comparison of modeling stability among different algorithms.

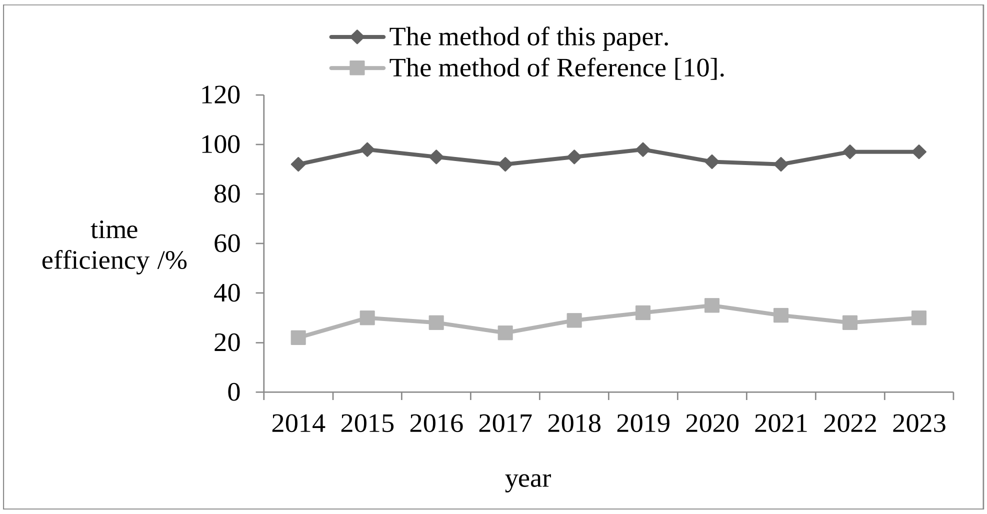

Figure 4. Comparison of modeling time efficiency among different algorithms.

A detailed analysis of Figures 2–4 provides a more in-depth understanding of the performance differences between the two algorithms. It becomes evident that the comprehensive effectiveness of the restaurant revenue optimization prediction model developed with the algorithm proposed in this paper surpasses that of the model based on the algorithm from reference [9,10] by a significant margin.

The key reason behind this superiority lies in the unique approach adopted during the model construction process. When utilizing the proposed algorithm to build the precision model for restaurant revenue optimization prediction, a series of meticulous steps are carried out. Firstly, a vector autoregression model is carefully constructed, taking into account the two crucial variables—restaurant revenue and local economy. This model serves as the foundation for capturing the complex dynamic relationships between these variables.

Subsequently, the Granger causality test is applied to rigorously examine the causal relationship between restaurant revenue and local economy. This test helps to identify the direction and strength of the influence, providing valuable insights into the underlying mechanisms. By accurately determining the causal linkages, the model can better capture the essence of the data and make more reliable predictions.

Furthermore, the proportion of the catering industry is precisely calculated. This step is of great significance as it allows for a more accurate assessment of the direct impact of the catering industry on the local economy. Based on this calculated proportion, a comprehensive statistical analysis of the correlation effect of local catering revenue is conducted. This involves exploring various aspects such as the interdependencies with other industries and the potential spillover effects. Through this detailed analysis, a more refined and accurate restaurant revenue optimization prediction precision model is successfully established, which in turn leads to better performance in terms of prediction accuracy, error rate control, stability, and time efficiency.

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