

Research on the Strategy of Hosting the Olympic Games Based on Entropy-Weighted Gray Correlation Analysis

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Abstract. Regarding the issue of Olympic Games hosting strategy, first, the entropy weight method and grey correlation analysis are used to construct the overall model. Secondly, the CGE model is used to comprehensively analyze the impacts of the two Olympic policies on production, national income, and national trade by considering land, income, and trade. Thirdly, the Transformer algorithm is used to make predictions to avoid the limitations of the CGE model. Finally, the predicted growth rates of Olympic tourism and GDP for the next year are used to comprehensively evaluate the two strategies of hosting the Olympics by season and by a fixed location. The study concludes that, based on the comprehensive impact of land, income, trade, and tourism, the weights for these factors are 0.26, 0.24, 0.24, and 0.26, respectively. Meanwhile, the comprehensive scores for hosting the Olympics by season and by a fixed location are 1.3569 and 1.2414, respectively.

Keywords: Entropy Weight Method; Grey Correlation Analysis; CGE Model.

1. Introduction

From the process of selecting the host city for the Olympics, it is evident that the International Olympic Committee (IOC) is facing a problem of decreasing interest from countries and cities to bid for the summer and Winter Olympics [1]. At the same time, the IOC and the world population are concerned about the lack of countries and cities willing to bid for the Olympics [2]. To reduce the burden of hosting such a large-scale event, the IOC has proposed two new feasible strategies for hosting the Olympics: (1) having a fixed location for both the summer and Winter Olympics, and (2) dividing the Olympic Games into four smaller groups and hosting four smaller Olympic events (such as winter, spring, summer, and autumn). To solve this problem, this article needs to select the optimal strategy for hosting the Olympics and consider various standards such as economic impact, land usage, human satisfaction (for athletes and spectators), travel, future improvement opportunities, and the reputation of the host city/country for comparison and analysis of the above strategies.

2. Materials and Methods

2.1. Data Source and Analysis

This article used the 2023 Mathematical Contest in Modeling Problem Z (<https://www.comap.com/>) and the 2015 Input-Output Table from the National Bureau of Statistics of China for analysis and research. Descriptive statistics were used to analyze the data, and the weightings for the selected indicators were determined to be 0.260714, 0.24173, 0.236935, and 0.260621.

2.2. Methodology

The entropy weight gray association evaluation method is composed of a combination of entropy weight method and gray association analysis method. The entropy weight method is an objective weighting method to determine the weight of each indicator according to the amount of information of an indicator, and the smaller the entropy of an indicator, the greater the degree of variation of the index. Simply put, for an indicator, if all respondents are satisfied with it the same, then the indicator has little impact on the entire comprehensive evaluation system, its weight is the lowest, the greater the degree of variation, the more information can be reflected, the greater the weight.

The steps for implementing the entropy weight law are as follows [3]:

Step1, standardized processing of entropy weight data:

$$Y_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \quad (1)$$

In Equation (1), X_{ij} is primeval data, X_i is the average of the first indicator of the sample.

Step2, calculate the information entropy of each indicator:

According to the definition of information entropy in information theory, the information entropy (E_j) of a set of data is:

$$E_j = -\ln(n)^{-1} \sum p_{ij} \ln p_{ij} \quad (2)$$

In formula (2), $p_{ij} = Y_{ij} / \sum Y_{ij}$, if $p_{ij} = 0$, define $\ln p_{ij} = 0$.

Step3, after the information entropy of each index is determined, the weight of each index is calculated by the information entropy as follows [4]:

$$W_i = \frac{1 - E_i}{k - \sum E_i} (i = 1, 2, \dots, k) \quad (3)$$

The core of the gray correlation analysis method is to establish the parent sequence by certain rules, take the value of each evaluation object as a subsequence, find the correlation degree between each subsequence and the parent sequence, and draw conclusions according to the size of the correlation, so as to analyze the degree of influence of each factor on the result. The steps to implement it are as follows:

Step1, determine the grey system indicator series and collect evaluation data:

In this paper, the maximum value in each index data is taken as the reference sequence, i.e. the parent sequence, which is marked as $X_0 = \{X_0(j) | j = 1, 2, \dots, n\}$, and the other indexes are taken as the comparison sequence of grey correlation analysis, which is marked as $X_i = \{X_i(j) | i = 1, 2, \dots, m; j = 1, 2, \dots, n\}$.

Step2, dimensionless processing of data:

Due to the data in each indicator is large, there is no need to forward processing, but due to the different dimensions of each indicator selected in this paper, the original data may be quite different, making it difficult to compare the indicators. In this paper, the Z-score standardization method is adopted, and the formula is:

$$Y_{ik} = \frac{X_{ik} - \mu_k}{\delta_k} \quad (4)$$

In formula (4), X_{ik} is the original data, μ_k is the mean value of the k th indicator of the sample, and δ_k is the standard deviation of the k th indicator of the sample.

Step3, calculation of the correlation coefficient: Let the correlation coefficient between $x_0(j)$ and $x_i(j)$ be $\xi_{0i}(j)$, which is calculated as follows [5]:

$$\xi_{0i}(j) = \frac{\min_i \min_j \Delta_i(j) + \delta \max_i \max_j \Delta_i(j)}{|x_0(j) - x_i(j)| + \delta \max_i \max_j \Delta_i(j)} \quad (5)$$

In Equation (5) δ is resolution factor which can reduce the error caused by the maximum value is too large, improve the significance level, the resolution coefficient is generally between 0—1, the closer the value of the resolution coefficient to 0 means that the stronger the resolution, usually the resolution coefficient is 0.5.

Step4, calculation of the degree of grey correlation. Because the correlation coefficient represents the correlation degree between data, which makes the correlation degree much and difficult to compare, it is necessary to synthesize the correlation coefficient into one value, and take the weight as the objective weight of each index obtained by the entropy method to obtain the weighted comprehensive correlation degree:

$$\xi_{0i} = \sum_{k=1}^n W_j(k) \xi_{0i}(j) \quad (6)$$

2.3. Results

At this point, the entropy weight grey correlation evaluation model for evaluating the two Olympic Games hosting strategies based on the comprehensive economic and land use measurement standards has been constructed. As for the solution of the model, this paper will write at the end of the paper after modeling and calculating the economic, land use, travel and other indicators.

3. Computable general equilibrium model framework construction

3.1. The establishment of simulation model

Computable general equilibrium model is a major tool for quantitative analysis of international popular economics and public policies. It is also called applied general equilibrium model. It is characterized by describing the interlocking relationships among various sectors of the national economy and various accounting accounts, and can describe, simulate and predict the impact of policy changes and economic activities on these relationships. This paper uses CGE model to analyze the economic impact of the two Olympic policies on host countries.

3.2. Analysis of experimental results

3.2.1. Production Module

In CGE model, the commonly used production functions are Cobb-Douglas production function, Leontief production function and CES production function (constant substitution elastic production function). Because Cobb Douglas production function and Leontief production function have linear or incremental scale returns and other restrictions, which do not conform to the actual economic situation, the production function in this paper selects three nested levels of CES production function. The domestic total output of each country is composed of intermediate inputs and value-added components in the form of CES function, which is the nested form of the first level of CES function. Labor and capital land as a whole constitute the value-added component in the nested form of the second level of CES function. Finally, capital and land constitute the total value-added of capital land in the nested form of the third level of CES function.

The first level is nested within the CES production function, and the mathematical expression for cost minimization is [6]:

$$\min_{QVA, QINTA} C = PVA \times QVA + PINTA \times QINTA \quad (7)$$

$$s.t. \quad QA = A^A [\delta^A QVA^{\rho A} + (1 - \delta^A) QINTA^{\rho A}]^{\frac{1}{\rho A}}$$

In Formula (7), C represents the cost of production; QA represents total outputs; QVA represents added value; $QINTA$ represents an intermediate input element; PVA and $PINTA$ represent the prices of industry added value and intermediate input factors respectively; A represents the scale factor; δ^A represents the sharing factor. Among them.

$$\rho = \frac{(1 - \lambda)}{\lambda} \quad (8)$$

In Formula (8) λ represents the substitution elasticity of CES function; The parameter ρ relates to the substitution elasticity λ . The substitution elasticity as an exogenous variable is collected through data as shown in Table 1, and the intermediate input decision is described by Le-ontief fixed coefficient function [7].

Table 1. Elasticity Coefficients for Each Function in Selected Industries.

Industry	Export Conversion Functions Resilience of Substitution	Armington Function Resilience of Substitution	Production Functions Resilience of Substitution	Value-added Functions Resilience of Substitution
Agriculture	-3	4	0.6	0.68
Food Manufacturing				
Tobacco Processing Industry	-1.5	1.5	0.8	0.71
Textile and Apparel Industry	-1.5	1.5	0.9	0.9
Petrochemical Industry	-1.5	0.75	1.1	0.96
Machinery Manufacturing	-1.5	0.5	1.1	0.85
Electrical machinery manufacturing	-1.5	0.5	1.1	0.85
Other Manufacturing	-1.5	0.5	1.1	0.91
Electricity, Heat, Gas, Water				
Production and Supply	-1	0.5	1.1	0.78
Construction Industry	-1	0.5	1.1	0.77
Wholesale and Retail Trade Industry	-1	0.5	1.3	0.84
Service Industry	-1	0.5	1.3	0.95
Public Administration	-1	0.5	1.3	0.95

Thus:

$$\frac{PVA}{PINTA} = \frac{\delta^A}{1 - \delta^A} \left(\frac{QINTA}{QVA} \right)^{1 - \rho^A} \quad (9)$$

$$PA \times QA = PVA \times QVA + PINTA \times QINTA \quad (10)$$

The second level of nesting describes that labor elements and capital land as a whole represent the total added value in the form of CES function, which can be obtained in the same way.

$$QVA = A^{VA} [\delta^{VA} QLD^{\rho^{VA}} + (1 - \delta^{VA}) QKLVA^{\rho^{VA}}]^{\frac{1}{\rho^{VA}}} \quad (11)$$

$$\frac{(1 + tval)WL}{PKLVA} = \frac{\delta^{VA}}{1 - \delta^{VA}} \left(\frac{QKLVA}{QLD} \right)^{1 - \rho^{VA}} \quad (12)$$

$$PVA \times QVA = (1 + tval)WL \times QLD + PKLVA \times QKLVA \quad (13)$$

Where QVA represents the total value added; QLD represents the producer's input into labor factors; $QKLVA$ represents the producer's overall investment in capital land; $tval$ represents the labor value added tax rate.

The third level of nesting describes the capital land added value formed by capital elements and land elements in the form of CES function.

Similarly:

$$QKLVA = A^{KLVA} [\delta^{KLVA} QKD^{\rho^{KLVA}} + (1 - \delta^{KLVA}) QLDD^{\rho^{KLVA}}]^{\frac{1}{\rho^{KLVA}}} \quad (14)$$

$$\frac{(1 + tvak)WL}{WLD} = \frac{\delta^{KLVA}}{1 - \delta^{KLVA}} \left(\frac{QLDD}{QKD} \right)^{1 - \rho^{KLVA}} \quad (15)$$

$$PKLVA \times QKLVA = (1 + tvak)WK \times QKD + WLD \times QLDD \quad (16)$$

By selecting the load prediction results of 403 and 411 lines. We can see that the actual values of the lines basically match the predicted values, but there are also some errors, especially in the peak period of electricity consumption, as shown in Table 1.

Among them, QKD represents the manufacturer's investment in capital elements; $QLDD$ represents the producer's input into land elements; $tvak$ represents capital appreciation tax rate.

3.2.2. Residents Module

In the CGE model, the consumer behavior is generally described by a simple linear consumption function or a Si Tong-Galley utility function. Generally speaking, in the CGE model, the resident consumption function is generally in the form of a Si Tong-Galley utility function, but the parameters of the consumption function are difficult to estimate, and in the visible data, it is difficult to obtain parameters that can be referenced. Therefore, a simple linear function form is adopted in the resident consumption function. The total labor income, capital income and foreign income of the residents in the resident income module function are [8]:

$$TYL = \sum_i w \cdot L_i \quad (17)$$

$$YHK = ratehk \cdot TYK \quad (18)$$

$$YHW = ratehw \cdot \sum_i PM_i \cdot QM_i \quad (19)$$

The total income of the residents is:

$$YHT = TYL + THK + YEH + YHG + YHW \quad (20)$$

In the resident expenditure module, the resident's consumption of products is [9]:

$$HD_i = \mu_{hi} \cdot (1 - sh) \cdot (1 - th) YHT / PQ_i \quad (21)$$

The meanings of each variable in the resident's module are shown in Table 2.

Table 2. Resident Module Function Parameter.

Paramant	Paramant Definition	Illustration
$ratehk$	Proportion of resident capital income	Total capital income includes capital gains and depreciation.
$ratehw$	Proportional coefficient of residents' foreign income	Residents' foreign income divided by their imports.
sh	Residents' saving proportion coefficient	Residents' savings divided by total residents' income
μ_{hi}	Proportional coefficient of residents' consumption of product i	Consumption of product I by residents as a proportion of total consumption

3.2.3. Trade Modules

Generally, in the CGE model, the CET function is generally adopted for the allocation of domestic products. The CET function is used to describe the optimal strategy for determining the allocation of products among different markets under certain production technology constraints. The domestic product demand function (the Armington assumption) is [10]:

$$\begin{aligned} \max_{QD_i, QM_i} \quad & PQ_i \cdot QQ_i - [PD_i \cdot QD_i + (1 + t_{mi}) PM_i \cdot QM_i] \\ s.t. \quad & QQ_i = \gamma_{mi} [\delta d_i (QD_i)^{\rho_{mi}} + \delta m_i (QM_i)^{\rho_{mi}}]^{\frac{1}{\rho_{mi}}} \end{aligned} \quad (22)$$

Same as above, we can get:

$$QD_i = \left(\frac{\gamma_{mi}^{\rho_{mi}} \cdot \delta d_i \cdot PQ_i}{PD_i} \right)^{\frac{1}{1-\rho_{mi}}} QQ_i \quad (23)$$

$$QM_i = \left(\frac{\gamma_{mi}^{\rho_{mi}} \cdot \delta m_i \cdot PQ_i}{(1 + t_{mi}) \cdot PM_i} \right)^{\frac{1}{1-\rho_{mi}}} QQ_i \quad (24)$$

Similarly, the CET function is [11]:

$$\begin{aligned} \max \quad & (PD_i \cdot QD_i + PE_i \cdot QE_i) - (1 + t_{indi}) \cdot PX_i \cdot QX_i \\ s.t. \quad & QX_i = \gamma_{ei} (\zeta d_i \cdot QD_i^{\rho_{ei}} + \zeta e_i \cdot QE_i^{\rho_{ei}})^{\frac{1}{\rho_{ei}}} \end{aligned} \quad (25)$$

Similarly, we can get:

$$QD_i = \left(\frac{\gamma_{ei}^{\rho_{ei}} \cdot \zeta d_i \cdot (1 + t_{indi}) \cdot PX_i}{PD_i} \right)^{\frac{1}{1-\rho_{ei}}} QX_i \quad (26)$$

$$QE_i = \left(\frac{\gamma_{ei}^{\rho_{ei}} \cdot \zeta e_i \cdot (1 + t_{indi}) \cdot PX_i}{PE_i} \right)^{\frac{1}{1-\rho_{ei}}} QX_i \quad (27)$$

The meaning of each variable in the trade module is shown in Table 3.

Table 3. Trade module function parameters.

Paramant	Paramant Definition
t_m^i	Commodity I Import Tariff Rate
γ_m^i	Armington Equation Commodity I Overall Transfer Parameters of Domestic Demand and Import Demand
δd_i	Armington Equation Commodity i Overall Transfer Parameters of Domestic Demand and Import Demand
δm_i	Parameter of commodity I import demand share in Armington equation
γ_e^i	CET function commodity I overall transfer parameters of domestic supply and export allocation
ζd_i	Share parameter of domestic supply goods for commodity i of CET function
ζe_i	CET function i share parameter of export supply of products
ρ_m^i	Armington Equation The correlation coefficient of substitution elasticity between imported goods I and domestic goods
ζe_i	CET function i share parameter of export supply of products
ρ_e^i	CET function sector commodity I conversion elasticity of domestic supply and export

In order to achieve macro-closure, the CGE model also needs the enterprise module, import and export module and investment = savings module. As these modules are the same as the standard computable general equilibrium (LHR model) model published by the International Food Policy Research Institute (IFPRI) Lofgren, Harris and Robinson, they will not be described in detail in this paper due to space limitations.

3.3. Final model building

Subsequently, we complete the construction of the CGE model using the classical Keynesian macro closure. At this point, the computable general equilibrium of integrated land, income and trade is fully constructed.

Based on the above model, the tourism growth rates of the two strategies were obtained, and combined with the entropy-weighted gray correlation evaluation model proposed in this paper, the scores (gray correlation) of the two strategies under the combined criteria of land use, national income, trade, and tourism were calculated as shown in Table 4.

Table4. Comparison results.

On a quarterly basis	At a fixed location
1.3569	1.2414

4. Conclusions

This paper makes up for the shortcomings of the equal proportional assignment of the gray correlation evaluation model through the entropy weight method, and constructs a comprehensive evaluation model of two Olympic strategies based on the entropy weight gray correlation evaluation model and the computable general equilibrium model as the framework. This paper integrates four major criteria, namely, land, income, trade and tourism, and conducts a comprehensive evaluation of the two strategies of holding by quarter and holding by fixed location, yielding scores of 1.3569 and 1.2414 respectively, indicating that the comprehensive effect of holding the Olympics by quarter is higher than that of holding the Olympics at a fixed location.

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