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Research Article

Evaluation Method of Performance of Cross-Border e-Commerce System Based on Fuzzy DEA Model

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Cross-border e-commerce trade is an important form of trade that is different from traditional international trade. Nowadays, cross-border e-commerce is more and more widely used in foreign trade activities. Cross-border e-commerce system has its own development constraints, such as the imperfection of cross-border e-commerce platforms, the security loopholes of cross-border payment, the slow development of supporting logistics, and the lag of policies, which will affect its development to varying degrees, thus affecting the performance of e-commerce enterprises in using cross-border e-commerce for foreign trade activities. Therefore, it is necessary to explore the factors of cross-border e-commerce system performance and compare the strength of various factors, which has certain theoretical and practical significance. Therefore, based on the analysis of performance data, this paper will establish a performance evaluation model for an e-commerce system, aiming at providing standards and a basis for performance evaluation of system performance. In order to continuously improve the accuracy of cross-border e-commerce performance evaluation and to achieve the accuracy of cross-border e-commerce evaluation and decision-making, a cross-border e-commerce system performance evaluation model based on the fuzzy DEA model is innovatively proposed. By combining the average analysis results of descriptive statistical data, the regression test is conducted on the performance evaluation samples of cross-border e-commerce systems. The fuzzy feature clustering method is used to classify and identify the performance of big data in the cross-border e-commerce system. According to the fusion results of cross-border e-commerce performance information, the principal component analysis and adaptive game decision are carried out, and the game decision model is established. Combined with the fuzzy DEA evaluation method, the performance of the cross-border e-commerce system can be quantified and evaluated. The F statistical analysis method is used to test the effectiveness of the performance evaluation of the cross-border e-commerce system. From the test results, it can be seen that the performance evaluation accuracy of the cross-border e-commerce system using this model is relatively high, and the confidence level is also relatively good. Finally, according to the conclusion of the study, the author puts forward the counter-measures for future research.

1. Foreword

With the rapid development of the e-commerce industry, the cross-border trade activities of e-commerce are increasingly prosperous, and the turnover of cross-border e-commerce has become amazing, showing a gradually increasing trend of development. The reliability evaluation of cross-border e-commerce system performance is the main factor affecting the stability of cross-border e-commerce ecosystem, and it is also an important reflection of the stability of cross-border e-commerce ecosystem. Based on DEA theory, this paper analyzes the evolution behavior of cooperation among elements of cross-border e-commerce ecosystem and provides new ideas and perspectives for the research on the stability of cross-border e-commerce ecosystem. At the same time, by combining the fusion and analysis of big data information, the specific performance evaluation of the cross-border e-commerce system is carried out, and the performance analysis and related rules of cross-border e-commerce are established. Through online financial supermarkets, third-

party information platforms, online financial management, and other platforms, the performance prediction evaluation of cross-border e-commerce can continuously improve the accuracy of performance evaluation of cross-border e-commerce systems and can also study the performance evaluation methods of the cross-border e-commerce systems, which is of great significance in optimizing the financial allocation system of cross-border e-commerce and improving the profits of cross-border e-commerce. [1].

The essential characteristic of the performance of a cross-border e-commerce system is a group of economic series. By adopting the methods of economic series and big data information processing and analysis, the quantitative analysis of the system performance of cross-border e-commerce can be realized, thus realizing the evaluation and evaluation of the accuracy of the system performance of cross-border e-commerce. Among the traditional methods, the performance evaluation methods of cross-border e-commerce systems mainly include the load-based balanced forecasting method, random vector analysis evaluation algorithm of e-commerce system performance, wavelet analysis-based evaluation algorithm of cross-border e-commerce system performance, time-frequency analysis-based evaluation algorithm of cross-border e-commerce system performance, and so on [2, 3].The performance evaluation model of a cross-border e-commerce system is constructed by extracting quantitative recursive entropy features, and the performance data of the cross-border e-commerce system are quantitatively analyzed recursively by using the nonlinear economic series analysis method. The accuracy of performance evaluation of cross-border e-commerce systems by this method is not particularly high. The fuzzy PID-based performance evaluation method of cross-border e-commerce systems usually uses association rules to extract features so as to realize the performance evaluation of cross-border e-commerce systems. However, there is a certain delay in processing the performance data of cross-border e-commerce systems, which may lead to low evaluation accuracy. In Reference [4], in view of the above-mentioned problems, this paper proposes a performance evaluation model for cross-border e-commerce systems based on a fuzzy DEA model. At the same time, combined with the results of descriptive statistical average analysis, we can carry out regression test on the performance evaluation samples of the cross-border e-commerce system, classify and identify the performance of big data of the cross-border e-commerce system by adopting the fuzzy feature clustering method, conduct principal component analysis and adaptive game decision-making according to the results of performance information fusion of the cross-border e-commerce, establish a game decision-making model, combine the fuzzy DEA evaluation method to realize quantitative evaluation on the performance of cross-border e-commerce system, and adopt the F statistic analysis method to test the effectiveness of performance evaluation of cross-border e-commerce system. Finally, we show the superior performance of this method in improving the accuracy of performance evaluation of cross-border e-commerce systems through empirical analysis.

2. Model Construction and Statistical Average Analysis Method of Statistical Series of Cross-Border e-Commerce System Performance

2.1. Construction of a Model Related to the Statistical Sequence of the Performance of Cross-Border e-Commerce System. The performance data of a cross-border e-commerce system is a set of nonlinear economic series, which can be analyzed and evaluated by the modern statistical series processing method. When modeling the performance data of a cross-border e-commerce system, the statistical series model is adopted to construct the method [5]. This paper analyzes the characteristics of the performance of cross-border e-commerce systems and sets a model for sampling a combination of performance data of m omnidirectionally monitored cross-border e-commerce systems. Given the performance data of a monitored cross-border e-commerce system, it can be expressed as

$$U = \{U_1, U_2, \cdots, U_N\}. \tag{1}$$

Among them, $U_i$is the specific evaluation component of cross-border e-commerce system performance, which is expressed as a D-dimensional random function; each data set U_i is normally correlated, assuming that U conforms to the K distribution function. In this case, the state transition equation of the performance model of the cross-border e-commerce system is expressed as

$$\begin{aligned} x(n) &= s(n) + v(n) \\ &= \omega_{k-1}^{(i)} \frac{p\left(y_k \mid X_k^{(i)}, Y_{k-1}\right) p\left(x_k^{(i)} \mid X_{k-1}^{(i)}, Y_{k-1}\right)}{q\left(x_k^{(i)} \mid \right)}. \end{aligned} \tag{2}$$

$s(n)$ represents the vector combination of cross-border e-commerce system performance data. $v(n)$ represents the interference component.

For the performance data series of cross-border e-commerce systems, feature reorganization is carried out, and any point $\mathbf{X}_n$, the nearest neighbor of the recombination space of the performance data series of the cross-border e-commerce system is expressed as:$\mathbf{X}_{\eta(n)}$, $R_{mn}$is defined as the distance between$\mathbf{X}_n$and $\mathbf{X}_{\eta(n)}$,with i as the abscissa and j as the ordinate, the vector distance representing the nonlinear state parameters of cross-border e-commerce system performance data by euclidean distance is as follows:

$$R_{mn} = \left\| \mathbf{X}_{\eta(n)} - \mathbf{X}_n \right\|_2^{(m)}. \tag{3}$$

We use the algorithm of average mutual information to calculate the embedding dimension of the performance reconstruction space of a cross-border e-commerce system. As m increases to $m+1$, the sliding average window of optimized cross-border e-commerce system performance data is as follows:

$$R_{(m+1)n} = \left\| \mathbf{X}_{\eta(n)} - \mathbf{X}_n \right\|_2^{(m+1)}. \tag{4}$$

The geometric invariants of the cross-border e-commerce system performance economic sequence are calculated, and the obtained equations$s_i = (x_i, x_{i+\tau}, \cdots, x_{i+(m-1)\tau})^T$is called the embedded space state vector of the local cross-border e-commerce system performance nonlinear economic sequence. We set the predictor to calculate$\mathbf{J}_{\mathbf{x}_i}^{(1)}$, and calculate the probability confidence interval of the performance economic series of cross-border e-commerce system as follows: $\left\{\delta \mathbf{x}_{i+1}(j_k) = \mathbf{x}_{jk+1} - \mathbf{x}_{i+1} \mid k \in 1, \cdots, N_b\right\}$, in the m-dimensional cross-border e-commerce system performance data series, the m-dimensional vector formed by combining the above statistical series features is

$$\% \ \mathbf{X}(n) = \{x(n), x(n+\tau), \cdots, x(n+(m-1)\tau)\}.n = 1, 2, \cdots, N. \tag{5}$$

When $R_{(m+1)n}$is larger than R_{mn}, it is considered as the projection of statistical information feature points of cross-border e-commerce system performance, and thus a statistical sequence model of cross-border e-commerce system performance is constructed [6].

2.2. Statistical Analysis of Performance Evaluation. We analyze the characteristics of modeling data for performance evaluation of cross-border e-commerce systems and perform statistical modeling by adopting the nonlinear statistical feature sequence analysis method. First of all, we collect the original performance data of the cross-border e-commerce system, adopt the principal component characteristic analysis model method of the performance evaluation of the cross-border e-commerce system [7], and get the regression test model of the performance evaluation modeling of the cross-border e-commerce system, which can be expressed as

$$\begin{aligned} \min_{0 \le \alpha_i \le c} W = \frac{1}{2} \sum_{i,j=1}^{l} y_i y_j \alpha_i \alpha_j K\left(x_i, x_j\right) \\ - \sum_{i=1}^{l} \alpha_i + b\left(\sum_{i=1}^{l} y_j \alpha\right). \end{aligned} \tag{6}$$

Combined with the auto-regressive moving average (ARMA) model, the performance evaluation of cross-border e-commerce is analyzed by big data [8], and the performance evaluation modeling distribution of cross-border e-commerce systems is obtained as follows:

$$x_n = \varphi_0 + \sum_{i=1}^{p} \varphi_i x_{n-i} + \sum_{j=0}^{q} \theta_j \eta_{n-j}. \tag{7}$$

$\{\eta_i\}$is the mean value of 0, the explanatory control variables with variance areσ^2, and $\varphi_0, \varphi_1, \varphi_2, \cdots \varphi_p$is the performance correlation distribution data of the cross-border e-commerce system. $\theta_1, \theta_2, \cdots \theta_q$is called the average coefficient of descriptive statistics of cross-border e-commerce management. At the same time, combined with the detection statistical analysis method, the characteristic matching is carried out, and an analytic hierarchy process is adopted to construct the statistics of quantitative performance evaluation. We can establish a model of principal component analysis, adaptive game decision, and the quantification and evaluation of the performance of cross-border e-commerce systems [9]. At the same time, we can use the F statistic analysis method to test the effectiveness of the performance evaluation of cross-border e-commerce systems, and we can get the fuzzy comprehensive decision-making function of the performance evaluation of the cross-border e-commerce systems with the following equation:

$$\mu_{B_i} = a_{B_i} + b_{B_i}\Delta + c_{B_i}\Phi. \tag{8}$$

$a_{B_i} = B_i/B_U + B_v$, $b_{B_i} = (B_U - B_i)(B_i - B_v)/(B_U + B_v)B_i$, and $c_{B_i} = B_U B_v/(B_U + B_v)B_i$. According to the above analysis method, combined with the results of descriptive statistical average analysis to test the sample regression of the performance evaluation of cross-border e-commerce system, we adopted the fuzzy feature clustering method to classify and identify the performance big data of the cross-border e-commerce system.

3. Model Optimization of Performance Evaluation of Cross-Border e-Commerce System

3.1. Fuzzy DEA Model and Performance Information Fusion. When using the results of descriptive statistical average analysis to test the regression of the performance evaluation samples of cross-border e-commerce system, we use fuzzy feature clustering method to classify and identify the performance of big data of cross-border e-commerce system, so as to optimize the design of the performance evaluation model of cross-border e-commerce system. In this paper, a performance evaluation model of the cross-border e-commerce system based on a fuzzy DEA model is proposed. The recursive graph of cross-border e-commerce system performance is constructed as $\mathbf{R}(i, j)$, and its calculation formula is

$$\mathbf{R}(i, j) = H\left(\varepsilon_i - d_{ij}\right).i, j = 1, 2, ..., N. \tag{9}$$

$H(.)$stands for Heavside function and $\epsilon$is the neighborhood radius. Through quantitative recursive analysis of performance series of the cross-border e-commerce system, another neighborhood matrix of nonlinear economic series reorganization is obtained:

$$\mathbf{B}_{x_i}^{(1)} = \left(\delta \mathbf{x}_{i+1}(j_1), \delta \mathbf{x}_{i+1}(j_2), \cdots, \delta \mathbf{x}_{i+1}\left(j_{N_b}\right)\right)^T. \tag{10}$$

Because ε is small enough, the fuzzy DEA evaluation function of performance data of the cross-border e-commerce system satisfies

$$\mathbf{B}_{\mathbf{x}_i}^{(1)} = \mathbf{B}_{\mathbf{x}_i}\left(\mathbf{J}_{\mathbf{x}_i}^{(1)}\right)^T \tag{11}$$

The functional of fuzzy DEA evaluation with $\mathbf{B}_{\mathbf{x}_i}^{\dagger}$ as $\mathbf{B}_{\mathbf{x}_i}$, between the statistical feature vectors$\mathbf{x}_i$and $\mathbf{x}_j$, the distance of cross-border e-commerce system performance evaluation is$\delta_{ij} = \|\mathbf{x}_i - \mathbf{x}_j\|$. When $\|\mathbf{x}_i - \mathbf{x}_j\| < \varepsilon$, we can get

$$\left(\mathbf{J}_{\mathbf{x}_i}^{(1)}\right)^T = \mathbf{B}_{\mathbf{x}_i}^{\dagger}\mathbf{B}_{\mathbf{x}_i}^{(1)}. \tag{12}$$

Form a super-neighborhood matrix of cross-border e-commerce system performance evaluation in the following reorganized state space:

$$\mathbf{B}_{x_i} = \left(\delta\mathbf{x}_i(j_1), \delta\mathbf{x}_i(j_2), \cdots, \delta\mathbf{x}_i\left(j_{N_b}\right)\right)^T. \tag{13}$$

When convergence criterion is satisfied, the characteristic quantity$\mathbf{X}_{\eta(n)}$of fuzzy paste DEA model state evaluation is the quantitative recursion point of $\mathbf{X}_n$:

$$\frac{\left|x_{\eta(n)+m\tau} - x_{n+m\tau}\right|}{\left\|\mathbf{X}_{\eta(n)} - \mathbf{X}_n\right\|_2^{(m+1)}} \geq R_{\text{tol.}} \tag{14}$$

$R_{tol} = 15$. According to the fusion results of the performance information of cross-border e-commerce, principal component analysis and adaptive game decision-making are carried out so as to evaluate and test the performance of cross-border e-commerce system.

3.2. Specific Performance Evaluation and Inspection of Cross-Border e-Commerce System. We calculate the performance economic sequence of the cross-border e-commerce system to obtain the set of three state parametersα, u, and $\sum$, for the performance evaluation of the cross-border e-commerce system, namely,

$$\begin{aligned} \alpha &= [\alpha_1, \alpha_2, \cdots, \alpha_k]. \\ u &= [u_1, u_2, \cdots, u_k], \\ \sum &= \left[\sum_1 \sum_1 \cdots \sum_k\right]. \end{aligned} \tag{15}$$

$Z = (U, V)$is assumed to be a collection of performance data u and statistical data vV of the cross-border e-commerce system. Combined with the fuzzy DEA evaluation method, the performance of cross-border e-commerce system is quantitatively evaluated, and the quantitative recursive entropy ratio of cross-border e-commerce system performance is calculated

$$R_m(r, i) = \frac{N(i)}{N - (m-1)\tau}. \tag{16}$$

The embedding dimension of the performance series of cross-border e-commerce systems in vector space is obtained, and the information entropy of the performance evaluation of cross-border e-commerce systems is calculated. The formula is

$$ApEn = \lim_{N \longrightarrow \infty} \left[AV_m(r) - AV_{m+1}(r)\right]. \tag{17}$$

According to the neighboring points of the initial state feature B_0 of the performance economic series of the cross-border e-commerce system, the average value of the performance quantitative evaluation of the cross-border e-commerce system is obtained by using the following formula:

$$AV_m(r) = \frac{1}{N - (m-1)\tau} \sum_{i=1}^{N-(m-1)\tau} \ln R_m(r, i). \tag{18}$$

$ENTR = -\sum_{l=l_{\min}}^{N-1} P(l) \cdot \ln P(l)$. For our single-component cross-border e-commerce system performance economic sampling sequence$\mathbf{x}_i$, we can use the F statistics analysis method to test the effectiveness of the performance evaluation of cross-border e-commerce system [10]. For the clustering between the feature points, for the cross-border e-commerce system performance economic series, the length of its vector feature trajectory is N, and a group of nonlinear statistical series is constructed. Combined with the above formula,

$$\begin{aligned} G\left(U \middle| \mu_k, \sum_k\right) &= (2\pi)^{-d/2} \left|\sum_k\right|^{-1/2} \\ &\times \exp\left[-\frac{1}{2}(U - u_k)^T \sum_k^{-1} (U - u_k)\right]. \end{aligned} \tag{19}$$

$G(U \mid \mu_k, \sum_k)$ is the control parameter value of cross-border e-commerce system performance evaluation; $p(U \mid \Theta)$is the information weighting of cross-border e-commerce system performance evaluation. According to the above analysis, we can establish a game decision-making model of performance evaluation and combine fuzzy DEA evaluation method to realize the performance evaluation of the cross-border e-commerce system.

4. Empirical Analysis and Testing

In order to verify the concrete application of this method in the performance evaluation of cross-border e-commerce systems, we can make an empirical analysis. The software used for data analysis is SPSS19.0. The sampling method of modeling data for performance evaluation of the cross-border e-commerce system mainly adopts the descriptive statistical analysis method, with performance value as the interpreted variable and earnings change and asset-liability ratio as the specific control variables. The detailed results of descriptive statistics for performance evaluation of the cross-border e-commerce system are shown in Table 1.

According to the above-mentioned descriptive statistical analysis results, the performance of cross-border e-commerce is predicted, and the prediction results are shown in Figure 1.

Analysis of Figure 1 shows that the accuracy and stability of cross-border e-commerce performance prediction using this method are higher. The *F*-test analysis method is used to evaluate the effectiveness of performance evaluation, and the comparison results are shown in Figure 2.

Analysis of Figure 2 shows that the accuracy of performance evaluation of the cross-border e-commerce system by using this model is high, and the confidence level is good.

Table 1: Descriptive statistical results of cross-border e-commerce system performance evaluation.

Variable	Code	Weight of contribution			Inspection value			Statistical value of judgment		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Surplus degree	IKS	2.543	5.891	3.676	5.434	9.454	7.545	4.135	6.655	5.544
Growth	FR	0.643	2.765	1.566	2.545	5.341	3.356	2.544	4.643	3.455
Company size	TP	2.423	5.744	3.454	4.456	8.565	6.655	5.436	6.213	5.565
Profitability	SOL	3.343	4.545	3.466	6.654	10.544	8.564	8.165	9.343	8.256
Asset-liability ratio	Size	2.454	3.656	2.654	5.565	9.564	7.554	5.565	6.245	5.265
Profit	ND	1.546	4.567	3.754	2.144	4.234	6.432	6.656	7.564	6.566

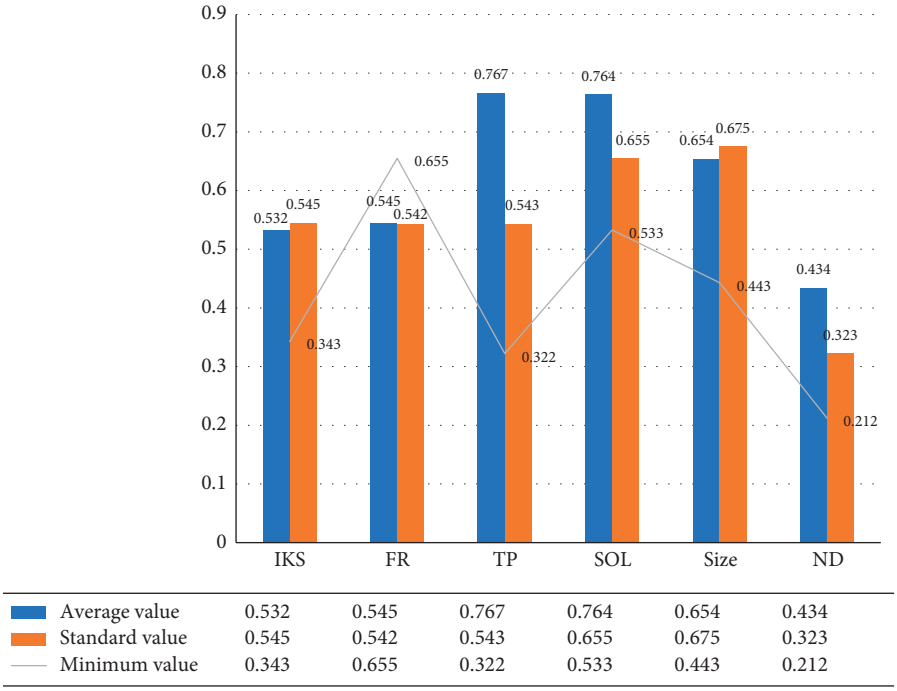

Figure 1: Performance prediction results of the cross-border e-commerce system.

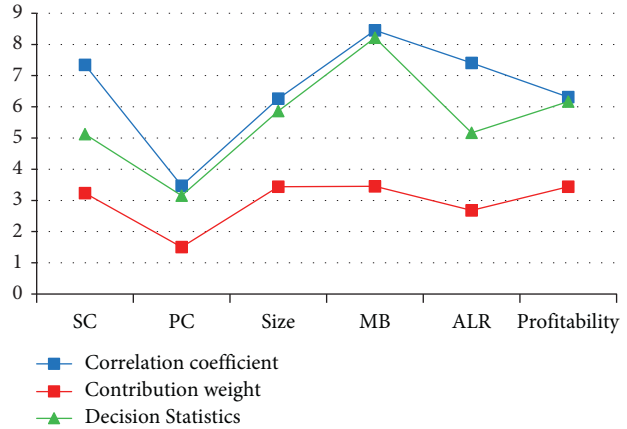

Figure 2: Effectiveness test of performance evaluation.

5. Tag

In today's business model of cross-border e-commerce, the reliability evaluation of the performance of cross-border e-commerce systems is a key measure for e-commerce enterprises to make decision-making arrangements. The performance evaluation model of the cross-border e-commerce system based on a fuzzy DEA model is proposed in this paper. Combining with the results of descriptive statistical average analysis, we test the sample regression of performance evaluation of the cross-border e-commerce system, classify and identify the performance of the cross-border e-commerce system by using the fuzzy clustering method, and conduct principal component analysis and adaptive game decision according to the specific fusion results of performance information of cross-border e-commerce, so that we can establish a game decision model. At the same time, the quantitative evaluation of the performance of the cross-border e-commerce system is achieved by combining the fuzzy DEA evaluation method, and the effectiveness of the performance evaluation of cross-border e-commerce systems is tested by using the F statistical analysis method. Through the research, we can know that the method in this paper has higher accuracy, better stability, and higher confidence level.

In the environment of e-commerce, the indicators of the implementation of the cross-border e-commerce system are established and evaluated. The establishment of an objective,

systematic, and comprehensive evaluation index system is helpful for enterprises to find out their own shortcomings and the gap with other enterprises and make improvements to better implement the performance evaluation accuracy. At the same time, it can increase the competitiveness of enterprises and improve customer satisfaction. More importantly, under the call of low-carbon economy, the performance evaluation still has great potential for development. It is conducive to the reuse of resources, the reduction of waste of resources, and the sustainable development of society. In the future, the further research direction will be to find out the common concerns between enterprises and customers and the establishment of information systems while establishing indicators, so as to better serve customers and adhere to the low-carbon economic development route.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon request.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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