Intelligent Pricing Model for Cross-border E-commerce Based on Artificial Intelligence

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***Abstract*—This study was carried out to explore an intelligent pricing model for cross-border e-commerce based on artificial intelligence (AI) An efficient pricing system was developed to integrate market factors, competitive strategies, costs, and user behavior. Through machine learning algorithms and real-time data analysis, the system automatically adjusts product prices to adapt to complex international market conditions. User satisfaction, product transaction goods, quantity, and price were estimated in the system to ensure the sustainability of the model and the accuracy of the prediction.**

Keywords—AI, cross-border e-commerce, smart pricing

I. INTRODUCTION

With the expansion of cross-border e-commerce, effective pricing strategies are demanded for enterprises to compete in the international market [1,2]. Traditional manual pricing methods are no longer able to cope with the complex and changing market environment. Artificial intelligence (AI) technology needs to be introduced to improve the accuracy and flexibility of pricing. In this study, market analysis, competitor strategies, cost management, and user behaviors were considered to construct a comprehensive cross-border e-commerce intelligent pricing model [3,4].

II. RECOMMENDATION ALGORITHMS

A. Least Squares

Parameters are estimated using linear regression models such as the Ordinary Least Squares (OLS) method. The goal of the least squares method is to minimize the sum of squares of the residuals between the observations and the predictions of the model. The loss function L is the residual sum of squares (1).

$$L = \sum_{i=1}^{n} (y_i - \overline{y_i})^2 \tag{1}$$

where y_i is the actual observed value for the first $_i$ sample and $\overline{y_i}$ is the predicted value of the model for the first $_i$ sample. The model parameter β is defined as (2).

$$\overline{\beta} = \arg\min_{\beta} \sum_{i=1}^{n} (y_i - \overline{y_i})^2 \tag{2}$$

To solve the closed-form solution of the least squares method, the partial derivatives of the loss function L for β must be obtained to make the partial derivatives zero (3,4).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + .. + \beta_p x_p + \varepsilon \tag{3}$$

$$L = \sum_{i=1}^{n} (y_i - \overline{y_i})^2 \tag{4}$$

The closed-form solution of the least squares method for the loss function L is obtained by taking partial derivatives of $\beta_0, \beta_1, \beta_2, ..., \beta_p$. Using the least squares method, the optimal model parameter was obtained, and an intelligent pricing model was constructed for cross-border e-commerce.

B. Economic Pricing Theory

Economics pricing theory is used to predict pricing behavior and strategy in economics, considering demand curve and price elasticity, marginal cost pricing, monopoly pricing, competitive pricing, and psychological pricing. The theory helps to understand the market structure, supply and demand relationship and enterprise behavior, and guide enterprises to develop pricing strategies in the market. In the design of the cross-border e-commerce smart pricing model, economics pricing theory plays an important role, By combining the factors of market demand, cost analysis, and competition, enterprises can develop smart pricing strategies and enhance the competitiveness and profitability of their products in the market.

III. MODEL CONSTRUCTION

A. Smart Pricing

To improve the classification accuracy and universality of product features, cross-border e-commerce product features were divided into two categories: basic features and other features. Basic features represent the common characteristics of similar products, which are the basic attributes. Basic features are directly related to the basic functions and the value of products. Other features reflect the uniqueness of the product, including the product's innovation, difference, and personalized design for specific consumer groups. In the cross-border e-commerce industry, enterprises focus on the multi-attribute and multi-functional characteristics of the product in product design and development to satisfy the needs of different consumer groups and enhance the competitiveness of the product and the market share [5].

Cross-border e-commerce enterprises may be producers, sellers, and providers of product features. In product design, enterprises need to consider the different needs and preferences of consumers and attract and satisfy them through different product features. The basic features present the use value of products which satisfies the basic consumption needs of consumers such as the function,

quality and brand of the products. Other features present the investment value of products, which attracts the attention of consumers and increases the added value of the products such as the appearance design of the products, the innovativeness, and the personalized customization [6]. Therefore, based on the available benefits as the market segmentation standard, the product features must be used to meet the needs of different consumer groups. Cross-border e-commerce products as products need to have multiple attributes and functions to satisfy the different needs of consumers. The basic features are the foundation and premise of a product to increase the use value, while the other features present the expansion and supplementation of the product to increase the investment value. The interconnection between the basic and other features and the use and investment values represent the product. Cross-border e-commerce enterprises need to understand the importance of product features and enhance the market competitiveness of products and user satisfaction by designing product features [7,8] (Fig. 1).

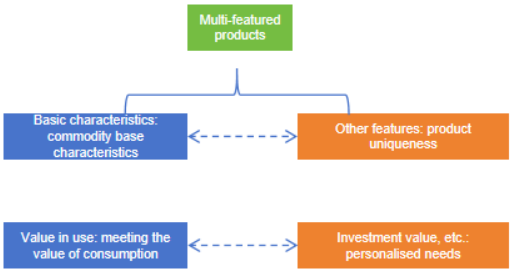

Fig. 1. Product features and value of cross-border e-commerce smart pricing model with multiple features for AI.

B. Data Collection

Data collection is a key step in AI-based smart pricing models for cross-border e-commerce. The data is used to train models and predict the results. In this study, historical sales data were collected from cross-border e-commerce platforms. The data included the number of products sold, sales price, and sales time. The data was used to understand the sales situation of the products and provide the model with the basis of historical sales trends and price changes. Competitor price information was also essential. The price data of competitors were collected including prices, promotional activities, and sales channels to understand the price level and competition in the market. The data on market demand is important and includes the users' search behavior, purchase intention, product preference, and other information to understand the demand in the market and formulate pricing strategies. External environmental data such as currency exchange rates, tariff policies, and seasonal factors were collected to establish the price and sales strategies of products [9,10].

In summary, data collection was crucial in the construction of the AI-based cross-border e-commerce smart pricing model. Collected data were used to analyze the market situation accurately, optimize the price strategy, and improve the competitiveness and sales effect of products (Fig. 2 and Table I).

TABLE I. PRODUCT CHARACTERISTICS AND DATA COLLECTION FOR PRICING MODEL WITH MULTIPLE FEATURES

Data type	Descriptive
Historical Sales Data	Includes information such as the number of products sold, sales price, sales time, etc., used to understand the sales situation and price trends of products.
Competitor Pricing Information	Collect pricing data on competitors selling similar products, including prices, promotions, sales channels, etc., for understanding pricing levels and competitive dynamics in the market.
Market demand data	This includes information on users' search behavior, purchase intention, product preference, etc., which is used to understand the market demand situation and provide reference for pricing strategy development.
External environmental data	These include external environmental factors such as currency exchange rates, tariff policies, seasonal factors, etc., which can affect product pricing and sales strategies.

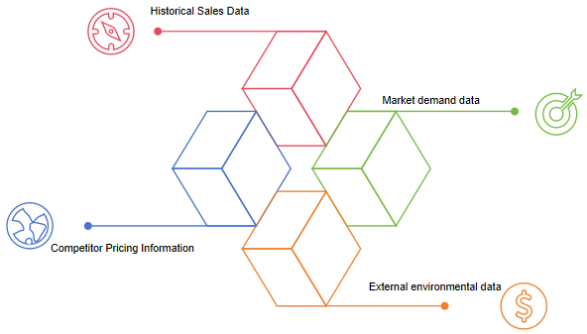

Fig. 2. Data types of cross-border e-commerce smart pricing model with artificial intelligence.

C. Smart Pricing Model

In cross-border e-commerce, the design of an intelligent pricing model is crucial to predict the optimal price of a product. The model is constructed by analyzing historical sales data, competitors' pricing strategies, and market demand. A least square method is normally used to build the model. In this study, historical sales data were collected from cross-border e-commerce platforms. Information such as the number of products sold, sales price, and sales time was obtained. Price data of competitors, and market demand data such as users' search behavior and purchase intention were also included [11]. For smartwatches, an intelligent pricing model was constructed using the least squares method to predict its optimal price [12]. Referring to the result, sample data including the sales quantity, price, and information of competitors were collected in this study. The sample data are shown in Table II.

TABLE II. SALES DATA OF COMPETITORS

Sales volume	Selling price ($)	Competitor Pricing ($)
100	150	160
120	140	155
90	160	165
110	145	158
130	155	162

The sample data were defined as quantity sold (x) and sales price (y).

$$x = [100,120,90,110,130] \quad (5)$$

$$y = [150,140,160,145,155] \quad (6)$$

Then, the parameters of the linear regression model were determined. The corresponding linear regression model was expressed as

$$y = \beta_0 + \beta_1 x \tag{7}$$

where β_0 is the intercept and β_1 is the slope (8, 9).

$$\beta 1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{8}$$

$$\beta_0 = \bar{y} - \beta_1 \bar{x} \tag{9}$$

where $\bar{x}$ and $\bar{y}$ are the mean of x and y.

The result of the linear regression model is

$$\bar{x} = \frac{1}{5}(100 + 120 + 90 + 110 + 130) = 110 \tag{10}$$

$$\bar{y} = \frac{1}{5}(150 + 140 + 160 + 145 + 155) = 150 \tag{11}$$

where $\beta_1 \approx -0.4107$, $\beta_0 = 195.177$

$$y = 195.177 - 0.4107\ x \tag{12}$$

The model was used to predict the price of a product for any number of sales. For example, when the number of sales is 150,

$$y = 195.177 - 0.4107 * 150 = 133.572 \tag{13}$$

The constructed model predicted that the price of the product was USD 133.572 for a sales quantity of 150.

Using the trained linear regression model and real-time market data, the optimal price of the product was predicted. With continuous monitoring and adjustment, the model can be optimized to improve the competitiveness and sales effect of the product. The least squares-based linear regression model was used to predict capability and support e-commerce enterprises to develop reasonable pricing strategies.

IV. Model Prediction

Company F was selected for the evaluation of the model. The data of Company F since July 2020 was collected and analyzed. Using the model, an accurate and reliable forecast of the transaction in the next 12 months was precited. Through in-depth mining and analysis of past transaction data, a model was constructed with factors to predict market trends, consumer behavior, and seasonal changes. These factors reflected market dynamics accurately. The model can be used to monitor and incorporate the latest market data and forecast transaction amounts. The prediction result of the model showed that model's forecast was similar to the actual value by timely adjusting the forecast for changes and uncertainties in the market (Fig. 3 and Table III).

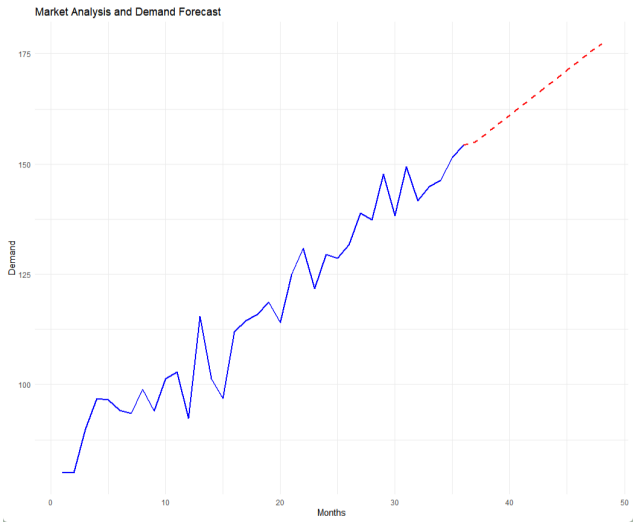

Fig. 3. Forecast of cross-border e-commerce transaction of Company F.

TABLE III. Forecast of Cross-border E-commerce Transaction of Company F

Moon	Projected amount ($ million)	moon	Projected amount ($ million)
1	154.9775	7	167.16
2	157.0079	8	169.1904
3	159.0383	9	171.2208
4	161.0687	10	173.2512
5	163.0992	11	175.2816
6	165.1296	12	177.312

V. Conclusions

An AI-based smart pricing model was constructed for cross-border e-commerce. The model showed excellent predictability considering dynamic market situations. Reasonable prices were suggested to improve profitability and competitiveness. However, compliance, user satisfaction, and data privacy still need continuous improvement. Future research is demanded to include user behavior to optimize the model to meet new market challenges. Regulations and safeguards also need to be considered for the sustainable development of enterprises. The results of this study provide guidance and references for cross-border e-commerce companies to develop smart pricing strategies.

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