

## Evaluating the Competitiveness of Agricultural Products in International Trade based on Fuzzy Analytic Hierarchy Processes

Yu-Jie Feng

Huazhong Agricultural University  
Wuhan Hubei 430070 China  
feng\_yujie2015@163.com

**Abstract** — This paper focuses on the problem of evaluating the competitiveness of agricultural products in international trade, which is a crucial point in agricultural modernization and international trade. An Index system for competitiveness evaluation of agricultural products in international trade is defined first, which is made up of eight indexes. Next, considering Analytic Hierarchy Processes (AHP) may require exact judgments which cannot be obtained, we use fuzzy judgments to replace accurate values. We define several triangular fuzzy numbers, membership functions are defined, and then the problem of agricultural products competitiveness evaluation in international trade is converted to an optimization problem. Finally, to verify the effectiveness of the proposed fuzzy AHP approach, we choose ten kinds of agricultural product to design an experiment scheme. Compared with normal AHP, our proposed method can achieve better performance, and the average competitiveness evaluation error rate of our proposed Fuzzy AHP and AHP are 8.3% and 5.58% respectively.

**Keywords**-Agricultural product, International trade, Fuzzy analytic hierarchy process, Index system, Membership function

### I. INTRODUCTION

As China has joined the World Trade Organization, the competitiveness of Chinese agricultural products in international trade has enhanced greatly, and it is influenced by several different factors<sup>[1]</sup>. For example, vigorous competition by the implementation of rule of market penetration, and greater effects of price competitiveness on international trade. All the above influencing factors may lower the competitiveness of Chinese agricultural products in the domain of international trade<sup>[2]</sup>. After attending the World Trade Organization, the Chinese agricultural products many face many opportunities and challenges, hence, it is great important to study on how to promote the competitiveness of Chinese agricultural products in international trade.

As is well known that, China has come into a period of fast economic growth after attending in WTO from the early 21th century. Therefore, Chinese agriculture faces some changes about internal and external environment changes. In particularly, as the market is open for other countries can attend the Chinese trade transactions<sup>[3][4]</sup>.

In order to evaluate the international competitiveness of agricultural products, the following Indicators we should consider carefully, such as 1) Changes of Export Market Share, 2) Revealed Comparative Advantage Index, 3) Production Price, 4) Dependency rate on Imports Indicators, 5) Trade Competitiveness in a given region<sup>[5]</sup>. After studying on the competitiveness in foreign countries, we find that some advanced countries have constructed a perfect international system. However, In China, the quality

of agricultural products in international trade should be enhanced<sup>[6]</sup>.

Based on the above analysis, in this paper, we focus on the problem of evaluating the competitiveness of agricultural products in international trade utilizing fuzzy analytic hierarchy process. The rest of the paper is organized as follows. Section 2 illustrates related works about applications of fuzzy analytic hierarchy process. In section 3, the Index system for competitiveness evaluation of agricultural products in international trade is provided. Section 4 proposes the proposed algorithm for competitiveness evaluation of agricultural products in international trade. To testify the effectiveness of the proposed algorithm, in section 5, experimental results are given. Finally, the conclusions are drawn in section 6.

### II. RELATED WORKS

In this section, the related woks about applying fuzzy analytic hierarchy process in several different domains are given and discussed.

Chen et al. proposed a new framework for teaching performance evaluation using the integration of fuzzy AHP and fuzzy comprehensive evaluation approach. Particularly, after obtaining the factors and sub-factors, the teaching performance index system was constructed. In this index system, the factor and sub-factor weights are calculated by the extent analysis fuzzy AHP approach. Utilizing the proposed fuzzy AHP approach in group decision-making can obviously enhance the quality of decision-making and lowering the system uncertainty<sup>[7]</sup>.

Lee et al. utilized fuzzy AHP in multi-attribute decision-making situations, and the authors introduced the fuzzy AHP in the field of construction management. Particularly, the authors concentrate on two different AHP methods via investigating weight vectors which are generated from a real case study. Additionally, four different fuzzy AHP methods are prepared by exploiting different fuzzy fundamental scales and weight aggregations<sup>[8]</sup>.

Noori et al. used a fuzzy AHP approach to prioritize weighting methods. In this work, genetic algorithm, rough set theory and fuzzy inference system are all used for feature weighting. Furthermore, feature weighting based on fuzzy inference system was creatively utilized in their works<sup>[9]</sup>.

Oztaysi et al. proposed a group decision making approach based on Analytic Hierarchy Process and Interval type-2 fuzzy sets on a real world ERP choosing problem with 6 criteria and 4 alternatives. The main innovations of this paper lie in that it utilized the interval type-2 fuzzy sets in the decision problem. Experimental results show that fuzzy group decision-making problem can be well solved utilizing the interval type-2 fuzzy sets<sup>[10]</sup>.

Apart from the above works, the fuzzy AHP algorithm has been used in other fields, such as ecodesign of products<sup>[11]</sup>, supplier selection<sup>[12]</sup>, Marine Accident Analysis<sup>[13]</sup>, Assessing coastal reclamation suitability<sup>[14]</sup>, Supplier selection in the airline retail industry<sup>[15]</sup>, Assessment Urban Welfare<sup>[16]</sup>, IOCG prospectivity mapping<sup>[17]</sup>, self-ignition risks of coal stockpiles<sup>[18]</sup>, Evaluating performance of Iranian cement firms<sup>[19]</sup>, Quantifying Failure Risk of Excavation Work<sup>[20]</sup>, assessing technical factors in aviation safety<sup>[21]</sup>.

### III. INDEX SYSTEM FOR COMPETITIVENESS EVALUATION OF AGRICULTURAL PRODUCTS IN INTERNATIONAL TRADE

To evaluate the competitiveness of agricultural products in international trade, the index system is proposed in advance (shown in Table.1)

TABLE.1 INDEX SYSTEM FOR COMPETITIVENESS EVALUATION OF AGRICULTURAL PRODUCTS IN INTERNATIONAL TRADE

Index ID	Index name
I1	Export market share change
I2	Revealed comparative advantage
I3	Production costs
I4	Import dependency rate
I5	Trade Competitiveness index
I6	Export growth advantage index
I7	Export product quality upgrading index
I8	Export dependence or export contribution rate

As is shown in Table.1, the proposed index system can cover major influencing factors about the competitiveness of agricultural products in international trade. I1 means the export market share of total world exports, which denotes the ratio of export market share, and this index can represent the competitiveness of change; I2 means the revealed comparative advantage, which refers a period of a country in a certain product exports accounted for the proportion of total exports in the world; I3 represent the same period consumption in different countries in the production of some products in the cost ratio, additionally, this ratio reflects the comparative advantage of different countries; I4 reflects the country's imports and domestic consumption ratio; I5 is used to measure a country in a certain export products international competitiveness situation from the point of view of overall performance in import and export; I6 means the advantage of export growth index that a country with a product's export growth rate and the country's total trade growth rate ratio, moreover it can also reflect the changes of product export advantage; I7 refers the export base period during the report period under several products; I8 denotes the total import and export volume with the same period of a certain product of the country's GDP ratio.

### IV. THE COMPETITIVENESS EVALUATION ALGORITHM BASED ON FUZZY ANALYTIC HIERARCHY PROCESS

Analytic hierarchy process is able to achieve a priority of the importance of each alternative. Therefore, an overall object is positioned at the top level, and the criteria in the middle level represents to the overall object. The elements at a specific level are represented as  $X_1, X_2, \dots, X_n$ . Exploiting the relative evaluations computed by a decision maker, a pairwise comparison matrix is given as follows.

$$B = \begin{pmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{pmatrix} \quad (1)$$

where this equation follows the reciprocal property  $b_{ij} \cdot b_{ji} = 1$ . Afterwards, the perfectly consistent case where the pairwise comparisons matrix is defined using  $w = (w_1, \dots, w_n)$  as follows.

$$B = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & \frac{w_n}{w_n} \end{pmatrix} \quad (2)$$

Then, with matrix  $B$ , a priority vector is computed by the following two equations.

$$Bw = nw \quad (3)$$

$$Bw = \lambda_{\max} w \quad (4)$$

where  $\lambda_{\max}$  represents the largest eigenvalue of matrix  $B$  and  $w$  means the weight vector. Furthermore, using  $\lambda_{\max}$ , the consistency index is defined as follows.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (5)$$

Based on the above definitions, framework of analytic hierarchy process is described in Fig. 1.

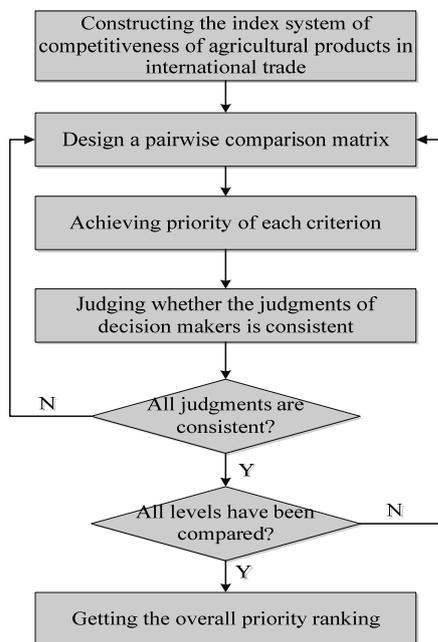


Fig.1 Framework of analytic hierarchy process

However, AHP requires exact judgments, it may be impossible to obtain precise judgments. Hence fuzzy judgments are suitable to replace accurate values.

We define the triangular fuzzy numbers  $\bar{M}$  as  $(n_1, n_2, n_3)$ , and then the membership functions are defined as follows.

$$\rho_{\bar{M}}(d) = \begin{cases} \frac{d - n_1}{n_2 - n_1}, & n_1 \leq d \leq n_2 \\ 0, & d < n_1 \cup d > n_3 \\ \frac{n_3 - d}{n_3 - n_2}, & n_2 \leq d \leq n_3 \end{cases} \quad (6)$$

where the equation  $n_1 \leq n_2 \leq n_3$  is satisfied. Firstly, 2 triangular fuzzy numbers  $\bar{M}_1(p_1^-, p_1, p_1^+)$  and  $\bar{M}_2(p_2^-, p_2, p_2^+)$  are defined. With the influencing factors about the problem of agricultural products competitiveness in the international trade, a matrix  $\bar{M}$  is defined as follows.

$$\bar{M} = \begin{bmatrix} 1 & \bar{p}_{12} & \dots & \bar{p}_{1n} \\ \bar{p}_{21} & 1 & \dots & \bar{p}_{2n} \\ \dots & \dots & 1 & \dots \\ \bar{p}_{n1} & \bar{p}_{n2} & \dots & 1 \end{bmatrix} \quad (7)$$

where  $p_{ij} \cdot p_{ji}$  is equal to 1,  $i, j$  are belonged to the range  $[1, n]$ , then triangular fuzzy number  $\bar{p}_{ij}$  is given as follows.

$$\bar{p}_{ij} = (z_{ij}^-, z_{ij}, z_{ij}^+) \quad (8)$$

Next, the problem of agricultural products competitiveness evaluation in international trade is solved by optimizing the following formula:

$$\min F_i = \sum_{v=1}^m M_{ij} \otimes \left( \sum_{u=1}^n \sum_{v=1}^m M_{ij} \right)^{-1}, 1 \leq i \leq n \quad (9)$$

Main ideas of the proposed fuzzy AHP can be explained in the following figure.

### V. EXPERIMENT

In this section, we conduct an experiment to testify the effectiveness of our proposed algorithm for competitiveness evaluation of agricultural products in international trade. For each agricultural product, the data we chosen can cover the above 8 indexes. Furthermore, we normalize all the data in the range  $[0,1]$ , and the data used in this experiment is shown in Table. 2.

TABLE.2 EXPERIMENTAL DATASET USED IN THIS EXPERIMENT.

ID	I1	I2	I3	I4	I5	I6	I7	I8
Agricultural product 1	0.552	0.646	0.718	0.475	0.485	0.907	0.577	0.827
Agricultural product 2	0.491	0.539	0.784	0.509	0.423	0.911	0.588	0.749
Agricultural product 3	0.457	0.728	0.708	0.508	0.480	0.994	0.573	0.706
Agricultural product 4	0.509	0.641	0.837	0.456	0.528	0.836	0.498	0.846
Agricultural product 5	0.463	0.659	0.859	0.533	0.578	0.912	0.475	0.788
Agricultural product 6	0.453	0.512	0.869	0.533	0.558	0.836	0.541	0.719
Agricultural product 7	0.438	0.633	0.705	0.453	0.532	0.968	0.571	0.801
Agricultural product 8	0.457	0.510	0.741	0.486	0.521	0.903	0.552	0.832
Agricultural product 9	0.421	0.702	0.785	0.499	0.415	0.892	0.499	0.794
Agricultural product 10	0.541	0.650	0.709	0.417	0.456	0.891	0.558	0.763

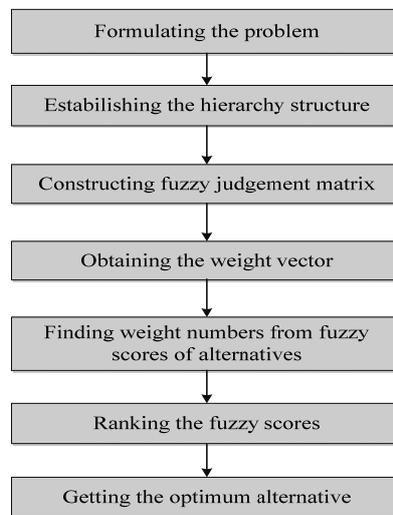


Fig.2 Flowchart of the fuzzy AHP.

Afterward, the task of our work is to pursue the index weight of the proposed index system using the fuzzy AHP method. After running the proposed fuzzy AHP algorithm, the index weight is shown in the following figure.

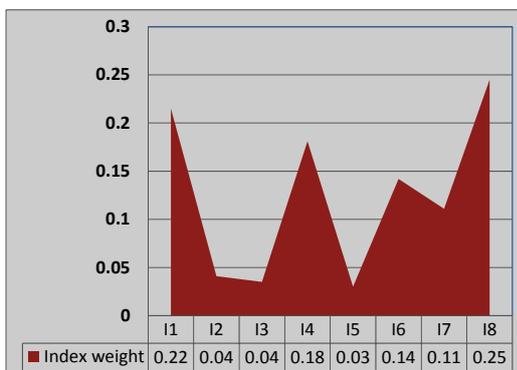


Fig.3 Index weight of agricultural products competitiveness in international trade.

Next, we will calculate the competitiveness value of agricultural products in international trade based on the index weight in Fig.3, and then the values of the competitiveness of agricultural products in international trade are illustrated in Table. 2 (All the products are ranking in a descending order).

TABLE.2 RANKING LIST ACCORDING TO COMPETITIVENESS ABILITY FOR THE TEN AGRICULTURAL PRODUCTS.

ID	Competitiveness value
Agricultural product 1	0.689
Agricultural product 5	0.672
Agricultural product 4	0.672
Agricultural product 7	0.672
Agricultural product 8	0.671
Agricultural product 3	0.663
Agricultural product 2	0.660
Agricultural product 10	0.656
Agricultural product 9	0.656
Agricultural product 6	0.637

In the following, we will compare the performance of our algorithm with AHP, and the experimental results are shown in Fig. 4

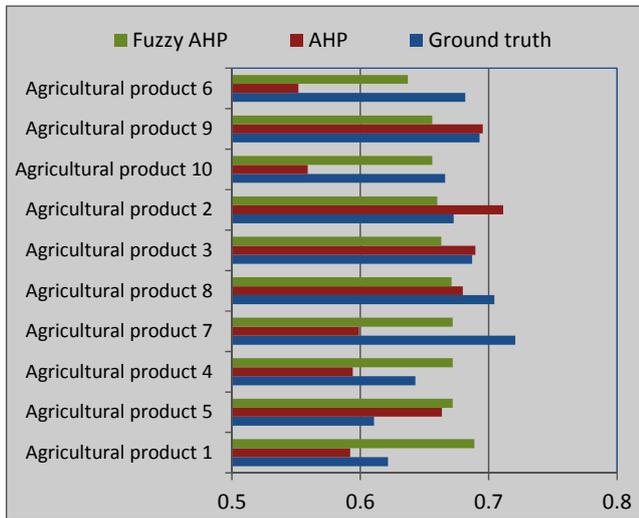


Fig. 4 Competitiveness evaluation for different method

From Fig. 4, we can calculate that the average competitiveness evaluation error rate of our proposed Fuzzy AHP and AHP are 8.3% and 5.58% respectively. The reasons lie in that 1) AHP only exploits crisp pair-wise judgments to derive weights without using the uncertainty of person’s intentions, and 2) when utilizing AHP for interval judgments, the measurement of inconsistencies is difficult to implement.

VI. CONCLUSION

In this paper, we aim to solve the problem of evaluating the competitiveness of agricultural products in international trade. Firstly, we proposed index system for competitiveness evaluation of agricultural products in international trade. Secondly, we use fuzzy judgments to replace accurate values. We define several triangular fuzzy numbers, and then membership functions are defined, and then the problem of agricultural products competitiveness evaluation in international trade is converted to an optimization problem. Thirdly, experimental results demonstrate the effectiveness of our proposed fuzzy AHP algorithm.

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