A competitiveness model of production-teaching-research cooperation mode for enterprises and universities based on fuzzy ideal domain

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Abstract

This paper proposes an improved competitiveness model of production-teaching-research cooperation mode for enterprises and universities based on fuzzy ideal domain to enhance the overall quality as well as the competitiveness of high-tech talents in universities and enterprises. Through the analysis of the cooperation mode and after standardization of indicators, we are able to get the comprehensive fuzzy correlation between evaluation object and fuzzy ideal domain based on fuzzy correlation calculation model. As a result, we can get the competitiveness of production-teaching-research cooperation mode. Empirical study shows that the algorithm and the model are effective.

Keywords: Universities; production-teaching-research cooperation mode; fuzzy ideal domain; multiple attribute evaluation; competitiveness model

1 Introduction

With the development of modern technology, enterprises are yearning for high-tech talents. Traditional ways of training talents by universities cannot meet the demand of the society or enterprises. Universities production-teaching-research cooperation mode is a new way out. On one hand, it nurtures professional technicians for enterprises. On the other hand, it provides an employment opportunity for universities students and increases their competitiveness and overall quality [1-3].

However, many factors need to be taken into account such as enterprises, schools and society. Some factors are dynamic and fuzzy. It is significant to explore the optimal production-teaching-research cooperation mode in order to increase the competitiveness of universities and enterprises [4-7]. Many researches have done relevant studies and yielded fruitful results. But the analysis of fuzzy information is far from enough. Therefore, this paper proposes a competitiveness model of production-teaching-research cooperation mode for enterprises and universities based on fuzzy ideal domain based on fuzzy theory so as to improve hi-tech talents training.

2 A competitiveness index model of production-teaching-research cooperation mode

Evaluation indicators of this production-teaching-research cooperation mode are selected under certain principles. (1) Scientific principle: indicators selected should reflect the features of production, teaching and research in a scientific way. (2) Principle of completeness: the competitiveness should be measured with a panoramic view. (3) Representative principle: indicators should be representable. Redundancy should be avoided in case that some indicators fail to measure the production, teaching or research well. (4) Measurable principle: quantitative indicators should be capable of being quantified and qualitative indicators should have clear denotation and connotation of value of a quantity. According to these principles, this paper proposes a new type of competitiveness model of production-teaching-research cooperation mode, as is shown in Tab. 1.

<table>
<thead>
<tr>
<th>Target layer</th>
<th>criteria layer</th>
<th>indicator layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A competitiveness model of production-teaching-research cooperation mode for enterprises and universities</td>
<td>cooperation input capacity $U$</td>
<td>hardware equipment input $U_{11}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>number of key laboratories $U_{12}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>number of university experts $U_{13}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>university scientific and technological achievements $U_{14}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Science and technology services $U_{15}$</td>
</tr>
</tbody>
</table>

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3 A competitiveness model of production-teaching-research cooperation mode for universities

3.1 STANDARDIZATION OF EVALUATION INDICATORS

Suppose there are \( m \) production-teaching-research cooperation modes between an enterprise and a university. In this mode, there are \( n \) criteria layers. And the \( U_i \)-th criteria layer has \( n_i \) evaluation indicators. There are \( 1 \leq i \leq m \) and \( 1 \leq j \leq n_i \). If the value of a quantity of \( k \)-th production-teaching-research cooperation mode about indicator \( u_{ij} \) is \( V\left(u_{ij}^{k}\right) \), we can get the value of a quantity matrix \( R \) of indicators in the criteria layer \( U_i \) for \( m \) modes:

\[
R = \begin{bmatrix}
V\left(u_{11}^{1}\right) & \cdots & V\left(u_{1n_1}^{1}\right) & \cdots & V\left(u_{m1}^{1}\right) \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
V\left(u_{11}^{m}\right) & \cdots & V\left(u_{1n_1}^{m}\right) & \cdots & V\left(u_{m1}^{m}\right) \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
V\left(u_{11}^{m}\right) & \cdots & V\left(u_{1n_1}^{m}\right) & \cdots & V\left(u_{m1}^{m}\right)
\end{bmatrix}
\]

If indicator \( u_{ij} \) is a positive indicator, then the standardized \( V\left(u_{ij}^{k}\right) \) is \( C\left(u_{ij}^{k}\right) \):

\[
C\left(u_{ij}^{k}\right) = \frac{V\left(u_{ij}^{k}\right) - \min_{1 \leq k \leq m} V\left(u_{ij}^{k}\right)}{\max_{1 \leq k \leq m} V\left(u_{ij}^{k}\right) - \min_{1 \leq k \leq m} V\left(u_{ij}^{k}\right)}
\]

If indicator \( u_{ij} \) is an adverse indicator, then the standardized \( V\left(u_{ij}^{k}\right) \) is \( C\left(u_{ij}^{k}\right) \):

\[
C\left(u_{ij}^{k}\right) = \frac{\max_{1 \leq k \leq m} V\left(u_{ij}^{k}\right) - V\left(u_{ij}^{k}\right)}{\max_{1 \leq k \leq m} V\left(u_{ij}^{k}\right) - \min_{1 \leq k \leq m} V\left(u_{ij}^{k}\right)}
\]
The standardized value of a quantity matrix $T$ of evaluation indicators is:

$$
T = \begin{bmatrix}
C(u_{ij}) & \cdots & C(u_{ij}^{\ell}) & \cdots & C(u_{ij}^{m}) \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
C(u_{ij}^{\ell}) & \cdots & C(u_{ij}^{\ell}) & \cdots & C(u_{ij}^{m}) \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
C(u_{ij}^{m}) & \cdots & C(u_{ij}^{m}) & \cdots & C(u_{ij}^{m})
\end{bmatrix}
$$

(5)

In particular, if $V(u_{ij}^{\ell}) = [v_a(u_{ij}^{\ell}), v_b(u_{ij}^{\ell})]$, when the indicator $u_{ij}$ is a positive one, the standardized $V(u_{ij}^{\ell})$ becomes $C(u_{ij}^{\ell})$:

$$
C(u_{ij}^{\ell}) = \begin{bmatrix} c_a(u_{ij}^{\ell}), c_b(u_{ij}^{\ell}) \end{bmatrix} = \begin{bmatrix} \frac{v_a(u_{ij}^{\ell}) - \min_{1 \leq k \leq m} v_a(u_{ij}^{k})}{\max_{1 \leq k \leq m} v_a(u_{ij}^{k}) - \min_{1 \leq k \leq m} v_a(u_{ij}^{k})} & \frac{v_b(u_{ij}^{\ell}) - \min_{1 \leq k \leq m} v_a(u_{ij}^{k})}{\max_{1 \leq k \leq m} v_b(u_{ij}^{k}) - \min_{1 \leq k \leq m} v_a(u_{ij}^{k})} \end{bmatrix}
$$

(6)

When $u_{ij}$ is an adverse indicator, the standardized $V(u_{ij}^{\ell})$ becomes $C(u_{ij}^{\ell})$:

$$
C(u_{ij}^{\ell}) = \begin{bmatrix} c_a(u_{ij}^{\ell}), c_b(u_{ij}^{\ell}) \end{bmatrix} = \begin{bmatrix} \frac{\max_{1 \leq k \leq m} v_a(u_{ij}^{k}) - v_a(u_{ij}^{\ell})}{\max_{1 \leq k \leq m} v_a(u_{ij}^{k}) - \min_{1 \leq k \leq m} v_a(u_{ij}^{k})} & \frac{\max_{1 \leq k \leq m} v_b(u_{ij}^{k}) - v_b(u_{ij}^{\ell})}{\max_{1 \leq k \leq m} v_b(u_{ij}^{k}) - \min_{1 \leq k \leq m} v_b(u_{ij}^{k})} \end{bmatrix}
$$

(7)

The standardized value of a quantity matrix $T$ of evaluation indicators is expressed as:

$$
T = \begin{bmatrix}
\begin{bmatrix} c_a(u_{11}^{\ell}), c_b(u_{11}^{\ell}) \end{bmatrix} & \cdots & \begin{bmatrix} c_a(u_{ij}^{\ell}), c_b(u_{ij}^{\ell}) \end{bmatrix} & \cdots & \begin{bmatrix} c_a(u_{im}^{\ell}), c_b(u_{im}^{\ell}) \end{bmatrix} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
\begin{bmatrix} c_a(u_{11}^{\ell}), c_b(u_{11}^{\ell}) \end{bmatrix} & \cdots & \begin{bmatrix} c_a(u_{ij}^{\ell}), c_b(u_{ij}^{\ell}) \end{bmatrix} & \cdots & \begin{bmatrix} c_a(u_{im}^{\ell}), c_b(u_{im}^{\ell}) \end{bmatrix} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
\begin{bmatrix} c_a(u_{11}^{m}), c_b(u_{11}^{m}) \end{bmatrix} & \cdots & \begin{bmatrix} c_a(u_{ij}^{m}), c_b(u_{ij}^{m}) \end{bmatrix} & \cdots & \begin{bmatrix} c_a(u_{im}^{m}), c_b(u_{im}^{m}) \end{bmatrix}
\end{bmatrix}
$$

(8)

### 3.2 Weight of Indicators Based on Entropy

Different indicators have different weight, which can be determined by entropy following these steps:

First, acquire the entropy $H_{ij}$ of indicator $u_{ij}$ based on its value of a quantity:

$$
H_{ij} = -\frac{1}{\ln(m)} \sum_{k=1}^{m} \frac{C(u_{ij}^{k})}{\sum_{k=1}^{m} C(u_{ij}^{k})} \ln \left( \frac{C(u_{ij}^{k})}{\sum_{k=1}^{m} C(u_{ij}^{k})} \right)
$$

(9)

Here prescribes that when $C(u_{ij}^{k}) = 0$, there is $\ln \left( \frac{C(u_{ij}^{k})}{\sum_{k=1}^{m} C(u_{ij}^{k})} \right) = 0$.

In particular, if $C(u_{ij}^{k}) = [c_a(u_{ij}^{k}), c_b(u_{ij}^{k})]$, the entropy $H_{ij}$ of indicator $u_{ij}$ is:

$$
H_{ij} = -\frac{1}{\ln(m)} \sum_{k=1}^{m} \frac{c_a(u_{ij}^{k}) + c_b(u_{ij}^{k})}{\sum_{k=1}^{m} (c_a(u_{ij}^{k}) + c_b(u_{ij}^{k}))} \ln \left( \frac{c_a(u_{ij}^{k}) + c_b(u_{ij}^{k})}{\sum_{k=1}^{m} (c_a(u_{ij}^{k}) + c_b(u_{ij}^{k}))} \right)
$$

(10)
If the evaluation indicator system has multi-layers, then when we try to figure out the weight of indicator in the upper layer, the evaluation membership or correlation degree of its corresponding indicators in the sub layer can serve as the value of a quantity for those in the upper layer. Repeat expression (9) to (11) to get the weight.

3.3 CONSTRUCT THE FUZZY IDEAL DOMAIN OF INDICATORS

All indicators after standardization are positive indicators and are measured by 0-1 scale. If the value of a quantity of indicator \( u_{ij} \) after standardization is \( C(u^0_{ij}) \), the fuzzy ideal domain of indicator \( u_{ij} \) in the criteria layer \( U_i \) is \( C(u^0_{ij}) \):

\[
C(u^0_{ij}) = \max_{1 \leq k \leq m} \left( C(u^k_{ij}) \right)
\]

(11)

Therefore, the fuzzy ideal domain of the criteria layer \( U_i \) is \( C^0(u^0_{ij}) \):

\[
C^0(u^0_{ij}) = \left( \max_{1 \leq k \leq m} \left( C(u^k_{ij}) \right) \right)
\]

(12)

In particular, if \( C(u^k_{ij}) = \left[ c_a(u^k_{ij}), c_b(u^k_{ij}) \right] \), then the fuzzy ideal domain of the criteria layer \( U_i \) is \( C^0(u^0_{ij}) \):

\[
C^0(u^0_{ij}) = \left[ \max_{1 \leq k \leq m} c_a(u^k_{ij}), \max_{1 \leq k \leq m} c_b(u^k_{ij}) \right]
\]

(13)

3.4 FUZZY CORRELATION MODEL

After the construction of the fuzzy ideal domain \( C(u^0_{ij}) \) of indicators and the fuzzy ideal domain \( C^0(u^0_{ij}) \) of relevant criteria layer, fuzzy decision-making analysis of \( m \) production-teaching-research cooperation modes can be operated. If the standardized value of a quantity of indicator \( u_{ij} \) in the k-th cooperation mode is \( C(u^k_{ij}) \), then the fuzzy distance \( D(u_{ij}) \) between it and its fuzzy ideal domain \( C(u^0_{ij}) \) of indicator is:

\[
D(u_{ij}) = \frac{1}{\sqrt{2}} \sqrt{\max_{1 \leq k \leq m} \left( c_a(u^k_{ij}) - c_a(u^0_{ij}) \right)^2 + \max_{1 \leq k \leq m} \left( c_b(u^k_{ij}) - c_b(u^0_{ij}) \right)^2}
\]

(14)

In particular, when \( P = 1 \), the fuzzy distance \( D(u_{ij}) \) is Hamming distance:

\[
D(u_{ij}) = \frac{1}{2} \left[ \max_{1 \leq k \leq m} \left( c_a(u^k_{ij}) - c_a(u^0_{ij}) \right) + \max_{1 \leq k \leq m} \left( c_b(u^k_{ij}) - c_b(u^0_{ij}) \right) \right]
\]

(16)

When \( P = 2 \), the fuzzy distance \( D(u_{ij}) \) is Euclidean distance:

\[
D(u_{ij}) = \frac{1}{2} \sqrt{\max_{1 \leq k \leq m} \left( c_a(u^k_{ij}) - c_a(u^0_{ij}) \right)^2 + \max_{1 \leq k \leq m} \left( c_b(u^k_{ij}) - c_b(u^0_{ij}) \right)^2}
\]

(17)

If the weight of indicator \( u_{ij} \) in the criteria layer \( U_i \) is \( w_{ij} \), the fuzzy correlation \( \kappa^k_i \) between the k-th cooperation mode about indicator \( u_{ij} \) and the fuzzy ideal domain \( C(u^0_{ij}) \) of indicator is:

\[
\kappa^k_i = \sum_{j=1}^{n} \left( w_{ij} \ast (1 - D(u_{ij})) \right)
\]

(18)
If the weight of indicator $u_j$ is $w_j$, the fuzzy correlation $\varphi_k$ between the k-th cooperation mode and all indicators and the fuzzy ideal domain $C(u_j^0)$ of indicator is:

$$\varphi_k = \sum_{i=1}^{n} (w_i \times \kappa^i)$$

(19)

According to optimization principle of fuzzy correlation, if there is:

$$\varphi_i = \max(\varphi_k), 1 \leq t \leq m$$

(20)

It then indicates that the t-th production-teaching-research cooperation mode is the best one. Based on that, follow-up plans for development can be made to bring more economic profits. Meanwhile, universities can strengthen cooperation with enterprises to provide a favourable environment for talents.

4 Case study and test

This paper takes cooperation modes between an enterprise and three universities at different stage as examples to prove that the model and the algorithm are effective. Through on-the-spot survey and after consultation with experts, data for evaluation indicators are available, as is shown in Table 2.

<table>
<thead>
<tr>
<th>criteria layer</th>
<th>indicator layer</th>
<th>Value of a quantity of indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>cooperation input capacity $U_1$</td>
<td>hardware equipment input $u_{11}$</td>
<td>Institute of higher learning A</td>
</tr>
<tr>
<td></td>
<td>number of key laboratories $u_{12}$</td>
<td>85-90</td>
</tr>
<tr>
<td></td>
<td>number of university experts $u_{13}$</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>univeristy scientific and technological achievements $u_{14}$</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Science and technology services $u_{15}$</td>
<td>75-80</td>
</tr>
<tr>
<td>talent training capacity $U_2$</td>
<td>number of scientific and technical talents trained $u_{21}$</td>
<td>80-85</td>
</tr>
<tr>
<td></td>
<td>number of papers and patents $u_{22}$</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>number of scientific and technical awards $u_{23}$</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>number of cooperation projects $u_{24}$</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>university-enterprise integration $u_{25}$</td>
<td>75-80</td>
</tr>
<tr>
<td></td>
<td>technology innovation capacity $u_{26}$</td>
<td>80-85</td>
</tr>
<tr>
<td>social output capacity $U_3$</td>
<td>conversion rate of scientific and technical achievements $u_{31}$</td>
<td>80-85</td>
</tr>
<tr>
<td></td>
<td>profit growth rate $u_{32}$</td>
<td>0.065</td>
</tr>
<tr>
<td></td>
<td>growth rate of cooperation production $u_{33}$</td>
<td>0.204</td>
</tr>
<tr>
<td></td>
<td>social services capacity $u_{34}$</td>
<td>75-80</td>
</tr>
<tr>
<td></td>
<td>resource utilization rate $u_{35}$</td>
<td>80-85</td>
</tr>
</tbody>
</table>

Standardize data in Table 2 and get Table 3.

<table>
<thead>
<tr>
<th>indicator layer</th>
<th>Value of a quantity of standardized indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>hardware equipment input $u_{11}$</td>
<td>fuzzy ideal domain</td>
</tr>
<tr>
<td>Institute of higher learning A</td>
<td>Institute of higher learning B</td>
</tr>
<tr>
<td>number of key laboratories $u_{12}$</td>
<td>1.0</td>
</tr>
<tr>
<td>number of university experts $u_{13}$</td>
<td>1.0</td>
</tr>
<tr>
<td>Indicator Layer</td>
<td>Fuzzy Distance of Evaluation Indicator</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Institute of higher learning A</td>
</tr>
<tr>
<td>university scientific and technological achievements $U_{14}$</td>
<td>0.667-1.0</td>
</tr>
<tr>
<td>Science and technology services $U_{15}$</td>
<td>0.667-1.0</td>
</tr>
<tr>
<td>number of scientific and technical talents trained $U_{21}$</td>
<td>1.0</td>
</tr>
<tr>
<td>number of papers and patents $U_{22}$</td>
<td>1.0</td>
</tr>
<tr>
<td>number of scientific and technical awards $U_{23}$</td>
<td>1.0</td>
</tr>
<tr>
<td>number of cooperation projects $U_{24}$</td>
<td>1.0</td>
</tr>
<tr>
<td>university-enterprise integration $U_{25}$</td>
<td>0.75-1.0</td>
</tr>
<tr>
<td>technology innovation capacity $U_{26}$</td>
<td>0.667-1.0</td>
</tr>
<tr>
<td>conversion rate of scientific and technical achievements $U_{31}$</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>profit growth rate $U_{32}$</td>
<td>1.0</td>
</tr>
<tr>
<td>growth rate of cooperation production $U_{33}$</td>
<td>1.0</td>
</tr>
<tr>
<td>social services capacity $U_{34}$</td>
<td>0.75-1.0</td>
</tr>
<tr>
<td>resource utilization rate $U_{35}$</td>
<td>0.667-1.0</td>
</tr>
</tbody>
</table>

We can get different fuzzy distance according to relevant expressions, as is shown in Table 4.

Table 4: Fuzzy distance of evaluation indicator of competitiveness in production-teaching-research cooperation mode
According to calculation expression of fuzzy correlation, here gets the fuzzy sequence of competitiveness, namely, \( \varphi = (0.261, 0.847, 0.703) \). There is \( \varphi_{max} = \varphi_2 \), which means university B is the most competitive. The enterprise can put more effort to enhance the cooperation with university B. It can help with talents nurturing of university B. Besides, C also has some competitiveness, though not as outstanding as B. But the enterprise is suggested to improve the key fields and continue the cooperation with C.

5 Conclusions

This paper studies the production-teaching-research cooperation between enterprises and universities and proposes an improved competitiveness model based on fuzzy ideal domain. By constructing the calculation model of fuzzy distance and fuzzy correlation, we are able to have a measurement on the quality of production-teaching-research cooperation modes. This paper’s research result can provide guidance on talents nurturing. Empirical study has proved that the algorithm and the model are effective. It also provides an approach to evaluate the competitiveness of production-teaching-research cooperation mode through computers.

Reference


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