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Evaluation of Women in Science and Technology

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Abstract. Women in science and technology (WIST) are important for promoting national competitiveness. Especially for developing countries, to promote the contribution of WIST in the labor market, it is vital for national competitiveness. Therefore, to explore women's role in the economy is very important for developing countries (OECD, 2006). How to increase women's contribution in science and technology and enhance their productivity is a significant research subject. The WIST's productivity must be understood. The productivity of WIST refers to the ratio of the amount of output that can be produced using the installed input. This research is to measure the productivity of 25 countries. In the process, a multiple criteria procedure is used to assess the WIST's efficiency in these nations. The goal is increasing and improving WIST's visibility and contribution in science and technological field. The paper shows that VIKOR and Entropy method is very appropriate for the development of such models. It is of special interest that this method provides the development of the multi-criteria evaluation models. A series of managerial implications are set forth and discussed.

Keywords: women in science and technology (WIST), productivity, national competitiveness

1. Introduction

The popularization of education and the awakening of feminine self-consciousness, along with the position of women in the job market have become more important than ever. Since the beginning of the 21st century, the subjects and issues of females developed in the science field had also received more concerns than before. However, women still encountered many frustrations on their works in the field of scientific research and career histories. Within the science and engineering (S&E) fields, the actual contributions and potentials of women in science and technological (WIST) are often ignored. In the past, the existence of prejudices against female scientists, and the traditional responsibility for taking care of their families that are added on them were making females unable to devote themselves to pursue the opportunities of self-realization as males. Therefore, their R&D achievement in the S&E fields may then be delayed [1]. Although women have gained the guarantees of fairness and the right to work, but the percentage of the women working in the S&E fields still have not subsequently progressed, especially in the high-level jobs [2]. Proves that women are just as productive as men; explains the contributions of women in the field of science, as well as the gender discrimination existing in manpower demand; encourages women to be involved in science-related work.

The problem of the complexity of performance evaluation makes the development and the application of standard models more difficult, while at the same time actually presents a motivation for the development of new, more flexible models, which, again, can be adapted to specific interest positions of those who compare the banks. The paper shows that VIKOR and Entropy method is very appropriate for the development of such models. It is of special interest that this method provides the development of the multi-criteria evaluation models.

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The VIKOR method was developed for multi-criteria optimization of complex systems. It is an effective technique for multi-criteria analysis and has been widely applied in compromise ranking problems in business management. It also determines the compromise ranking list and the compromise solution obtained with the initial (given) weights. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi-criteria ranking index based on the particular measure of "closeness" to the "ideal" solution [3]. In the process of multi-objective decision-making on performance evaluation, people often consider relative importance of each evaluation factors or objects. The most direct and simple method is to give each factors weights. This paper has used the entropy weight coefficient method, and carries on the analysis and the processing subjective data. That is, through analyzing the inherent links between factors, the relative importance between factors is marked and calculated to get the weight of factors. The new model was applied to the comprehensive evaluation on exploration potentiality of regional rainwater resource. The analysis result showed that introducing the entropy theory into grey relational analysis method is scientific the proposed model is reasonable and the evaluation precision of the VIKOR method has been improved.

The paper is organized as follows. In the next section, we review the methods of VIKOR and Entropy. Then, the integrated method is applied to the performance of women human resource of science and technology and, finally, there appears a concluding section with the main results of the paper.

2. The VIKOR Method

This study uses this method to evaluate the performance of WIST and rank the priority for them accordingly. This research applies VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) to find out the best alternative among these countries. The basic idea of VIKOR is to find out the positive ideal solution and negative ideal solution. This method determines the compromise ranking-list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial (given) weights [3]. Furthermore, we can priority the order from the set of the alternatives and then determine the best one in the presence of conflicting criteria. The following sections will show the computational procedure of VIKOR. The mathematics concept borrowed from Opricovic and Tzeng (2004) [3] and Tzeng, Lin & Opricovic [4].

3. Entropy Method

Entropy was originally thermodynamic conception and an uncertainty measurement of system state. Information represents ordered degree but entropy represents disordered degree of system in information theory. The two is equal in value but opposite in sign. If the lower information entropy value of one objective, the higher variation of index value and quantity of message, the weighting should be higher. On the contrary, the higher information entropy value of one objective, the lower variation of index value and quantity of message, the weighting should be lower. So entropy could be calculated based on the variation of index value. The weighting of all indexes was calculated and then the objective conclusion of comprehensive evaluation was obtained [5]. It measures the degree of uncertainty that exists in a system. The entropy weight is really certain and objective, though the index value is subjective. The way to combine subjective with objective method, overcame the shortage of the tradition subjective weight, lead into the entropy weight, made the evaluation result is more accurate and valid. The concrete steps for deciding index weight based on entropy method are as followings.

The decision matrix A of multi-criteria problem with m alternatives and n index is shown as following equation:

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} x_1 & x_2 & \cdots & x_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & & x_{2n} \\ \vdots & & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array}$$

Where $x_{ij}\,(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n)$ is the performance value of the ith alternative to the jth factor.

Definition in the entropy technique:

Step 1: The set projection of the factor: P_{ij}, it is a relative frequency:

$$P_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{5}$$

Step 2: Entropy: the output entropy of the jth factor according to the information theory is the following equation.

$$E_j = -k \sum_{i=1}^{m} P_{ij} \ln(P_{ij}) \quad j = 1, 2, \cdots, n \tag{6}$$

Where k represents a constant: $k = \frac{1}{\ln m}$, which guarantees that $o \le E_j \le 1$.

Step 3: Calculate the weight of entropy

The degree of diversification d_j of the information provided by the factor j can be defined as following equation

$$d_j = \left|1 - E_j\right| \quad \forall j \tag{7}$$

Then the weight of entropy of jth factor could be defined as:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, \quad \forall j \tag{8}$$

There are many different research applied entropy method to calculate the weighting. To base on the definition of entropy to derive the discrete type of entropy, and it calls grey entropy [6]. To adopted grey related TOPSIS method to construct evaluation model for human resources evaluation based on Entropy weight [7]. To put forward the entropy weight matter-element appraisal model for quantitative analysis to virtual enterprise risk [8]. They were gave a method of entropy weight coefficient that is applied to calculate the weight of factors and decrease subjective judgment on the effect of the weight coefficient [9]. They propose a combined entropy weight and TOPSIS method for information system selection [10]. To applies Grey Relational Analysis and Entropy weights into fuzzy design theory, and solve the problem of three levels structure fuzzy comprehensive evaluation [11]. To review the evaluation and entropy weight when it's necessary and give an approach about the multiple objective decision methods, and at the end, give a more accurate and credible engineering item choice.

4. Empirical illustrations

In this section, we present a numerical example to illustrate how the proposed method can be used. Therefore, in this paper, VIKOR method was extended to develop a methodology for solving performance evaluation problems. To validate the application of the model and to examine its effectiveness, the proposed extension methodology was used for deriving performance order of different countries. The performance evaluation model of women human resource of science and technology was established.

4.1 Determine the criteria weights using Entropy method

This paper gives a method of entropy weight coefficient that is applied to calculate the weight of factors and decrease subjective judgment on the effect of the weight coefficient. The entropy method can greatly improve the performance of women human resource of science and technology in twenty-five countries by overcoming the shortcomings of conventional methods that only use either the subjective or the objective weights.

Then we calculate the weight of entropy by using Eq. (6) to Eq. (8). The entropy weight Table 1 just follows as Table 1. Table 1 shows the relative weight of different evaluation criteria for the performance of women human resource of science and technology, which obtained by Entropy method. The weights for each criterion are: C_1 (0.099), C_2 (0.114), C_3 (0.119), C_4 (0.195), C_5 (0.198), C_6 (0.204) and C_7 (0.071). From

the Entropy results, we can understand the first two important factors for the performance of women human resource of science and technology are C_6(0.204) and C_5(0.198). Moreover, the less important factor is C_7(0.071).

Table 1 Criteria weighting by entropy method

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
E_j	3.289	3.624	3.743	5.503	5.577	5.694	2.628
d_j	2.289	2.624	2.743	4.503	4.577	4.694	1.628
w_j	0.099	0.114	0.119	0.195	0.198	0.204	0.071

Note: (1) High-tech export; (2) Science Paper; (3) Advanced research programmes; (4) Business Enterprise Sector: Women researchers as a percentage of total researchers (based on headcount); (5) Government Sector: Women researchers as a percentage of total researchers (based on headcount); (6) Higher Education sector: Women researchers as a percentage of total researchers (based on headcount); (7) R&D Expense

4.2 Estimating the performance and ranking the alternatives

This paper focus on determining the best performance evaluation model of women human resource of science and technology among these countries; so, we assume that questionnaire have collected completely and will start with building dataset that are collected. We can undertake to construct dataset with VIKOR method. As mentioned previously, the consensus weights of criteria identified through the Entropy methodology are shown in Table 1 and each countries evaluation of alternatives are given as Table 2. In addition, this research calculates the normalized value and the results are shown in Table 3.

Table 3 Normalized gap-values of twenty-five countries

		Criteria						
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Alter-natives	Austria	0.098	0.113	0.118	0.173	0.122	0.130	0.070
	Belgium	0.096	0.112	0.118	0.122	0.143	0.105	0.070
	Czech Republic	0.098	0.113	0.118	0.142	0.125	0.124	0.071
	Denmark	0.099	0.113	0.119	0.083	0.121	0.109	0.070
	Finland	0.098	0.113	0.118	0.143	0.093	0.043	0.070
	France	0.067	0.075	0.097	0.120	0.137	0.122	0.060
	Germany	0.000	0.034	0.000	0.177	0.154	0.149	0.049
	Greece	0.099	0.113	0.118	0.048	0.099	0.092	0.071
	Hungary	0.098	0.114	0.119	0.104	0.112	0.103	0.071
	Iceland	0.099	0.114	0.119	0.002	0.084	0.046	0.071
	Ireland	0.096	0.114	0.119	0.124	0.125	0.099	0.071
	Italy	0.096	0.085	0.089	0.124	0.104	0.117	0.068
	Japan	0.042	0.000	0.097	0.195	0.196	0.193	0.000
	Korea	0.053	0.100	0.112	0.183	0.198	0.204	0.067
	Mexico	0.093	0.113	0.117	0.082	0.149	0.114	0.071
	Netherlands	0.082	0.106	0.117	0.184	0.150	0.154	0.070
	New Zealand	0.099	0.113	0.119	0.152	0.151	0.027	0.071
	Norway	0.099	0.113	0.119	0.123	0.116	0.081	0.070
	Poland	0.099	0.112	0.109	0.067	0.101	0.067	0.071
	Portugal	0.099	0.113	0.104	0.068	0.000	0.014	0.071
	Slovak Republic	0.099	0.114	0.119	0.000	0.089	0.050	0.071
	Spain	0.099	0.096	0.106	0.064	0.066	0.091	0.069
	Sweden	0.098	0.110	0.115	0.080	0.117	0.000	0.070
	Switzerland	0.093	0.110	0.117	0.118	0.164	0.150	0.070
	Turkey	0.099	0.111	0.117	0.078	0.158	0.088	0.071

5. Conclusions and Remarks

A woman in the labor market participation rate is an important indicator of long-term economic growth is a key element. For developing countries, to promote the success of women in science and technology in the labor market, it is vital for national competitiveness. Therefore, to explore women's role in the economy is very important for countries. Adding fuel to the flames in the knowledge-based economy, science and technology talent to become the country's competitive edge-driven elements, how to increase women's participation rate in the field of science and technology, planning career development of women and enhance their productivity and become an important research subject.

The result point out the important criteria for evaluate WIST performance includes “Business Enterprise Sector: Women researchers as a percentage of total researchers”, “Government Sector: Women researchers as a percentage of total researchers”, and “Higher Education sector: Women researchers as a percentage of total researchers”. Nations can facilitate the performance of WIST by increasing its women researchers as a percentage of total researchers. The further research can explore that how to improve the gaps in each criteria based on Network Relationship Map (NRM) and capture the complex relationships among these evaluation criteria. The NRM is not only to find out the most important criteria but also to measure the relationships among these evaluation criteria.

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