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Research Article

Evaluation and Empirical Research on Medical Universities' Performance in a Hierarchical Context Based on Individual Advantage Identification Perspective

Zhu Zhu,[1] Jian-Feng Jia,[2] Shi-Tong Huang,[3] Yu-Xin Jiao,[2] and Sen Liu[4]

[1]*School of Information, Liaoning University, Shenyang 110167, Liaoning Province, China*
[2]*School of Business Administration, Northeastern University, Shenyang 110167, Liaoning Province, China*
[3]*School of Management, Henan University of Science and Technology, Luoyang 471000, Henan Province, China*
[4]*School of Business Administration, University of Science and Technology Liaoning, Anshan 114051, Liaoning Province, China*

Correspondence should be addressed to Jian-Feng Jia; jfjia@mail.neu.edu.cn

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Based on the literature review on medical education and university performance evaluations and from the perspective of individual advantage identification, an evaluation method of medical universities' performance in a hierarchical context was proposed. This study designs a method system, including individual learning benchmarking from the individual perspective, group learning benchmarking from the democratic perspective, and benchmarking of single and overall indicators. From the perspective of the most favorable to medical universities, this study applies the designed research methods to the performance evaluation of medical universities and takes 15 medical universities in China as samples to conduct an empirical research. The following conclusions were found. First, the method helps form various development modes of medical universities in the individual advantage characteristic context. Second, the method not only shows objectivity but also provides a basis for how medical universities find individual and integral benchmarking. Finally, the method demonstrates the democracy feature, which provides a basis for how relevant departments allocate resources and formulate policies.

1. Introduction

With the rapid development of a knowledge-based economy, competition among countries increasingly depends on the contribution of knowledge. Given the existence of professional production institutions and knowledge and culture dissemination, higher education plays a lead role in education development and competition. Higher education is a core force in leading and promoting national economic construction, social development, technological innovation, and cultural prosperity [1–4]. Medical universities are a significant component of higher education institutions. Compared with other types of higher education, medical education is a trinity among teaching, scientific research, and medical service. Scientific research and talent cultivation in medical universities provide cutting-edge information and the latest knowledge system for medical research and support medical services extending to other fields. Therefore, exploring medical university construction and development has critical theoretical and practical significances. The structure of higher education in the world is increasingly showing a trend of diversification; the trend of popularization of higher education is obvious. Our exploration of the evaluation of medical universities will help medical universities avoid blindly following the trend to a certain extent and provide a reference in formulating reasonable development planning and management decision.

Medical education has high specialization degree characteristics, such as evident practicality, expensive education cost, long training period, and high social expectation. Medical university evaluation must differ from other university types. Faced with current technological, economic,

and social changes in demand, the manner in which medical universities learn from the evaluation of other university types, highlight and position their own mission and characteristics, and avoid weaknesses in their development is being explored. Therefore, a scientific performance evaluation of medical universities cannot be done without two research works: one is the evaluation content; the other is the evaluation method. Based on the review of the two elements, this article constructs a basic framework of medical university performance evaluation composed of individual advantage evaluation ideologies, identification methods, and operation rules, and designs a method system, which also through the empirical data verifies the designed research methods.

2. Literature Review

2.1. Review of Medical Education Evaluation. Existing literature has paid close attention to medical education evaluation, with its main concerns on medical teaching, professional, and education program evaluations. Medical education evaluation affects the development of medical education. Evaluation focuses on worth, whereas research focuses on truth [5, 6]. However, they all ultimately seek evidence for development, and both should be synergistic [7]. Researchers should assume a rational view on the relationship between medical education research and evaluation [8]. Medical education is confronting with the integration of biomedical advances and clinical practices, and it needs to pay attention to teaching and learning practice and evaluation, as well as relevant theories, such as cognitive and learning science theories, which influences medical education evaluation [9, 10]. Medical educators use evaluation application, general evaluation, methodology, evaluation models, and various evaluation research in the medical education context to fully understand medical education evaluation and to improve their subsequent medical education practice [8, 11–13]. Faculty and social accountability in medical schools are the key points of medical education evaluation [14–16]. Related industry evaluation standards and programs in the medical field are also useful in basic medical education, especially for medical universities to amend original evaluations [17, 18]. Medical education evaluation can help corresponding subjects select medical school candidates, training programs, and faculty staff, as well as improve health care quality and optimize medical education outcomes and clinical practices [19]. Related studies have provided different medical education evaluation perspectives and have laid the foundation for theoretical and practical research. School evaluations are a necessary education content [20–22]. It can be seen that the existing evaluation of medical education mainly focuses on medical teaching, medical majors or courses, medical education programs, medical teachers, and the social responsibility of medical universities; the comprehensive performance evaluation of medical universities is still limited. Most existing research studies fail to solve the evaluation of the overall performance of a medical university, nor the specific performance level of a medical university in the whole medical higher education industry. This shows space for further research on this topic.

2.2. Review of University Performance Evaluation. University construction and development cannot be separated from the scientific and effective implementation of evaluation work. Research on university evaluation is not only limited to medical universities but also can provide a reference for medical university evaluation. Owing to different research purposes and concerns, scholars have carried out overall evaluations on the efficiency of universities as the research object, as well as on the teaching quality, research output, talent training, and other contents of individual evaluations. Ahn et al. [23] were the first to use the data envelopment analysis (DEA) method to compare the efficiency of running 161 universities with doctoral qualifications in the US, including 108 public and 53 private universities between 1984 and 1985. Breu and Raab [24] and Johnes [25] also conducted similar university evaluation studies using the DEA method. Qi et al. [26] used the TOPSIS method to evaluate the academic performance of 33 research-oriented universities in China. Ding and Zeng [27] combined the entropy and TOPSIS methods to assess the education quality of 68 affiliated universities in China. Chen et al. [28] used a questionnaire statistical analysis method to analyze the high internationalization education in research-oriented universities in China. Similarly, Mo [29] utilized a questionnaire statistical analysis to compare the undergraduate training models of 15 research-oriented universities in China. These studies have not only enriched university research content but also provided feasible evaluation methods for related research.

2.3. Research Framework. In summary, research on medical university evaluation is still limited, and medical university development is the center of medical education that cannot be neglected. Medical universities focus on innovative medical knowledge and technology production, dissemination, and application and aim to produce high-level medical scientific research. They also cultivate professional medical elites, whose basic characteristics can be described from the school philosophy and condition, faculty, disciplinary structure, scientific research achievement, talent cultivation, social service, and academic reputation and influence. Medical university performance refers to the social effect of and contribution made by medical universities in the creative production, dissemination and application of medical knowledge, technology and scientific research, and cultivation of medical professionals in a certain period [30–34]. The above description of medical universities can undoubtedly affect medical universities' performance evaluation characteristics. Thus, constructing a corresponding evaluation indicator system is necessary. In addition, considering different medical university characteristics and resources, a simple panel data comparison and sorting does not fully explain the current operating status and individual advantages of medical universities. The real role of medical university evaluation aside from ranking is to provide operational mode guidance and reference for future improvement. Individual characteristics

of universities should be tapped, and objects should be evaluated from the most favorable perspective. However, numerical comparison, statistical analysis [35], DEA [36, 37], entropy [38], TOPSIS [39], and other methods cannot fully meet evaluation needs, making the design of a new evaluation method necessary.

The medical education system in each country is different. For example, in the United States, the medical university mainly refers to the medical school in a comprehensive university, and students will not enter the medical schools before they finish four years of undergraduate education. In Asia, in countries such as Japan and China, the definition of medical university is diversified and various types of medical universities coexist. Medical universities mainly include independent medical universities, medical schools, medical colleges, and medical schools in comprehensive universities. At the early stage, a total number of 124 medical colleges and universities have been independently set up in China. After nearly 20 years of integration into comprehensive universities, medical schools of comprehensive universities have coexisted with independent medical universities nowadays. A total number of 76 existing full-time medical universities exist in China and belong to two management systems, respectively: the central and the local. These universities are categorized into three types based on professional division: Chinese medicine universities, medical universities, and pharmaceutical universities. They are further divided into three levels according to overall strength and school scale: medical universities, medical colleges, and medical schools. 15 universities in the 76 medical universities are currently named after the Medical University. This research mainly focuses on the performance evaluation of medical universities. The current scope is limited to independent medical universities granted with doctorate right.

Therefore, the main purpose and contribution of this study lie in the following factors. First, this study integrates existent research results and constructs a basic framework of medical university performance evaluation, which is composed of individual advantage evaluation ideologies, identification methods, and operation rules which embody the democracy feature. Second, this study designs a method system, including individual learning benchmarking from the individual perspective, group learning benchmarking from the democratic perspective, and benchmarking of single and overall indicators. This method supports the management decision of multiple hierarchical structures. Third, from the perspective of the most favorable to medical universities, this study applies the designed research methods to the performance evaluation of medical universities in China; it helps form various modes of medical universities in the individual advantage characteristic context and provides a basis for relevant government departments to allocate resources and formulate policies.

3. Method Design

Weight coefficient has an important guiding role in comprehensive evaluation, representing people's understanding of the importance of different indicators and embodying value orientation. Evaluated objectives often have their own different values when facing the same evaluation indicators because of the diverse resources and abilities of individuals. Moreover, people tend to form various individual advantages based on different values as they grow. Therefore, when using weight coefficient to show people's different value orientations, it can also be called "value parameter," and weight coefficient set constitutes a value parameter structure. When identifying the value parameter structure from the most favorable point of view to evaluated objects, it becomes a value arrangement. Such arrangement is under the consensus evaluation indicator system and based on the same evaluation function and can be accepted easily, although the identification result is not an actual individual advantage. This value parameter structure can be regarded as a specific arrangement of the evaluated objects' individual advantage, and thus, it is called the individual advantage characteristic structure [40].

Compared with traditional evaluation methods which pay too much attention to the interests of experts and decision makers, our individual perspective focuses on how to reflect the interests of the evaluated objects and improve the passive position of them and then employee evaluation or decision based on the characteristics of the evaluated objects. For example, scholars such as Jacobi and Hobbs [41], Roy et al. [42], and Cooper et al. [43] attempted to apply or modify evaluation techniques to do so. Due to individual differences and limitations of observations, the individual advantage is a tendency inferred from behavioral outcomes. It is not necessarily the innate individual advantage of the evaluated objects, but the comparative advantage of each individual through data mining, based on the specific evaluated problem and the group of evaluated objects. When it comes to the process of mathematical modeling, in view of the value-oriented function and normative features of the weight coefficient and under the principle of not violating the public values, we calculate the individual's preference weights to depict their individual advantages (more on its mathematical expressions and feasibility arguments can be found in reference [44–47]).

As for the object of this study, different medical universities have various individual advantages in their development, that is, various medical universities often have their own superiority in the consensus performance indicators, which show a different weight arrangement when represented on weight coefficients. According to Zhao and Jia [48] and Jia et al. [47], the construction and application of the individual advantage identification method in the single-layer indicator system had been discussed. However, the performance indicator system features hierarchical structure because of the complex performance of medical universities. Accordingly, the individual advantage characteristics of medical universities also show a hierarchical structure. Therefore, identifying their individual advantages in a hierarchical context is the core and key issue of this study.

In this study, we constructed a consensus medical universities' performance evaluation indicator system, collected relevant performance indicator data of each

medical university, and used the ideal point utility function to apply and expand the abovementioned individual advantage identification ideas. According to the hierarchical structure indicator system, the relevant models are constructed, and the weights (individual advantage characteristics) of each medical university on each indicator are solved layer by layer, and relevant evaluations are carried out accordingly.

3.1. Problem Description. Evaluated objects are assumed to be composed of n medical universities: $o_1, o_2, \ldots, o_n$. Furthermore, the performance evaluation system is assumed to be a three-layered structure (additional layers can be analyzed). Among them, the top layer z is composed of m middle-layer indicators: $y_1, y_2, \ldots, y_m$. The standardly processed basic-level indicator vector of jth medical university is $\mathbf{r}_i(j) = [r_{i1}(j), r_{i2}(j), \ldots, r_{ip_i}(j)]^\tau$ (without generality loss, assuming that all are converted into efficiency indicator data).

3.2. Identification Method of Individual Advantage Characteristics in a Hierarchical Context. According to the construction idea and research experience of the individual advantage characteristic identification method under single-layer indicators [40, 47, 48], such characteristics can be identified per layer in a hierarchical context.

3.2.1. Identification of Individual Advantage Characteristics in Basic-Layer Indicators. From the point of view of the most favorable to j^{th} medical university, the following objective planning model can be constructed to determine the individual advantage characteristics of middle-layer indicator y_i in its subindicator:

$$\min \left\{d^2_{\omega(j)}\left(\mathbf{r}_i(j), \mathbf{r}^*_i\right)\right\} = \sum_{k=1}^{p_i} \omega^2_{ik}(j)\left[r_{ik}(j) - r^*_{ik}\right]^2,$$
$$\text{s.t.} \quad \begin{cases} \sum_{k=1}^{p_i} \omega_{ik}(j) = 1, \\ \omega_{ik}(j) \geq 0,\ i = 1, 2, \ldots, m;\ k = 1, 2, \ldots, p_i. \end{cases} \tag{1}$$

In Model (1), $\boldsymbol{\omega}_i = [\omega_{i1}, \omega_{i2}, \ldots, \omega_{ip_i}]]^\tau$ is a value parameter vector. Model (1) denotes that, for medical university j, when the basic-layer indicator and ideal values belonging to y_i are determined by seeking the optimal solution of the value parameter vector $\boldsymbol{\omega}^*_i(j) = [\omega^*_{i1}(j), \omega^*_{i2}(j), \ldots, \omega^*_{ip_i}(j)]^\tau$, the individual advantage characteristic structure of y_i in its basic-layer indicator can be obtained.

3.2.2. Identification of Individual Advantage Characteristics in Middle-Layer Indicators. For medical university j, input $\boldsymbol{\omega}^*_i(j) = [\omega^*_{i1}(j), \omega^*_{i2}(j), \ldots, \omega^*_{ip_i}(j)]^\tau$ back into Model (1), and its indicator value in y_i, $s^*_i(j) = \sqrt{\sum_{k=1}^{p_i}[\omega^*_{ik}(j)]^2[r_{ik}(j) - r^*_{ik}]^2}$ can be obtained. Given that $\omega^*_i(j)$ is the optimal solution of Model (1), $s^*_i(j)$ becomes evidently optimal. Considering that $s^*_i(j)$ represents the weighted distance value of the underlying subindicator and the ideal value of y_i, $s^*_i(j)$ value should be 0 in the ideal state. The objective planning Model (2) can be constructed according to Model (1) to identify the individual advantage characteristics of university j's top-layer indicator in the middle-layer indicator.

$$\min\ z^2_{\mu(j)} = \sum_{i=1}^{m} \mu^2_i(j)\left[s^*_i(j)\right]^2,$$
$$\text{s.t.} \quad \begin{cases} \sum_{i=1}^{m} \mu_i(j) = 1, \\ \mu_k(j) \geq 0,\ i = 1, 2, \ldots, m. \end{cases} \tag{2}$$

3.2.3. Solution Method for Identifying Individual Advantage Characteristics of Layers. If $\boldsymbol{\omega}^*_i(j) = [\omega^*_{i1}(j), \omega^*_{i2}(j), \ldots, \omega^*_{ip_i}(j)]^\tau$ is marked as the optimal solution of Model (1), then its solution can be seen from the nature of the boundary closed interval continuous function. According to the optimality principle of Kuhn–Tucker, the optimal solutions are as follows: ① When no variable coefficient is equal to 0 in the objective function, $r_{ik}(j) \neq r^*_{ik}$ becomes

$$\omega^*_{ik} = \frac{1}{\left(r_{ik}(j) - r^*_{ik}\right)^2 \sum_{k=1}^{pi} 1/\left(\left(r_{ik}(j) - r^*_{ik}\right)^2\right)},$$
$$i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n. \tag{3}$$

② When several variable coefficients are equal to 0 in the objective function, the sum of these coefficients' corresponding variables should equal 1, whereas other variables should equal 0.

Similarly, if $\boldsymbol{\mu}^*(j) = [\mu^*_1(j), \mu^*_2(j), \ldots, \mu^*_m(j)]^\tau$ is marked as the optimal solution of Model (2), then the following applies. ① When no variable coefficient is equal to 0 in the objective function, $y^*_i(j) \neq 0$ becomes

$$\mu^*_i(j) = \frac{1}{\left[y^*_i(j)\right]^2 \sum_{i=1}^{m} 1/\left(\left[y^*_i(j)\right]^2\right)},$$
$$i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n. \tag{4}$$

② When several variable coefficients are equal to 0 in the objective function, the sum of these coefficients' corresponding variables should equal 1, whereas other variables should equal 0.

3.3. Performance Evaluation Method Based on Individual Advantage Characteristics in Hierarchical Context

3.3.1. Individual Agent Evaluation. Individual agent evaluation refers to all medical university evaluations from the point of view most favorable to medical universities and with its individual advantage characteristic as the value parameter. This model meets the needs of evaluated objects to evaluate the performance from the perspective of highlighting their own advantages. Although it ranks the group from their own perspective to obtain the best

evaluation results, the model helps evaluated objects to be clearly aware of their own advantages in the actual group performance.

Corresponding to the identification results of individual advantage characteristic layers from the point of view most favorable to medical university j, put the individual agent evaluation for all the performances of evaluated universities in the middle-layer indicator y_i and mark the evaluation value as $c_i(j,q)$, thereby obtaining

$$c_i(j,q) = \sqrt{\sum_{k=1}^{p_i} [\omega_{ik}^*(j)]^2 [r_{ik}(q) - r_{ik}^*]^2}, \quad j = 1,2,\ldots,n;\ q = 1,2,\ldots,n;\ i = 1,2,\ldots,m. \tag{5}$$

In formula (5), $r_{ik}(q)$ is the basic-layer indicator value of qth medical university because it represents distance. The smaller the evaluation value $c_i(j,q)$ is, the better medical university q performs in the indicator y_i under the value parameter $\omega_i^*(j)$ of individual advantage characteristics of medical university j.

Similarly, if $g(j,q)$ is marked as the individual agent evaluation value of evaluated object q in the top-layer indicator under the value parameter structure $\mu^*(j)$ of medical university j, then

$$g(j,q) = \sqrt{\sum_{i=1}^{m} [\mu_i^*(j)]^2 [y_i^*(q)]^2}, \quad j = 1,2,\ldots,n;\ q = 1,2,\ldots,n;\ i = 1,2,\ldots,m. \tag{6}$$

3.3.2. Democratic Agent Evaluation. Democratic agent evaluation refers to the evaluation based on the comprehensive consideration of all individual advantage characteristics of evaluated objects. Evaluation results are usually more easily accepted by evaluated objects because their individual advantage characteristics are considered. Based on the calculated results of Models (1), (3), and (5) from the point of view most favorable to j^{th} university, the democratic agent evaluation result of medical university q in the middle-layer indicator y_i is

$$C_i(q) = \frac{1}{n}\sum_{j=1}^{n} c_i(j,q) = \frac{1}{n}\sum_{j=1}^{n} \sqrt{\sum_{k=1}^{p_i} [\omega_{ik}^*(j)]^2 [r_{ik}(q) - r_{ik}^*]^2}, \quad j = 1,2,\ldots,n;\ q = 1,2,\ldots,n;\ i = 1,2,\ldots,m. \tag{7}$$

Similarly, based on the calculation results of Models (2), (4), and (6) from the point of view most favorable to j^{th} university, the democratic agent evaluation result of medical university q in the top-layer indicator is

$$G(q) = \frac{1}{n}\sum_{j=1}^{n} g(j,q) = \frac{1}{n}\sum_{j=1}^{n} \sqrt{\sum_{i=1}^{m} [\mu_i^*(j)]^2 [y_i^*(q)]^2}, \quad j = 1,2,\ldots,n;\ q = 1,2,\ldots,n;\ i = 1,2,\ldots,m. \tag{8}$$

Based on the above results, if we arrange individual and democratic agent evaluation values in ascending order, then the sorting result of all evaluated objects on the corresponding indicators can be obtained.

4. Empirical Research on the Performance Evaluation of Chinese Medical Universities

4.1. Indicator System Construction of Medical Universities' Performance Evaluation. The indicator system mainly solves the problem of "what is being evaluated." Researchers have proposed the performance evaluation indicator system of different universities according to different purposes [49]. In respect of the system, this study mainly draws lessons from the research results obtained by the University Research Team of Chinese Universities' Alumni Association Network (CUAA). The main considerations are as follows. First, the University Research Team of CUAA has been carrying out research for 15 consecutive years since 2003, consistently updating and improving research results and has built an authoritative, open, transparent, objective, and impartial evaluation indicator system of Chinese universities that is in line not only with world standard [50–52] but also with Chinese feature [53]. Second, "Pyramid" principle [54] and "News Hole" theory [55–57] are used when selecting evaluation indicators. Both also strictly screen high-level, iconic, authoritative, and impartial indicators, as well as a continuous, objective, and transparent indicator set to ensure that the final evaluation results feature simplicity, comparability, operability, repeatability, and sustainability. Third, the indicator system has the following four advantages. First, high-end indicators encourage colleges and universities to pursue excellence in talent cultivation and scientific research. Second, contribution is preferred, in which international standards of indicators and Chinese characteristics are considered; worldwide effect of universities and their national and regional contribution are highlighted. Third, overall plan maintains balanced teaching, research, and different individual evaluation indicator types. Finally, comprehensive consideration starting from three university functions, namely, talent cultivation, scientific research, and social service, in which the system evaluates core indicators, such as teaching, scientific research, social service, and international influence.

Drawing lessons from the research results obtained by the CUAA, the medical university indicator system consists of eight indicators: teaching quality, discipline construction, faculty, scientific research achievement, base, and project, as well as school positioning and international influence. The connotation and measurement of indicators are consistent

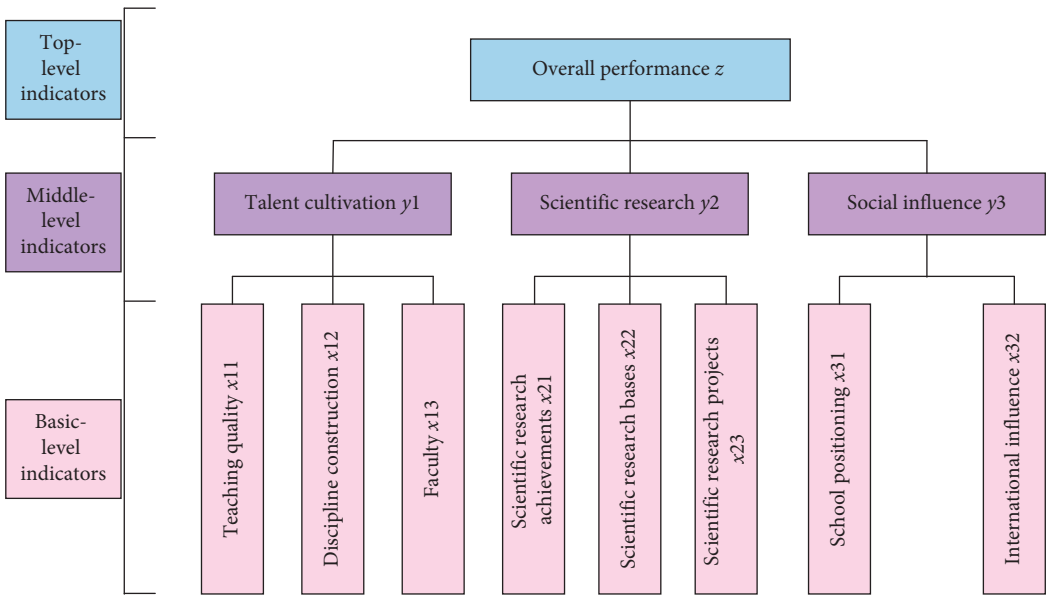

Figure 1: Performance evaluation indicator system of medical universities.

with the results obtained by the University Research Team of CUAA. Among them, teaching quality, discipline construction, and faculty reflect the talent cultivation of medical universities. Scientific research achievements, bases, and projects reflect the scientific research situation of medical universities. School positioning and international influence reflects the social influence of medical universities. In summary, the indicator system of this research is shown in Figure 1.

4.2. Selection and Collection of Samples and Performance Data of Medical Universities. This study selects the top 15 medical universities ranked by the University Research Team of CUAA as research samples. The basis of such selection is that the 15 universities are all in the lead in talent cultivation, scientific research, and social influence, which represent strong research value.

Data on teaching quality, discipline construction, faculty, as well as school positioning and international influence come from the official website of the Chinese Alumni Network. Data on scientific research bases are from the official websites of the 15 medical universities. Data on scientific research achievements and projects are from the University Science and Technology Statistics Compilation released by the Science and Technology Division of China's Ministry of Education.

4.3. Data Processing and Calculation

4.3.1. Data Standardization. Indicators involved in this study are all efficient. Thus, original data standardization must only be dimensionless. This study adopts the Min-Max standardization method, and the specific formula is as follows:

$$r_{ik}(j) = \frac{f_{ik}(j) - \min f_{ik}}{\max f_{ik} - \min f_{ik}}. \tag{9}$$

In formula (9), $f_{ik}(j)$ denotes the kth basic-layer indicator value in the ith middle-layer indicator of jth medical university. $\max f_{ik}$ and $\min f_{ik}$ denote all maximum and minimum values of medical universities in the kth basic-layer indicator, respectively.

4.3.2. Identification of Individual Advantage Characteristics in Hierarchical Context. Put the standardly processed data into Models (1) and (2) and then calculate them through formulas (3) and (4). Finally, the individual advantage characteristic structure of the 15 medical universities in indicator layers can be obtained, as shown in Tables 1 and 2.

4.3.3. Individual Agent Evaluation Results of Medical Universities Based on Individual Advantage Characteristics in Hierarchical Context. Input the data of Tables 1 and 2 into formulas (5) and (6), respectively, and individual agent evaluation results of medical universities in indicator layers can be obtained. This study shows only the individual agent evaluation results of the 15 universities in the middle-layer indicator "Talent Cultivation" (Table 3) and the top-layer indicator "Overall Performance of Medical Universities" (Table 4) because of limited space. Interested readers may contact the author for the individual agent evaluation results in the middle-layer indicators "Scientific Research" and "Social Influence."

4.3.4. Democratic Agent Evaluation Results Based on Individual Advantage Characteristics of Medical Universities in Hierarchical Context. Input the data of Tables 1 and 2 into formulas (7) and (8), respectively, and the democratic agent

Table 1: Individual advantage characteristic structure in basic-layer indicators.

Univ.	y_1			y_2			y_3	
	x_{11}	x_{12}	x_{13}	x_{21}	x_{22}	x_{23}	x_{31}	x_{32}
#1	0.1378	0.2087	0.6536	0.0000	0.5000	0.5000	0.5000	0.5000
#2	0.0000	1.0000	0.0000	0.0003	0.9979	0.0018	1.0000	0.0000
#3	0.4789	0.1218	0.3993	0.2292	0.6330	0.1378	1.0000	0.0000
#4	0.1111	0.6818	0.2072	0.3026	0.2936	0.4038	0.2744	0.7256
#5	0.5000	0.0000	0.5000	0.2922	0.3000	0.4078	1.0000	0.0000
#6	0.0000	1.0000	0.0000	0.7941	0.0424	0.1635	0.2237	0.7763
#7	0.3411	0.3779	0.2810	1.0000	0.0000	0.0000	0.1950	0.8050
#8	0.3238	0.2582	0.4180	0.0765	0.7633	0.1601	0.5000	0.5000
#9	0.1656	0.6463	0.1881	0.1192	0.3080	0.5728	0.3236	0.6764
#10	0.1703	0.5873	0.2424	0.3334	0.2591	0.4074	0.0178	0.9822
#11	0.2871	0.2250	0.4879	0.6834	0.0497	0.2669	1.0000	0.0000
#12	0.3087	0.2850	0.4062	0.2727	0.3622	0.3651	0.4861	0.5139
#13	0.2556	0.2373	0.5071	0.1613	0.1301	0.7086	0.3349	0.6651
#14	0.2553	0.4538	0.2909	0.5715	0.1640	0.2645	0.3729	0.6271
#15	0.2368	0.5488	0.2144	0.4580	0.3436	0.1984	0.4443	0.5557

Table 2: Individual advantage characteristic structure in middle-layer indicators.

Univ.	Overall performance z		
	y_1	y_2	y_3
#1	0.0000	0.5000	0.5000
#2	0.5000	0.0000	0.5000
#3	0.0000	0.0000	1.0000
#4	0.7132	0.1761	0.1107
#5	0.5000	0.0000	0.5000
#6	1.0000	0.0000	0.0000
#7	0.0000	1.0000	0.0000
#8	0.2514	0.6492	0.0994
#9	0.4313	0.4475	0.1211
#10	0.1642	0.0754	0.7604
#11	0.0000	0.0000	1.0000
#12	0.5148	0.3154	0.1698
#13	0.2831	0.5164	0.2005
#14	0.2429	0.5908	0.1663
#15	0.3548	0.4741	0.1712

Table 3: Individual agent evaluation results in the middle-layer "Talent Cultivation."

Univ.	Individual agent evaluation according to the perspective of the ith medical university														
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
#1	1	3	1	2	2	3	1	1	2	1	1	1	1	1	1
#2	4	1	5	3	5	1	3	4	3	3	4	3	4	3	3
#3	6	12	4	13	4	12	9	7	13	13	6	8	6	11	12
#4	5	4	7	4	6	4	4	5	4	4	5	5	5	4	4
#5	3	12	2	12	1	12	7	3	12	11	3	4	3	8	11
#6	2	1	3	1	3	1	2	2	1	2	2	2	2	2	2
#7	8	7	6	7	7	7	5	6	7	7	7	6	7	6	7
#8	12	12	12	14	12	12	12	12	14	14	12	12	12	13	14
#9	11	5	11	6	11	5	8	10	6	6	11	10	11	7	6
#10	9	5	9	5	9	5	6	8	5	5	9	7	9	5	5
#11	7	9	8	9	8	9	10	9	9	9	8	9	8	9	8
#12	10	9	10	10	10	9	11	11	10	10	10	11	10	10	10
#13	13	15	13	15	13	15	15	13	15	15	13	13	13	15	15
#14	14	9	15	11	14	9	14	15	11	12	14	15	14	14	13
#15	15	8	14	8	15	8	13	14	8	8	15	14	15	12	9

Table 4: Individual agent evaluation results in the top-layer indicator "Overall Performance of Medical Universities."

Univ.	Individual agent evaluation according to the perspective of the ith medical university														
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
#1	1	2	1	1	2	3	6	1	1	1	1	1	1	4	1
#2	2	1	1	3	4	1	11	2	2	6	1	2	2	9	4
#3	3	4	1	13	3	12	9	5	15	3	1	7	14	11	10
#4	10	7	6	4	7	4	8	8	6	7	6	5	9	8	5
#5	6	4	1	12	1	12	13	13	14	8	1	6	12	13	13
#6	9	6	6	2	6	1	2	11	3	5	6	3	3	2	3
#7	4	10	6	7	8	7	1	3	5	4	6	4	4	1	2
#8	11	14	6	14	12	12	15	4	10	15	6	11	11	14	12
#9	5	8	6	6	11	5	10	6	4	9	6	10	5	10	8
#10	8	8	6	5	9	5	7	10	7	2	6	8	8	6	6
#11	7	3	1	9	5	9	3	14	8	13	1	9	6	3	7
#12	15	12	6	10	10	9	13	12	12	14	6	12	13	15	14
#13	13	15	6	15	13	15	11	15	13	10	6	13	7	12	15
#14	12	12	6	11	14	9	4	9	9	11	6	14	10	5	9
#15	14	11	6	8	15	8	5	7	11	12	6	15	15	7	11

evaluation results of 15 medical universities can be obtained. This study shows only the democratic agency evaluation results of the 15 medical universities in the middle-layer indicator "Talent Cultivation" (Table 5) and the top-layer indicator "Overall Performance of Medical Universities" (Table 6). Interested readers may contact the author for the democratic agency evaluation results of the two middle-layer indicators "Scientific Research" and "Social Influence."

5. Result Analysis

First, from the point of view most favorable to evaluated objects, the individual advantage characteristic structure reflects the good condition of medical universities across different indicators. The greater the weight coefficient, the better the condition in an indicator. In Table 1, the individual advantage characteristic structure of university #9 in terms of talent cultivation in basic-layer indicators is (0.1656, 0.6463, 0.1881), which indicates that its most evident advantage is discipline construction from the point of view most favorable to university #9. Moreover, its individual advantage characteristic structure in terms of scientific research in basic-layer indicators is (0.1192, 0.3080, 0.5728), which indicates that the most evident advantage of university #9 is scientific research project from its most favorable point of view. In terms of social influence in basic-layer indicators, the individual advantage characteristic structure of university #9 is (0.3236, 0.6764), which indicates that its most evident advantage is an international influence from the point of view most favorable to university #9. In terms of the middle-layer indicators in Table 2, the individual advantage characteristic structure of university #9 is (0.4313, 0.4475, 0.1211), which indicates that its most evident advantage is scientific research from the point of view most favorable to university #9.

The above results imply that clarifying the advantages and characteristics of medical universities by determining their individual advantage characteristic structure is possible due to their different growing processes and resource endowments. Moreover, the results are conducive to diversifying the development models of medical universities under various individual advantage characteristic conditions.

Table 5: Comprehensive evaluation value and ranking in the middle-layer indicator "Talent Cultivation."

Ranking	Univ.	Comprehensive evaluation
1	#1	0.0828
2	#6	0.1338
3	#2	0.2062
4	#4	0.2732
5	#10	0.3498
6	#7	0.3693
7	#9	0.3827
8	#5	0.4625
9	#11	0.4753
10	#12	0.5002
11	#3	0.5102
12	#15	0.5597
13	#8	0.5696
14	#14	0.5933
15	#13	0.6432

Table 6: Comprehensive evaluation value and ranking of the top-layer indicator "Overall Performance of Medical Universities."

Ranking	Univ.	Comprehensive evaluation
1	#1	0.1832
2	#2	0.2934
3	#11	0.3807
4	#3	0.4050
5	#6	0.4637
6	#5	0.4648
7	#7	0.4724
8	#10	0.5166
9	#4	0.5211
10	#9	0.5373
11	#14	0.5654
12	#15	0.5731
13	#12	0.6295
14	#8	0.6363
15	#4	0.5211

Second, individual agent evaluation results reflect the actual performance of medical universities. Table 3 shows that Universities 1 and 3 ranked 1st and 12th in the individual agent evaluation result of the middle-layer indicator "Talent Cultivation," respectively. Moreover, Table 4 shows that their rankings are 1st and 4th in the individual agent evaluation result of the top-layer indicator "Overall Performance of Medical Universities." Individual agent is evaluated from the point of view most favorable to evaluated objects. Thus, the evaluation result is more acceptable than the conventional evaluation model, and the university that did not rank first actively seeks benchmarking. In Tables 3 and 4, University 1 ranked first both in "Talent Cultivation" and "Overall Performance of Medical Universities" and becomes a single and overall benchmarking, respectively.

The above results imply that when all participating medical universities are evaluated in accordance with their individual advantage characteristic structure most favorable to them, they cannot assure to be ranked first. Such situation not only highlights the research method objectivity but also provides a basis for medical universities to find a single and overall benchmarking for research.

Third, democratic agent evaluation results reflect the final evaluation finding based on individual advantage characteristics of all evaluated objects. In Table 3, the top five medical universities are #1, #6, #2, #4, and #10 in terms of the democratic agent evaluation results of the middle-layer indicator "Talent Cultivation." Table 4 shows that the top five medical universities are #1, #2, #11, #3, and #6 in terms of the democratic agent evaluation results of the top-layer indicator "Overall Performance of Medical Universities."

The above results imply that the ranking results in the sub- and overall indicators not only indicate the individual advantage characteristics of medical universities but also embody democratic characteristics. Evaluation results must be objective and fair so that a basis for relevant departments is provided to make decisions on resource allocation and policy making.

6. Conclusion and Limitations

6.1. Conclusion. Based on the characteristics of medical universities' education evaluation, this study constructed a comprehensive evaluation method of medical universities' performance from the perspective of individual advantage identification. Using this assessment method, this study conducted an empirical analysis of the performance of 15 medical universities in China. The analysis results show the following: First, this method provides tools for medical universities to identify their own individual advantages from top-layer indicators, middle-layer indicators, and basic-layer indicators, which is conducive to the development of diversified medical universities under different individual advantage characteristic modes. Second, this method seeks single and overall benchmarking for the medical universities from the perspective of individual agent evaluation, which provides a basis for promoting their development. Third, this method evaluates the overall performance of medical universities from the perspective of democratic agent evaluation, which provides a decision-making basis for the management department to formulate resource allocation policies.

6.2. Limitations. This study still has two main limitations. On one hand, the indicator system of this study is constructed on the basis of the medical universities' common value cognition. This value cognition may change with the development of the times. Therefore, in the future, when evaluating the performance of medical universities, it is necessary to reconstruct the evaluation indicator system based on the changes in the situation. On the other, this study examined only the data of 15 Chinese medical universities, which verifies the scientificity and rationality of the proposed method. In the future, we can consider empirical research on cross-country comparison based on the expansion of sample size.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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References

[1] N. B. Tuma and A. J. Grimes, "A comparison of models of role orientations of professionals in a research-oriented university," *Administrative Science Quarterly*, vol. 26, no. 2, pp. 187–206, 1981.

[2] K. Mohrman, W. Ma, and D. Baker, "The research university in transition: the emerging global model," *Higher Education Policy*, vol. 21, no. 1, pp. 5–27, 2008.

[3] M. Hladchenko, H. F. de Boer, and D. F. Westerheijden, "Establishing research universities in Ukrainian higher education: the incomplete journey of a structural reform," *Journal of Higher Education Policy and Management*, vol. 38, no. 2, pp. 111–125, 2016.

[4] R. Hollingsworth, "Higher education: the making of US academia," *Nature*, vol. 541, no. 7638, pp. 461-462, 2017.

[5] R. S. Gold and C. E. Basch, "Research and evaluation: an overview," *Health Education*, vol. 17, no. 5, pp. 29–52, 1986.

[6] H. L. Miller, "An overview of the evaluation," *International Journal of Educational Research*, vol. 27, no. 2, pp. 93–97, 1997.

[7] J. A. Fain, "Is there a difference between evaluation and research?," *The Diabetes Educator*, vol. 31, no. 2, pp. 150–155, 2005.

[8] H. A. Ferris and M. E. Collins, "Research and evaluation in medical education," *International Journal of Higher Education*, vol. 4, no. 3, pp. 104–111, 2015.

[9] V. Curran, J. Christopher, F. Lemire, A. Collins, and B. Barrett, "Application of a responsive evaluation approach in medical education," *Medical Education*, vol. 37, no. 3, pp. 256–266, 2003.

[10] V. L. Patel, N. A. Yoskowitz, and J. F. Arocha, "Towards effective evaluation and reform in medical education: a cognitive and learning sciences perspective," *Advances in Health Sciences Education*, vol. 14, no. 5, pp. 791–812, 2009.

[11] M. Tavakol, L. D. Gruppen, and S. Torabi, "Using evaluation research to improve medical education," *The Clinical Teacher*, vol. 7, no. 3, pp. 192–196, 2010.

[12] M. Tavakol and R. Dennick, "The foundations of measurement and assessment in medical education," *Medical Teacher*, vol. 39, no. 10, pp. 1010–1015, 2017.

[13] S. K. Dotters-Katz, "Medical education: how are we doing?," *Medical Education*, vol. 52, no. 1, pp. 5–7, 2018.

[14] M. B. Abrahams and C. P. Friedman, "Preclinical course-evaluation methods at U.S. and Canadian medical schools," *Academic Medicine*, vol. 71, no. 4, pp. 371–374, 1996.

[15] M. Das, J. H. Lanphear, and R. Ja'afar, "Faculty evaluation of educational strategies in medical schools," *Medical Teacher*, vol. 16, no. 4, pp. 355–361, 1994.

[16] S. Leinster, "Evaluation and assessment of social accountability in medical schools," *Medical Teacher*, vol. 33, no. 8, pp. 673–676, 2011.

[17] V. Ruhe and J. D. Boudreau, "The 2011 Program Evaluation Standards: a framework for quality in medical education programme evaluations," *Journal of Evaluation in Clinical Practice*, vol. 19, 2012.

[18] S. Tackett, J. Grant, and K. Mmari, "Designing an evaluation framework for WFME basic standards for medical education," *Medical Teacher*, vol. 38, pp. 291–296, 2016.

[19] J. Kiger, "Evaluating evaluations: an ouroboros for medical education," *Medical Education*, vol. 51, no. 2, pp. 131–133, 2017.

[20] S. Brown, "School effectiveness research and the evaluation of schools," *Evaluation & Research in Education*, vol. 8, no. 1-2, pp. 55–68, 1994.

[21] J. R. Sanders and E. J. Davidson, "A model for school evaluation," in *International Handbook of Educational Evaluation*, pp. 807–826, Springer, Dordrecht, Netherlands, 2003.

[22] J. P. Keeves, N. Hungi, and T. Afrassa, "Measuring value added effects across schools: should schools be compared in performance?," *Studies in Educational Evaluation*, vol. 31, no. 2-3, pp. 247–266, 2005.

[23] T. Ahn, A. Charnes, and W. W. Cooper, "Some statistical and DEA evaluations of relative efficiencies of public and private institutions of higher learning," *Socio-Economic Planning Sciences*, vol. 22, no. 6, pp. 259–269, 1988.

[24] T. M. Breu and R. L. Raab, "Efficiency and perceived quality of the nation's "top 25" National Universities and National Liberal Arts Colleges: an application of data envelopment analysis to higher education," *Socio-Economic Planning Sciences*, vol. 28, no. 1, pp. 33–45, 1994.

[25] J. Johnes, "Efficiency and productivity change in the english higher education sector from 1996/97 to 2004/5," *Manchester School*, vol. 76, no. 6, pp. 653–674, 2008.

[26] W. Qi, X. J. Chen, Y. Zhang, T. Yan, and F. Li, "Research on the academic performance evaluation method of Chinese research universities based on TOPSIS," *China Higher Education Research*, vol. 1, pp. 15–19, 2010.

[27] L. Ding and Y. Zeng, "Evaluation of Chinese higher education by TOPSIS and IEW—the case of 68 universities belonging to the Ministry of Education in China," *China Economic Review*, vol. 36, pp. 341–358, 2015.

[28] C. G. Chen, M. C. Zeng, D. M. Wen, L. X. Weng, and Z. Yu, "The survey and evaluation indicators for internationalization of research-oriented universities in China," *Peking University Education Review*, vol. 7, pp. 116–135, 2009.

[29] J. F. Mo, "Talents cultivation modes in Chinese research universities: conceptual model and basic features," *China Higher Education Research*, vol. 9, pp. 69–76, 2016.

[30] M.-H. Huang, H.-W. Chang, and D.-Z. Chen, "Research evaluation of research-oriented universities in Taiwan from 1993 to 2003," *Scientometrics*, vol. 67, no. 3, pp. 419–435, 2006.

[31] J. Hyvärinen, "Evaluation of Tekes funding for research institutes and universities—the role of talent," *Research Evaluation*, vol. 18, no. 5, pp. 365–373, 2009.

[32] F. Li, Y. Yi, X. Guo, and W. Qi, "Performance evaluation of research universities in Mainland China, Hong Kong and Taiwan: based on a two-dimensional approach," *Scientometrics*, vol. 90, no. 2, pp. 531–542, 2012.

[33] F. Zong and L. Wang, "Evaluation of university scientific research ability based on the output of sci-tech papers: a D-AHP approach," *PLoS One*, vol. 12, no. 2, p. e0171437, 2017.

[34] J. Johnston and A. Reeves, "Assessing research performance in UK universities using the case of the economics and econometrics unit of assessment in the 1992–2014 research evaluation exercises," *Research Evaluation*, vol. 26, no. 1, pp. 28–40, 2017.

[35] M. Stec and M. Grzebyk, "The implementation of the strategy Europe 2020 objectives in European Union countries: the concept analysis and statistical evaluation," *Quality & Quantity*, vol. 52, no. 1, pp. 119–133, 2018.

[36] J. Nazarko and J. Šaparauskas, "Application of DEA method in efficiency evaluation of public higher education institutions," *Technological and Economic Development of Economy*, vol. 20, no. 1, pp. 25–44, 2014.

[37] A. Flokou, V. Aletras, and D. Niakas, "A window-DEA based efficiency evaluation of the public hospital sector in Greece during the 5-year economic crisis," *PLoS One*, vol. 12, no. 5, Article ID e0177946, 2017.

[38] T. Kvålseth, "Entropy evaluation based on value validity," *Entropy*, vol. 16, no. 9, pp. 4855–4873, 2014.

[39] C. L. Hwang and K. Yoon, *Multiple Attribute Decision Making: Methods and Applications*, Springer-Verlag, New York, NY, USA, 1st edition, 1981.

[40] X. N. Zhao, C. H. Zhu, Y. M. Wang, and J. F. Jia, *Methodology and Application of Jingyou Evaluation*, Science Press, Beijing, China, 1st edition, 2012.

[41] S. K. Jacobi and B. F. Hobbs, "Quantifying and mitigating the splitting bias and other value tree-induced weighting biases," *Decision Analysis*, vol. 4, no. 4, pp. 194–210, 2007.

[42] A. Roy, P. Mackin, J. Wallenius et al., "An interactive search method based on user preferences," *Decision Analysis*, vol. 5, no. 4, pp. 203–229, 2008.

[43] W. W. Cooper, J. L. Ruiz, and I. Sirvent, "Selecting non-zero weights to evaluate effectiveness of basketball players with DEA," *European Journal of Operational Research*, vol. 195, no. 2, pp. 563–574, 2009.

[44] X. N. Zhao, B. D. Liu, and H. M. Xu, "A study on the impact of the thought of conforming to the natural rule on the progress of human society," *Science, Technology and Dialectics*, vol. 23, no. 2, pp. 32–35, 2006.

[45] Z. Zhu and Y. L. Zhu, "Modeling supplier selection and the use of individual advantage characteristics for high-quality supply Chain design," in *Proceedings of the International Conference on Industrial Engineering & Engineering Management*, Beijing, China, October 2009.

[46] S. Liu and X. N. Zhao, "Identification and evaluation method of individual advantage characteristics for hybrid information," *Operations Research and Management Science*, vol. 27, pp. 123–135, 2018.

[47] J. F. Jia, X. N. Zhao, and S. M. Sun, "An evaluation method of organizational performance based on the comparative advantage and empirical research," *Scientific Research and Management*, vol. 32, pp. 151–159, 2011.

[48] X. N. Zhao and J. F. Jia, "The performance evaluation method and empirical research on construction of research-oriented universities of China: based on the view of comparative advantage characteristics," *R&D Management*, vol. 19, pp. 108–115, 2007.

[49] R. E. Bedggood and J. D. Donovan, "University performance evaluations: what are we really measuring?," *Studies in Higher Education*, vol. 37, no. 7, pp. 825–842, 2012.

[50] D. D. Dill, "The regulation of academic quality: an assessment of uuniversity evaluation systems with emphasis on the United States. University Evaluation for the Future," in *International Trends in Higher Education Reform*, pp. 27–37, National Institute for Educational Policy Research in Japan (NIER), Tokyo, Japan, 2003.

[51] N. Sombatsompop, T. Markpin, P. Ratchatahirun, W. Yochai, C. Wongkaew, and N. Premkamolnetr, "Research performance evaluations of Thailand national research universities during 2007–2009," *Information Development*, vol. 26, no. 4, pp. 303–313, 2010.

[52] D. B. Smith and C. C. Gadbury-Amyot, "Process evaluation of a teaching and learning centre at a research university," *Assessment & Evaluation in Higher Education*, vol. 39, no. 4, pp. 427–442, 2014.

[53] X. Wu and D. Jia, "Scientific and ethical reflections on academic corruption in universities: on the science research evaluation system in China's Universities," *Chinese Education & Society*, vol. 40, no. 6, pp. 67–76, 2007.

[54] R. J. Passonneau and A. Nenkova, "Evaluating content selection in human-or machine-generated summaries: the pyramid scoring method," Report No. CUCS-025-03, Columbia University, New York City, NY, USA, 2003.

[55] R. L. Jones and R. E. Carter Jr., "Some procedures for estimating "news hole" in content analysis," *Public Opinion Quarterly*, vol. 23, no. 3, pp. 399–403, 1959.

[56] D. Riffe, C. F. Aust, T. C. Jones, B. Shoemake, and S. Sundar, "The shrinking foreign newshole of the New York Times," *Newspaper Research Journal*, vol. 15, no. 3, pp. 74–88, 1994.

[57] I. R. McDonald and R. G. Lawrence, "Filling the 24×7 news hole: television news coverage following september 11," *American Behavioral Scientist*, vol. 48, no. 3, pp. 327–340, 2004.