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Modelling of Evaluation in the Social Contribution of Higher Education Based on K-K-T Optimization

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Abstract

Evaluation method based on Karush–Kuhn–Tucker (K-K-T) optimization for social contribution of higher education is presented in this paper. By considering both direct and indirect contribution, a comprehensive evaluation model including social contribution to economy, science, technology and society is investigated. Evaluation metrics of the model are designed according to the contribution value and the contribution balance degree. The optimal solution to the model-driven objective function is obtained based on K-K-T optimization. The proposed model can be used as a quantitative evaluation scheme for the social contribution of higher education, and the associated results can be utilized as a reference for optimizing the resources and improving the social contribution of higher education.

Key words: K-K-T optimization; Higher education; Social contribution; Evaluation method

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INTRODUCTION

The 21st century is the era of knowledge economy. In such a context, competitions among countries initially rely on the competition of talents and education, especially higher education. As an important part in knowledge industry, higher education plays a critical role in economy through transmitting and creating knowledge, developing science and technology, and cultivating excellent talents. The impact of higher education on economic growth, scientific and technological progress, and social development has received more and more attention. In addition, the associated research on higher education and its development has become one of the hot topics in the fields of education, economy, and social sciences.

In general, basic functionalities of higher education include education, scientific research, and social service, which can be interpreted as transmitting knowledge, creating knowledge, and leveraging knowledge. On one hand, the ultimate goal of creating and transmitting knowledge is to take advantage of knowledge. On the other hand, the ultimate goal of education and scientific research is to provide services to society and to contribute the society. Since its birth, higher education has made great contributions to the social development. Meanwhile, the contribution to the society reflects the value and meanings of higher education.

China takes *rejuvenation of the nation through development of science, education and talents* as the basic national policy. Thus, education is the basic approach to achieving this goal. As the highest level of education, higher education is playing an irreplaceable role in economic development, cultural construction, and social construction. Since the implementation of reform and opening up, China has constantly increased investment in higher education and promoted the reform of higher education, significantly improving the scale, level, and coverage of education.

With the further social reform enforced by the government, the future development and policy of higher education have important impacts on higher education itself and even the social construction. The research on how and how much higher education contributes the society can be used to scientifically evaluate the social

contribution of higher education from diverse aspects and to optimize the limited higher educational resources. The mentioned research is promising to promote the higher education development. In addition, it can help enhance the capability of higher education in contributing the society and make the policy planning more focused.

Aiming to achieve this goal, based on the research with regard to social contribution of higher education, a scientific and reasonable evaluation model is proposed in this paper. It can be utilized as a comprehensive evaluation model for social contribution of higher education. To objectively investigate social contribution of higher education, we present a method to maximize the social contribution of higher education and propose a reference for the optimization of limited higher education resources.

1. RELATED WORK

1.1 Social Contribution of Higher Education

Higher education can contribute the society in diverse perspectives. Basically, the contribution can be respectively divided into economic development contribution, science and technology development contribution, and social development contribution (Zhao, 2003).

Specifically, the contribution to economic development is mainly reflected through the promotion and improvement in economic growth, industrial structural adjustment, the quality and efficiency of human resources. The contribution to science and technology development is mainly reflected by the contribution to major scientific research projects, patents, and academic articles and monographs. The contribution to social development is mainly reflected by the improvement in national quality, employment rate, and crime rate.

Most existing researches only focus on the contribution of higher education to economy. Plato, Karl Marx and lots of western scholars suggested that education can promote economic growth in varying degrees (Cai, 2003). Since Robert M·Solow (Solow, 1956), there has been some classic researches on the contribution of education to economic development, such as the research based on Human Capital Management (Barro, 1997, 1998), the research based on Information Economics (Spilerman, 1977; Yang, 2002), the research based on New Growth Theory (D. Romer, 1996; P. M. Romer, 1990) and so on. With the rapid development of China's economy development and the increase in investment on higher education, Chinese scholars have been taking the qualitative researches on contribution of higher education to economy (Li, 2002; Liu & Sun, 2005; Ye, 2005). Current researches have proved that higher education should promote economic growth, while ignoring its comprehensive impact on industrial structure, economic growth efficiency and so on.

Although it has been learnt for a long time that higher education plays an important role in science and technology development, the research on contribution of higher education to science and technology just begins its horizon (Liu, 2012). Scholars suggest some specific policies by investigating contribution of higher education to technological innovation (Zhang, 2003; Zhang & Lai, 2009; Gao, Kang & Du, 2010). The authors in (Sun, 2010) discussed how higher education effects technological innovation. The authors in (Varsakelis, 2006) analyzed the data from 29 countries and proved the positive relationship between investment in higher education and the increase in technological innovation. With the rapid development of knowledge economy and the increasingly prominent role of science and technology in national competitions, research on the contribution of higher education to science and technology has been widely and deeply performed. In addition, the authors in conducted the research on contribution of higher education to social stability. Since the research on contribution of higher education to social development just begun, there is little attention to comprehensive research on social contribution of higher education.

1.2 Evaluation Methods of Contribution of Higher Education to the Society

In the field of evaluation methods, current researches on the evaluation of the comprehensive and overall social contribution of higher education basically focus on the evaluation of contribution of higher education to economics. The evaluation methods of contribution of higher education to economic growth are mature, in which the evaluation metrics include contribution rates of the enhancement in national income, the increasing speed of gross domestic product, the productivity and so on (Cui, 1999). Common used methods in these researches include Cobb-Douglas production function, T. W. Shultz's method of estimating the rate of return on investment, Granger Causality Tests and empirical studies based on economic theory. According to current research, the most important issue for establishing the evaluation models of contribution of higher education to economics is to choose the reasonable evaluation criteria and evaluation parameters.

Until now, there is little research on contribution of higher education to society in terms of economics, science and technology, and culture. Some scholars realized that it is inefficient to evaluate contribution of higher education only by economic growth. Therefore, they began to study contribution of higher education to economic development. With the further development of higher education and society, the interactions between them become more and more significant. Scientific design of evaluation parameters in social contribution and synthetic evaluation of

social contribution of higher education is an important direction towards the research on contribution of higher education to the society.

2. DESIGN OF EVALUATION MODEL FOR SOCIAL CONTRIBUTION OF HIGHER EDUCATION

2.1 The Constitution of the Social Contribution of Higher Education

Since the development of higher education has different degrees of effect on economy, science and social development, the research on the social contribution of higher education should synthesize the aspects of these contributions as many as possible. Meanwhile, consider the interaction between constraints and promotion among economic development, science and technology development, and social development, it can be concluded that one aspect will impact on the other aspects in at least one way. When higher education contributes to one aspect directly, the development of this aspect will contribute to others accordingly. To be specific, the higher education makes both direct and indirect contributions to economy development, science and technology development, and social development. Therefore, in our proposed evaluation model of contribution of higher education to society, both direct and indirect contributions are considered. The block diagram of the social contribution of higher education is shown in Figure 1.

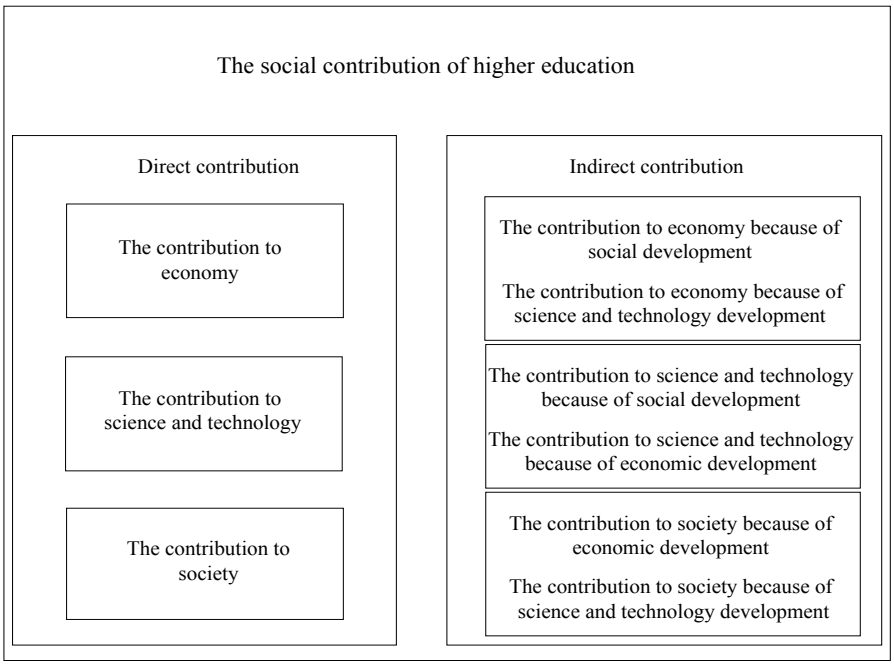

Figure 1
Block Diagram of the Social Contribution of Higher Education

2.2 The Evaluation Objects of the Social Contribution of Higher Education

In this paper, the social contribution of higher education is divided into three parts: contribution to economic development, contribution to science and technology development, and contribution to social development, respectively. We take social contribution rate of higher education and social contribution balance of higher education as the final objectives to evaluate the metric of contribution of higher education to society.

The contribution rate refers to the ratio of the increment of a certain elements to the increments of all elements. The social contribution rate of higher education is the ratio of the increment of invest, scale and quality of higher education to the increment of social development.

The contribution balance refers to the difference of the contribution rates from every single aspect. The social contribution balance of higher education is the difference of contribution of higher educations to economic development, science and technology development, and social development.

The evaluation objectives designed in this paper can evaluate the degree of contribution of higher education to society, unveil the difference of contribution to every aspect and provide reference for making policies.

2.3 Evaluation Model

According to the block diagram of the contribution of higher education to society and the evaluation objectives described above, an evaluation model of contribution of higher education to society is proposed, as shown in Figure 2.

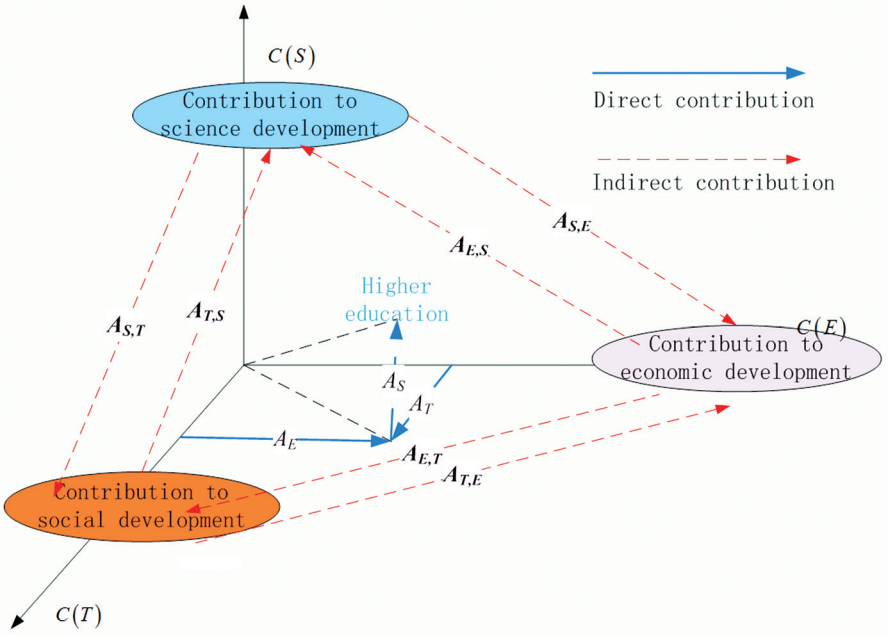

Figure 2

Figure 2
Evaluation Model Framework of the Social Contribution of Higher Education

In Figure 2, C(E) axis refers to contribution of higher education to economic development. C(T) axis refers to contribution of higher education to science and technology development. C(S) axis refers to contribution of higher education to social development. Each aspect can be divided into direct contributions and indirect contributions. The direct contributions and the indirect contributions of these three axes determine contribution of higher educations to society together.

The society contribution rate of higher education can be described as

$$C_{\text{total}} = W_E \cdot C_{\text{total}}(E) + W_T \cdot C_{\text{total}}(T) + W_S \cdot C_{\text{total}}(S) \quad (1)$$

In (1), $C_{\text{total}}(E)$, $C_{\text{total}}(T)$, and $C_{\text{total}}(S)$ refer to contribution of higher education to economic development, science and technology development, and social development respectively (including direct and indirect contributions).

$$\begin{aligned} C_{\text{total}}(E) &= A_E + A_T A_{T,E} + A_S A_{S,E} \\ C_{\text{total}}(T) &= A_T + A_E A_{E,T} + A_S A_{S,T} \\ C_{\text{total}}(S) &= A_S + A_E A_{E,S} + A_T A_{T,S} \end{aligned} \quad (2)$$

W_E, W_T, W_S are the weights of contribution of higher education to economic development, science and technology development, and social development in the comprehensive contribution, respectively. A_E, A_T, A_S represent the direct contributions of higher education to each aspect, and $A_T A_{T,E}$ mean the indirect contribution of higher education to economic development through contribution to science and technology, $A_S A_{S,E}$ are indirect contribution of higher education to social development through contribution to economics, respectively.

Social contribution balance of higher education can be defined as

$$\Phi_{\text{total}} = \frac{\left(\sum_{s\in(E,T,S)} C_{\text{total}}(s)\right)^2}{3\times\sum_{s\in(E,T,S)} C_{\text{total}}{}^2(s)} \quad (3)$$

When contribution of higher educations to economy are imposed, the contribution in science and technology and in society are equal, we thus can get the maximum balance, i.e., $\Phi_{\text{total}}=1$.

2.4 The Optimization of Higher Education Resource

In the context with a constant external environment, such as policies, the contribution of higher education mainly depends on the investment, which includes capital cost and talent cost. Because all these resources are limited, hence how to make the best use of these limited resources in order to enhance social contribution of higher education and balance all aspects of contribution is an interesting issue in the higher education research.

In this paper, the cost of capital is denoted as α and the talent cost is expressed as β. α and β only effect the direct contribution of higher education. Then, A_E, A_T, A_S are functions with respect to α and β, i.e., $A_E(\alpha_E,\beta_E)$, $A_T(\alpha_T,\beta_T)$ and $A_S(\alpha_S,\beta_S)$. They are continuous and differentiable.

The emphasis of this paper is to establish the evaluation model and propose the solution method. Due to space limitations, the specific value of the parameters, such as the weights of each index in the model, and the expression of contribution of higher education in each aspect are not discussed in this paper. Therefore, in order to perform the optimization of higher education resource, we assume that W_E, W_T, W_S and interactions among economic development, science and technology development, and social development are constants,

and all of them are independent of the investment in education resource. The objective function of investment in education resource and the social contribution of higher education can be formulated as:

$$\begin{aligned} &\max C_{\text{total}} \\ \text{s.t.}\quad &\sum_{s\in(E,T,S)} \alpha_s \le \alpha \\ &\sum_{s\in(E,T,S)} \beta_s \le \beta \\ &\Phi_{\text{total}} = 1 \end{aligned} \tag{4}$$

where α_E and β_E denote the investment in education for economic development, such as students cultivation and external social training. α_T and β_T refer to the investment in education for science and technology development, such as research funding. α_S and β_S represent the investment of education for social development, such as the investment on employment guidance). The above objective function is to maximize the social contribution of higher education with the limited resource and balance of the contribution in all aspects.

To solve this optimization function, we can get a Lagrange function:

$$\begin{aligned} L(\alpha,\beta,\lambda) = C_{\text{total}} &- \lambda_1\left(\sum\nolimits_{s\in(E,T,S)}\alpha_s - \alpha\right) \\ &- \lambda_2\left(\sum\nolimits_{s\in(E,T,S)}\beta_s - \beta\right) + \lambda_3\left(\Phi_{\text{total}} - 1\right) \end{aligned} \tag{5}$$

The K-K-T (Karush-Kuhn-Tucker) conditions can be describe as

$$\begin{cases} \nabla_\alpha L(\alpha,\beta,\lambda) = 0 \\ \nabla_\beta L(\alpha,\beta,\lambda) = 0 \\ \lambda_1\left(\sum\nolimits_{s\in(E,T,S)}\alpha_s - \alpha\right) = 0 \\ \lambda_2\left(\sum\nolimits_{s\in(E,T,S)}\beta_s - \beta\right) = 0 \\ \left(\Phi_{\text{total}} - 1\right) = 0 \end{cases} \tag{6}$$

Taking the derivative with respect to the resource investment, i.e.,

$$\begin{aligned} &\frac{\partial L}{\partial \alpha_S} = W_E\frac{\partial C_{total}(E)}{\partial \alpha_s} + W_T\frac{\partial C_{total}(T)}{\partial \alpha_s} + W_S\frac{\partial C_{total}(S)}{\partial \alpha_S} - \lambda_1 + \lambda_3\frac{\Phi_{total}}{\partial \alpha_S} = 0 \\ &\frac{\partial L}{\partial \beta_S} = W_E\frac{\partial C_{total}(E)}{\partial \beta_S} + W_T\frac{\partial C_{total}(T)}{\partial \beta_S} + W_S\frac{\partial C_{total}(S)}{\partial \beta_S} - \lambda_2 + \lambda_3\frac{\Phi_{total}}{\partial \beta_S} = 0 \\ &\frac{\partial L}{\partial \alpha_E} = W_E\frac{\partial C_{total}(E)}{\partial \alpha_E} + W_T\frac{\partial C_{total}(T)}{\partial \alpha_E} + W_S\frac{\partial C_{total}(S)}{\partial \alpha_E} - \lambda_1 + \lambda_3\frac{\Phi_{total}}{\partial \alpha_E} = 0 \\ &\frac{\partial L}{\partial \beta_E} = W_E\frac{\partial C_{total}(E)}{\partial \beta_E} + W_T\frac{\partial C_{total}(T)}{\partial \beta_E} + W_S\frac{\partial C_{total}(S)}{\partial \beta_E} - \lambda_2 + \lambda_3\frac{\Phi_{total}}{\partial \beta_E} = 0 \\ &\frac{\partial L}{\partial \alpha_T} = W_E\frac{\partial C_{total}(E)}{\partial \alpha_T} + W_T\frac{\partial C_{total}(T)}{\partial \alpha_T} + W_S\frac{\partial C_{total}(S)}{\partial \alpha_T} - \lambda_1 + \lambda_3\frac{\Phi_{total}}{\partial \alpha_T} = 0 \\ &\frac{\partial L}{\partial \alpha_S} = W_E\frac{\partial C_{total}(E)}{\partial \beta_T} + W_T\frac{\partial C_{total}(T)}{\partial \beta_T} + W_S\frac{\partial C_{total}(S)}{\partial \beta_T} - \lambda_2 + \lambda_3\frac{\Phi_{total}}{\partial \beta_T} = 0 \end{aligned} \tag{7}$$

Upon the condition that:

$$\begin{aligned} &\frac{\partial C_{total}(E)}{\partial \alpha_s} = A_{S,E}\frac{\partial A_S}{\partial \alpha_S}, \frac{\partial C_{total}(T)}{\partial \alpha_s} = A_{S,T}\frac{\partial A_S}{\partial \alpha_S}, \frac{\partial C_{total}(S)}{\partial \alpha_S} = \frac{\partial A_S}{\partial \alpha_S} \\ &\frac{\partial C_{total}(E)}{\partial \beta_S} = A_{S,E}\frac{\partial A_S}{\partial \beta_S}, \frac{\partial C_{total}(T)}{\partial \beta_S} = A_{S,T}\frac{\partial A_S}{\partial \beta_S}, \frac{\partial C_{total}(S)}{\partial \beta_S} = \frac{\partial A_S}{\partial \beta_S} \\ &\frac{\partial C_{total}(E)}{\partial \alpha_E} = \frac{\partial A_E}{\partial \alpha_E}, \frac{\partial C_{total}(T)}{\partial \alpha_E} = A_{E,T}\frac{\partial A_E}{\partial \alpha_E}, \frac{\partial C_{total}(S)}{\partial \alpha_E} = A_{E,S}\frac{\partial A_E}{\partial \alpha_E} \\ &\frac{\partial C_{total}(E)}{\partial \beta_E} = \frac{\partial A_E}{\partial \beta_E}, \frac{\partial C_{total}(T)}{\partial \beta_E} = A_{E,T}\frac{\partial A_E}{\partial \beta_E}, \frac{\partial C_{total}(S)}{\partial \beta_E} = A_{E,S}\frac{\partial A_E}{\partial \beta_E} \\ &\frac{\partial C_{total}(E)}{\partial \alpha_T} = A_{T,E}\frac{A_T}{\partial \alpha_T}, \frac{\partial C_{total}(T)}{\partial \alpha_T} = \frac{A_T}{\partial \alpha_T}, \frac{\partial C_{total}(S)}{\partial \alpha_T} = A_{T,S}\frac{A_T}{\partial \alpha_T} \\ &\frac{\partial C_{total}(E)}{\partial \beta_T} = A_{T,E}\frac{A_T}{\partial \beta_T}, \frac{\partial C_{total}(T)}{\partial \beta_T} = \frac{A_T}{\partial \beta_T}, \frac{\partial C_{total}(S)}{\partial \beta_T} = A_{T,S}\frac{A_T}{\partial \beta_T} \end{aligned} \tag{8}$$

Then we have

$$\frac{\partial L}{\partial \alpha_S} = [W_E A_{S,E} + W_T A_{S,T} + W_S + \lambda_3 \frac{\partial \Phi_{total}}{\partial A_S}] \frac{\partial A_S}{\partial \alpha_S} - \lambda_1 = 0$$
$$\frac{\partial L}{\partial \beta_S} = [W_E A_{S,E} + W_T A_{S,T} + W_S + \lambda_3 \frac{\partial \Phi_{total}}{\partial A_S}] \frac{\partial A_S}{\partial \beta_S} - \lambda_2 = 0$$
$$\frac{\partial L}{\partial \alpha_E} = [W_S A_{E,S} + W_T A_{E,T} + W_E + \lambda_3 \frac{\partial \Phi_{total}}{\partial A_E}] \frac{\partial A_E}{\partial \alpha_E} - \lambda_1 = 0$$
$$\frac{\partial L}{\partial \beta_E} = [W_S A_{E,S} + W_T A_{E,T} + W_E + \lambda_3 \frac{\partial \Phi_{total}}{\partial A_E}] \frac{\partial A_E}{\partial \beta_E} - \lambda_2 = 0$$
$$\frac{\partial L}{\partial \alpha_T} = [W_S A_{T,S} + W_E A_{T,S} + W_T + \lambda_3 \frac{\partial \Phi_{total}}{\partial A_T}] \frac{\partial A_T}{\partial \alpha_T} - \lambda_1 = 0$$
$$\frac{\partial L}{\partial \beta_T} = [W_S A_{T,S} + W_E A_{T,S} + W_T + \lambda_3 \frac{\partial \Phi_{total}}{\partial A_T}] \frac{\partial A_T}{\partial \beta_T} - \lambda_2 = 0 \quad (9)$$

Since $\Phi_{total} - 1 = 0, \lambda_3 \frac{\partial \Phi_{total}}{\partial \alpha} = 0$, and the interaction among economic development, science and technology development and social development are constants, we thus can set

$W_E A_{S,E} + W_T A_{S,T} + W_S = C_1$, $W_S A_{E,S} + W_T A_{E,T} + W_E = C_2$, $W_S A_{T,S} + W_E A_{T,E} + W_T = C_3$.

Therefore,

$$\lambda_1 = C_1 \frac{\partial A_S}{\partial \alpha_S} = C_2 \frac{\partial A_E}{\partial \alpha_E} = C_3 \frac{\partial A_T}{\partial \alpha_T} \quad (10)$$

$$\lambda_2 = C_1 \frac{\partial A_S}{\partial \beta_S} = C_2 \frac{\partial A_E}{\partial \beta_E} = C_3 \frac{\partial A_T}{\partial \beta_T} \quad (11)$$

Since $\alpha_S + \alpha_E + \alpha_T = \alpha$ and $\beta_S + \beta_E + \beta_T = \beta$, if A_S, A_E and A_T are all given, according to (9), (10) and (11), we can get the optimal solution to α_S, α_E, α_T and β_S, β_E, β_T, i.e., showing that the optimal solution of how to allocate the limited education resource is achieved.

The evaluation model proposed in this paper is flexible and compatible. The model and the objective are not affected by specific A_S, A_E and A_T. It can be combined with current research on contribution of higher educations to economy, science and technology and society to make the comprehensive evaluation of higher education. Except that, the utilization of the restricted education can be optimized according to actual higher education resource such as cost of capital and talent cost.

CONCLUSIONS

As higher education contributes to society in diverse perspectives, evaluating the contribution of higher education to society should take multiple aspects into account. In this paper, starting from contribution of higher educations to economic development, science and technology development and social development, by considering both direct and indirect contribution, the evaluation model of contribution of higher education to society is established and analyzed. With contribution of higher education to society and balance of contributions to economy, science and technology, and society as evaluation objectives, the proposed evaluation model can be used as a quantitative evaluation scheme for the social contribution of higher education, and the associated optimal results obtained by K-K-T optimization can be utilized as a reference for optimizing the resources and improving the social contribution of higher education.

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