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Comprehensive Social Contribution Oriented Resources Optimization Model for Higher Education

ZHANG Xilin[a],*; LI Shiming[a]

[a] University of Electronic Science and Technology of China, Chengdu, Sichuan, 611731, China.
*Corresponding author.

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Abstract

In light of the shortage of the higher education resource, the optimal allocation of higher education resources is investigated in this paper. The optimization model of higher education resources is designed based on the comprehensive contribution of higher education in such aspects as economy, science and technology, and society. The solution of the model can be achieved by our proposed resources allocation algorithm based on particle swarm. By optimizing the allocation of higher education resources, the capability of social contribution of higher education is improved, and a reference scheme is provided to make efficient and reasonable use of limited resources of higher education.

Key words: Higher education; Social contribution; Resources allocation; Particle swarm

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INTRODUCTION

Reinvigorating the country through science and technology is the basic national policy of China, and adhering to education is the important foundation of the basic nation policy. As the highest level in education levels, higher education has made great contribution to the national economic construction, cultural construction and social development since birth. Especially in the current era of knowledge economy, higher education has become an important knowledge industry and an important means to enhance the comprehensive national strength, to transfer and create knowledge, develop science and technology, the task of training advanced talents. The quality and level of higher education has an important influence on a country's overall national quality, level of economic development, science and technology innovation ability, social and cultural development. As a result, the researches on higher education and its development direction are attracting more and more attention, and become one of hotspots in the field of education, economy, and social sciences.

Through long-term development and evolution, higher education has formed the basic functions including education, research and social service (Pan, 1995; Weng, 2001). Higher education inherits, create and use of knowledge by performing basic functions, and serves the society by its outputs, contributing to the progress of all aspects of the development of society. Therefore, contribution to society is the ultimate sign of the value and significance of higher education also is the ultimate standard of higher education quality and level, which is the aim for countries over the world of actively engaging and developing higher education.

The level, scale and output of higher education are all depending on higher education resources. Since the reform and open, China continually increases investment in higher education and promotes higher education reform to improve the scale, level and coverage of higher education greatly. But the higher education resources are still in short supply compared with world first-class country. In education spending, for example, in 2012 financial expenditures on education of the country is 4% of GDP, which just reaches the baseline of the world. And the average of the value in the world is around 7%. It is about 9% in developed countries. Under the current national conditions, increasing educational resources by a

large margin is not reality, so the problem of the shortage of higher education resources is difficult to be solved in a short time. Therefore, we must focus on efficient utilization and resources allocation optimization to make full use of the limited higher education resources and make higher education can play a more important role in economic, technological and social development and can make a greater contribution to the society.

In this paper, we study for enhancing the ability of social contribution of higher education and focus on higher education resources allocation optimization. Through thoroughly research on social contribution of higher education, we design a comprehensive optimization model of social contribution of higher education resources and solve the optimal problem based on particle swarm. According to that we try to explore how to maximize the social contribution of higher education under the condition of limited resources and provide a reference for the optimal utilization of higher education resources.

1. RESOURCES ALLOCATION AND SOCIAL CONTRIBUTION OF HIGHER EDUCATION

1.1 Resources Allocation of Higher Education

Higher education makes a contribution for the social development by the education achievements and the education achievements relies on the investment of higher education resources. Generally, the higher education resources include human resources, material resources, financial resources, etc. Human resources reflect the abilities of higher education institutes in terms of student culture, science and technology innovation and society service, including teaching personnel, scientific research personnel. Material resources generally refers to the materialized form of higher education investment, including all kinds fixed assets like teaching site, research site, scientific devices and so on. Financial resources are mainly used for the funding of higher education, including teachers' salaries, research fund, student scholarships, social services, social services spending and so on.

From the current researches on higher education resources allocation, the researches of foreign scholars are mainly based on case study and empirical analysis, in which many statistical analysis methods such as linear regression analysis method, data envelopment analysis method etc are used to evaluate and investigate the efficiency and achievements of resources allocation (Amy, Reuven, & Micahel, 2000; Susan & Cheryl, 2004; Hooshang, Geraint, & Reza, 2002). The researches of domestic scholars mainly include the macro policy researches such as behavior main bodies, market mechanisms and government functions of the higher education resources allocation and so on (Zeng, 2003; Xia & Zhang, 2006; Yang, 2001), meanwhile the status quo analysis and efficiency evaluation of regional higher education resources allocation are also included (Dong, 2003; Zhai, 2006). Existing researches mainly focus on the analysis and evaluation of the resource allocation, whereas the researches with optimization of resources allocation with some optimization goal are rare.

1.2 Social Contribution of Higher Education

Higher education influences many aspects of the development of society, and the social contribution consists of the contributions to development of economic, technology, society and many other aspects (Zhao, 2003). And the primary improvement and enhancement can be observed in economic increasing, industrial structure adjusting, the quality of workers and the efficiency of labor; to the development of technology, the main contribution can be acquired from major scientific projects, the production of patents and technological rewards, the dissertation and bookmaking; to the society, higher education can improve the quality of residents, raise the employment rate, and reduce degree of prevalence of offence.

The current related researches pay more attention to the contribution of higher education to the development of economic. In this aspect, many western scholars propose the opinions that education can promote the increasing of economic in various degrees (Cai, 2003), and from the beginning of Solow (Solow & Robert, 1957), many classical researches have appeared about the dedication of education to the development of economic.

In the contribution of higher education to development of technology, although people are conscious of that higher education has significant influence to the development of technology; the detailed exploration has just started (Liu, 2012). Some researchers promote specific suggestions to corresponding politics, through studying the contribution of higher education to the development of technology. With the rapid development of the era of knowledge economy, and technology playing an important role in country competitive power, the research are gradually permeating and solidifying. Furthermore, the concrete research to the higher education to the development of society has also begun. However, the synthetic study to economic, technology and society are not enough.

1.3 The Relationship Between Higher Education Resource and Social Contribution

The system of higher education form the production of higher education achievement though investment of manual labor, material resources, financial and other resources. Higher education makes contributions to the many aspects of development in society through its outputs' effects on the development of economic, technology and society. Social contribution is the ultimate value of higher education, also is the embodiment of the

eventually return of higher education. Current existing researches related to higher education resources focus on the relationship between the investment and achievement output, ignoring the influences of higher education resources investment on all aspects of social development. As a result, this paper investigates the optimization of higher education resources allocation from the perspective of social contribution.

According to the results and contribution to the society generated by the higher education resources investment, higher education resources can be divided into three aspects including investment to promote investment to promote economic development (such as investment for students cultivation, technology training, etc.), investment to promote technology development (such as investment for science research, technology development) and investment to promote society development (such as investment for social public welfare, construction of spiritual civilization). In each aspects, the resources including human resources, material resources and financial resources. Higher education for the comprehensive contribution of the society is finally formed through the investment of these resources, as shown in Figure 1.

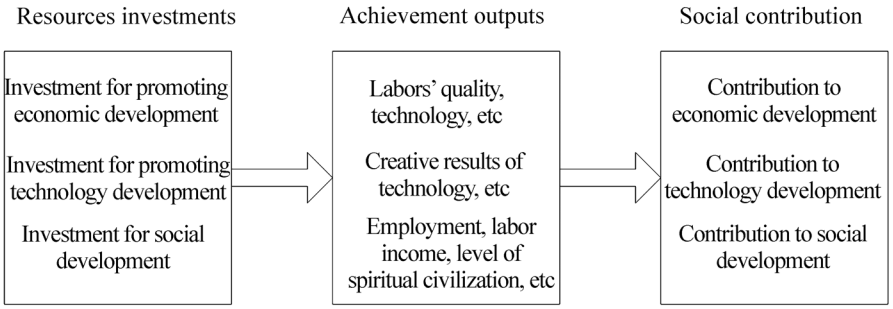

Figure 1
Resource-Input and Social Contribution of Higher Education

2. COMPREHENSIVE SOCIAL CONTRIBUTION ORIENTED RESOURCES OPTIMIZATION MODEL

2.1 Comprehensive Social Contribution of Higher Education

In this paper, resources of higher education are optimized to enhance the ability of higher education in comprehensive social contribution. 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 all the aspects of these contributions. At the same time, considering the interaction of constraints and promotion among economic development, science and technology development and social development, which means that one aspect will impacts on the other aspects in one way or another. When higher education contributes to one aspect directly, the development of this aspect will contribute to others at the same time. That is, the higher education makes both direct and indirect contributes to economy development, science and technology development and social development. So in the model of the evaluation for higher education contribution to society in this paper, both direct contributions and indirect contributions are considered.

The comprehensive social contribution of higher education can be defined 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 which $C_{\text{total}}(E)$, $C_{\text{total}}(T)$, $C_{\text{total}}(S)$ represent the contribution of higher education to economic development, technology development and social improvement (including the direct and indirect contribution) respectively, which can be written as

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

W_E, W_T, W_S represent the weights of the contribution of higher education to economic development, technology development and social improvement in the comprehensive contribution respectively. A_E, A_T, A_S represent the direction contributions to economic development, technology development and social improvement of higher education respectively, and $A_T A_{T,E}$ is the indirect contribution to economic development due to the contribution to technology development of higher education, $A_S A_{S,E}$ is the indirect contribution to economic development due to the contribution to social development of higher education,and other parameters are defined similarly.

2.2 Resources Optimization Model Design of Higher Education

In this paper, the human resource investment is indicated as α, the material resource investment is indicated

as β, and he financial resource investment is indicated as γ. Under the circumstance with a constant external environment, such as policies, the contribution of higher education mainly depends on the investment. Besides, the resources investment would only influence the direct contributions, and would not influence the indirect contributions. And then, A_E, A_T , A_S can be indicated as functions of α, β and γ, which are $A_E(\alpha_E, \beta_E)$, $A_T(\alpha_T, \beta_T)$ and $A_S(\alpha_S, \beta_S)$. They are continuous and differentiable.

The emphasis of this paper is to establish the resources optimization model and propose the method to solve it. 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 research the optimization of higher education resource, we assume that W_E,W_T,W_S and interaction among economic development, science and technology development and social development are constants, nothing with the investment of education resource. The optimization functions of investment of education resource and the social contribution of higher education as:

$$\begin{aligned} &(\mathbf{P1}) \quad \max C_{\text{total}} \\ &\text{s.t.} \quad C1: \sum_{s\in(E,T,S)} \alpha_s \le \alpha \\ &\qquad C2: \sum_{s\in(E,T,S)} \beta_s \le \beta \\ &\qquad C3: \sum_{s\in(E,T,S)} \gamma_s \le \gamma \\ &\qquad C4: \Phi_{\text{total}} = 1 \end{aligned} \tag{3}$$

α_E, β_E and γ_E refer to the investment of education for economic development, α_T, β_T and γ_T refer to the investment of education for science and technology development, α_S, β_S and γ_S refer to the investment of education for social development. α,β,γ refer to the total human resources, material resources and financial resources can be invested respectively. Considering that the balance of the development of higher education on the various social aspects, we take the balance in comprehensive contribution of higher education as one of the constraint conditions. The balance of the higher education comprehensive contribution can be defined as

$$\Phi_{\text{total}} = \frac{\left(\sum_{s\in(E,T,S)} C_{\text{total}}(s)\right)^2}{3\times\sum_{s\in(E,T,S)} {C_{\text{total}}}^2(s)} \tag{4}$$

When the economic, technology and social contribution of higher education are equal, the degree of the balance achieve the maximum, and meanwhile Φ_{total}=1.

This optimization model aims to allocate various resources to maximize the social contribution of higher education, with the considerations of limited total resources and the balance for various aspects in the comprehensive contributions of higher education.

3. ADAPTIVE RESOURCES ALLOCATION OF HIGHER EDUCATION BASED ON PARTICLE SWARM

3.1 Equivalent Objective Function

According to the description of problem P1, the objective function is to maximize the total utility function of higher education. Condition C4 constrains the fairness for all aspects of contributions to make higher education develop balanced. Obviously, fairness and total utility function is not always in positive relationship, which is to say that there is always constraint relationship between efficiency and fairness. From mathematical perspective, fairness constraint makes the problem's solution space into nonlinear relation, which brought more difficulty to problem solving. In order to deal with the relationship between the objective function and the fairness, we propose an equivalent objective function to eliminate fairness constraint on the total utility function. According to the expression of C4, we can see that the fairness is required to stay the largest when resources are allocated in problem P1, as a result, problem P1 can be equal to a multi-objective problem:

$$\begin{aligned} &(\mathbf{P2}) \quad \max C_{\text{total}} \,\&\&\, \max \Phi_{\text{total}} \\ &\text{s.t.} \quad C1: \sum_{s\in(E,T,S)} \alpha_s \le \alpha \\ &\qquad C2: \sum_{s\in(E,T,S)} \beta_s \le \beta \\ &\qquad C3: \sum_{s\in(E,T,S)} \gamma_s \le \gamma \end{aligned} \tag{5}$$

Although the fairness constraint has been transformed into the objective function in P2, the complexity of the solution is not reduced. To decrease the complexity of the solution, problem P2 can be simplified as:

$$\max C_{\text{total}} \,\&\&\, \max \Phi_{\text{total}} \rightarrow \max \Phi_{\text{total}} \tag{6}$$

Despite the arrow on the left are sufficient conditions on the right side of the problem, but not necessary conditions. In most cases, if the inequality constraint conditions C1, C2 and C3 establish, two objective functions can be approximately equal. Besides, the constraint conditions C1, C2, C3 can be transfer into the objective function by using penalty functions.

$$\begin{aligned} &(\mathbf{P3}) \max \Phi_{\text{total}} \\ &\rightarrow \max \begin{pmatrix} \Phi_{\text{total}} - \varpi_1 \left|\alpha - \alpha_S - \alpha_E - \alpha_T\right| - \varpi_2 \left|\beta - \beta_S - \beta_E - \beta_T\right| \\ -\varpi_3 \left|\gamma - \gamma_S - \gamma_E - \gamma_T\right| \end{pmatrix} \\ &= \max L \end{aligned} \tag{7}$$

In which

$$\varpi_1 \left|\alpha - \alpha_S - \alpha_E - \alpha_T\right| - \varpi_2 \left|\beta - \beta_S - \beta_E - \beta_T\right| - \varpi_3 \left|\gamma - \gamma_S - \gamma_E - \gamma_T\right|$$

can make sure that the resources are fully used, which means that the utility function can be maximized. Once

the resources are underused or is beyond the scope constraint, the objective function will be punished, meanwhile $\varpi_1, \varpi_2, \varpi_3$ represent the punish degrees to different resources. The original problem can be converted into solving the resource allocation, which can make the adjusted objective function L the largest.

3.2 Optimization Algorithm of Resources Allocation Based on Particle Swarm

In order to solve the difficult problems like P3, researchers have proposed a lot of biological heuristic algorithm based on swarm intelligence, which can provide effective feasible solutions to complex problems in a certain period of time. Compared to other algorithms, particle swarm algorithm has better global search ability and faster search in existing biological heuristic algorithms (Udgata, Kumar, & Sabat, 2010). As a result, we propose a suboptimal solution based on particle swarm.

Standard swarm particle algorithm contains the following steps:

(1)Structure the particles to be solved in the problem;

(2)Create the topology of the particles, and initialize the search parameters;

(3)Calculate the fitting value (objective function value) of each particle, and record the global optimal particle and the optimal location of each particle;

(4)Renew the location of particles;

(5)Return to step (2) until all the conditions of the problem are satisfied.

According to the basic steps above, an optimization algorithm of resource allocation for higher education based on particle swarm is proposed.

According to the characteristics of problem P3, we firstly structure the particle. Denote the ith particle as $\mathbf{particle}_i$, in which the elements are arranged as capital, human and material cost as Figure 2.

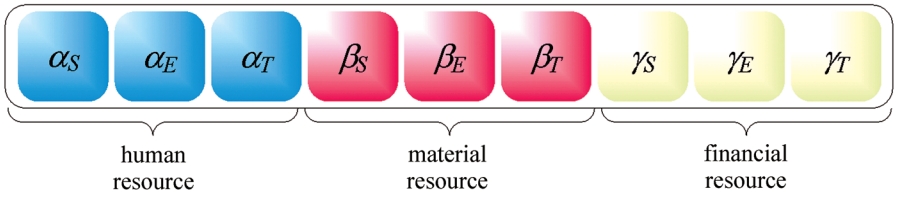

Figure 2
Particle of Higher Education Resource

In the above structure, the particle is initialized by using the average principle, and for the Ith particle, the initialized value is:

$$\begin{aligned}
&\alpha_S^i = \frac{\alpha}{3} + n_{\alpha_S} \quad \beta_S^i = \frac{\beta}{3} + n_{\beta_S} \quad \gamma_S^i = \frac{\gamma}{3} + n_{\gamma_S} \\
&\alpha_E^i = \frac{\alpha}{3} + n_{\alpha_E} \quad \beta_E^i = \frac{\beta}{3} + n_{\beta_E} \quad \gamma_E^i = \frac{\gamma}{3} + n_{\gamma_E} \\
&\alpha_T^i = \frac{\alpha}{3} + n_{\alpha_T} \quad \beta_T^i = \frac{\beta}{3} + n_{\beta_T} \quad \gamma_T^i = \frac{\gamma}{3} + n_{\gamma_T}
\end{aligned} \tag{8}$$

In which $n_{\alpha_S}, n_{\alpha_E}, n_{\alpha_T}, n_{\beta_S}, n_{\beta_E}, n_{\beta_T}, n_{\gamma_S}, \quad , n_{\gamma_T}$ are random variables which follow Gaussian distribution, for increasing the diversities of the initial particles.

When the value of each element in $\mathbf{particle}_i$ is determined, the variables above can be replaced into equation (7), and the objective function L can be achieved, which is denoted as L_i. $\max_i L_i = GL$, and its particle location is $G\mathbf{particle} = \mathbf{particle}_{\arg\max_i L_i}$. We also denote that the best location of each particle in history as $P\mathbf{particle}_i$. After the particle structure is established, the locations of the particles need to be adjusted continuously for searching the optimal solutions. The renew rate of the ith particle is $\mathbf{velocity}_i$, and in the renew process of each particle, the particle renew rate is firstly renewed as the following equation.

$$\mathbf{velocity}_i = \chi \begin{pmatrix} \mathbf{velocity}_i + c_1\omega_1\left(P\mathbf{particle}_i - \mathbf{particle}_i\right) \\ +c_1\omega_1\left(G\mathbf{particle} - \mathbf{particle}_i\right) \end{pmatrix} \tag{10}$$

In which χ is the inertia coefficient in the particle swarm algorithm, variables ω_1 and ω_2 are random positive integers, follow the uniform distribution in [0, 1]. Clerc and Kennedy (2002) gave the expression of the inertia coefficient.

$$\chi = \frac{2}{\left|2 - c - \sqrt{c^2 - 4c}\right|}, c > \chi\left(c_1 + c_2\right) > 4 \tag{11}$$

In which $c_1 = c_2 = 1.149445$.

After the velocity of particle is renewed, the location of each particle can be renewed as following.

$$\mathbf{particle}_i = \mathbf{particle}_i + \mathbf{velocity}_i \tag{12}$$

So the optimization algorithm of resources allocation for higher education based on particle swarm can be organized as:

Algorithm 1: Resources allocation for higher education based on particle swarm

(1) Initialize particle i according to equation (8).

(2) Calculate the fitting value L_i according to equation (7).

(3) Calculate *GL*, *G***particle**, and renew *P***particle**$_i$, **velocity**$_i$ and **particle**$_i$.

If *GL* satisfies the stop condition of resource allocation, the algorithm stops; otherwise, return to step 2.

By running the proposed algorithm, the resulting solution achieved when the algorithm stops is the optimal solution of optimization problem. The solution can reach the largest comprehensive contribution of higher education to society, meanwhile make balanced among all aspects of the contribution.

CONCLUSIONS

Shortage of higher education resource is one of the main factors which restrict the development of higher education at present. In the condition that higher education resources can't significantly increase in the short term, the limited resources allocation has to be optimized. In this paper, the resources allocation of higher education is optimized with the goal of improving the ability of social contribution of higher education. The higher education resource optimization model is established to maximize the comprehensive social contribution of higher education and balance the social contribution, which comprehensively and scientifically describes the optimization problems of higher education resources. On this basis, the higher education resource allocation algorithm based on particle swarm algorithm is proposed and the solving methods of higher education resource optimization model is presented, which provides the reference for the more efficient and reasonable use of limited resources of higher education.

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