Comparative study on economic contribution rate of education of China and foreign countries based on soft computing method

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\textbf{A B S T R A C T}

Economic contribution rate of education (ECRE) is the key factor of education economics. This article selected China, South Korea, United States and other countries for a total of 15 samples, and put the data of the same period under the framework of soft computing, to simulate the production chain of “education–potential human capital–actual human capital–economic growth”. The basic idea is: Firstly, 15 countries are softly categorized according to the level of science and technology (S&T) progress. Secondly, potential human capital and actual human capital establish the internal correlation (fuzzy mapping) in the same classification, and we conceptualize actual human capital as one production factor, joined with the other two production factors, fixed asset and land, to set up the fuzzy mapping to economic growth, and then calculate economic contribution rate of education of China and foreign by two fuzzy mapping of them. Thirdly, this paper analyzes the present state and differences in the development of education between China and foreign according to different ECRE, and offers proposals for promoting the education in China.

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1. Introduction

As the economy-globosity and the knowledge-economy-era have come, it has become the world’s hotspot that human advance and deepen the cognition to education constantly, along with effects on economy and society by development of education. Economists gradually recognize the importance of education to economic growth since Schultz [1] and Denison [2], after whom, a growing number of economists [3,4,18,19] began to put education in endogenous variables as the impel of one country’s economic growth. Because of influence of human capital theory, the effects of economic contribution rate of education have been studied extensively in theory and empirical. As we say, education plays a significant role in economic growth. Traditional measures of economic contribution rate of education have not only transformed the classic belief that education is pure consumer activity, but also made people realize quantitatively the economic contribution rate of education. On the other hand social economic system is typically extensive and contains many complicated social economic factors. With the development of current technology and economy, more and more factors interact within the complicated social economic systems. The traditional statistical measures on ECRE are deficient. Therefore, it is necessary to search for a new computing method that could not only improve over the traditional computing methods in these areas but also help to reveal the true relationship between education and economic development. The new method shall have features as follows:

Firstly, the social economic system is highly nonlinear, massive, complex and polytypy, which requires the method employed to do research into it the ability to map highly nonlinearly and to process massively parallel, as well as the capacity to self-learn and to be adaptive.

Secondly, the method is also required to be capable of processing fuzzy concept and making full use of the existing qualitative knowledge due to the uncertainty and ambiguity of social economic system.

Finally, the method should also be to some extent stable and ignorant of fault when used to tackle the incompleteness and shortage of the data.

Soft computing (Zadeh, 1973) (SC) [20] is an newly developed computing method that possesses the above characteristic and that combines various knowledge, technologies, and methods to set up an intelligent system to solve the complicated actual problems under uncertain and inaccurate circumstances. Similar to human brain, in order to solve complex problems, SC uses multiple techniques simultaneously in the computation in a harmonious
manner. In this paper we present a soft computing technique, which consists of artificial neural networks for pattern recognition and self-adjustment to evolving environment, fuzzy system for reasoning and decision-making and genetics algorithm for the optimization of system. These three techniques are considered as complementary and synergistic partners rather than competing methods.

Therefore, in this paper, according to different of the data collect, and we choose select representative country, such as South Korea, the United States, Britain and other countries for a total of 15 samples, and put the data of the same period of time of each country under the framework of soft computing, simulate the production chain of “education–potential of human capital–actual human capital–economic growth”. We select Soft Computing (Zadeh, 1973) (SC), a newly developed computing method that combines various knowledge, technologies, and methods to set up an intelligent system to solve the complicated actual problems under uncertain and inaccurate circumstances. In this paper we present a soft computing technique, which consists of artificial neural networks for pattern recognition and self-adjustment to evolving environment, fuzzy system for reasoning and decision-making and genetics algorithm for the optimization of system. These three techniques are considered as complementary and synergistic partners rather than competing methods. The new study thinking, and study methods for craft brother to consult and exchange, so have made the better result [7].

In this paper, the idea is detailed as follows. Firstly, the target systems (countries or regions) are classified in a fuzzy fashion according to technological progress (S&T) progress by GA-ISODATA [8–10]. Within the same cluster, we then compute the potential human capital induced from education. At the same time, we separate the actual human capital from GDP directly and set up the internal correlation (fuzzy mapping) between these two kinds of human capitals. Secondly, we introduce the fuzzy mapping between three production factors (including actual human capital) and economic growth. Thirdly, we define and compute ECRE as the multiplication between the rate of economic growth with respect to actual human capital and the rate of actual human capital with respect to potential human capital. The schema of computing ECRE is shown in Fig. 1.

2. Calculation of human capital

Scholars discovered that measurement of human capital is difficult. On the basis of previous research, we have found that measurement of human capital can be divided into two classes: input and output measurement method. These two methods essentially respectively correspond to the measurement of potential human capital and actual human capital.

2.1. The relationship between human capital and potential actual human capital

Human capital could be divided as potential human capital and actual human capital [11]. The potential human capital consists of the input of education, professional training, and health care. But not all the potential human capital can improve personal income and national economic growth. If it makes the greatest capabilities, the worker will be able to fully release the potential value, and engender actual human capital. Actual human capital is represented by the actual performance of workers in social activity and materialized in products and services. It reflects that the factor input emphasized in econometrics should be part of the flow in production process, and only this part of human capital, which is involved in actual production activities and which did not enter areas of production activities, can be regarded as potential resources. Therefore, there is a relationship of conversion between the potential human capital and actual human capital, and the size of conversion degree is different and difficult to measure in different region, time and system [12].
Table 1
The proportion of workers of different level of education and the average number of years of education.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Education</th>
<th>Junior School (%)</th>
<th>Senior School (%)</th>
<th>Higher School (%)</th>
<th>(H_1)</th>
<th>(H_2)</th>
<th>(H_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td></td>
<td>0.6</td>
<td>49.6</td>
<td>27.2</td>
<td>4.6440</td>
<td>4.6080</td>
<td>1.0880</td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td>35.5</td>
<td>35.3</td>
<td>29</td>
<td>5.9880</td>
<td>3.8580</td>
<td>1.1600</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td>17.2</td>
<td>30.3</td>
<td>52.5</td>
<td>6.0000</td>
<td>4.9680</td>
<td>2.1000</td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td>10.29</td>
<td>58.27</td>
<td>31.44</td>
<td>6.0000</td>
<td>5.3826</td>
<td>1.2576</td>
</tr>
<tr>
<td>Bulgaria</td>
<td></td>
<td>21.7</td>
<td>55</td>
<td>23.3</td>
<td>6.0000</td>
<td>4.6980</td>
<td>0.9320</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td>26.9</td>
<td>46.9</td>
<td>26.2</td>
<td>6.0000</td>
<td>4.3860</td>
<td>1.0480</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td>17.3</td>
<td>58.9</td>
<td>23.8</td>
<td>6.0000</td>
<td>4.9620</td>
<td>0.9520</td>
</tr>
<tr>
<td>Poland</td>
<td></td>
<td>15.3</td>
<td>71.8</td>
<td>12.9</td>
<td>6.0000</td>
<td>5.0820</td>
<td>0.5160</td>
</tr>
<tr>
<td>Romania</td>
<td></td>
<td>32.3</td>
<td>57.1</td>
<td>9.1</td>
<td>5.9100</td>
<td>3.9720</td>
<td>0.3640</td>
</tr>
<tr>
<td>United Kingdom</td>
<td></td>
<td>17.5</td>
<td>47.4</td>
<td>26.8</td>
<td>5.5020</td>
<td>4.4520</td>
<td>1.0720</td>
</tr>
<tr>
<td>Holland</td>
<td></td>
<td>30.9</td>
<td>45.2</td>
<td>23.5</td>
<td>5.9760</td>
<td>4.1220</td>
<td>0.9400</td>
</tr>
<tr>
<td>Spain</td>
<td></td>
<td>52</td>
<td>19.6</td>
<td>27.9</td>
<td>5.9700</td>
<td>2.8500</td>
<td>1.1160</td>
</tr>
<tr>
<td>Israel</td>
<td></td>
<td>14.4</td>
<td>35.1</td>
<td>49.6</td>
<td>5.9460</td>
<td>5.0830</td>
<td>1.9840</td>
</tr>
<tr>
<td>South Korea</td>
<td></td>
<td>14.2</td>
<td>43.7</td>
<td>24.9</td>
<td>4.9680</td>
<td>4.1160</td>
<td>0.9960</td>
</tr>
<tr>
<td>China</td>
<td></td>
<td>31.42</td>
<td>55.325</td>
<td>5.335</td>
<td>5.5116</td>
<td>3.5412</td>
<td>0.1868</td>
</tr>
</tbody>
</table>

Data Source: from World Bank database and International Statistical Yearbook.
Notes: \(H_1\), \(H_2\) and \(H_3\) respectively denote Junior, Senior, Higher mean years of schooling of laborer.

2.2. Calculation of human capital

(1) Calculation of potential human capital from input oriented. It is taken into account the indicators simplicity and data feasibility. Specific methods, including academic index method, Technical grade method, education investment method, and mean years of schooling method. The most representative is the laborer mean years of schooling method measurement potential human capital. It is not only concise, of data availability and reliability, but also can be ruled out “academic index method”, “technical grade method” subjective factors. Therefore, this article only selects the mean years of schooling method to calculate the potential human capital, as shown in Table 1.

(2) Calculation of actual human capital from output oriented. In this section, I present the theory that formalizes the concept of human capital used in this paper and provides the basis for its measurement across countries in the following section. Since I am borrowing from Mulligan, Sala-i-Martin and Jeong [13–15], I will only present the essentials relevant for the measurement in this paper. The technology is identical across countries and is represented by the production function:

\[ Y_t = A_t H_t^\alpha \]  

(1)

where \(Y_t\) is the aggregate output, \(H_t\) is the aggregate human capital input, \(A_t\) is the factor other than human capital input such as the physical capital input, and \(\alpha \in (0, 1)\) is the human capital input share parameter. The aggregate human capital input is the linear sum of individual human capital inputs, and people are immobile across economies, so we can write:

\[ H_t = \int_0^1 h(i, j) DJ \]  

(2)

In a number of assumptions and transformation, we can derive:

\[ H_t = \frac{\alpha Y_t}{W_t} \]  

(3)

That is, the aggregate human capital input of an economy is the aggregate labor income divided by the wage rate for a unit of human capital input.

Consider two economies \(i\) and \(j\). We have

\[ \frac{H_{ti}}{H_{tj}} = \frac{Y_{ti} W_{ij}}{Y_{tj} W_{ij}} = \gamma \frac{Y_{ti}}{W_{ij}} \]  

(4)

where \(W_{ij}\) and \(W_{ij}\) are the average wages of workers with little education in economies \(i\) and \(j\), respectively and \(\gamma = W_{ij}/Y_{ij}\).

According to the principle proposed by Jeong [4], industrial workers participate mainly in physical work with less skill requirement. Therefore we mainly selected the eight industrial workers. The eight industries are: textile and garment industry, printing and publishing industry, chemical manufacturing, and other chemical products manufacturing industry, steel industry, machinery manufacturing, power production industry, and the construction industry. In accordance with the International Labor Organization (LABOCT) criteria classification, we passage the average wage of workers of eight sectors to seek \(\hat{w}_i\).

The details of computing actual human capital in China are as following

\[ Y_i(t)(i = 1, 2, \ldots, k) \text{is the GDP in i-th region and in t-th year } \text{arv}\;Y_i(t) \text{is per-capita GDP}. \text{W}_i(t)(j = 1, 2, \ldots, s) \text{is the general wage in i-th region, in j-th industry and in t-th year. arv}\;W_i(t) \text{is per-capita wage in i-th region, in j-th industry and in t-th year.} \]  

\[ \text{The general time. arv}\;W_i(t) \text{and arv}\;W_j(t) \text{are worked out by the following equations:} \]

\[ \text{arv}\;Y_i(t) = \frac{\sum_{t=1}^t \text{arv}\;Y_i(t)}{T} \]  

(5)

\[ \text{arv}\;W_i(t) = \frac{\sum_{j=1}^s \sum_{t=1}^T \text{arv}\;W_i(t)}{T \times s} \quad i = 1, 2, \ldots, n \]  

(6)

where \(n\) is the number of regions. The benchmark region is selected China. Its subscript is zero. The relative value of the per-capita GDP and per-capita wage in each region corresponding to the benchmark region is worked out by the following equations:

\[ \text{arv}\;\hat{Y}_i = \frac{\text{arv}\;Y_i}{\text{arv}\;Y_0} \]  

(7)

\[ \text{arv}\;\hat{W}_i = \frac{\text{arv}\;W_i}{\text{arv}\;W_0} \]  

(8)

Form Eqs. (7) and (8), then the actual human capital in i-th region is worked out by the following equation:

\[ H_i = \frac{\text{arv}\;\hat{Y}_i}{\text{arv}\;\hat{W}_i} \]  

(9)

The results in Table 6, the numerals in brackets are the comparative value of different regions to China according to relative index.
3. Soft sort

As a result of the impact of Scientific and S&T progress, on the one hand, the same kinds of human capital of workers at different levels of S&T progress to economic growth contribution is different in the country or region, and sometimes cannot be compared; on the other hand, as a result of various countries (regions), national wage levels are different. In order to understand the macro-economic level of the income difference between the total growth, many different countries must be softly sorted by S&T progress. In order to categorize 15 country (China and foreign country) based on their S&T progress. We extend the Cubb–Douglas function to the following form:

\[ Y = F(x_1, x_2, \ldots, x_n; t) = AKL_1 N_1^\alpha L_2 N_2^\beta L_3 N_3^\gamma \]  \hspace{1cm} (10)

where \( \alpha, \beta \) and \( \gamma \) are constants, and \( A \) denotes the factor of S&T progress. It is assumed that \( \alpha + \beta + \gamma = 1 \) (i.e., a constant scale of economies). \( K, L \) and \( N \) represent the investment of fixed asset, labor, and land, respectively. It is clear from Eq. (10) that

\[ A = YK_1^{-\alpha}L_1^{-\beta}N_1^{-\gamma} \]  \hspace{1cm} (11)

This equation describes the dependence of S&T progress on economic output, capital investment, labor investment, and land investment. The land investment is relatively stable. Therefore, we only focus on per-capita economic output, fixed asset investment and labor capital. Based on Eq. (11), and the data listed in Table 5. We use GA-ISODATA [7–9] to softly categorize country based on their S&T progress.

We can obtain the optimal number of cluster is 3 applying the algorithm GA-ISODATA in Table 2, and according to the criterion of maximum membership degree, we further obtain the result of this partition as presented in Table 3.

It is found from Table 3: Although the level of their scientific and technological progress can be regarded as the same category, the membership degree is different. United States is 0.8664 and France is 0.7864 in the first cluster; China belong to the third category are 0.9920, with little difference between Bulgaria and other countries in the third category country. It can be said that Table 3 is generally the result of classification, while Table 2 is divided into more detailed in each category by S&T progress. The classification by GA-ISODATA reasonably reflects the situation of economic development in China and other 15 countries.

The first cluster is the most developed region and there are many high-quality labor force, superior technology talents and excellent managers. As a matter of fact, the five countries, United States, France, Germany, etc. in the first cluster are the economic and cultural centers of world with the most advanced technology.

The second cluster region is more developed countries. Although these countries are relatively small in area and population, they have relatively strong economic power, science and technology, the overall level of which is relatively developed, such as South Korea, one of the “Asian four small dragons”, as well as scientific and technological power in Israel.

The third cluster region is developing countries. Although these countries’ level of technological development have a certain difference, they have relatively more poor people, low level of population education, relatively low degree of industrial modernization and relatively low overall level of technological development, so we put them in the same cluster as developing countries.

4. Implementation of fuzzy systems

Fuzzy logic and neural networks combine fuzzy artificial neural networks (FANN). Fuzzy logic is used to express brain macroscopically capability with language and concepts. FANN deal with all kinds of fuzzy information based on membership function and series of rules. So FANN has many strong points like fuzzy logic and neural networks. We seek to establish the correlation between the potential human capital and the actual human capital and the correlation between the latter and the economic growth in order to calculate the contribution of education to the economic growth.

4.1. The source of the data and related notes

It is obvious that the difference of the statistics caliber and data acquisition channels may cause different conclusions. Therefore, all data is extracted from International Statistical Yearbook, World Bank data, International Yearbook of Labor Statistics by ILO and China Statistical Yearbook to ensure the reliability of the data. According to data availability, the potential of human capital and arable land area is 2001 year data; the calculation of other data is based on the average of 1999–2003 (equivalent to 2001 data). Compared with existing research, in the case of uniform-diameter, data obtained is relatively comprehensive, objective and relatively new. Data processing results are shown in Tables 1 and 6. The main indicators data in this paper is as follows:

1. The amount of labor, average number of years of education, measurement of potential human capital. Considering that not all the potential human capital can improve personal income and national economic growth, the paper selects the employed population as the input of labor factor in the following production function. We obtain the employed population of every country in 2001, the proportion of workers of different level of education from the China Statistical Yearbook, China Yearbook

### Table 2
Membership degree of country.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Cluster One</th>
<th>Cluster Two</th>
<th>Cluster Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td>0.0591</td>
<td>0.8810</td>
<td>0.0599</td>
</tr>
<tr>
<td>Australia</td>
<td>0.4998</td>
<td>0.4480</td>
<td>0.0522</td>
</tr>
<tr>
<td>Canada</td>
<td>0.1969</td>
<td>0.7656</td>
<td>0.0376</td>
</tr>
<tr>
<td>United States</td>
<td>0.8664</td>
<td>0.1012</td>
<td>0.0325</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.0156</td>
<td>0.0382</td>
<td>0.9462</td>
</tr>
<tr>
<td>France</td>
<td>0.7864</td>
<td>0.1503</td>
<td>0.0613</td>
</tr>
<tr>
<td>Germany</td>
<td>0.9320</td>
<td>0.0577</td>
<td>0.0102</td>
</tr>
<tr>
<td>Poland</td>
<td>0.0096</td>
<td>0.0259</td>
<td>0.9645</td>
</tr>
<tr>
<td>Romania</td>
<td>0.0887</td>
<td>0.1455</td>
<td>0.7658</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.6193</td>
<td>0.3392</td>
<td>0.0414</td>
</tr>
<tr>
<td>Holland</td>
<td>0.2552</td>
<td>0.6588</td>
<td>0.0860</td>
</tr>
<tr>
<td>Spain</td>
<td>0.0283</td>
<td>0.9586</td>
<td>0.0151</td>
</tr>
<tr>
<td>Israel</td>
<td>0.0898</td>
<td>0.6938</td>
<td>0.2164</td>
</tr>
<tr>
<td>South Korea</td>
<td>0.0025</td>
<td>0.0055</td>
<td>0.9920</td>
</tr>
</tbody>
</table>

### Table 3
Classification of provinces and cities based on S&T progress.

<table>
<thead>
<tr>
<th>Classification</th>
<th>United States, France, Germany, Australia, United Kingdom</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first cluster</td>
<td></td>
</tr>
<tr>
<td>The second cluster</td>
<td>South Korea, Canada, Holland, Spain, Israel, New Zealand</td>
</tr>
<tr>
<td>The third cluster</td>
<td>Bulgaria, Poland, Romania, China</td>
</tr>
</tbody>
</table>

In this paper, the total investment of fixed capital in each year of each country.

(2) Total investment of fixed capital consists of fixed capital stock and increased fixed capital investment. To exclude the impact of price change, we convert the nominal increased fixed capital investment to the actual ones by adjusting the price indicator of fixed capital investment based on the year of 1978, all the data of which derive from United States Statistics data (1994–2003). Accordingly, the yearly total fixed capital investment can be defined as the depreciated fixed capital stock $K_g$ at the beginning of the year added by the increased counterparts. The depreciation ratio is assumed as $D$, and the formula is therefore described as following: $K_g = K_g^0 (1 - D) + K_t$. Considering the depreciation ratio vary from developed countries to developing ones, this paper takes 5.5% as the first and second cluster's depreciation ratio and 5% as the third cluster's after comprehensive account of the research results of other scholars such as Lee Jingwen (1998), Mankiw (1992), Islam (1995).

(3) In current research, annual GDP or annual average per capita GDP is widely used to reflect the economic total. Since GDP is intensely correlated with a country's scale while average per capita GDP can truthfully represent a country's average level of income, this paper chooses the latter as the gross indicator to calculate economy increase in China and foreign countries. To exclude the impact of price factor, we convert the annual nominal GDP, which is from International Statistical Yearbook and World Bank data, to annual actual GDP before weighted summation of the each country's annual GDP.

(4) Other source of data. The population and the area of arable land are from International Statistical Yearbook and World Bank Data while the level of wages of workers referred derives from Labor Statistics Yearbook by ILO, all of which is limited to be in the year 2001 due to data availability except for population.

Then according to the availability, integrity, reliability of the data, this article selected China, South Korea, United States and other countries for a total of 15 samples.

4.2. The structure and calculation of FANN1

The FNN1 structure is shown in Fig. 2. The function of FANN1 is to obtain parameters of fuzzy sets represented by using the self-organization and self-learning of artificial neural networks, which

![Fig. 2. Topology structure of FANN1.](image-url)
is based on the fuzzy neural network of TSK and gives the local approximate linear equations of non-linear systems through the fuzzy rules. The FANN1 can be used to realize the fuzzy mapping from potential human capital (induced from education) to actual human capital (materialized in the commodity and service). The functions of respective layers in the FANN1 are as follows:

Layer (i): n nerve cells are included within this layer. The inputs and outputs of each nerve cell are the same and equal to the individual component of input vectors.

Layer (ii): This is the fuzzy layer including c × n nerve cells. There are c groups, and each group consists of n cells. Each cell gives the 1-dimensional membership function (MF) \( \mu_{A_i}(x_j) \sim \mu_{A_i}(X_i) \) \( i = 1 \sim c \).

Layer (iii): This is the calculation layer including c nerve cells. The calculation of n-dimensional MF \( \mu_{A_i}(X) \) for group i is achieved by each nerve cell, \( i = 1 \sim c \). The MF is the product of n Gaussian functions,

\[
\mu_{A_i}(X) = \prod_{j=1}^{n} \mu_{A_j}(x_j) = \prod_{j=1}^{n} \exp \left\{ - \left[ \frac{x_j - a_{ij}}{\sigma_{ij}} \right]^2 \right\} \quad i = 1 \sim c. \quad (12)
\]

Layer (iv): This is the reasoning layer with c nerve cells. The reasoning calculation is described in Eq. (5) and carried out by fuzzy rules \( R_i \), \( i = 1 \sim c \) for each nerve cell,

\[
\mu^i(X) = \max \left\{ \mu_{A_i}(X), \mu_{A_i}^{(i)}, \ldots, \mu_{A_i}^{(c)} \right\} \quad 1 \leq p \leq c.
\]

The condition is guaranteed from \( \mu_{A_i}^{(i)}(X), \ i = 1 \sim c \).

Layer (v): This is the defuzzifier layer, which generates c groups of random coefficients \( (b_{i0}^0, b_{i1}^1, \ldots, b_{ic}^c) \), \( i = 1 \sim c \) and uses input vector \( X \) along with \( \mu^i(X) \sim \mu^i(x) \) obtained by Layer 4 and Eq. (4) to give

\[
y = \frac{\sum_{i=1}^{c} \left( b_{i0}^0 + b_{i1}^1 x_1 + \cdots + b_{ic}^c x_n \right) \mu^i(X)}{\sum_{i=1}^{c} \mu^i(X)}. \quad (13)
\]

Parameter c in the FANN1 is obtained from GA-ISODATA. The learning purpose of the FANN1 is to identify the parameters \( a_{ij} \), \( \sigma_{ij} \) and \( (b_{i0}^0, b_{i1}^1, \ldots, b_{ic}^c) \) \( i = 1 \sim c \), by obtaining the smallest sum of error squares of FANN1’s output and objective output (sample points).

### 4.3. Fuzzy mapping between mean years of schooling of workers and actual human capital

Constructing a linear function of the fuzzy neural network system (FNN1), we implement fuzzy mapping between potential human capital (per capita number of years of education) and actual human capital in order to obtain education to contribution rate of actual human capital.

Table 1 shows the mean years of schooling of workers and the relative ratio of the actual human capital as compared to that of China for all 15 countries. The potential human capital for each education level equals to the corresponding Mean years of schooling of workers, which serves as the input of FANN1. The actual human capital from different countries serves as the output of FANN1 in which China is chosen as the benchmark or reference countries (columns 5, 6 and 7 in Table 1). According to the Back Propagation (BP) algorithm [16,17], the FANN1 as inputs such as primary, junior and tertiary education and output such as actual human capital is trained. Table 4 lists the corresponding consequent parameters of the three fuzzy rules and the consequent parameters \( b_j(i = 1, 2, 3) \) of each rule describe the respective contribution rate of labor from three education levels to the actual human capital. \( b_0 \) represent constant term, by factors other than education (training, experience and health) formed, it is uneducated workers to the contribution size of actual human capital. Three types of areas for the three cluster education contribute to the actual human capital. Put data \( (b_0, b_{11}, b_{21} and b_{31}) \) scaling in Table 4.

### 4.4. Fuzzy mapping between production factors and economic growth

Human capital is composed of education, health and experience. So we can structure FNN2 like FNN1, which can get human capital contribution rate of education.

In the cluster with the same technology level, we set up a fuzzy mapping from production factors (fixed asset investment, human capital investment, and land investment) to GDP (all in per capita). The actual human capital in the 2nd and 7th column of Table 5, whereas the 3rd and 8th of Table 5 is the inflation-adjusted per capita fixed asset investment., and the 4th and 9th column of Table 5 is the per-capita land of individual regions in 2001. The weighted average sum of GDP in different regions from 1999 to 2003 is given in the 5th and 10th column of Table 5.

### Table 4

<table>
<thead>
<tr>
<th>Cluster</th>
<th>( b_0 )</th>
<th>( b_{11} )</th>
<th>( b_{21} )</th>
<th>( b_{31} )</th>
<th>( s = \sum_{j=0}^{3} b_j )</th>
<th>( b_0 + b_{11} + b_{21} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>0.195843</td>
<td>0.165308</td>
<td>0.130185</td>
<td>0.083221</td>
<td>0.574557</td>
<td>0.659140869</td>
</tr>
<tr>
<td>Two</td>
<td>0.151689</td>
<td>0.131990</td>
<td>0.090826</td>
<td>0.031953</td>
<td>0.406458</td>
<td>0.626802769</td>
</tr>
<tr>
<td>Three</td>
<td>0.126411</td>
<td>0.100804</td>
<td>0.050160</td>
<td>0.021875</td>
<td>0.29925</td>
<td>0.577573935</td>
</tr>
</tbody>
</table>

### Table 5

<table>
<thead>
<tr>
<th>Countries</th>
<th>Human capital</th>
<th>Fixed assets</th>
<th>Plantation acreage</th>
<th>Average GDP</th>
<th>Countries</th>
<th>Human capital</th>
<th>Fixed asset</th>
<th>Plantation acreage</th>
<th>Average GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td>1.0288</td>
<td>1.75</td>
<td>3.800</td>
<td>15256</td>
<td>Romania</td>
<td>1.1967</td>
<td>0.20</td>
<td>4.28</td>
<td>1945.2</td>
</tr>
<tr>
<td>Australia</td>
<td>1.0827</td>
<td>3.14</td>
<td>24.38</td>
<td>21592</td>
<td>United Kingdom</td>
<td>1.137</td>
<td>2.29</td>
<td>0.974</td>
<td>25929</td>
</tr>
<tr>
<td>Canada</td>
<td>1.0243</td>
<td>2.57</td>
<td>14.584</td>
<td>23422.3</td>
<td>Holland</td>
<td>0.8907</td>
<td>2.97</td>
<td>0.571</td>
<td>25941</td>
</tr>
<tr>
<td>United States</td>
<td>1.3103</td>
<td>2.96</td>
<td>6.0500</td>
<td>35185</td>
<td>Spain</td>
<td>1.0341</td>
<td>2.11</td>
<td>3.320</td>
<td>15802</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.9066</td>
<td>0.16</td>
<td>4.2600</td>
<td>1867.5</td>
<td>Israel</td>
<td>0.9709</td>
<td>1.84</td>
<td>5.380</td>
<td>17546</td>
</tr>
<tr>
<td>France</td>
<td>1.4222</td>
<td>2.51</td>
<td>3.00</td>
<td>23673.4</td>
<td>South Korea</td>
<td>0.908</td>
<td>1.68</td>
<td>0.355</td>
<td>10850.3</td>
</tr>
<tr>
<td>Germany</td>
<td>1.1943</td>
<td>2.91</td>
<td>1.43</td>
<td>24822.1</td>
<td>China</td>
<td>1.0000</td>
<td>0.15</td>
<td>1.130</td>
<td>943</td>
</tr>
<tr>
<td>Poland</td>
<td>0.9426</td>
<td>0.35</td>
<td>3.39</td>
<td>4732.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6
Economic contribution rate of each production factor.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Precondition parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$w_0$</td>
</tr>
<tr>
<td>One</td>
<td>0.155713</td>
</tr>
<tr>
<td>Two</td>
<td>0.128834</td>
</tr>
<tr>
<td>Three</td>
<td>0.014868</td>
</tr>
</tbody>
</table>

Table 7
ECRE of different regions.

<table>
<thead>
<tr>
<th>Countries</th>
<th>ECRE</th>
<th>Countries</th>
<th>ECRE</th>
<th>Countries</th>
<th>ECRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td>0.072519184</td>
<td>France</td>
<td>0.143785536</td>
<td>Holland</td>
<td>0.09251291</td>
</tr>
<tr>
<td>Australia</td>
<td>0.115400633</td>
<td>Germany</td>
<td>0.15638378</td>
<td>Spain</td>
<td>0.06792525</td>
</tr>
<tr>
<td>Canada</td>
<td>0.085319198</td>
<td>Poland</td>
<td>0.095635384</td>
<td>Israel</td>
<td>0.068454743</td>
</tr>
<tr>
<td>United States</td>
<td>0.150667502</td>
<td>Romania</td>
<td>0.097233339</td>
<td>South Korea</td>
<td>0.080360078</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>0.095656825</td>
<td>United Kingdom</td>
<td>0.126752584</td>
<td>China</td>
<td>0.09579067</td>
</tr>
</tbody>
</table>

We set up an input/output model with the fixed asset, human capital, land as the input vector, and the corresponding GDP as the output, according to the BP algorithm applied to FANN2 with inputs such as fixed asset, actual human capital, land and output such as GDP. The rule consequent represents the corresponding per-capita GDP. The weighted values of the consequent $w_j$, $i=1, 2, 3; j=0, 1, 2, 3$ are the constant term and the coefficients before variables $x_1, x_2, x_3$ in the corresponding linear functions. Variables $x_1, x_2, x_3$ represent the per capita fixed asset investment, actual human capital and precipitate the land, respectively. $w_j$ after normalized treatment, we gain the actual human capital to the economy growth size of ECRE, as is shown in Table 6.

4.5. Contribution rate of education to economic growth

ECRE equals to contribution rate of potential human capital to actual human capital multiplied the contribution rate of actual human capital to economic growth.

The ECRE in the $ith$ ($i=1, 2, 3$) region is $r_i$ from Tables 4 and 6. In the first cluster:

$$r_1 = \frac{w_{11}}{s} \times \frac{b_{11} + b_{12} + b_{13}}{s} = 0.162728335$$

In the second cluster:

$$r_2 = \frac{w_{21}}{s} \times \frac{b_{21} + b_{22} + b_{23}}{s} = 0.064885266$$

In the third cluster:

$$r_3 = \frac{w_{31}}{s} \times \frac{b_{31} + b_{32} + b_{33}}{s} = 0.095793327$$

According to the matrix regions of each country in Table 3, and types of education contribution to economic rates, we can gain all regions economic contribution rate of education is: $c_i = \sum_{i=1}^{3} w_i r_i$. The results shown in Table 7.

In which $c_i$ representive of the first areas $i$ education to economic growth in the contribution rate, $\mu_i$ as part of the first $i$ of the membership categories, $r_i$ for the first category $i$ areas of education in the contribution rate of economic growth.

We can see from Table 7, the economic contribution of education is different, due to the national education, human capital and economic development caused by different speed. In China, the economic contribution of education was 9.58 percent, lower than the United States, France, Germany, Australia, the United Kingdom and other countries, and higher than many countries in the second category. The size of ECRE of the different countries is shown in Fig. 3. The major causes are; in the first category areas, the economic contribution rate of education is high in developed countries. Because, first, the Government put education as the top priority of government work, then education has strong financial resources and financial investment is no spare capacity left. Enterprises, and individuals in education also devoted great enthusiasm. Second, they have a good rule of law and institutional environment. Because, a good economic basis for the development of education provides a solid material foundation, and a relatively democratic political
environment to education make decision-making more scientific and rationality. So, in the first cluster countries, ECRE are high.

The ECRE of China’s education is in the middle level. It mainly benefits from China’s education level, China’s workers by education level of the average number of years of rapid growth and more people accepted into higher education work. And the Chinese government places more and more emphasis on education and human capital accumulation in economic development. Government clearly made that “we must make hundreds of millions of high-quality workers, tens of millions of specialized personnel and a large number of top-notch creative talents” in 2006 years. Since the reform and opening up, the economy has maintained a rapid growth. Over the past decade, the economy has been maintained at between 8% and 10%, which were all conducive to education to economic growth. This protects ECRE of China in the middle level, and higher than some other countries such as South Korea 8.03%, Netherlands 9.25%, Spain 6.79% and other countries of the main reasons.

But we should also see that China’s overall education is at a lower level of development. In particular, it is subject to a very low proportion of the population of higher education, and educational level of workers, mainly in primary education and secondary education, industrial structure is bound in relatively low levels – that is, their main choice of workers is manual worker, low-tech, due to mode of production and production systems were limited, so less demanding level of education workers, who cannot be brought into full play for Economic growth effects of knowledge. Education funding is a bottleneck problem, the relative lack of education funding, hampering the development of education, which is encumber in education on economic growth. They are a direct result of the economic contribution of education and China is lower than that in developed countries the main reason for.

In the second category such countries as South Korea and other countries, the economic contribution of education is relatively low, mainly due to human capital to enhance the ‘bottleneck’ problem. This practice shows that human capital development to a certain level is very difficult to significantly enhance the consistent point of view [5,6]. The countries such as Bulgaria, Romania and Poland that have low levels of their education and economies lower the starting point. But in recent years the country’s development speed of economic and education were faster rising, so ensure that the three countries economic contribution of the of Education at a higher level.

5. Conclusion

Based on the educational economics’ basic principles, in this paper, a new soft computing method is proposed which is the quantitative analysis of the ECRE based on the theory of fuzzy mathematics. This new method overcomes the indirect, lag, and long-term nature of education to economic growth and the result is convincing. At the same time it provides a new thought for ECRE. The research for fifteen countries by this method indicates that Chinese ECRE is in the middle level because of fast development of Chinese education, big increased range of per capita number of years and quick pace of economic development. However, the Chinese education development is in the low level and there is a great gap compared with developed countries. Therefore Chinese education has a large development space and potential. Government should further strengthen administration propulsion and accelerate the education entirety development.

Therefore, it has very important significance to develop education, improve population quality, and change population Great Power into the talented person powerful country, all of which play a drive economic growth role for China with abundant labor force and short of human capital.

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