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Applying Grey Relational Analysis and Grey Decision-Making to evaluate the relationship between company attributes and its financial performance—A case study of venture capital enterprises in Taiwan

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Abstract

For the study on the financial performance, there are many limitations in using traditional statistic methods. The grey system theory proposed by the study is to supplement the limitations of using traditional statistic methods and it's more suitable to evaluate the financial performance of business. This study used six financial indicators to classify twenty items of financial ratios as research variables through the Globalization Grey Relational Analysis (GRA), to find the significant financial ratio variables and other financial indicators affecting the financial performance of venture capital enterprises in Taiwan, and it applied Grey Decision-Making (GDM) to arrange the total performances of the sample venture capital enterprises in order. Finally, this study uses GM(0, N) model to analyze the six variables of firm attributes and the differences between using different firms' attribute variables and financial performance of venture capital enterprises as the result.

Keywords: Grey Relational Analysis; Grey Decision-Making; GM(0, N); Venture capital enterprises

1. Introduction

According to the statistical datum of Taiwan Venture Capital Association, there were more than 199 venture capital enterprises in Taiwan before 2005 and their invested capital had also more than 4,660,000,000 USD. The venture capital enterprise is very important for the development of high-tech industries in Taiwan. The difference between the venture capital enterprises and general investment enterprises is that the investment of venture capital is in new hi-tech industry. Therefore, they face more uncertainties and higher risk than general investment enterprises. At the beginning the government of Taiwan offered financial subsidiaries of investment to stockholders of the venture capital enterprises in order to encourage the private investment to participate in the development of venture capital enterprises.

However, the government of Taiwan canceled the financial subsidiaries of investment to the stockholders of the venture capital enterprises in 2000 because of the cause of tax equity. It affected the stockholders' willingness of continuing investments on venture capital enterprises. Therefore, we used the variables of financial ratio to measure financial performance of the venture capital enterprises in Taiwan from 2001 to 2003 and assisted the venture capital enterprises to

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understand the relationship between enterprise attribute and financial performance to improve their total operational performance.

Generally, about the relative research topic on the venture capital enterprises, there are three directions: a) the study on the relationship between the characteristic and performance of the venture capital enterprises [2,12,18]; b) the study on factors which influence the reward of investment [3,6,9]; and c) the evaluation of operational performance by the venture capital enterprises [8].

Two previous research methods frequently used on the relationship between attribute and financial performance of venture capital enterprises were the factor analysis and regression analysis methods. Multivariate statistical methods need a large number of data to analyze, and the distribution of the data must be the normal distribution. However, normally, it is difficult to obtain the interior data from the venture capital enterprises. Therefore, traditional multivariate statistical methods could have a hard time obtaining a persuasive explanation. According to what was mentioned above, multi-attribute method may be used to solve the problem [1,14]. This study proposes Deng' method [4] to supplement the limitations of using traditional statistic methods. The grey system theory has been extensively applied on many fields, such as financial institutions, advertising agencies, management [7,10,11,15], etc.

This study tried to achieve the following purposes: a) to use six financial indicators to classify twenty items of financial ratios as research variables through the Globalization Grey Relational Analysis (GRA) to extract the significant financial ratio variables and financial indicators which affect the financial performance of venture capital in Taiwan; b) to apply Grey Decision-Making to evaluate financial performance in the sampled enterprises and arrange them into order; and c) to employ GM(0, N) model to analyze different company attributes, which influence the financial performance among enterprises.

2. Research design

2.1. Research variables

2.1.1. Financial ratio variables

Six financial indicators are conducted as the research structure, and each corresponding financial ratio item is the measuring variable. The variable code definitions are as follows:

i. The ability of pay short-term debt: current ratio (X_1), quick ratio (X_2), and cash ratio (X_3);
ii. The cash flow: cash-flow ratio (X_4), and cash reinvestment ratio (X_5);
iii. The capital structure: debt to total assets ratio (X_6), debt to net value ratio (X_7), long-term investment to total assets ratio (X_8);
iv. The profitability: the ratio of returns on total assets after taxes (X_9), the ratio of return on equity after taxes (X_{10}), operating income to total assets ratio (X_{11}), income before taxes to total assets ratio (X_{12}), and gross profit ratio (X_{13});
v. The growth rate: total assets growth rate (X_{14}), operating income growth rate (X_{15}), and net income growth rate (X_{16});
vi. The operating efficiency on assets: operating revenues to total assets ratio (X_{17}), operating revenues to net value ratio (X_{18}), operating revenues to long-term investment ratio (X_{19}), operating revenues to current assets ratio (X_{20}) (Table 1).

2.1.2. Company attribute variables

Six selected attribute variables of venture capital enterprises were used in this study, and the variable code definitions are as follows: capital (Y_2), company founded years (Y_3), the type of financial funding management (Y_4), the total number of investment companies (Y_5), the total number of companies which invest abroad (Y_6), and the ratio of companies which invest abroad (Y_7).

3. Methodology

3.1. Basic model of Grey Relational Analysis (GRA)

The GRA is a quantitative analysis to explore the similarity and dissimilarity among factors in developing dynamic process [4]. The theory proposes a dependence to measure the correlation degree of factors; the more similarities develop, the more factors correlate. It uses the grey relational grade to measure the relational degree of factors. The related methods and theories of the GRA are described in the following:

3.1.1. The basic model of grey systems theory

The original series formed by $P(X)$ is:

$$x_i = ((x_i(1), x_i(2), x_i(3), \cdots, x_i(k)) \in X \quad (1)$$

where: $k=0,1,2,3,\cdots,\ n \in N$, $i=0,1,2,3,\cdots,\ m \in X$.

Before calculating the grey relational grade, we must perform data pre-processing [5]. This step is called "grey relational generating". Therefore, the series data can be treated with the following three situations and the

Table 1
The synthetic effect weighting of three years (takes mean)

	Synthetic effect weighting	Year 2001	Year 2002	Year 2003	Total period	Rank
X_1	Current ratio	0.2297	0.2283	0.2180	0.2253	10
X_2	Quick ratio	0.2298	0.2283	0.2179	0.2253	10
X_3	Cash ratio	0.2003	0.1953	0.2145	0.2034	16
X_4	Cash-flow ratio	0.2026	0.1783	0.2109	0.1973	19
X_5	Cash reinvestment ratio	0.2102	0.2249	0.2222	0.2191	14
X_6	Debt to total assets ratio	0.2014	0.1871	0.2086	0.1990	18
X_7	Debt to net value ratio	0.2001	0.1942	0.2084	0.2009	17
X_8	Long-term investment to total assets ratio	0.2132	0.2034	0.2089	0.2085	15
X_9	The ratio of returns on total assets after taxes	0.2321	0.2427	0.2400	0.2383	7
X_{10}	The ratio of return on equity after taxes	0.2338	0.2437	0.2400	0.2392	6
X_{11}	Operating income to total assets ratio	0.2375	0.2479	0.2342	0.2399	5
X_{12}	Income before taxes to total assets ratio	0.2382	0.2474	0.2376	0.2411	4
X_{13}	Gross profit ratio	0.1994	0.1732	0.2146	0.1957	20
X_{14}	Total assets growth rate	0.2249	0.2328	0.2273	0.2283	8
X_{15}	Operating income growth rate,	0.2263	0.2222	0.2145	0.2210	13
X_{16}	Net income growth rate	0.2364	0.2309	0.2067	0.2247	12
X_{17}	Operating revenues to total assets ratio	0.2380	0.2448	0.2413	0.2414	3
X_{18}	Operating revenues to net value ratio	0.2380	0.2446	0.2418	0.2415	2
X_{19}	Operating revenues to long-term investment ratio	0.2391	0.2470	0.2405	0.2422	1
X_{20}	Operating revenues to current assets ratio	0.2312	0.2294	0.2168	0.2258	9

linearity of normalization to avoid distorting the normalized data.

There are three regimes [17]:

i. If the expectancy is larger-the-better (e.g., the benefit), then it can be expressed by

$$x_i^*(k) = \frac{x_i^{(0)}(k) - \min.x_i^{(0)}(k)}{\max.x_i^{(0)}(k) - \min.x_i^{(0)}(k)} \tag{2}$$

ii. If the expectancy is smaller-the-better (e.g., the cost and defects), then it can be expressed by

$$x_i^*(k) = \frac{\max.x_i^{(0)}(k) - x_i^{(0)}(k)}{\max.x_i^{(0)}(k) - \min.x_i^{(0)}(k)} \tag{3}$$

iii. If the expectancy is nominal-the-better (e.g., the age), and when the targeted value is

$$x_i^*(k) = 1 - \frac{|x_i^{(0)}(k) - \mathrm{OB}|}{\max.\{\max.[x_i^{(0)}(k)] - \mathrm{OB}, \mathrm{OB} - \min.[x_i^{(0)}(k)]\}} \tag{4}$$

where:

(i) $x_i^*(k)$: The value of grey relation.
(ii) $\min.x_i^{(0)}(k)$: $x_i^{(0)}$ The minimum value.
(iii) $\max.x_i^{(0)}(k)$: $x_i^{(0)}$ The maximum value.
(iv) OB: $x_i^{(0)}(k)$ object value.

3.1.2. Grey relational grade

In the grey relational space, $\{P(X);\Gamma\}$, the sequence $x_i=((x_i(1), x_i(2), x_i(3),\ldots, x_i(k))\in X$ exists, the grey relation coefficient are $\gamma(x_i(k),x_j(k))$ and described in the following:

3.1.2.1. Partial analysis: When there is only a sequence $x_0(k)$ to be the referable sequence and the others are comparable sequence, the definition of the grey relational grade is as follows:

The grey relational grade[19]

$$\Gamma_{0i} = \Gamma(x_0(k), x_i(k)) = \frac{\bar{\Delta}_{\max.} - \bar{\Delta}_{0i}}{\bar{\Delta}_{\max.} - \bar{\Delta}_{\min.}} \tag{5}$$

where:

(i) x_0 represents referable sequence, x_i represents comparable sequence.
(ii) $\bar{\Delta}_{0i} = ||x_{0i}||_\rho = \left(\sum_{k=1}^n [\Delta_{0i}(k)]^2\right)^{\frac{1}{2}}$.
(iii) $\Delta_{0i}=\|x_0(k)-x(k)\|$: The (k) difference's absolute value between x_0 and x_i.
(iv) $\Delta_{\min.} = \forall_{j\in i}^{\min} \forall^{\min} k\|x_0(k)-x_i(k)\|$.
(v) $\Delta_{\max.} = \forall_{j\in i}^{\max} \forall^{\max} k\|x_0(k)-x_i(k)\|$.

3.1.2.2. Globalization Grey Relational Analysis: When sequences, $x_i(k)$, could be the referable sequence and others are the comparable sequences, the definition of the grey relational grade is as follows:

If $\Gamma_{ij} = \Gamma(x_i, x_j) = 1 - \frac{\bar{\Delta}_{ij}}{\Delta_{\max.}}$, then it could get $m\times m$ grey relational grades $r(x_i, x_j)$. After putting all of the grey relational grades in order, then we can get an $m\times m$ matrix; it's called "grey relational matrix R" as follows:

$$R = \begin{bmatrix} \Gamma_{11} & \Gamma_{12} & \ldots & \Gamma_{1m} \\ \Gamma_{21} & \Gamma_{22} & \ldots & \Gamma_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \Gamma_{m1} & \Gamma_{m2} & \ldots & \Gamma_{mm} \end{bmatrix} \tag{6}$$

After getting the matrix model, every element is the weighting of grey relational grade and the method of getting weighting is as follows:

a) Build the grey relational matrix R.
b) Calculate the characteristic weighting of the grey relational matrix R.
c) Calculate the characteristic vector quantity P as $P^{-1}RP=\text{diag}\{\lambda_1,\lambda_2,\cdots,\lambda_m\}$.
d) Choose the largest characteristic vector corresponding to the largest value $\lambda_{\max}$, and the value $\lambda_{\max}$ is the weighting.

The weighting in terms of grey relational matrix could explain the significant evaluation in a system, this study applied globalization GRA to evaluate the relationship between attributes and financial performance of venture capital enterprises and to rank the influence degree. According to the result, the significant financial variables were selected to evaluate the financial performance of venture capital enterprises through Grey Decision-Making. Finally, each company's financial performance was ranked.

3.2. The model of Grey Decision-Making (GDM)

The main points of GDM are the following: "when it comes up Event (A), Strategy (B) is used to deal with", is called "Situation, S". While choosing the best strategy to deal with the events, it's called Decision-Making.

a) Situation:
If a_i is the event and b_j is the strategy, $S_{ij}=(a_i,b_j)$ is the situation using j strategies to deal with i events.
b) Effect weighting:
Make $S_{ij}=(a_i,b_j)$ to be the situation, and P to be the target. The effect sample of strategy "b_j" is as "u_{ij}^p". Make M to be mapping, then we could get $M(u_{ij}^p)=r_{ij}^p$ and X^+ is the positive space. If M is satisfied with
i. $M(u_{ij}^p)=r_{ij}^p\in r^p\Rightarrow r_{ij}^p\in[0,1]$
ii. $r_{ij}^p\in X^+$
then M is called the mapping of effect measure. There are three types as in the following:
c) Upper Effect Measure (The maximum better)

$$r_{ij}^p=\frac{u_{ij}^p}{u_{\max}},\; u_{\max}=\max.\max.\{u_{ij}^p\} \tag{7}$$

where: $i=1,2,3,\cdots,n$; $j=1,2,3,\cdots,m$.
In above formula u_{ij}^p is situation "S_{ij} "'s effect weighting; $u_{\max.}$ is the maximum effect weighting of situation "S_{ij}", and $0\le r_{ij}^p\le 1$.

d) Lower Effect Measure (The minimum better)

$$r_{ij}^p=\frac{u_{ij}^p}{u_{\min}},\; u_{\min}=\min.\min.\{u_{ij}^p\} \tag{8}$$

where: $i=1,2,3,\cdots,n$; $j=1,2,3,\cdots,m$.
In the above formula u_{ij}^p is situation "S_{ij} "'s effect weighting; $u_{\min.}$ is the minimum effect weighting of situation "S_{ij}", and $0\le r_{ij}^p\le 1$.
e) Medium Effect Measure (The nominal effect)

$$r_{ij}^p=\frac{\min.\{u_{ij}^p,u_0\}}{\max.\{u_{ij}^p,u_0\}} \tag{9}$$

where: $i=1,2,3,\ldots,n$; $j=1,2,3,\ldots,m$.
In the above formula u_0 is the nominal effect weighting of effect sample "u_{ij}^p".

3.3. GM(0, N) model

The formula of GM(0, N) is defined as follows:

$$a_1z_1^{(1)}(k)=\sum_{j=2}^{N}b_jx_j^{(1)}(k)=b_2x_2^{(1)}(k)+b_3x_3^{(1)}(k)+\cdots+b_Nx_N(k) \tag{10}$$

where $z_1^{(1)}(k)=0.5x_1^{(1)}(k-1)+0.5x_1^{(1)}(k)$ $k=2,3,4,\cdots,n$ and put it into each weighting of (A). Then, we have the following:

$$\begin{aligned}a_1z^{(1)}(2)&=b_2x_2^{(1)}(2)+\cdots+b_Nx_N^{(1)}(2)\\a_1z^{(1)}(3)&=b_2x_2^{(1)}(3)+\cdots+b_Nx_N^{(1)}(3)\\&\cdots\cdots\cdots\\a_1z^{(1)}(n)&=b_2x_2^{(1)}(n)+\cdots+b_Nx_N^{(1)}(n)\end{aligned} \tag{11}$$

Then divide the above formulas by a_1, and transform them into matrix style.

$$\begin{bmatrix}0.5x_1^{(1)}(1)+0.5x_1^{(1)}(2)\\0.5x_1^{(1)}(2)+0.5x_1^{(1)}(3)\\\vdots\\0.5x_1^{(1)}(n-1)+0.5x_1^{(1)}(n)\end{bmatrix}=\begin{bmatrix}x_2^{(1)}(2)\cdots x_N^{(1)}(2)\\x_2^{(1)}(3)\cdots x_N^{(1)}(3)\\\vdots\\x_2^{(1)}(n)\cdots x_n^{(1)}(n)\end{bmatrix}\begin{bmatrix}\frac{b_2}{a_1}\\\frac{b_3}{a_1}\\\vdots\\\frac{b_N}{a_1}\end{bmatrix} \tag{12}$$

Let $\frac{b_j}{a_j}=\hat{b}_m, m=2,3,4,\ldots,N$, then Eq. (12) can be rearranged as

$$\begin{bmatrix} 0.5x_1^{(1)}(1)+0.5x_1^{(1)}(2) \\ 0.5x_1^{(1)}(2)+0.5x_1^{(1)}(3) \\ \vdots \\ 0.5x_1^{(1)}(n-1)+0.5x_1^{(1)}(n) \end{bmatrix} = \begin{bmatrix} x_2^{(1)}(2)\cdots x_N^{(1)}(2) \\ x_2^{(1)}(3)\cdots x_N^{(1)}(3) \\ \vdots \\ x_2^{(1)}(n)\cdots x_N^{(1)}(n) \end{bmatrix} \begin{bmatrix} \hat{b}_2 \\ \hat{b}_3 \\ \vdots \\ \hat{b}_N \end{bmatrix}$$

Now we use the formula $\hat{B}=(Y^TY)^{-1}Y^TX$ to find the weighting of a_1 and b_j, j=2,3,4,..., N, where

$$X=\begin{bmatrix} 0.5x_1^{(1)}(1)+0.5x_1^{(1)}(2) \\ 0.5x_1^{(1)}(2)+0.5x_1^{(1)}(3) \\ \vdots \\ 0.5x_1^{(1)}(n-1)+0.5x_1^{(1)}(n) \end{bmatrix}, Y=\begin{bmatrix} x_2^{(1)}(2)\cdots x_N^{(1)}(2) \\ x_2^{(1)}(3)\cdots x_N^{(1)}(3) \\ \vdots \\ x_2^{(1)}(n)\cdots x_N^{(1)}(n) \end{bmatrix},$$

$$B=\begin{bmatrix} \hat{b}_2 \\ \hat{b}_3 \\ \vdots \\ \hat{b}_N \end{bmatrix} \tag{13}$$

Through the matrix to use B to find out the result of $\hat{b}_m$, the weighting of $\hat{b}_m$ also means the degree of comparative sequences to normality sequences. This study utilized GM(0, N) model to explore the relationship between company's financial performance and attributes in order to understand which attributes could affect financial performance most.

4. Application

4.1. Sample collection

Through data collection, this study chose the top 20 venture capital enterprises of Taiwan. They all have complete financial data from 2001 to 2003, such as: Jih-Hsu, Te-An, Te-Pang, Ta-Ya, Hui-Hua, Chien Kung, Fu Pang, Shou His, Shuang Sheng , Hsu Yang, Ou Hua, I Ting, Han Tung, Chuan Chiu, Chia Cheng, Hsu Hsu, Sheng Hua, Pao Tung, Hung Cheng, and Ching Ying.

4.2. Using globalization GRA to analyze the financial ratio variables

The calculating course of GRA is as follows:

a) Firstly, to measure the effect between the financial ratio variables and the financial performance of venture capital enterprises.
b) Data pre-processing: before calculating the grey relational grade, we have to perform data pre-processing in order to make sure how to deal with each variable data. The chosen twenty financial ratio variables, except the variables of "debt to total assets ratio" (X_6), and "debt to net value ratio" (X_7) using the expectancy are smaller-the-better effect, are larger-the-better effect.
c) Input the twenty financial ratio variables of each year into Matlab toolbox and calculate the grey relation coefficient by using the globalization GRA method [19]. Then we could get a 20×20's grey relational matrix (please see the Appendices A B C).
d) Apply MALAB software to calculate the weighing λ of grey relational matrix and the corresponding characteristic vector of largest weighting. The characteristic vector is considered as weighting of each variable. This study tried to transfer the original eigen-vectors into the normalization state Z, and then use logic switching method to transfer value Z to a fractional number. The formula of logic switching method is as follows:

$$Y_i = 1/(1+e^{-f_i})\times 100 \tag{14}$$

where:
(i) Y_i = The fractional number
(ii) f_i = The value after normalizing
(iii) i = Period.
e) After adding the average financial ratio variables, we could get the top ten financial ratio variables affecting the operating performance as follows: the ratio of returns on equities after taxes (X_{10}), the ratio of returns on total assets after taxes (X_9), income before taxes to total assets ratio (X_{12}), operating income to total assets ratio (X_{11}), net income growth rate (X_{16}), operating income growth rate (X_{15}), total assets growth rate (X_{14}), current ratio (X_1), quick ratio (X_2) and debt to net value ratio (X_7).

After getting the effect of corporate attribute to financial performance, the financial indexes are arranged in order from high to low as follows: "the profitability", "the operating efficiency on assets", "the ability of paying short-term debt", "the growth rate", "the cash flow" and "the capital structure". The result shows that "the profitability", "the operating efficiency on assets" and "the ability of paying short-term debt" in these six financial indicators could reflect the financial performance ability of venture capital enterprises.

4.3. Applying GDM to analyze the venture capital enterprises' financial performance

After finishing the above calculations, we could find six financial ability indicators, which affect venture capital enterprises most. Next, it is to apply the six financial ability indicators with financial ratios through GDM to arrange the order of 20 venture capital enterprises.

The calculating course of GDM is as follows: The selecting criterion of financial ratio variables must be higher than the total average value (50.40435). Therefore, to fit in with the criterion of financial variables they are “current ratio” (X_1), “quick ratio” (X_2), “cash reinvestment ratio” (X_5), and “the ratio of returns on total assets after taxes” (X_9).

4.4. The measure of influence on the financial performance due to company's attribute

The study used GDM to get the average value of the synthetic effect weighting by each year and representing the financial performance of sample enterprises. Put the six company’s attribute variables: capital (Y_2), founded years (Y_3), the type of funding management (Y_4), the total number of investment companies (Y_5), the total number of companies which invest abroad (Y_6), the ratio of companies which invest abroad (Y_7) to GM(0, N) tool box [16,13]. After calculation, we can explore the relationship between attributes and financial performance of venture capital enterprises. The result is shown in Table 2.

From Table 2, it is found that the attributes of Y_7 “the ratio of companies which invest abroad” affect the financial performance the most (0.5373). The rest of other sequences are: (Y_3), 0.0123, founded years; (Y_6), 0.0101, the total number of companies which invest abroad; (Y_4), 0.0077, the total number of investment companies; (Y_2), 0.0070, the total number of investment companies; and (Y_5), 0.0063, the type of funding management.

Table 2
The effect of corporate attribute to financial performance

Attribute variables	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7
The $\lvert b_i \rvert$ value	0.0070	0.0123	0.0077	0.0063	0.0101	0.5373
Rank	5	2	4	6	3	1

5. Conclusions

This study used 6 financial indicators to classify twenty items of financial ratios as research variables through the globalization GRA to find the significant financial ratio variables and finanial indicators that affect the financial performance of venture capital enterprises from 2001 to 2003 in Taiwan, and it applied GDM to arrange the sampled enterprises of the total performance orderly (cardinal). The descriptions of research result are as follows:

1. By using globalization GRA the research result showed that the top 5 affect financial ratios of the 20 financial ratios are: operating revenues to long-term investment ratio (X_{19}), operating revenues to net value ratio (X_{18}), operating revenues to total assets ratio (X_{17}), income before taxes to total assets ratio (X_{12}), and operating income to total assets ratio (X_{11}). Therefore, to improve the financial performance it is suggested to increase the above-mentioned items.
2. According to the financial performance model through GDM, we can find that the higher weighting of synthetic effects shows the better financial performance of the venture capital enterprises. Thus, it could get a higher ranking.
3. The main purpose of the research not only manipulates GM(0, N) model to analyze the historical data but also aims to meet the accuracy of the mathematics of GM(0, N) model.

By using the GM(0, N) to explore influence degree of a company’s attributes that affect its financial performance, the result shows (Y_7) the ratio of companies which invest abroad > (Y_3), founded years > (Y_6), the total number of companies which invest abroad > (Y_4), the type of funding management > (Y_2), capital > (Y_5), and the total number of investment companies.

In conclusion, there is a significant relationship between attributes and financial performance of venture capital enterprises. Investors have to evaluate and understand the performance and attribute factors of venture capital enterprises to decrease the investment risks. The grey system theory is suitable for testing the relationship between attributes and financial performance of venture capital enterprises, and is the important method for investors to find out the more objective and successful investment target.

Appendix A. The variable of financial ratio in year 2001 (Grey relational grade matrix)

R=[1 0.992577 0.526493 0.481319 0.544937 0.504533 0.499713 0.600678 0.624583 0.633103 0.69885 0.684506 0.499833 0.62112 0.700584 0.655014 0.726732 0.724778 0.706797 0.739276;
0.99257 1 0.528875 0.483127 0.543857 0.507326 0.502493 0.599813 0.624129 0.632818 0.697965 0.683739 0.499397 0.626277 0.698963 0.655809 0.725476 0.723522 0.705071 0.737751;
0.526458 0.52884 1 0.689662 0.579438 0.798575 0.807523 0.619176 0.502095 0.496424 0.483611 0.484109 0.737808 0.566571 0.476851 0.489238 0.496793 0.495215 0.490956 0.485739;
0.481319 0.483127 0.689691 1 0.729107 0.748065 0.755964 0.598424 0.591959 0.577737 0.520727 0.531185 0.763089 0.520883 0.522309 0.539727 0.454804 0.455272 0.474162 0.441158;
0.544837 0.543857 0.579477 0.729107 1 0.657872 0.648961 0.630464 0.708866 0.697566 0.60434 0.62544 0.620421 0.56032 0.530703 0.614808 0.481016 0.481599 0.503596 0.465111;
0.504533 0.507326 0.798597 0.748056 0.657872 1 0.974827 0.634856 0.532254 0.517594 0.458558 0.469087 0.75619 0.555523 0.48083 0.506831 0.439345 0.438574 0.436989 0.44204;
0.499713 0.502493 0.807543 0.755964 0.648961 0.974827 1 0.630254 0.521921 0.507907 0.451041 0.461302 0.767798 0.547877 0.47934 0.499854 0.434701 0.433921 0.432019 0.437808;
0.600678 0.599813 0.619212 0.598424 0.630464 0.634856 0.630254 1 0.621617 0.621166 0.59665 0.61352 0.56851 0.59962 0.52437 0.6333 0.5696 0.56869 0.55542 0.57938;
0.624583 0.624129 0.502136 0.591959 0.708866 0.532254 0.521921 0.621617 1 0.959618 0.77472 0.82278 0.55444 0.61819 0.59645 0.79275 0.61929 0.61962 0.64681 0.59198;
0.633103 0.632818 0.496465 0.577737 0.697566 0.517594 0.507907 0.621166 0.959618 1 0.797718 0.8506 0.54392 0.62338 0.60597 0.80549 0.63419 0.63451 0.66294 0.60527;
0.69885 0.697965 0.48365 0.520727 0.604434 0.458558 0.451041 0.59665 0.774715 0.797175 1 0.91129 0.5092 0.63664 0.6899 0.76987 0.74292 0.74295 0.77353 0.70728;
0.684506 0.683739 0.484149 0.531185 0.62544 0.469087 0.461302 0.613522 0.822775 0.8506 0.91129 1 0.51134 0.6459 0.66342 0.80601 0.7138 0.71407 0.7448 0.67649;
0.499833 0.499397 0.737832 0.763089 0.620421 0.75619 0.767798 0.568514 0.554439 0.543916 0.5092 0.51134 1 0.51908 0.49643 0.53678 0.45414 0.45451 0.4696 0.44252;
0.624112 0.626277 0.5666606 0.520883 0.56032 0.555523 0.547877 0.599615 0.618189 0.623383 0.63664 0.6459 0.51908 1 0.67873 0.68194 0.73332 0.73415 0.74285 0.71686;
0.700584 0.698963 0.476886 0.522309 0.530703 0.48083 0.47934 0.524369 0.59645 0.605973 0.6899 0.66342 0.49643 0.67873 1 0.65838 0.78609 0.78644 0.78222 0.8031;
0.655014 0.655809 0.489277 0.539727 0.614808 0.506831 0.499584 0.633303 0.792752 0.805492 0.76987 0.80601 0.53678 0.68194 0.65838 1 0.72441 0.72498 0.7595 0.68135;
0.726732 0.725476 0.496829 0.454804 0.481016 0.439345 0.434701 0.569599 0.61929 0.634187 0.74292 0.7138 0.45414 0.73332 0.78609 0.72441 1 0.99585 0.9394 0.89166;
0.724778 0.723522 0.49525 0.455272 0.481599 0.438574 0.433921 0.568689 0.619617 0.634508 0.74295 0.71407 0.45451 0.73415 0.78644 0.72498 0.99585 1 0.94008 0.89132;
0.706797 0.705071 0.490993 0.474162 0.503596 0.436989 0.432019 0.555422 0.64681 0.662644 0.77353 0.7448 0.4696 0.74285 0.78222 0.7595 0.9394 0.944008 1 0.85512;
0.739276 0.737751 0.485774 0.441158 0.465111 0.44204 0.437808 0.579382 0.59198 0.605271 0.70728 0.67649 0.44252 0.71686 0.8031 0.68135 0.89166 0.89132 0.85512 1]

According to the GGRG method, the maximum lambda=12.9079, hence, eigen-vector for each factor is

0.2297 0.2298 0.2003 0.2026 0.2102 0.2014 0.2001 0.2132 0.2321 0.2338
0.2375 0.2382 0.1994 0.2249 0.2263 0.2364 0.2380 0.2380 0.2391 0.2312

Appendix B. The variable of financial ratio in year 2002 (Grey relational grade matrix)

R=[1 0.999518 0.513439 0.409082 0.626202 0.493782 0.519616 0.541608 0.666205 0.671175 0.720508 0.720256 0.343504 0.719424 0.753262 0.860231 0.659665 0.661483 0.69595 0.845916;
0.999518 1 0.513414 0.409216 0.626439 0.493781 0.519609 0.54161 0.666367 0.671333 0.720669 0.720385 0.343495 0.71941 0.753306 0.860434 0.659814 0.66163 0.696097 0.846233;
0.513439 0.513414 1 0.673829 0.530895 0.728151 0.643444 0.603575 0.579708 0.575204 0.540319 0.545629 0.692242 0.589545 0.552471 0.490825 0.53957 0.529652 0.533478 0.475477;
0.409082 0.409216 0.673829 1 0.521593 0.691521 0.645819 0.604195 0.50286 0.499945 0.479499 0.477454 0.839919 0.439401 0.426626 0.418681 0.502389 0.504076 0.48684 0.410932;
0.626202 0.626439 0.530895 0.521593 1 0.495269 0.54277 0.615813 0.752094 0.756613 0.788154 0.76389 0.472007 0.638482 0.555662 0.609069 0.773043 0.778867 0.781909 0.626224;
0.493782 0.493781 0.728151 0.691521 0.495269 1 0.778447 0.721165 0.501928 0.499268 0.473147 0.468781 0.710976 0.496513 0.491994 0.462621 0.500361 0.491077 0.479651 0.477831;
0.519616 0.519609 0.643444 0.645819 0.54277 0.778447 1 0.739617 0.535207 0.531252 0.516874 0.514664 0.592104 0.536559 0.523761 0.525248 0.553891 0.540606 0.525767 0.506084;
0.541608 0.54161 0.603575 0.604195 0.615813 0.721165 0.739617 1 0.588384 0.589457 0.571579 0.568174 0.598477 0.560013 0.566867 0.550117 0.58781 0.583612 0.576939 0.563624;
0.666205 0.666367 0.579708 0.50286 0.752094 0.501928 0.535207 0.588384 1 0.983761 0.864379 0.884271 0.476141 0.724149 0.646484 0.674905 0.844175 0.840185 0.839319 0.658576;
0.671175 0.671333 0.575204 0.499945 0.756613 0.499268 0.531252 0.589457 0.983761 1 0.873309 0.89353 0.473758 0.726905 0.651006 0.680688 0.849663 0.845818 0.843468 0.663139;
0.720508 0.720669 0.540319 0.479499 0.788154 0.473147 0.516874 0.571579 0.864379 0.873309 1 0.939515 0.460888 0.760086 0.682556 0.731863 0.869709 0.87453 0.9055875 0.722404;
0.720256 0.720385 0.545629 0.477454 0.76389 0.468781 0.514664 0.568174 0.884271 0.89353 0.939515 1 0.455118 0.755671 0.691262 0.733734 0.864257 0.866763 0.893466 0.709652;
0.343504 0.343495 0.692242 0.839919 0.472007 0.710976 0.592104 0.598477 0.476141 0.473758 0.460888 0.455118 1 0.458442 0.509399 0.406284 0.476557 0.478533 0.464311 0.41117;
0.719424 0.71941 0.589545 0.439401 0.638482 0.496513 0.536559 0.560013 0.724149 0.726905 0.760086 0.755671 0.458442 1 0.768931 0.751826 0.756952 0.753262 0.783055 0.758172;
0.753262 0.753306 0.552471 0.426626 0.555622 0.491994 0.523761 0.566867 0.646484 0.651006 0.682556 0.691262 0.509399 0.768931 1 0.868242 0.625977 0.626465 0.651375 0.79568;
0.859917 0.860121 0.490057 0.417899 0.608294 0.461825 0.524467 0.549329 0.674223 0.67996 0.73129 0.733163 0.405537 0.751291 0.86801 1 0.678805 0.679401 0.708681 0.891757;
0.659665 0.659814 0.53957 0.502389 0.773043 0.500361 0.553891 0.58781 0.844175 0.849663 0.869709 0.864257 0.476557 0.756952 0.625977 0.679479 1 0.972886 0.922681 0.698644;

0.661483 0.66163 0.529652 0.504076 0.778867 0.491077 0.540606 0.583612 0.840185
0.845818 0.87453 0.866763 0.478533 0.753262 0.626465 0.680068 0.972886 1 0.933364
0.699484;
0.69595 0.696097 0.533478 0.48684 0.781909 0.479651 0.525767 0.576939 0.839319
0.843468 0.905875 0.893466 0.464311 0.783055 0.651375 0.709305 0.922681 0.93364 1
0.72392;
0.845916 0.846233 0.475477 0.410932 0.626224 0.477831 0.506084 0.563624 0.658576
0.663139 0.722404 0.709652 0.41117 0.758172 0.795568 0.891978 0.698644 0.699484
0.723792 1]

According to the GGRG method, the maximum lambda=13.3086, hence, eigen-vector for each factor is

0.2283 0.2283 0.1953 0.1783 0.2249 0.1871 0.1942 0.2034 0.2427 0.2437
0.2479 0.2474 0.1732 0.2328 0.2222 0.2309 0.2448 0.2446 0.2470 0.2294

Appendix C. The variable of financial ratio in year 2003 (Grey relational grade matrix)

R=[1 0.999024 0.554809 0.414906 0.576794 0.453044 0.450979 0.500445 0.588855 0.589904
0.608503 0.602322 0.467541 0.58212 0.925247 0.422331 0.64119 0.650451 0.656647
0.818325;
0.999024 1 0.555659 0.414729 0.577644 0.452917 0.450852 0.500292 0.588538 0.589581
0.608073 0.601961 0.46736 0.581622 0.926122 0.422205 0.64072 0.649961 0.656123
0.817528;
0.554809 0.555659 1 0.639938 0.659217 0.674943 0.676306 0.682725 0.56681 0.565426
0.566028 0.561916 0.584038 0.659835 0.548574 0.619039 0.569406 0.565099 0.564753
0.563936;
0.414906 0.414729 0.639938 1 0.651937 0.707853 0.711972 0.627126 0.599981 0.596948
0.546422 0.578953 0.754222 0.586909 0.393018 0.782722 0.571294 0.55862 0.578304
0.461624;
0.576794 0.577644 0.659217 0.651937 1 0.65087 0.648473 0.657958 0.577875 0.577763
0.600505 0.564873 0.63936 0.73736 0.577044 0.587425 0.638057 0.634931 0.63254
0.594978;
0.453044 0.452917 0.674943 0.707853 0.65087 1 0.987832 0.691949 0.53002 0.529328
0.494495 0.514659 0.7027 0.534529 0.435324 0.758993 0.524923 0.519304 0.513105
0.421149;
0.450979 0.450852 0.676306 0.711972 0.648473 0.987832 1 0.689463 0.53036 0.529643
0.492112 0.51201 0.706854 0.531284 0.433329 0.763 0.524077 0.5164 0.511662 0.419629;
0.500445 0.500292 0.682725 0.67126 0.657958 0.691949 0.689463 1 0.547834 0.546215
0.57821 0.532182 0.656127 0.61082 0.477951 0.664174 0.526232 0.524093 0.506209
0.520201;
0.588855 0.588538 0.566381 0.599981 0.577875 0.53002 0.53036 0.547834 1 0.990919
0.804715 0.907319 0.615041 0.695519 0.595626 0.558915 0.777856 0.784044 0.785015
0.602955;
0.589904 0.589581 0.565426 0.596948 0.577763 0.529328 0.529643 0.546215 0.990919 1
0.808727 0.91322 0.611595 0.692855 0.596446 0.556039 0.779845 0.785116 0.782617
0.604032;
0.608503 0.608073 0.566028 0.546422 0.600505 0.494495 0.492112 0.57821 0.804715
0.808727 1 0.84678 0.545973 0.698156 0.61268 0.502927 0.7834 0.791516 0.785986
0.647279;
0.602322 0.601961 0.561916 0.578953 0.564873 0.514659 0.51201 0.532182 0.907319
0.91322 0.84678 1 0.584413 0.668907 0.609194 0.537461 0.773156 0.780145 0.792958
0.62681;

0.467541 0.46736 0.584038 0.754222 0.63936 0.70727 0.706854 0.656127 0.615041 0.611595
0.545973 0.584413 1 0.621527 0.43776 0.793176 0.590296 0.576035 0.577964 0.448036;
0.582074 0.581576 0.659794 0.58686 0.737323 0.534479 0.531233 0.610775 0.695479
0.692814 0.698116 0.668863 0.621482 1 0.570883 0.551022 0.695352 0.699442 0.681211
0.608478;
0.925247 0.926122 0.548574 0.393018 0.577044 0.435324 0.433329 0.477951 0.595626
0.596446 0.61268 0.609194 0.434776 0.57093 1 0.405287 0.629079 0.639104 0.650742
0.837513;
0.422283 0.422158 0.618999 0.782692 0.58738 0.758961 0.762968 0.664135 0.558869
0.555992 0.502877 0.537414 0.793147 0.551022 0.405241 1 0.541678 0.530233 0.54178
0.426987;
0.64119 0.64072 0.569406 0.571294 0.638057 0.524923 0.524077 0.526232 0.777856
0.779845 0.7834 0.773156 0.590296 0.695392 0.629079 0.541725 1 0.966448 0.888699
0.658907;
0.650451 0.649961 0.565099 0.55862 0.634931 0.519304 0.5164 0.524093 0.784044 0.785116
0.791516 0.780142 0.576035 0.699481 0.639104 0.530281 0.966448 1 0.903548 0.670441;
0.656647 0.656123 0.564753 0.578304 0.63254 0.513105 0.511662 0.506209 0.785015
0.782617 0.785986 0.792958 0.577964 0.681251 0.650742 0.541825 0.88699 0.903548 1
0.671604;
0.818325 0.817528 0.563936 0.461624 0.594978 0.421149 0.419629 0.520201 0.602955
0.604032 0.647279 0.62681 0.448036 0.608523 0.837513 0.427034 0.658907 0.670441
0.671604 1]

According to the GGRG method, the maximum lambda=12.8439, hence, eigen-vector for each factor is

0.2180 0.2179 0.2145 0.2109 0.2222 0.2086 0.2084 0.2089 0.2400 0.2400
0.2342 0.2376 0.2146 0.2273 0.2145 0.2067 0.2413 0.2418 0.2405 0.2168

References

[1] Felix T.S. Chan, S.H. Chung, Multicriterion genetic optimization for due date assigned distribution network problems, Decision Support Systems 39 (4) (2005) 661–675.
[2] P.Y. Chen, The Determinant Factors of Operating Performance on Venture Capital Company in Taiwan, Master Thesis, Department of Economics, National Taipei University (2002).
[3] J.H. Cochrane, The risk and return of venture capital, Journal of Financial Economics 75 (1) (January 2005) 3–52.
[4] J.L. Deng, The introduction of grey system, Journal of Grey System 1 (1) (1989) 1–24.
[5] K.H. Hsia, M.Y. Chen, M.C. Chang, Comments on data preprocessing for Grey Relational Analysis, Journal of Grey System 7 (1) (2004) 15–20.
[6] R.M. Inderst, H.M. Muller, The effect of capital market characteristics on the value of start-up firms, Journal of Financial Economics 72 (2004) 319–356.
[7] C.Y. Kung, C.R. Cheng, Grey assessing the performance of enterprise outsourcing management, Journal of Grey System 16 (1) (2004) 63–72.
[8] Y.D. Lee, The Evaluation of Performance Model for The Venture Capital Company-Grey Relation Method Applied, Master Thesis, Department of Business Administration, Da-Yeh University, (2002).
[9] P.M. Lee, S. Wahal, Grandstanding, certification and the underpricing of venture capital backed IPOs, Journal of Financial Economics 73 (2004) 375–407.
[10] C.T. Lin, P.F. Hsu, Selection of advertising agencies using Grey Relational Analysis and analytic hierarchy process, Journal of International Marketing and Marketing Research 26 (3) (2001) 115–128.
[11] C.T. Lin, S.Y. Yang, Selection of Home mortgage loans using Grey Relational Analysis, Journal of Grey System 11 (4) (1999) 359–368.
[12] F.G. Liu, A Study on the Characteristic of Venture Capital Company and Operating Performance in Taiwan, Master Thesis, Institute of International Business, National Donghwa University (2001).
[13] S.F. Liu, Y. Lin, Grey Information, Springer, London, 2006.
[14] D. Schuff, O. Turetken, John D'Arcy, A multi-attribute, multi-weight clustering approach to managing "e-mail" overload, Decision Support Systems 42 (3) (2006) 1350–1365.
[15] Y.C. Tu, C.T. Lin, M.W. Fang, Application of Grey Relational Analysis to evaluating shopping mall projects in Taiwan, Journal of Grey System 13 (4) (2001) 68–77.
[16] K.L. Wen, Grey Systems Model and Prediction, Yang's Scientific Press, USA, 2004.
[17] J.H. Wu, C.B. Chen, An alternative form for grey relational grades, Journal of Grey System 11 (1) (1999) 7–12.

[18] B.T. Yen, A Study on the Relationship between Corporate Attributes and Financial Performance of Taiwanese Venture Capital, Master Thesis, Department of Accounting, National Cheng Kung University (1999).
[19] M.L. You, C.W. Wang, C.K. Yeh, The development of completed grey relational analysis toolbox via Matlab, Journal of Grey System 9 (1) (2006) 57–64.

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