Research on the Performance Evaluation of Innovative Method Training and Popularization in Zhejiang Province

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***Abstract*—In order to exam the innovative training and popularization effect in Zhejiang province, firstly we constructed an evaluation index system. It's from the perspective of performance and includes three big aspects of economic, technological and social profit. Then we applied AHP to determine the weight of each index. Next, we used a linear comprehensive evaluation model to calculate the application effect scores. After that, we simulated an example and applied the method of time series analysis to fit the sequence and predict scores with the aid of EViews. Finally we used a paired samples Wilcoxon signed-rank test to examine the remarkability of the training work. According to the analysis, we can draw a conclusion that the training and popularization effect is remarkable when the real annual growth rate of the effect score is 8.5% and we should continue to carry out this training method.**

Keywords-innovative training, performance evaluation, data simulation, time series analysis

I. INTRODUCTION

Recently, with the deepening of the implementation of national technology innovation project in China, enterprises' innovative activities are being increasingly active. Zhejiang province has started innovative training work in 2007, and has created a series of innovative training process and method step by step. It directly serves for enterprises to build innovative teams and cultivate innovative ability. According to "the twelfth five-year development plan of science and technology of Zhejiang province", our province shall first become an innovative province throughout the country in 2015. However considering the general condition, the technological innovative ability of enterprises is still weak, which mainly displays in lack of innovation talents which leads to the weak ability of independent R&D; shortage of R&D input and unreasonable allocation of resources which increases the difficulty of the promotion of innovative ability.

At this moment, innovative work is particularly important. By examining the early effect of the innovative training and popularization work, we can learn the performance and existing problems so as to put forward corresponding suggestions and countermeasures. There are many qualitative analysis over this problem, but few quantitative evaluation models. Therefore, to put up with a scientific performance evaluation method is of great importance. This article is based on the perspective of the enterprises' innovation performance to evaluate the training and popularization effect in Zhejiang province.

II. THE ESTABLISHMENT OF APPLICATION EFFECT EVALUATION INDEX SYSTEM

The training and popularization performance of enterprises is ultimately reflected upon their technological innovative achievements. To examine the early effect, we should evaluate the application effect of technological innovation. For enterprises' innovative achievements are broad and various, it's difficult to use a unified scale. In order to objectively and truly reflect and evaluate enterprises' achievements, generally we take economic profit, social profit, technological contribution and so on as factors of the evaluation. Given that the research subject of this article is innovative enterprises, we only consider economic profit, technological profit and social profit.

Innovative economic profit includes several intensity indexes such as "Share of new products", "Sales growth rate of new products", "Overall labor productivity" and "The annual growth rate of company's profits and tax" [5], combined with the quantity indexes like "Annual added sales revenue of new products" etc. This combination can avoid blocking the role of traditional non-innovative factors (like cheap labor force) which also contribute a lot to the company's growth. Economic profit is the most direct reflection of the application effect of innovative achievements.

Technological profit involves "Patents per thousand R&D staff" which can reflect the enterprises' independent innovative ability, "Technical standards per thousand developers" which refers to the numbers of enterprises carrying out or participating in setting the international,

national or provincial industry standards and so on [2, 5, 7], others are shown in TABLE I below. In the meantime, we should consider "New products" which is the direct technological effect.

Social profit, which includes the social reputation of enterprise and its brand, can be regarded as a comprehensive reflection on the effectiveness of the application. We use "The status of enterprise in the industry" and "Market share of new products" to measure the brand intensity. The social reputation of the enterprise can be reflected by "Customers' satisfaction" and "Employees' loyalty".

According to the above, we can draw the structure of the index system which is shown in TABLE I:

TABLE I. ENTERPRISE INNOVATIVE METHOD TRAINING AND APPLICATION EFFECT EVALUATION INDEX SYSTEM

First-level index	Second-level index	Symbol	Third-level index	Symbol
Innovative method training and application effect evaluation index system	Innovative economic profit	U_1	Share of new products	U_{11}
			Sales growth rate of new products	U_{12}
			Annual added sales revenue of new products	U_{13}
			The annual growth rate of company's profits and tax	U_{14}
			Overall labor productivity	U_{15}
			Annual R&D projects cost savings	U_{16}
	Innovative technological profit	U_2	Patents per thousand R&D staff	U_{21}
			Technical standards per thousand developers	U_{22}
			Technological innovative projects per thousand R&D staff	U_{23}
			Technological achievement awards	U_{24}
			New products	U_{25}
	Innovative social profit	U_3	The status of enterprise in the industry	U_{31}
			Market share of new products	U_{32}
			Employees' loyalty	U_{33}
			Customers' satisfaction	U_{34}

III. THE DETERMINATION OF THE INDEX WEIGHT OF THE EVALUATION INDEX SYSTEM

Considering the complexity of the evaluation index system, we adopt analytic hierarchy process (AHP) to calculate the corresponding weight of every index which is put forward by T. L. Saaty et al. in the 1970s in order to reducing the difficulty to compare different factors and improve the accuracy [3]. The main process of AHP includes three steps. First, we should build the paired comparison matrix. After we have built the matrix, we should test the consistency of it. The index we use is CR=CI/RI, in which CI=(λ_{max}-n)/(n-1) and the values of RI are shown in TABLE II, n is the number of indexes. If CR<0.10, it means the matrix is good, otherwise we should build a matrix again. Finally, we should calculate the maximum eigenvalue λ_{max} of the matrix and its corresponding eigenvector W. We can get the weight vector by unifying the eigenvector W.

TABLE II. VALUES OF RI

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Lin Yan gave "innovative technological output", "innovative economic profit" and "R&D ability" the weight ratio of 2:1:2 [4]; Yin et al gave "innovative technological profit", "technical innovation management" and "financial profit" and "social profit" these four indexes the weight ratio of 3:2:1:1 [6]; Chen Jin et al. gave "economic profit", "direct technical profit", "accumulated technical profit" the weight ratio of 3:3:2 [1]. In sum, we get the paired comparison matrix as below:

$$A_1 = \begin{pmatrix} 1 & 1/2 & 1 \\ 2 & 1 & 3 \\ 1 & 1/3 & 1 \end{pmatrix}$$

Use Matlab to test the consistency, we can get that CR_1=0.0176<0.1, which means that the matrix is good. Thus we can calculate the maximum eigenvalue λ_{1max} = 3.0183, with the corresponding eigenvector W_1= (0.3778, 0.8650, 0.3302), so the index weight vector w_1 is (0.2402, 0.5499, 0.2099). The weights of second-level and third-level indexes are shown in TABLE III below.

TABLE III. SECOND-LEVEL AND THIRD-LEVEL INDEX WEIGHTS

Second-level index	Weight	Third-level index	Weight
U_1	0.24	U_{11}	0.23
		U_{12}	0.20
		U_{13}	0.15
		U_{14}	0.11
		U_{15}	0.11
		U_{16}	0.20
U_2	0.55	U_{21}	0.23
		U_{22}	0.15
		U_{23}	0.12
		U_{24}	0.11
		U_{25}	0.39
U_3	0.21	U_{31}	0.29
		U_{32}	0.20
		U_{33}	0.17
		U_{34}	0.34

IV. SIMULATION AND ANALYSIS OF THE APPLICATION EFFECT EVALUATION

A. Data Processing

Zhejiang province officially carried out the innovative method training work in 2009, according to “the 253 innovative enterprises annual report of 2010”, we can get data which is corresponding to the evaluation index of 2008. We randomly choose ten innovative enterprises, and preprocess the data.

- It’s obviously unreasonable to add up all innovative achievements directly for there are different levels, so we use weighted summation. For “technical standards”, we set the weight of international hosting as 27, international participating and national presiding as 9, national participating and industry hosting as 3 and industrial participating as 1; similarly for “technological award”, set national as 9, provincial as 3 and others as 1. For “technological innovative project”, national is 3, provincial is 1, and for “patent”, the weight of patent of invention is 15, patent of utility model is 5 and design patent is 2.
- For “customer satisfactory”, “staff loyalty” and “The status of enterprise in the industry”, we obtain the value by questionnaire and then standardized it.
- There are different attribute, measurement unit and evaluation criteria, so it’s necessary to unify the dimension. Here we use min-max normalization, the standardized formula is:

$$x' = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{1}$$

x_{max}, x_{min} are the maximum and the minimum of a certain index respectively. Thus the original value can be mapped to the values in the [0, 1] interval.

B. Evaluation Simulating

According to the index weight table, we use the following linear comprehensive evaluation model to calculate the 2008’s scores of those 10 enterprises. x_{ij} is the j^{th} index of the i^{th} object, ω_j is j^{th} index’s weight, and y_i is the i^{th} object’s evaluation score:

$$y_i = \sum_{j=1}^{m} \omega_j x_{ij} \tag{2}$$

We assume that each innovative enterprise’s score grows by the annual growth rate which obeys the uniform distribution of 0.05 to 0.10. Use Matlab to generate the 10 enterprises’ annual growth rate from 2002 to 2007, and then simulate the score according to the 2008’s score. Following are the results:

TABLE IV. THE RANDOM ANNUAL GROWTH RATE OF EACH INNOVATIVE ENTERPRISE (%)

Enterprise	**Annual Growth Rate**					
	2002	***2003***	***2004***	***2005***	***2006***	***2007***
1	9.07	5.79	8.28	8.53	7.19	6.38
2	9.53	9.85	5.18	5.16	6.91	8.40
…	…	…	…	…	…	…
9	9.79	8.96	8.28	9.75	8.55	7.93
10	9.82	9.80	5.86	5.17	8.77	6.12

TABLE V. THE APPLICATION EFFECT EVALUATION SCORE FROM 2002 TO 2008 (100 TIMES EXPANDED)

Enterprise	**Application Effect Evaluation Score**						
	2002	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***
1	13.16	14.35	15.19	16.44	17.85	19.13	20.35
2	8.45	9.26	10.17	10.70	11.25	12.03	13.04
…	…	…	…	…	…	…	…
9	8.60	9.44	10.28	11.13	12.22	13.26	14.32
10	10.49	11.52	12.64	13.38	14.08	15.31	16.25

C. Results Analyzing

Because the innovative training effect has certain hysteresis, we build the time series model to analyze and forecast the evaluation values from 2010 to 2012 without the effect of training work using the comprehensive score sequence from 2002 to 2008. We apply both trend and stochastic analysis of the non-stationary sequence after testing the stationarity of the series and compare different models. Take enterprise 1 for example:

TABLE VI. NONSTATIONARY SEQUENCE MODELCOMPARISON

Model		**Parameters’ remarkability**	R^2	**AIC**	$D.W$
Trend	***Linear***	remarkable	0.996	-0.434	1.255
	Quadratic	remarkable	0.996	-0.456	1.269
	exponential	remarkable	0.998	-6.68	2.507
Stochastic	***ARIMA(0,1,1)***	remarkable	0.426	-0.515	1.09

According to the TABLE VI, we choose the exponential model to fit and forecast, the results are shown in the figures below:

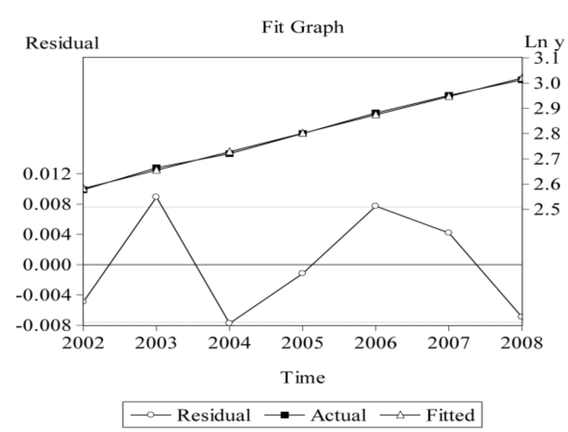

Figure 1. sequence comparison and residual diagram

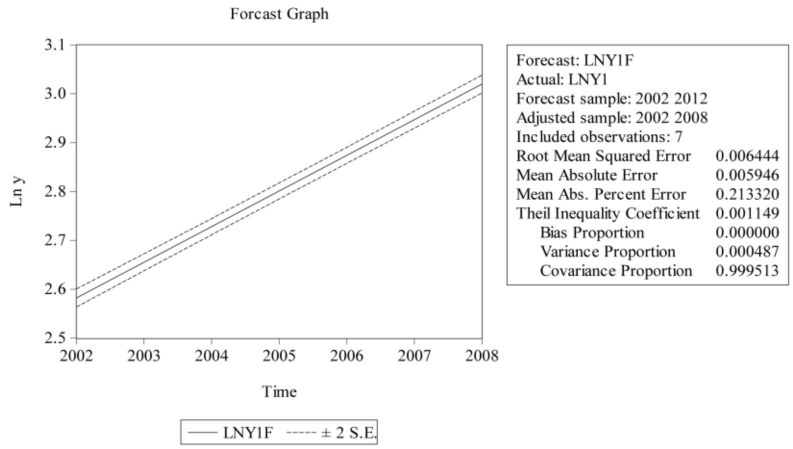

Figure 2. application effect evaluation score prediction result

According to the results, the fitting expression of enterprise 1 is y=exp(0.073t–143.495), and the prediction results of 2010 to 2012 are 23.71004, 25.50473 and 27.43527 (t means time). Similarly, we can get the most suitable model for other 9 innovative enterprises. Among them enterprises 3, 4, 6, 7 and 9 adopt exponential model from which we can infer that these enterprises are in rapid development. Enterprise 5 adopts linear model which may results from its declining innovation performance growth, and the expression is y=0.594t–1182.481 (t means time). For enterprises 2, 8 and 10, all those models can't fit the sequence very well, so we adopt exponential smoothing model. According to experience that when the smoothing coefficients are between 0.05 and 0.3, the fitting can be regarded as good. For example, the enterprise 2's fitting expression is $\tilde{y}_t = 0.14y_t + 0.86\tilde{y}_{t-1}$, $\tilde{y}_0 = y_1$ (t means time). All the predicted scores are as follows:

TABLE VII. THE PREDICTED SCORES OF THE ENTERPRISE FROM 2010 TO 2012(100 TIMES EXPANDED)

Enterprise	Scores		
	2010	***2011***	***2012***
1	23.710	25.505	27.435
2	14.476	15.232	15.989
3	16.506	17.852	19.308
4	23.781	25.626	27.613
5	11.459	12.053	12.647
6	28.909	31.097	33.451
7	21.068	22.748	24.562
8	31.495	33.153	34.811
9	17.080	18.598	20.250
10	18.215	19.185	20.156

Finally, we test the overall significance of the effect in Zhejiang province. Take the year of 2010 for example, assume that the annual growth rate of the score after the training work is α. Make α varies from 6% to 9%, use SPSS to test the paired samples' p-value, the results are shown in Fig. 3 below:

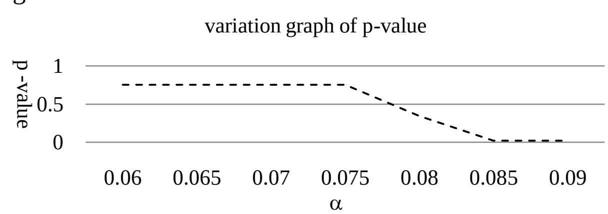

Figure 3. p-value varies by the annual growth rate α

Fig. 3 illustrates that when the annual growth rate is around 8.5%, we can draw the conclusion that the innovative training work's application effect is remarkable.

V. CONCLUSION AND SUGGESTIONS

According to our hypothesis, the average annual growth rate without training is 7.5%, and the results show that when the average annual growth rate with training is 8.5%, we can accept that the training effect is remarkable. So we can't easily negate the performance of present training work without evaluating objectively and comprehensively. Of course we must point out that due to the idealization of data simulation assumptions, the above examining analysis is just as an example to reference. Based on the analysis, here we put forward some suggestions:

- Strengthen the training and development of the R&D personnel to improve enterprise's independent R&D ability from the source.
- Apply innovative achievements into reality to improve the transformation efficiency of innovative achievements.
- Increase R&D investment and at the same time pay attention to the rational allocation of resources to improve the efficiency of enterprises' training work.

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