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EVALUATING INNOVATION CAPABILITIES FOR SCIENCE PARKS: A SYSTEM MODEL

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Abstract. Science parks have played an important role in promoting innovation, entrepreneurship, growth of knowledge-based companies and in turn economic growth within their regions. In this paper, an evaluation system for measuring innovation capability for science parks has been developed, including Innovation Organization Sub-System (IOSS, mainly for high-tech firms), Innovation Support Sub-System (ISSS, e.g., technology intermediaries) and Innovation Environmental Sub-Systems (IESS). Based on the empirical study on Qingdao Science Park (1994-2008), this paper has demonstrated the use of the system for evaluation and measurement of innovation capabilities for a science park. The findings reveal that the evolution law explained by the evaluation system fitted with three components is consistent with the actual evolution process of the Qingdao Science Park. It confirms that this evaluation system bears a good explanatory power for the development of Science Park. In addition, recommendations to improve the capabilities of continuous innovation for science parks are also given.

Keywords: innovation, innovation capability, science parks, factor analysis, china.

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1. Introduction

Science parks were established to stimulate the formation and development of new technology-based firms (Siegel *et al*. 2003; Sun and Lin 2009). When combined effectively with various institutions (e.g. government, research institutions and universities), science parks have played an important role in promoting innovation, entrepreneurship, growth of knowledge-based companies and in turn economic growth within their regions (Adekola *et al*. 2008; Lindelof

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and Lofsten 2003). Such science parks were first originated in the western world; especially, the remarkable development of Silicon Valley and Route 128 in the U.S. Observers have noted that science parks help create an innovative environment which can breed a continuous stream of innovations in an environment of information sharing and knowledge spillover (Yam *et al.* 2004), both across and between firms and academic institutions, via informal channels (Saxenian 1996). Because of the technology integration, high value addition and valid spillover mechanism of knowledge and technique, science parks have strong creative advantages (Hu 2007). Hence, both developed and under-developed countries have tried to mimic the American success stories by encouraging formation of science parks. Better-known examples of such parks include Cambridge in the U.K., Sophia-Antipolis of France, Tsukuba in Japan, and Taiwan's Tsinchu Science Park (Vaidyanathan 2008).

Although science parks in China have been growing rapidly in the past decade, a few successful examples have been noted (Hu 2007). However, a series of issues need to be faced, such as irrational allocation of resources, incomplete innovation network, the lack of innovation environment and so forth, which affect continuous improvement of innovation capabilities for science parks (Liu and White 2001; Tan 2006). There is, to our knowledge, a paucity of studies on evaluating innovation capabilities of science parks in China. This paper aims to develop a model to measure innovation capabilities of science parks. A case study is conducted based on the Qingdao Science Park, one of the national science parks. It is hoped to provide a better understanding on how to improve innovation capabilities of science parks in China.

2. Previous works

The success of science parks in promoting technology transfer and attracting clusters of highly innovative firms has motivated countries from around the world in an attempt to promote regional development (Tan 2006). Harper and Georghiou (2005) described the process and outcomes of an exercise that used the 'success scenario' methodology to develop a shared vision of the future of business-university linkages in the city region of Manchester. They presented a scenario in five dimensions: infrastructure, human resources, university missions, inward investment, and networking.

Colombo and Delmastro (2002) compared a sample composed of 45 Italian new technology-based firms (NTBFs) which at the beginning of 2000 were located on a technology incubator within a science park with a control sample of off-incubator firms. Aspects considered include the personal characteristics of founders of NTBFs, the motivations of the self-employment choice, the growth and innovative performances of firms, propensity towards networking, and access to public subsidies. They found that Italian parks managed to attract entrepreneurs with better human capital, as measured by educational attainments and prior working experience. In addition, on-incubator firms show higher growth rates than their off-incubator counterparts. They also perform better in terms of adoption of advanced technologies, attitude to participating in international R&D programs, and establishment of collaborative arrangements, especially with universities.

Bakouros *et al.* (2002) compared the three science parks of Greece and found that they were not the same in terms of the links between universities and industries. Informal links have been developed between firms and local universities; however, only the firms located at one science park have developed formal links, while the formal links of the companies of the other two parks are at the infancy level by then. Synergies between on-park companies are limited only to commercial transactions and social interactions (Sofouli and Vonortas 2007). The research-type synergies are completely absent in all the three parks. By investigating a science park in Hungary, the first institute of the kind in Central Eastern Europe, Palmai (2004) found some signs that indicated saturation of the company's virtual incubation activity.

As Vaidyanathan (2008) indicated, the government of India established the software science parks of India (STPI) scheme and opened numerous software parks around the country. These parks have played a critical role in the growth of India's software sector. In recent years, private software parks have also been established in different parts of India. The government of India is now promoting biotechnology (biotech) parks to encourage growth of this emerging sector. Biotech-Information Technology (Bio-IT) park is the next type of park that the government is planning to promote.

Lai and Shyu (2005) explored the innovation capacity in two different science parks across the Taiwan Strait. They chose the Zhangjiang High-Tech Park (ZJHP) of China and the Hsinchu Science-based Industrial Park (HSIP) of Taiwan to compare their innovation capacity. They developed a model to analyze the science parks in innovation capacity across the Taiwan Strait and found differences in determinants for innovation capacity between the ZJHP and HISP, such as the "basic research infrastructure", "sophisticated and demanding local customer base", and "the presence of clusters instead of isolated industries".

Tan (2006) investigated a specific example of an industry cluster in China, the Beijing Zhongguancun (ZGC) Science Park, which has accommodated the largest cluster of semiconductor, computer, and telecommunication firms in China, consisting of both domestic and foreign invested firms. Tan (2006) examined the origin and growth of industry cluster in a traditionally heavily regulated economy and region, its role in promoting technology transfer and innovation, and challenges that firms will face in the future.

Chan and Lau (2005) provided an assessment framework of technology incubators in the science park, including advantages from pooling resources, sharing resources, consulting services, positive effect from higher public image, networking advantages, clustering effect, geographic proximity, cost subsidies and funding support. Using business development data of six technology start-ups in the Hong Kong Science Park, the framework is then applied to examine the effectiveness of incubators from the perspective of venture creation and development process. They found that the benefits required by technology founders at different stages of development are varied and therefore, the general merits that are claimed by incubators as useful to technology start-ups are debatable.

3. Research methodology

3.1. System for evaluating innovation capabilities for science parks

Based on the literature review (Chan and Lau 2005; Palyvoda 2008; Zeng *et al.* 2010), this paper has developed a system for evaluating the innovation capabilities of science parks in

China. The system is composed of the Innovation Organization Sub-System (IOSS, mainly high-tech firms), the Innovation Support Sub-System (ISSS, e.g., technology intermediaries) and the Innovation Environmental Sub-Systems (IESS), as shown in Fig. 1.

Various elements of sub-system in the synergic system are summarized in Table 1.

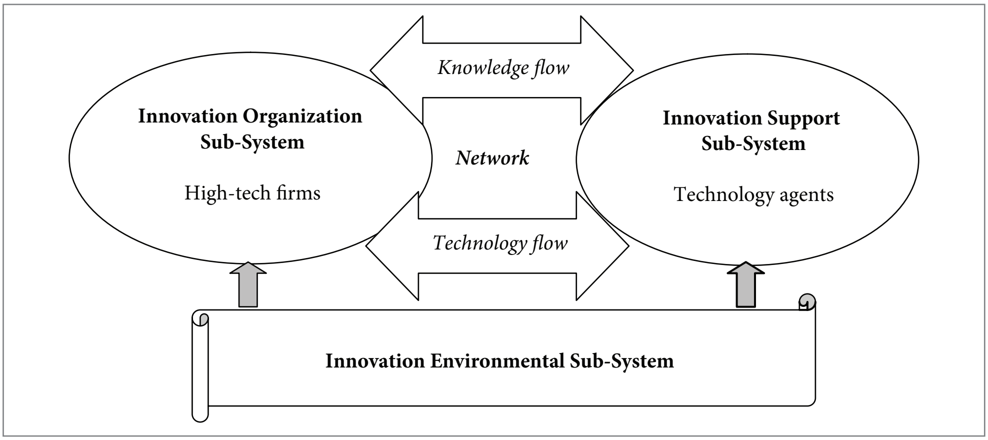

Fig. 1. Innovation System for Science Parks

Table 1. Elements of Innovation System for Science Parks

Sub-System	Element	Sub-Element
Innovation Organization Sub-System (IOSS)	Innovative Firms	Manufacturers (high-tech firms), Related enterprises (e.g. suppliers, vendors, distributors and customers), Competitive enterprises, etc.
	Research Institutions	Knowledge production institutions (e.g. universities and research institutions), Technical production institutions (R&D departments of large enterprises, the laboratories in the university, etc.)
Innovation Support Sub-System (ISSS)	Innovation Infrastructure	Hardware infrastructure (transportation, communications and utilities, etc.), Soft elements of the environment for cluster innovation (technology, cultural facilities, information services, training services, management systems, etc.).
	Technology Intermediaries	Information technology intermediaries (e.g. non-profit making government agencies, business information intermediary), Technology agents, Innovation incubators, Regional technology centers, etc.
Innovation Environmental Sub-Systems (IESS)	Policies and Regulations	Industry policies, Technology policies, Tax incentives, Policies on SMEs incubators and other related policies.
	Cultural Environment	Local social and cultural environment (social customs, values, etc.), Cluster culture of innovation within the network (e.g. informal organizations, tacit knowledge), Innovative culture system of high-tech enterprise (sense of innovation, teamwork, entrepreneurship, etc.)
	Financial Environment	Financial institutions, Credit system, Risk investment, Capital market system, etc.

From Table 1, it shows that IOSS includes the innovative firms and research institutions. Innovative firms are the most important part of science parks. Research institutions are the main source of knowledge spill and technology sharing (Mu and Lee 2005). ISSS, consisting of facilities for innovation and technology intermediaries, could provide correlative services for IOSS. IESS, which can provide clusters with a suitable environment and a system protection, is an indispensable part for continuous innovation of science parks.

3.2. Evaluation indicators

In this paper, evaluation indicators, proposed by the science and technology development strategy of the Chinese research group (2005), are used for assessing innovation capability for science parks, including IOSS, ISSS and IESS, as listed in Table 2.

Table 2. Indicators for evaluating Innovation Capability for Science Parks

Sub-System	Indicator
IOSS	Ratio of R&D funding to the regional GDP (X_1)
	Newly granted patents per millions of people (X_2)
	Ratio of R&D spending to the regional total technology spending (X_3)
	Ratio of R&D staff to employees (X_4)
	Regional GDP per capita (X_5)
	Ratio of exports to the total income from technology, industry and trade (X_6)
	Gross industrial output value (X_7)
	Annual growth rate of R&D staff (X_8)
	Annual growth rate of R&D expenses (X_9)
	Ratio of annual growth rate of profits to the total income from technology, industry and trade (X_{10})
ISSS	Annual growth rate of high-tech enterprises (X_{11})
	The ratio of internet users (X_{12})
	Turnover of technology market (X_{13})
	The number of technology intermediaries (X_{14})
	The number of practitioners in technology intermediaries (X_{15})
	The annual number of incubators graduated (X_{16})
IESS	*The degree of being protected for Intellectual Property in cluster (X_{17})
	*The satisfactory degree to clusters policy (X_{18})
	*The degree of industry correlation (X_{19})
	*The degree of cluster cooperation (X_{20})
	Annual growth rate of regional investment (X_{21})
	The total fund for incubators (X_{22})

Note: * The indicators are measured by a qualitative index, which needs to be quantified.

3.2.1. Innovation Organization Sub-System

The indicators of IOSS, including the innovation capability of inputs, outputs and growth, are used to evaluate the innovative sustainability of firms, universities and research institutions. The innovative input capability mainly involves the input for R&D funding and R&D staff (Zhou and Leydesdorff 2006; Zeng *et al.* 2009). The extent of input determines the intensity of innovative activities, the effectiveness of innovative output and the sustainability of firms' innovation (Motohashi and Xiao 2007). The innovative output capability includes the regional GDP per capita and the total income from technology, industry and trade. The output performance of innovation focuses on whether it could create more wealth and facilitate growth of regional GDP and its contributions to the regional economic development. The innovative growth capability, involving the annual growth rate of R&D staff (Squicciarini 2008) and expenses, is the combination of innovation in the latitude of time and space and reflects the dynamic characteristics of innovation in clusters. In short, the IOSS is the core of the continuous operation for cluster innovation and the main source of continuous innovative capability.

3.2.2. Innovation Support Sub-System

The indicators of ISSS include innovation infrastructure and technology intermediary. Innovation infrastructure involves information facilities of science parks. Obviously perfect infrastructure will be in favor of the continuous innovation of clusters. The technology intermediary consisting of technology transfer centers and incubators is regarded as the bridge for knowledge spill and technology diffusion (Sofouli and Vonortas 2007).

3.2.3. Innovation Environmental Sub-Systems

The indicators of IESS include policies and regulations, cluster and financial environments. Policy environment indicators examine the supportive intensity of the government in the development of clusters and the degree of protection to intellectual property rights in clusters. Cluster environment indicators, which can provide an impetus for the development of firms in clusters, explore the extent of collaboration of universities, industries, the government and the degree of industrial correlativity in clusters. Financial environment indicators, including government investment and funds for incubators, are to evaluate the degree of funding support from financial institutions or local governments.

4. Model development

4.1. The model

Factor analysis is a statistical analysis method for managing problems with multiple-variable data. Its basic principle is to trim down a large number of initial variables into a linear combination of a few factors, which are used to reveal and explain a complex socio-economic phenomenon. Therefore, factor analysis is used widely to establish a simple structural model to reveal the essential relationship among complicated data sets.

The model of factor analysis can be represented by Equation (1):

$$X = AF + \varepsilon. \tag{1}$$

Specifically, the model of factor analysis assumes that each random variable X_i that can be observed depends on a small number of random variables $F_1, F_2, \ldots F_m$ (Common Factor) of non-observation and Unique Factor ε_i. Therefore, Equation (1) can be transformed into Equation (2):

$$X_i = a_{i1}F_1 + a_{i2}F_2 + \ldots + a_{im}F_m + \varepsilon_i, \tag{2}$$

where a_{ij}, known as Factor loading, denotes the load of variable i acting on factor j. Then, these random variables are assumed in Equations (3)–(7):

$$E(F_j) = 0, \tag{3}$$

$$Cov(F_i, F_j) = \begin{pmatrix} 1 & & & & \\ & \cdot & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & & 1 \end{pmatrix}_{p \times p} = I_p{}^{1}, \tag{4}$$

$$E(\varepsilon_j) = 0, \tag{5}$$

$$Cov(\varepsilon_i, \varepsilon_j) = diag\left(\sigma_1^2, \sigma_2^2, \ldots, \sigma_p^2\right) = D^2, \tag{6}$$

$$Cov(F_i, \varepsilon_j) = 0, \tag{7}$$

Based on these assumptions, the model exhibits the following characteristics:

1. The mean of each Common Factor is 0 and the variance is 1. Furthermore, there is no correlation among all the Common Factors.
2. The mean of Unique Factor is 0, with unequal variances and no correlation between them.
3. There is no correlation between Common Factors and Unique Factors.

4.2. Case study

Since early 1990s, the Chinese government has established science parks in 53 major cities under its 'Torch' Program, a science and technology initiative to promote technology transfer

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[1] Equation (4) indicates that the variances of all Common Factors are 1, and there is no correlation among all the Common Factors.

[2] Equation (6) indicates that the variance of Unique Factor is σ_i^2, and there is no correlation among all the Unique Factors.

and diffusion (Guan and Ma 2007; Hu 2007). In this study, the Science Park at Qingdao, one of the national science parks, is chosen for investigation. The data[3] from 1994 to 2008 are collected. Based on the formation and growth of the Science Park at Qingdao, 22 indicators are employed as the original variables to gauge the innovation capability of the Science Park.

To compare data of different dimensions, the improved Efficacy Factor Method is adopted to standardize and normalize the original data.

The formula is shown in Equation (8).

$$\left.\begin{array}{l} d_i = \left[(X_i - X_{\min})/(X_{\max} - X_{\min})\right] \times 40 + 60(\text{When } i \text{ is a positive indicator }) \\ d_i = \left[(X_i - X_{\max})/(X_{\min} - X_{\max})\right] \times 40 + 60(\text{When } i \text{ is a negative indicator}) \end{array}\right\}^{4} \qquad (8)$$

In Equation (8), d_i represents the relative value of the indicator i after standardization and normalization. And the range of d_i is from 60 to 100. X_i is the true value of the indicator i. The variable $X_{\max}$ denotes the maximum value of the time series and $X_{\min}$ denotes the minimum value of the time series. $X_i - X_{\min}$ means the difference between the true value and the minimum value for indicator i when it is a positive indicator, and $X_i - X_{\max}$ means the difference between the true value and the maximum value for indicator i when it is a negative indicator.

In our study, $X_{\max}$ is the maximum value for the indicator i during the period from 1994 to 2008, and $X_{\min}$ is the minimum value for the indicator i during the period from 1994 to 2008. As all 22 indicators in this study are positive, $X_i - X_{\min}$ is the difference between the true value and the minimum value for indicator i during the period from 1994 to 2008, and $X_{\max} - X_{\min}$ is the difference between the maximum value and the minimum value for indicator i during the period from 1994 to 2008.

5. Results and analysis

In this paper, the statistical software, SPSS 16.0, is used to analyze the 22 original indicators. As the number of indicators is larger than the number of samples, the KMO and Bartlett's Test of Spherical cannot be exercised. Consequently, the suitability of analyzing by Factor Analysis is based on the results of Correlation Matrix and Anti-Image Correlation Matrix (Hair *et al.* 1995). From the results of data analysis, the *P*-value of correlation coefficient matrix is less than 0.05 and the correlation coefficient between variables is larger than 0.3 (when most of the correlation coefficients are less than 0.3 in the correlation matrix, it is not suitable to use Factor Analysis) (Mulaik 1990). Moreover, most values of Anti-Image Correlation Matrix are small. Accordingly, there are significant correlations between indicators so that it is appropriate to adopt Factor Analysis. In addition, the communalities test of indicators shows that most of the communalities are larger than 0.85, which indicates that the common factors have a strong explanatory power and thus Factor Analysis is effective.

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[3] Data source: China Statistics Yearbook on Science Parks (1994-2008). The surveyed data is collected from Science Park of Qingdao city in China.

[4] When *i* is a positive indicator, it means the bigger the true value for *i*, the better of the evaluation result will be. While when *i* is a negative indicator, it means the lesser the true value for *i*, the better of the evaluation result will be. In this paper, all 22 indicators are positive.

In Step 2, in light of the standardized correlation coefficient matrix, factor eigenvalues and cumulative variance of innovation capability of science parks are obtained (see Table 3).

Table 3. Total Variance explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	15.638	71.083	71.083	12.307	55.939	55.939
2	2.186	9.936	81.018	4.890	22.229	78.169
3	1.594	7.244	88.262	2.221	10.094	88.262

Note: Extraction Method- Principal Component Analysis.

'Principal Component Analysis' is applied to extract irrelevant linear combination of variables. From Table 3, it shows that three main eigenvalues of correlation coefficient matrix are extracted. The first component has the maximum variance of 15.638, accounting for 71.083% of the total variance and the cumulative percentage of standard deviation of three components together achieves at 88.262% (the total number of factors extracted is determined by the cumulative variances with contributions more than 85%). That reveals that the information described by the 22 initial variables can be reflected by these three components. Therefore, the method of Principal Component Analysis is applied to extract the first three factors as the integrated component. The findings show that it is satisfactory that the first three factors can describe most of the information of the initial variables.

To illustrate the significance of factors more clearly and analyze the actual problem more pertinently, factor loadings are rotated to make the typical variables of each component more prominent. Furthermore, the method of Varimax is adopted, which is an orthogonal rotation method, making each factor bearing the least variance while having the maximum load. The rotated component matrix is shown in Table 4.

From Table 4, it shows that the component F_1 mainly explains the variables of X_1, X_3, X_4, X_5, X_{12}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}, X_{20}, in which the variables of X_1, X_3, X_4, X_5 denote indicators of input and output, and the variables of X_{12}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}, X_{20} represent indicators of growth of continuous innovation for science parks. Thus, the component F_1 reflects the level of continuous innovation for science parks.

Also, the component, F_2, can embrace the variables of X_8, X_9, X_{11} which are the main estimative indicators for innovation efficiency. Consequently, the component F_2 reflects the efficiency of continuous innovation for science parks.

The variables of X_5, X_6 and X_7 as the evaluated indicators for measuring the effect of sustainable innovation are included in F_3. Thus, F_3 reflects the effect or impact of continuous innovation for science parks. Specific naming of components is summarized in Table 5.

Table 4. Rotated Component Matrix [a]

Variable	Component		
	1	**2**	**3**
X_4	0.952	0.084	0.050
X_{20}	0.952	0.150	0.015
X_{19}	0.943	0.214	–0.095
X_{17}	0.930	0.277	0.112
X_1	0.926	0.150	–0.060
X_{18}	0.912	0.222	–0.290
X_5	0.863	0.487	0.008
X_3	0.856	0.471	0.029
X_{15}	0.852	0.508	0.048
X_{21}	0.843	0.214	0.418
X_{12}	0.821	0.175	0.329
X_{16}	0.785	0.593	0.135
X_{22}	0.761	0.636	–0.038
X_{14}	0.759	0.556	0.283
X_2	0.515	0.743	0.112
X_{13}	0.640	0.724	0.178
X_{10}	0.672	0.693	0.171
X_6	0.034	–0.675	–0.015
X_7	0.665	0.670	0.284
X_{11}	–0.281	–0.090	–0.811
X_9	0.123	–0.374	–0.762
X_8	–0.172	–0.444	0.574

Notes: Extraction Method–Principal Component Analysis; Rotate Method–Varimax with Kaiser Normalization; [a]Rotation converged in six iterations.

Table 5. Naming of Component

	Component F_1	**Component F_2**	**Component F_3**
Variable	X_1, X_3, X_4, X_5, X_{12}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}, X_{20}, X_{21}, X_{22}	X_8, X_9, X_{11}	X_2, X_6, X_7, X_{10}, X_{13}
Naming of component	Level component of innovation capabilities for science parks	Efficiency component of innovation capabilities for science parks	Effect component of innovation capabilities for science parks

In order to investigate the significance of variables to components and start the comprehensive evaluation, the following steps are adopted to calculate the component scores. To minimize the error, regression is used to estimate components and obtain the Component Score Coefficient Matrix with the results tabulated in Table 6. Thus, according to the coefficient matrix and observed values of variables, component scores are calculated.

Table 6. Coefficient Matrix of Component Scores

Variable	**Component**		
	1	**2**	**3**
X_1	0.137	−0.121	−0.051
X_2	0.109	−0.121	0.140
X_3	0.055	0.038	−0.035
X_4	0.155	−0.167	0.009
X_5	0.053	0.046	−0.047
X_6	0.109	−0.135	−0.345
X_7	−0.024	0.150	0.075
X_8	0.058	−0.224	0.325
X_9	0.150	−0.325	0.052
X_{10}	−0.025	0.089	−0.391
X_{11}	−0.065	0.232	−0.015
X_{12}	−0.027	0.170	0.017
X_{13}	−0.039	0.190	0.018
X_{14}	0.017	0.077	0.084
X_{15}	0.047	0.055	−0.029
X_{16}	0.015	0.102	0.007
X_{17}	0.109	−0.076	0.022
X_{18}	0.121	−0.063	−0.171
X_{19}	0.127	−0.091	−0.074
X_{20}	0.141	−0.133	−0.014
X_{21}	0.104	−0.115	0.180
X_{22}	0.003	0.143	−0.082

Notes: Extraction Method–Principal Component Analysis. Rotate Method–Varimax with Kaiser Normalization.

The various individual component scores are calculated from Equation (9):

$$
\begin{aligned}
F_1 &= 0.137X_1 + 0.109X_2 + 0.055X_3 + \ldots + 0.104X_{21} + 0.003X_{22}, \\
F_2 &= -0.121X_1 - 0.121X_2 + 0.038X_3 + \ldots - 0.115X_{21} + 0.143X_{22}, \\
F_3 &= -0.051X_1 - 0.140X_2 - 0.035X_3 + \ldots + 0.180X_{21} - 0.082X_{22}.
\end{aligned}
\tag{9}
$$

Note that b_j stands for the contribution rate of variance for each component, and

$$b_j = \lambda_j / P; \tag{10}$$

where λ_j is the eigenvalues of J in the initial correlation matrix and $P = \lambda_1 + \lambda_2 + \ldots + \lambda_m$;

Then, the composite evaluation score is expressed in Equation (11):

$$F = \sum_{j=1}^{m} b_j F_i, i = 1,2,\ldots,n. \tag{11}$$

In this paper, $F = b_1 \times F_1 + b_2 \times F_2 + b_3 \times F_3; i = 1,2,3; j = 1,2,3; viz. m = 3;$

$$\begin{aligned} b_1 &= 15.638 / 19.418 = 0.805, \\ b_2 &= 2.186 / 19.418 = 0.113, \\ b_3 &= 1.594 / 19.418 = 0.082, \\ F &= 0.805 \times F_1 + 0.113 \times F_2 + 0.082 \times F_3. \end{aligned} \tag{12}$$

Hereby, we obtain the individual component scores and the composite component scores for the period of 1994–2008 for the Science Park at the Qingdao city in China. The results are shown in Table 7.

Table 7. Component Scores of Innovation Capability of Qingdao Science Park

Year	F_1	Ranking	F_2	Ranking	F_3	Ranking	F	Ranking
1994	–1.743	15	0.261	7	–0.042	6	–1.377	15
1995	–1.443	13	0.263	6	–0.377	10	–1.163	14
1996	–1.447	14	0.537	4	–0.203	8	–1.121	13
1997	–0.898	12	–0.523	11	1.109	3	–0.691	12
1998	–0.568	11	–0.531	12	0.600	4	–0.468	11
1999	–0.525	10	–0.205	10	0.128	5	–0.435	10
2000	0.164	9	–0.913	13	–0.721	13	–0.030	9
2001	0.742	5	–1.612	14	–0.294	9	0.391	8
2002	0.961	2	–1.799	15	1.140	2	0.664	5
2003	0.614	8	–0.053	9	–0.514	11	0.446	6
2004	0.712	6	0.160	8	–1.801	15	0.444	7
2005	0.874	3	0.264	5	–0.736	14	0.673	4
2006	0.850	4	0.840	3	–0.072	7	0.773	2
2007	0.684	7	1.777	1	–0.635	12	0.699	3
2008	1.022	1	1.533	2	2.418	1	1.194	1

From Table 7, the degree of continuous innovation at the Qingdao Science Park can be abstracted. The composite capability of continuous innovation shown in Table 7 is derived according to the actual development trends and the internal growth process of Science Park based on a holistic view. The score of capability of continuous innovation for the Qingdao Science Park is the highest in 2008 when compared with those of previous years. Although, it underwent a decline from the year 2003 to 2004, and 2007, the composite component score (Viz. F) has, as a whole, been increasing annually (see Fig. 2).

Then, trends of scores of the three individual components are shown in Table 7 and Fig. 3.

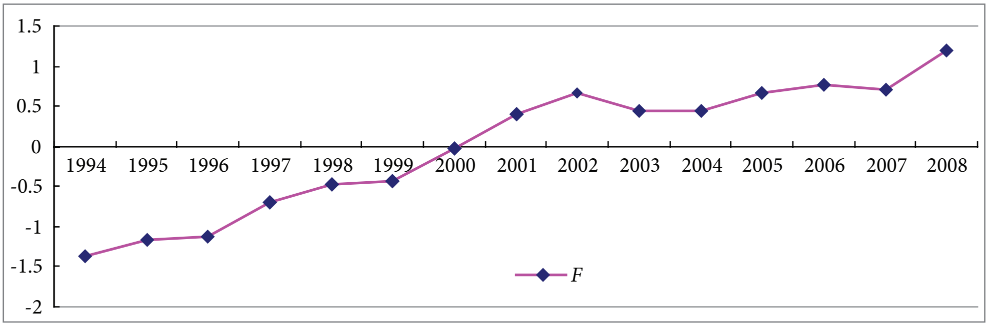

Fig. 2. Composite Component Score (F) of Qingdao Science Park (1994-2008)

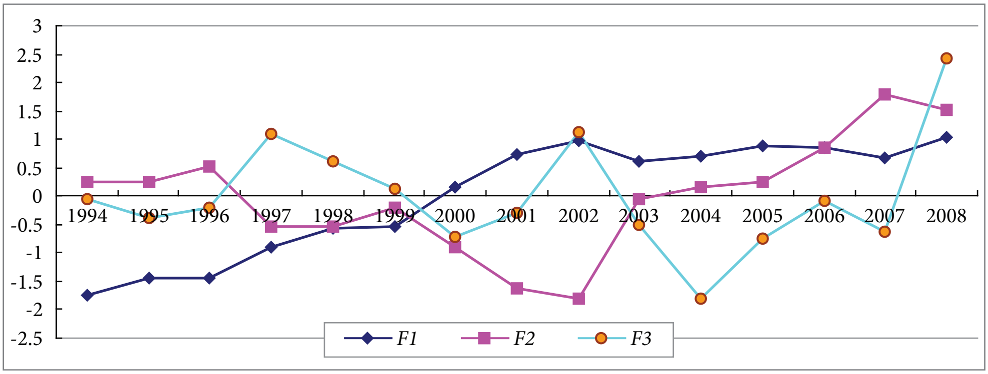

Fig. 3. Individual Component Scores of Qingdao Science Park (1994-2008)

From Fig. 3, the component score of F_1 (viz. level component of continuous innovation for science parks) has almost increased steadily (especially from a negative value into a positive value gradually) for the years of 1994 to 2008, which implies that the level of continuous innovation of the Qingdao Science Park in China has been improved gradually. The main reason is that the various parties have increased the inputs of innovation elements (especially the input of R&D expenses and R&D staff), which can upgrade the capacities of input and output of continuous innovation.

The trend of component scores for F_2 (viz. efficiency component of continuous innovation for science parks) shows some irregularity and the score shows a rapid downward trend for the years of 1997 to 2002, and reached the lowest point in 2002, resulted from the decrease of input of R&D funds and staff. All these factors have led to inefficient innovation effect, low growth rate of technology firms and slow pace of development. In 2007, the score of F_2 reached the maximum of 1.777, which mostly related to the increase in investment of R&D and the increase of high-tech firms. While the score of F_2 decrease in 2008 and the possible reason lies in the impact of the world financial crisis.

Irregularity is shown in the trend of the component scores for F_3 (viz. effect component of continuous innovation for science parks), which implies the deficient input and insufficient government regulation resulting in decrease in patents, foreign exchange, exports and industrial output. In 2008, the score of F_3 reached the maximum of 2.418 during the years of 1994–2008, which mostly related to the increase in funds and investment of science and technology (e.g. the increases of R&D personnel and the increases of profits). While the score of F_3 bottoms out in 2004 and the fundamental reason lies in the weak sustainable growth capability. Moreover, temporary increase in investment is unable to strengthen the innovation capability continuously.

Based on the above analysis, it indicates that the three components (F_1, F_2 and F_3) abstracted via the method of Factor Analysis can adequately explain the evaluation indicators of continuous innovation for science parks. On the other hand, the evolution law explained by the evaluation system fitted by three components is consistent with the actual evolution process of the Qingdao Science Park. Therefore, the empirical results confirm that this evaluation system bears a good explanatory power.

6. Concluding remarks

"Science Park", an important means of forming a regional cluster leading to sustainable regional developments, has made significant achievements recently in China. However, the capability to continuous innovation of science parks remains weak. Based on the empirical results of the previous analysis, the main reasons are as follows:

Firstly, there is a lack of effective innovative culture between universities and research institutions (including public and private ones). A proper innovative culture can accelerate the flow rate of innovation production, spillover and diffusion for universities and research institutions that can determine the sustainability of innovation. In this aspect, the science parks in China are confronted with serious problems of lack of cooperation. Even more seriously, the proportion of talent is low and there is a lack of cooperation between high-tech firms, universities and research institutions, so that an effectively interactive mechanism has not been built up in the science parks of China.

Secondly, environmental concerns for continuous innovation are inadequate. Most science parks in China are formed under the privilege of preferential policies, good transportation infrastructure and the abundant supply of low-cost labor, which can attract both domestic and foreign firms. These science parks can hardly enjoy a genuine "synergy effect" and "innovation culture" and the cooperative relationship between the upstream industries and downstream industries is not yet well established. It results in fewer intercourse and collaboration within and across the innovative parts, among firms, government agencies, universities and research institutions.

Therefore, it is crucial for science parks to enhance the linkages and cooperation among universities, research institutions and firms so as to promote a sustainable development and continuous innovation in the regional economy.

To overcome the problems, the intercourse and sharing of technical know-how between firms, research institutions and universities should be strengthened in order to improve innovation capability. In this regard, the role of universities for the regional economic development needs to be given full play. Given the lack of resources and experienced staff in technology transfer offices of some universities, current activities in technology transfer should be supported and strengthened. Also, there needs to be some channels for high-tech firms to access university technologies. Furthermore, university technology could be marketed as an "outsourcing route" for R&D activities of some firms.

In addition, the innovative infrastructure in science parks should be further strengthened, which include optimizing the regional environment, making full use of these infrastructure and public building products, increasing government funding to the university–industry interface to provide higher level of transparency, encouraging communication, establishing an efficient information network to accelerate flow of information, strengthening construction of technology intermediaries, and improving the professional quality of employees. Technology intermediaries, a bridge to connect the firms with research institutions, play an important role at the process of the regional sustainable development. What more important for science parks are to perfect the technology intermediaries and establish an effective mechanism to capitalize on the synergy effect of research institutions, universities and firms by turning them into a "commonwealth of the intermediary market". Meanwhile, the government policies on technology innovation are indispensable, which can target large, multi-disciplinary and long-term programs by emphasizing the "selection and concentration" strategy for the efficient use of R&D resources.

Finally, the key leading to success of science parks is to establish a favorable culture for regional sustainable innovation. To form a good environment, science parks may need to foster a culture that encourages innovation, entrepreneurship and a proper environment conducive to the free flow of innovation ideas and know-how (e.g. talents, technology, information and knowledge, etc.).

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MOKSLO IR TECHNOLOGIJŲ PARKŲ INOVACINIO PAJĖGUMO ĮVERTINIMAS: SISTEMOS MODELIS

S. X. Zeng, X. M. Xie, C. M. Tam

Santrauka. Mokslo ir technologijų parkai yra labai svarbūs diegiant naujoves, skatinant verslumą ir žiniomis grįstų bendrovių augimą. Tai savo ruožtu skatina ekonominį regionų augimą. Šiame straipsnyje aprašoma sukurta mokslo ir technologijų parkų inovacinio pajėgumo įvertinimo sistema, kurioje yra organizacijos inovacijų posistemis (skirtas daugiausia aukštųjų technologijų įmonėms), inovacijų paramos posistemis (skirtas, pavyzdžiui, technologijų platintojams) ir inovacijų aplinkos posistemis. Minėta įvertinimo sistema buvo pritaikyta remiantis Qingdao mokslo ir technologijų parko (1994–2008) empirine tyrimo studija. Išvados rodo, kad inovacinio pajėgumo tyrimo įvertinimo sistema pagal tris komponentus atitinka faktinę Qingdao mokslo ir technologijų parko raidą. Tai patvirtina įvertinimo sistemos naudingumą vertinant mokslo ir technologijų parkų plėtrą. Straipsnyje pateikiamos rekomendacijos, kaip pagerinti naujovių diegimą mokslo ir technologijų parkuose.

Reikšminiai žodžiai: inovacijos, inovacinis pajėgumas, mokslo ir technologijų parkai, faktorinė analizė, Kinija.

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