An Empirical Study on the City Innovation Capacity: the Case of Dalian of China[*]

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Abstract　Enhancing enterprises as leading roles in innovation system has become an urgent and important issue for improving the current innovation level and setting up innovative cities and country. This paper takes city capacity as research object and builds urban innovation capability evaluation index system and models based on relevant literature reviews. Adopting projection pursuit calculation method, this paper takes the city of Dalian in China as an example to do empirical comparison analysis, explores the main problems in building city innovation capacity and proposes suggestions on improving city innovation capacity.
Key words　City innovation; Innovation capacity; Independent innovation

1 Introduction

In the fifth plenary session of the 16th central committee, enhancing independent innovation capacity becomes a national development strategy that has been put in a prominent position and plays a key role in adjusting the industrial structure and changing the mode of economic growth. Enterprises play the leading role in enhancing capacity of independent innovation and setting up independent innovation system. National technical innovation system made a clear statement that enterprises are the focus and leading role of technological innovation. The report of the 17th CPC national congress reaffirms enterprises as leading role in innovation "We will step up our efforts to establish a market-oriented system for technological innovation, in which enterprises play the leading role and which combines the efforts of enterprises, universities and research institutes, and guide and support the concentration of factors of innovation in enterprises, thereby promoting the translation of scientific and technological advances into practical productive forces." Enhancing enterprises as leading role in innovation system has become an urgent and important issue for improving the current innovation level and setting up innovative cities and innovative country.

The direct aim of independent innovation is to expand the scale of economy effectively and efficiently. Thus enterprises are the most suitable roles of pushing forward this process that combine the scientific research and economy. In a market economy, the status and role of enterprises are so important that cannot be replaced by any other type of institutions. The country's overall capacity of innovation cannot be enhanced unless enterprises improve their capacity of independent capacity of innovation. Nearly a hundred years of history of the world's industrial development shows that the most significant technologies with tremendous effects coming form enterprises. For example, Bell Labs in the field of communication, Ford in enterprises field and Boeing in plane manufacturing field are all leaders in independent innovation. At present, the world top 500 enterprises create and possess 80% investment in the scientific and technological research and development and 71% of technological innovation of the world. Meanwhile, 62% of technology transfers are conducted between the top 500 enterprises. It has become an indisputable fact that enterprises are playing the leading role of independent innovation in worldwide scope.

2 Literature Review

The concept of innovation was firstly put forward by Austrian-American economist-Joseph. Schumpeter in 1912, in his book "Theory of Economic Development". Schumpeter defined innovation as a transfer of production function, or a new combination of production function with the aim of obtaining potential excess profits. After that, Solow carried out in-depth researches in technological innovation and proposed two prerequisites of technological innovation, that is the source of new ideas and the development of the subsequent stages of implementation in his paper " the innovation in capital

process: review of Schumpeter's theory"[1]. The process of technological innovation: the launching of a new scientific industry is the first article entitled with innovation that was written by McLaughlin and published in American economic review in 1950. In 1962, Inos pointed out that technological innovation results from the combination of several functions including the invention selection, capital accumulation, organization establishment, plan formulation, worker recruitment and market exploration in the article "the invention and innovation in oil-processing industry"[2]. Freeman defined technological innovation as the entire process of technology, craft and commercialization, which lead the introduction to market of the new product and the commercial application of new craft and technology in the article "research of success and failure in industrial innovation"[3]. Mansfield believed that technological innovation is the "various steps of introducing a new product or new process including technology, design, production, finance, management and marketing[4]." In "The anatomy of successful innovations", Marquis and Myers defined that innovation is a collection of technology reformation, arguing innovation is a complex process of activities originating from the conception of an idea or an invention followed by subsequent commercialization of this idea. In 1981, Larry E. Westphal proposed the capacity of technological innovation is the integration of capacity in organizing, adapting and acquiring technology and information. Seven Muller thought innovation is the integrated capacity of new product invention, production technology improvement, reserving and organizing[5]. Burgelman said the capacity of innovation involves the available resources, the knowledge of industry competitors and environment, the organization's culture and the exploiting strategy.

3 The Capacity Innovation Evaluation and Comparison

Evaluation indicators and evaluation data selection is the key for setting up a scientific evaluation system. But it is hard to select an indicator system that can reflect accurately the real content of evaluation factors. This paper focuses on the capacity of independent innovation of industrial enterprises, uses the existing statistical data and related survey data and selects the key indicators which reflect the nature of evaluation factors to make an objective evaluation of the capacity of independent innovation.

3.1 Data selection

This study selects the cities of Shenyang, Changchun, Jinan, Chongqing, Nanjing, Qingdao, and Xiamen as comparing cities because these capital cities or coastal open cities are characterized with higher capacity of independent innovation which enables Dalian set a higher standard and use it as the development goal. Indicators are selected from the relevant data of industrial enterprises in cities mentioned above and selecting time is in 2007.   Specific indicators and data are showed in the Table 1below:

3.2 Index system

In order to evaluate the capacity of independent innovation of Dalian in a comprehensive and objective manner, this study identifies 4 primary indicators involving innovation resources, innovation activities, innovation outputs capacity and innovation environment and 10 secondary indicators including the proportion of science and technology personnel, Industrial added value , product sales revenue, proportion of technology expenditures accounting for products sales revenue, proportion of R&D expenditures accounting for the sales revenue, proportion of the number of enterprises taking the scientific and technological activities, patent number, proportion of new product accounting for sales revenue, proportion of financial funds sales revenue, the proportion of loans from financial institutions.

Table 1   Industrial Enterprises Innovation of Major Domestic Cities in 2007

Item	Innovation resources			Innovation activities			Innovation outputs capacity		Innovation environment	
Unit	%	100 million	100 million	%	%	%	%	%	%	%
Dalian	2.7	977	3384	1.62	0.7	31.5	243	13.4	6	6.78
Shenyang	5.6	914	3218."	1.22	0.7	8.7	483	14.5	16.8	11.2
Changchun	5.5	6.4	2014	1.94	0.5	8.2	255	37.8	1.46	0.22
Jinan	6.2	798	2491	2.38	1.4	10	799	17.8	2.63	3.49
Qingdao	4.9	1515	5080	1.74	1.1	6.8	770	32.4	2.2	5.55
Xiamen	3.5	574	2311	2.18	0.9	12.7	523	12.1	2.1	9.35
Chongqing	5.7	845	3201	2.36	1	33.3	721	29.1	5.5	10.3
Nanjing	6.4	1153	4714	1.63	0.8	8.2	738	14.95	5.95	3.5

Source: processing in accordance with data of statistical yearbook of municipalities

3.3 Evaluation method choice

The main factors that affect the quality of the evaluation include Evaluation index system design and Evaluation method selection. On the base of establishing evaluation index system, the weight selection of the evaluation index is one of key factors that make evaluation accurate, objective and effective. In this paper, we choose Projection Pursuit Method of Evaluation to empower the indexes that represent independent innovation capacity of enterprises, according to the method, human factors are excluded in the process of evaluation, the process does not be affected by the elements from experts and knowledge structure of Evaluation staff, experience of job and preferences either. The benefit of Objectively Empowering Method is that evaluation index can be selected, even if an index is very important, but the change extent of the value is little among objects being evaluated, the impact of the index generated in the process of evaluation is not large, that is, its contribution is very small.

In this paper, we transform constraints into the target function firstly, so, Multi-objective optimization problems are formed, then, through multi-objective genetic algorithm to achieve the calculation of projection pursuit. Among the Algorithms, the Programming Algorithm is finally achieved through Matlab programming language. The Projection Pursuit Method is calculated as follows briefly:

Projection Pursuit is that project high-dimensional data on low-dimensional space, then, through the low-dimensional space of projection to analyze the characteristics of high dimensional data, in fact, it is a statistical method to deal with complex multi-factor problems. The calculation steps can be summarized as:

(1) Setting up the data of projection

Set up original data as $x(i,j)$ $(i=1,2,……n_p)$, among them, n, n_p represents the number of original data and the number of evaluation index respectively, then, normalize $x(i,j)$, we can get $x^*(i,j)$.

(2) Calculating projection value

Set up $a=(a_1,a_2,\cdots a_{np})$ as projection direction, project $x^*(i,j)$ on a, then, value of one-dimensional projection z_i can be got ,

$$Z_i = \sum_{j=1}^{n_p} a_j \, x^*(i,j) \quad i=1,\cdots n \tag{1}$$

(3) Setting up Projection Objective Function

Obviously, as to the data of index value evaluated by system, different projection direction reflects different structural characteristics, integrated approaches and means of data mining. In the process of general evaluation, the characteristics of projection values should be spread as: the local projection points should be intensive as far as possible, it is best to unite into a number of collections of points; on the overall, the projection points should spread as far as possible. Then there is an objective function for the projection:

$$f(a)=SzDz$$

In the formula, Sz is the standard deviation of projection value Z_i; Dz is the local density of Z_i which represents projection value;

$$S_z = [\sum_{i=1}^{n} (Z_i - E_z)^2 / (n-1)]^{0.5}$$
$$D_z = \sum_{i=1}^{n} \sum_{j=1}^{n} (R - r(i,j)u(R - r(i,j)), E(z) = \overline{z} , \tag{2}$$

$r(i,j)=z_i-z_j$, $R=0.1Sz$, $U(t)=1(t)$

4) Optimizing the projection objective function, determining the optimal projection direction

Solve the Maximization Problem of Projection target function and estimate the best projection direction, that is:

$$\text{Max Q(a)}= SzDz, \quad \sum_{j=1}^{np} a^2(j) = 1 \tag{3}$$

3.4 Analysis of evaluation results

According to the standardization, we deal with the data of the table that inflect innovation of Industry and enterprise above scale in cities, then, compute with Genetic Algorithm of 1000 generations, and then, we can find the optimal projection value in order to calculate the weight. The data standardized and the results of weight calculation are as showed in the Table 2.

Dalian ranked fifth of the eight cities in the capacity of comprehensive innovation and stayed in the middle class of the selected sub-provincial cities. Considering the inherent components of the capacity of innovation, Dalian industrial enterprises performed better in innovation resources and environment, which need to improve in innovation activities and innovation outputs capacity. From the aspect of

innovation resource, Dalian developed in a good condition which indicates that Dalian had good industrial infrastructures, made better use of science and technology resource leading to great contribution to local economy. However, the scientific and technological personnel accounts for a small proportion of all workers. On the one hand, Dalian industrial enterprises are mainly composed by equipment manufacturing enterprises and labor-intensive enterprises resulting in large amount of industrial workers. On the other hand, Dalian is short of the amount of the scientific and technological personnel especially talent with leadership.

Table 2   The Data Standardized and the Results of Weight Calculation

Item	Innovation resources			Innovation activities			Innovation outputs capacity		Innovation environment	
	Proportion of S & T personnel	Industrial added value	Product sales revenue	Proportion of technology expenditures accounting for products sales revenue	Proportion of R&D expenditures accounting for the sales revenue	Proportion of the number of enterprises engaged in the S & T activities	Patent number	Proportion of new product accounting for sales revenue	Proportion of financial funds sales revenue	The proportion of loans from financial institutions
Max	6.4	1514.7	5079.8	2.38	1.38	33.3	799	37.8	16.8	11.2
Min	2.7	574	2013.6	1.22	0.54	6.8	243	12.1	1.46	0.23
Max-min	3.7	940.7	3066.2	1.16	0.84	26.5	556	25.7	15.34	10.98
Dalian	0	0.4282	0.4469	0.3448	0.1905	0.9321	0	0.0506	0.2959	0.5975
Shenyang	0.7837	0.3616	0.3927	0	0.1667	0.0717	0.3507	0.0934	1	1
Changchun	0.7567	0.0317	0	0.6207	0	0.0528	0.0215	1	0	0
Jinan	0.9459	0.2378	0.1557	1	1	0.1207	1	0.2218	0.0763	0.2978
Qingdao	0.5945	1	1	0.4483	0.6667	0	0.9478	0.7899	0.0482	0.4854
Xiamen	0.2162	0	0.0970	0.8276	0.4048	0.2226	0.5035	0	0.0417	0.8315
Chongqing	0.8108	0.2885	0.3872	0.9828	0.5476	1	0.8597	0.6615	0.2634	0.9180
Nanjing	1	0.6155	0.8807	0.3534	0.3571	0.0528	0.8902	0.1109	0.2927	0.2987
Weight	0.0498	0.1584	0.3607	0.0549	0.3208	0.0245	0.0154	0.0084	0.0254	0.0385

Table 3   Ranking of Various of Capacity of Innovation

Item	Ranking of innovation resource	Ranking of innovation activities	Ranking of innovation outputs capacity	Ranking of innovation environment
Dalian	4	6	8	4
Shenyang	3	7	7	1
Changchun	8	8	5	8
Jinan	6	1	3	7
Qingdao	1	3	1	5
Xiamen	7	4	6	3
Chongqing	5	2	2	2
Nanjing	2	5	4	6

From the perspective of innovation activities, Dalian ranked No.6 in all the evaluated cities with low evaluation. This is mainly because there are no sufficient funds and investment in enterprise technology and science activities compared with other cities, the same happens to R and D activities. Despite the local government and enterprises increasing the input to innovation there still exists some gap between Dalian and other cities. After examining the main reasons, the overall low sale profitability comes to the focus. Although the profitability increases in recent years, 3%-4% cannot be a satisfying number. Under this profitability level, the investment funded by enterprises still accounts for 80% of the total investment in Dalian, that is not an easy task. From another perspective, the reality resulted in the enterprises lack the courage and enthusiasm to invest in high-input and high-risk projects.

Table 4   Ranking of Capacity of Enterprise Innovation of Selected Cities

Ranking	1	2	3	4	5	6	7	8
city	Qingdao	Nanjing	Jinan	Chongqing	Dalian	Shenyang	Xiamen	Changchun

Dalian had huge gap in the enterprise innovation output capacity and ranked the last in this capacity comparison. This phenomenon demonstrated that the industrial enterprises of Dalian do not have enough

capacity to understand and satisfy the market demands. They also lack the capacity to improve market share through adjusting products according to consumer and competitor feedbacks. On the one hand, the government should set up an effective information platform for innovation and increase intellectual property protection, and encourage enterprise independent innovation. On the other hand, enterprises should take advantage of the its nature of connecting to market directly and sensitive mechanism of knowing market demands in order to better transform the scientific and technological achievements into new products and expand market share. From the innovation environment, the industrial enterprises of Dalian ranked better which shows the government and financial institutions exhibit more support to independent innovation and increase the capital investment proportion. The good institutional and financial environments mainly benefit from the better emphasis of enhancing innovation of Dalian, as well as the formulation and implementation of policy in encouraging enterprise independent innovation and building innovation environment.

4 Suggestions on Enhancing the City Innovation Capacity
4.1 Selecting scientific and original innovation model based on independent innovation
The selection of innovation model should be under the guidance of country and city independent innovation strategy and establish scientific positioning in accordance with the development level and specific circumstances such as strength. Enterprises without strong economic and technological strength should adopt the model of "improving the independent innovation capacity based on imitation" which focuses on the digestion, absorption and re-innovation, combined with the necessary integrated innovation. When the enterprises develop to the growth stage and accumulate a certain amount of economic and technological strength, the model of "improving the independent innovation capacity based on cooperation" should be taken. In this model, integrated innovation played a vital role with the help of necessary original innovation and digestion, absorption and re-innovation. And with proper arrangement of intellectual property ownership, share and protection the enterprises can also select to communicate and cooperate with R&D institutions and enterprises extensively. After reaching the mature stage characterized with great economic and technological strength, enterprises should vigorously promote integrated innovation, while strengthening the original innovation. The enterprises with great strength, leading enterprises of industry or high-tech enterprise can apply the model of "improving the independent innovation capacity entirely based on independent innovation", which aim to actively develop strategies for high-tech, especially with independent intellectual property of core technologies and key technologies. The enterprises can also develop re-innovation by combining the introduced foreign advanced technology and independent innovation properly. Different models are selected to apply according to different enterprises, industries and stages.
4.2 Fulfilling the role of city innovation and improving innovation capacity
Enterprises fulfill the role of enhancing the innovative capacity embodied in three aspects: Firstly, enterprises should increase investment and become the main roles in research and development input. Inputs are the material foundation for enterprises to innovate and only with the combination of the necessary capital investment and intellectual conditions, scientific and technological innovation can be developed. The second is the expansion of internal and external cooperation, which becomes the main technological innovation activities. Enterprises must cultivate their own independent innovation capacity and focus on building the culture of independence, open and innovation. From the outside of the enterprises, it is necessary to strengthen the cooperation with research institutes and universities. Enterprises should keep close contact with markets and play the key role in "enterprises, universities and research institutions," trigger the whole chain and promote every party to face the reality and explore the market. The third for main body of innovation is to rely on new technologies to develop new products and apply the innovations. The urban innovation main bodies should play the leading role and try to speed the transformation of the scientific research resource into enterprises products and services tailored to market leading enterprise development, even the whole industry development.
4.3 Paying great attention to the role of market in innovation and take advantage of domestic and foreign scientific and technological resources
Enterprises should keep on innovating based on market demand changes. And enterprises should pay attention to market information, concern about the changes in the market and try to coordinate the relationships of R&D, production and market. Market demands guide and trigger innovation. Enterprises realize the expansion of innovation chain to society demands and market. There is an organic combination of innovation and industrial chain seeking for market, efficiency and development

and competitive advantages. Meanwhile, enterprises should learn and utilize domestic and foreign scientific and technological resources in order to enhance innovation and efficiency, to make up for the lack of enterprise R&D capability. It is necessary to strengthen the cooperation with domestic advanced areas and enterprises with considerable strength in order to absorb advanced technology and management. It is suggested to accelerate the pace of absorbing international advanced technology, make full use of global scientific and technological resources. The enterprises with proper conditions should establish R&D center abroad to obtain core technology and outsource the R&D function to specialized R&D and design enterprises by using the way of third-party technology supply. Also the enterprises should carry out a broad variety of cooperation with foreign famous enterprises, outstanding R&D institutions to enhance the negotiating capacity, learning ability and transforming ability and upgrade the level of cooperation, so as to continuously upgrade and enhance the endogenous capacity of enterprise technology.

4.4 Speeding up the system and innovation management to provide strong support for technological innovation

There is an inseparable relationship among technological innovation, system innovation and management innovation. Enhancing enterprise technological innovation capacity depends on effective organization and mechanisms to carry out rational allocation of resources, especially the need to rationalize all kinds of relations, to eliminate the institutional barriers affecting scientific development and independent innovation, and to create an institutional environment inspiring managers and technical personnel creativity. The innovation system combining enterprises, universities and research institutes should be set up and new mechanism integrating technical innovation, enterprise development and social progress should be formed. The best combination of human, material and financial resources in funding and incentives are sought to enhance independent innovation effectiveness. Organizational management should be improved, digestion and absorption of some key, strategic technology and independent innovation should be strengthened, investment in R&D efforts should be increased and the capacity of innovation should be enhanced. The main efforts should be concentrated on the key technology by taking advantages of cooperation among enterprises, research institutes, and universities. Various obstacles affecting innovation should be removed from system, mechanism and management.

5 Conclusion

Enhancing enterprises as leading roles in innovation system has become an urgent and important issue for improving the current innovation level and setting up innovative cities and country. Dalian had huge gap in the enterprise innovation output capacity and ranked the last in this capacity comparison. This phenomenon demonstrated that the industrial enterprises of Dalian do not have enough capacity to understand and satisfy the market demands. They also lack the capacity to improve market share through adjusting products according to consumer and competitor feedbacks. So enhancing the urban innovation capacity should selecting scientific and rational innovation model based on independent innovation, fulfilling the role of main body of innovation, improve innovation capacity, paying great attention to the role of market in innovation and take advantage of domestic and foreign scientific and technological resources, speeding up the system and management innovation to provide strong support to technological innovation.

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