

# COMPREHENSIVE EVALUATION ON INDEPENDENT INNOVATION SYSTEM BASED ON CROSS-EFFICIENCY DEA MODELS

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## ABSTRACT

The construction of regional independent innovation system is the base for development of regional economy and improvement of competition capability. The main aim of this article is measure the efficiency of regional independent innovation system. Based on the framework of independent innovation system theory, the involved factors and indexes were indentified in this paper. Moreover, taking 17 regions in Shandong province in China as empirical analysis case, the comprehensive evaluation of those regions were calculated by applying cross-efficiency DEA model. Integrating to the real conditions in those regions and referencing on the calculation results, we proposed the corresponding suggestions and measures on the construction of regional independent innovation system in the view of whole Shandong province and 17 regions separately.

**Keywords:** *Independent Innovation, Cross-Efficiency DEA Model, Comprehensive Evaluation*

## 1. INTRODUCTION

The independent innovation system is both a pivotal supporting force of regional economy development and an important component of national independent innovation system. The construction of independent innovation system with typical advantages can enhance regional independent innovation ability and the international market competitiveness. Regional independent innovation is a critical path for regional S&T development and economic development. Shandong province has entered the key period for construction of well-off society and skip of enrich people & strong. Independent innovation system should be integrated to strategic adjustment of the economic structure, regional economic development strategy and ecological construction in Shandong province. Only speed up the establishment of enterprises as the main body, the market as the guidance, and production-study-research combined independent innovation system, can we form the industrial developing pattern with advanced S&T and innovation. The economic development mode should be transferred from increasing material resource consumption to dependence on the progress of S&T development, high quality of workers and innovation management. Only construct the independent

innovation system well in every city and even the whole province and take the construction independent innovation capability as key point, vigorously implement the innovation drive and talents strategy, improve the core competitiveness of each city, and promote the scientific development of each city, can we maintain the economic and social development in stable and rapid way.

Since the 1990s, the academic evaluation of regional innovation capability has been studied in academic field thoroughly. British scholar Cooke and Mogen proposed the concept of "regional innovation system", and described the regional innovation system theory and empirical research in detail[1,2]. Bjorn T. Asheim et. al.[3], David Doloreux and Saeed Parto [4] did the research in specific areas, such as the innovation ability, enriched the regional innovation theory, and so on.

The research on regional innovation system in China began in the 1990s, Sunying and Wang Jici introduced the basic concept and basic theory of the regional innovation system[5], and in his book "the innovation space - enterprise cluster and regional development", the regional innovation system and regional economic development relationship and enterprise cluster development were studied. Wang Delu took Zhongguancun as the main research object and analyzed its regional innovation system



elements, organization structure and operation mechanism[6]. Gai Wenqi proposed the framework of regional innovation network system, which involved enterprises, universities and research institutions, government and intermediary institutions and regional financial institutions as the regional innovation network nodes, where innovation network will be occurred completely by each node in a process of collaborative innovation group activities and decentralized decision-making process[7].

Many scholars also applied different evaluation methods to evaluate the ability of regional innovation system, which includes the National Development Strategy Research Group pressed "China regional innovation ability report" in 2003; Guan Jiancheng et. al. evaluated Chinese regional innovation system's innovation efficiency and ability [8]; Liu Yulin, Hu Zhijian evaluated inter-provincial regional innovation in China [9]; Li Jing, Bai Junhong calculated the innovation efficiency based on provincial panel data[10].

In summary, the studies mentioned above mainly focused on the evaluation object in big cities, while for the whole province evaluation research is relatively less. In the application of evaluation, they mostly used cross section data and historical data, however the analysis and judgment on the comprehensive evaluation of the characteristics and the future trend are rare; evaluation method mainly using the static evaluation, such as analytic hierarchy process (AHP) and incidence matrix method, while the reliability is obviously insufficient.

**2. CROSS-EFFICIENCY DEA PRINCIPLE AND MODEL**

To calculate the relative efficiency of multiple inputs and multiple output system for each of decision making unit, denoted as DMUs, DEA expresses many defects in calculation, especially in the case that most of DMUs are efficient by using traditional DEA models, which will bring more uncertainty to comprehensive evaluation results. In order to overcome the defects of DEA model in measuring, using the cross-efficiency DEA methodology was proposed. Cross-efficiency DEA is the use of other units when effective corresponding weight vector determined the efficiency of decision making units calculated mean, therefore, this model is also a kind of group evaluation method. In traditional CCR model, assume that  $X_{ij}$  and  $Y_{rj}$  were the  $j$ th DMU's  $i$ th ( $i = 1, 2, \dots, m$ ) input vector and the  $r$ th ( $r = 1, 2, \dots, s$ )

output vector separately. The CCR programming model for  $j_0$ th DMU can be expressed as following:

$$(p)_{CCR} \begin{cases} \max E_{j_0} = u^T y_{j_0} \\ s.t. \omega^T x_j - \mu^T y_j \geq 0 \\ \omega^T x_{j_0} = 1 \\ j = 1, 2, \dots, t, \omega \geq 0, \mu \geq 0 \end{cases} \quad (1)$$

By calculating model (1), the optimal value for  $j_0$ th DMU can be drawn, denoted as

$$v_i^* = (v_{1j}^*, v_{2j}^*, \dots, v_{mj}^*), u_r^* = (u_{1j}^*, u_{2j}^*, \dots, u_{sj}^*).$$

By using the above weight distribution, we can get the cross efficiency value for other DMUs, the formula can be shown as:

$$E_{ks} = \frac{\sum_r u_{rk}^* y_{rs}}{\sum_i v_{ik}^* x_{is}} \quad (2)$$

The  $E_{ks}$  representation for decision making units DMUs, the optimal weight calculation of DMUs value  $E_{kk}$  as decision unit DMU<sub>k</sub> corresponding CCR efficiency value Cross-efficiency can through the table below to determine.

Table 1: Cross-Efficiencies Matrix

DMU	1	2	3	4	...	n
1	$E_{11}$	$E_{12}$	$E_{13}$	$E_{14}$	...	$E_{1n}$
2	$E_{21}$	$E_{22}$	$E_{23}$	$E_{24}$	...	$E_{2n}$
3	$E_{31}$	$E_{32}$	$E_{33}$	$E_{34}$	...	$E_{3n}$
4	$E_{41}$	$E_{42}$	$E_{43}$	$E_{44}$	...	$E_{4n}$
...	...	...	...	...	...	...
n	$E_{n1}$	$E_{n2}$	$E_{n3}$	$E_{n4}$	...	$E_{nn}$

  

Cross-efficiency	$E_1$	$E_2$	$E_3$	$E_4$	...	$E_5$
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In Table 1,  $E_{kk}$  is the CCR efficiency value in traditional DEA model,  $E_{ks}$  is the efficiency for  $s$ th DMUs by using optimal weight of DMU<sub>k</sub>. The cross-efficiency value can be calculated as following:

$$e_k = \frac{1}{n} \sum_{\forall s} E_{sk} \quad (3)$$

That is calculated for each column in the matrix of mean, sometimes in the course of calculation in order to avoid the influence of  $E_{kk}$  efficiency value, we use the following formula to calculate cross-efficiency value.

$$\omega_k = \frac{1}{n-1} \sum_{\forall s \neq k} E_{sk} \quad (4)$$

Cross-efficiency model calculation can avoid single decision unit in the evaluation of the weight distribution of favoritism, and through the group



evaluation model for the evaluation result, therefore, this model and the method not only can overcome the shortage of the DEA model calculation, but also can get more accurate comprehensive evaluation results.

### 3. THE CONSTRUCTION OF THE REGIONAL INDEPENDENT INNOVATION INDEX SYSTEM

The construction of index system is the premise and key step to realize comprehensive evaluation, and only scientific and reasonable evaluation system can obtain accurate and effective comprehensive evaluation results. Therefore, we constructed the comprehensive evaluation index system of regional innovation system of comprehensive evaluation index system by following the scientific principle, the feasibility principle, the comparability principle, integrity principle, the functional principle, guidance principle and measurability principle.

Innovation resources refers to the innovation activities all the resources necessary, such as personnel, funds, information, natural resources, etc. In the innovation behavior subject, the enterprise as technical innovation main body role, scientific research institutions and universities are mainly responsible for knowledge innovation, the government is the main body of institutional innovation, and intermediary is the bridge connecting production. Regional independent innovation ability is the innovation input, process and output and related factors set in the area under special conditions. Thus input and output is still mainly based on the evaluation of regional independent innovation capacity. And the following indexes are representative obvious, so as to select the following index.

Table 2: Regional Independent Innovation Ability Evaluation Index

The 1st level index	The 2nd level index	The 3rd level index
(a) Innovation ability	(a-1) Human resources investment	(a-1-1) the city's R&D activity unit number (a)
		(a-1-2) The R&D personnel (people)
		(a-1-3) The R&D personnel reduced full-time equivalent (per year)
		(a-1-4) Large and medium-sized enterprise R&D personnel (people)
	(a-2) Financial	(a-2-1) the R&D expenditure (ten thousand Yuan)

resources investment	(a-2-2) The R&D funds to GDP ratio (%)
	(a-2-3) Large and medium-sized enterprise R&D funds (ten thousand Yuan)
	(b-1) Innovation output capacity of knowledge, technology innovation ability
(b) The innovation output capacity	(b-1-1) Patent applications (item)
	(b-1-2) An application for a patent for invention number (item)
	(b-1-3) Has the invention patent number (item)
(b-2) Economic creativity	(b-2-1) municipal industrial enterprises above designated size industrial output (ten thousand Yuan)
	(b-2-2) Various cities industrial enterprises above designated size gross output value of new and high technology industries (ten thousand Yuan)
	(b-2-3) High and new technology industrial output value accounted for the proportion of gross industrial output value (%)

### 4. EMPIRICAL ANALYSIS

#### 4.1 Data Collection

According to Shandong province 2011 year book, we can collect 2011 statistic data based on the indexes mentioned on Table 2. Because of the limited pages of this paper, we didn't list the original data of indexes. If you are interested in the original statistic data, you can send email to ty0608@163.com.

#### 4.2 Using CCR Model to Calculate Efficiency

According to the traditional DEA model CCR model, we can get the CCR efficiency value for each of DMU. The calculation results can be listed on the second column on Table 3.

Table 3: Calculation Results With CCR Model And Cross-Efficiency DEA Model

Region	CCR efficiency	cross-efficiency value	Ranks with Cross-efficiency
Jinan	1	0.998444	1
Qingdao	1	0.926436	2
Zibo	0.8898	0.825844	5
Zaozhuang	1	0.574834	15
Dongying	1	0.803923	6
Yantai	1	0.921338	3
Weifang	0.7417	0.891621	4
Jining	1	0.746788	8
Taian	1	0.677672	11
Weihai	0.9257	0.795516	7
Rizhao	1	0.697664	10
Laiwu	1	0.633613	13



Linyi	0.8807	0.729315	9
Dezhou	1	0.586106	14
Liaocheng	1	0.652659	12
Binzhou	0.3783	0.392537	17
Heze	1	0.546406	16

On the second column in Table 4, we can see that there are more than one city efficiency value is 1. Based on the conception of traditional DEA model, the efficiency value is equal to 1 meaning the DMU has high performance in regional independent innovation capability. There are 12 DMUs are CCR efficient in 17 regions in Shandong Province. However, we cannot classify the performance of efficient DMUs. To overcome the shortcoming of traditional DEA model, we will apply cross-efficiency in next section.

#### 4.3 Using Cross Efficiency DEA To Measure Efficiency

Through the calculation, cross efficiency of each decision-making unit values are listed in the third and fourth column in Table 4. Referencing on the calculation results on Table 4, we can be seen that there are some cities, such as Jinan, Qingdao, Yantai, reached on the high level of independent innovation system, on the other hand, there are other cities, such as bin Zhou, ZaoZhuang, heze, etc., with not ideal results. This is because, like Jinan, Qingdao, yantai, the city's economy is relatively developed, which involved many universities, scientific research institutions, and abundant human resources. Secondly, those regions also have many large and medium-sized enterprises, enterprise scientific research personnel and scientific research ability. At the same time, the government in S&T and education of fiscal also spends more on those regions. So, those cities have obvious advantages in regional innovation. In contrast, such as binzhou, ZaoZhuang, laiwu city, there is no such a good innovation condition. So, the corss-efficiency values are lower than others.

## 5. CONCLUSION

### 5.1 Measurements And Suggestions In The View of Shandong province

(1) Establish incentive mechanism for talents. Talents are the core resources of independent innovation. There are many development personnel in Shandong province, but the high-level innovative talents are shortage. Accordingly, we should construct incentive mechanism for talents to absorb the talents of high level and strengthen the talent internationalization and enhance the talent training efforts.

(2) Construct the independent innovation system with enterprise as main body. Only when

enterprises become the main body of the independent innovation, can we transfer the independent innovation achievement to material wealth productivity and competitiveness. Shandong province should focus on supporting and cultivating with independent intellectual property rights and the famous brand of national large enterprise to increase the independent brand of propaganda, improve the independent brand value, enlarge its market share, and increase Shandong products in domestic and international market competitiveness.

(3) Vigorously promote university-industry cooperation. The key to improve a regional independent innovation ability is to establish the enterprise as the main body, the market as the guidance and the combination of technical innovation system. This is not only the trend of development of the economy and S&T, but also the important guarantee of enhancing the ability of independent innovation in Shandong province. Universities and scientific research institutions carry out basic research high-tech research, and try to reach the technological breakthrough. Enterprises transfer universities and research institutions' research achievements into productivity. Promote research learning, constantly strengthen the scientific research ability, and constantly realize the transformation of S&T achievements, and then we can continuously to achieve the ultimate goal "production" to create wealth for cities. At the same time, each unit to promote each other, mutual coordination, common development, form a creative system.

(4) Strengthen the protection of intellectual property rights. Further establish and perfect the patent work operation mechanism, management service system and supporting policies. On the other hand, we should intensify IPR publicity training efforts, increase the whole society's awareness of IPR protection and overall quality. Moreover, leading enterprises should establish and perfect the intellectual property management system. Government should improve the patent administrative law enforcement team, strengthen the illegal infringement behavior crackdown, improve the patent administrative law enforcement ability and level, and strive to build help protect invention, promote technological innovation and development of the high-tech industry in the good legal system and market environment. At last, we should vigorously promote patent technology industrialization, increase the independent intellectual property rights in the technology and products, improve the proportion of our city with





independent intellectual property rights as the main contents of the comprehensive competitive power.

(5) Intensify environmental support capability of strength. The so-called environmental protection ability refers to the cultural environment and economic environment. Due to the independent innovation is uncertain and thereby risk, especially the original science and technology innovation. Therefore, the government should through some fiscal and monetary policy to the innovation main body subsidies and support for encouraging innovation.

### 5.2 Measurements And Suggestions In The View of Cities

(1) Strengthening regional cooperation and integration, increase efforts to introduce S&T projects. Taking the independent innovation achievement advanced city as benchmarking, strengthen the regional cooperation. At the same time, collect domestic and international scientific research project information through multiple channels, establish a scientific and technological project library, to provide enterprises with S&T project service. At same time, taking the project as a link, promote local enterprises and domestic and international enterprises, especially large and medium-sized industrial enterprise cooperation. Moreover, we also should increase S&T investment promotion efforts.

(2) Increase S&T investment, and promote the regional internal plan as a whole and integration. According to provisions of the regulations in the national S&T progress method and provincial S&T progress, both city and county levels of financial application technology R&D funds shall be accounted for according to the budget spending 1.3% a year and the proportion of the increase in the growth rate is not lower than the requirements of financial arrangements, therefore we should play the role in guiding government good investment. And enterprise should carry sufficient technical development funds, technology development funds accounted for the proportion of sales income general enterprise to achieve 2%, large and medium-sized enterprises to reach 4%, high and new technology enterprise to achieve 6%. Taking the R&D cost in enterprises as their profit index and establishing the evaluation index system of enterprise independent innovation, we should take the enterprise R&D ability construction and independent innovation, independent research and development products as an important achievement of performance assessment indicators. We also should perfect investment risk evaluation system, establish and perfect the venture capital exit value-

added mechanism and business operation mode. To broaden the financing channels, widely absorbs the folk capital to participate in scientific and technological innovation.

(3) Strengthen the construction of the talents team. Fully play the core function of talent in role of independent innovation, enhance the talent especially S&T talents and efforts to introduce based on the actual data of each city. Implement different training plan to speed up the technology talented person echelon construction, and strive to create a rational structure, the innovation ability of high-quality S&T personnel and management personnel team. At the same time, optimize the environment, improve service, distinguish special fund and other measures, both at home and abroad. To attract talents, we should pay great attention to the leader especially in the field of S&T, entrepreneurs and talents who can bring a project to start a business. Actively create conditions and create talents pioneer park, we should construct "green channel" for them according the international standard. Gradually set up with international standards in the personnel system and salary system, so as to offer the development of the city planning strategy.

(4) Perfect the incentive mechanism of S&T. Reform the S&T achievements incentive measures, increase rewards project, improve the rewards amount, give play to the guiding role of the government rewards, and encourage the innovative scientific and technological personnel. Add international S&T cooperation award to reward for economic and social development personnel who has made outstanding contribution in their research field. Perfect the talents as the core of the incentive mechanism to absorb high-level talents, strengthen the talent internationalization and enhance the talent training efforts.

(5) Strengthen intellectual property protection. Further to establish and perfect the patent work operation mechanism, management service system and supporting policies. To intensify IPR publicity training efforts, increase the whole society's awareness of IPR protection and overall quality. On the other hand, we should guide enterprises to establish and perfect the intellectual property management system and improve the patent administrative law enforcement team, strengthen the illegal infringement behavior crackdown, improve the patent administrative law enforcement ability and level, and strive to build help protect invention, promote technological innovation and development of the high-tech industry in the good legal system and market environment. Moreover,



we should vigorously promote patent technology industrialization, increase the independent intellectual property rights in the technology and products, improve the proportion of our city with independent intellectual property rights as the main contents of the comprehensive competitive power.

#### ACKNOWLEDGEMENTS

The main work of this paper is supported and sponsored by Young Foundation of Ministry of education, humanities and social science research projects (11YJC630100), project of Shandong Economic and Information Technology Committee (No.2012EI107; No.2012EI106) and the Fundamental Research Funds for the Central Universities (11CX04031B).

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