Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 14 (4): 333-340, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.333.340

Analysis on the Gaps of Innovation Capabilities of China's High-Tech Industries Based on the Theil Entropy and Gini Coefficient

Gui Huangbao
School of Management and Economics,
North China University of Water Resources and Electric Power, China

Abstract: High-tech industry is an important engine of China's economic growth. The large gaps of innovation capabilities in high-tech industries between different regions will affect the coordinated development of regional economies. This study, employing the model of Theil entropy and the Gini coefficient, measures the spatial and temporal gaps of innovation capabilities of China's high-tech industries, based on patent applications in high-tech industries from 1995 to 2010. The results show that the gaps of the innovation capabilities in high-tech industries between different regions in China are large and furthermore, the gaps reveal expanding tendency. Moreover, this study illustrates that the innovation capability disparities between different regions are the prior factor influencing the development of China's high-tech innovation capabilities while the internal differences of different regions have less impacts. Finally, this study finds that the largest gap of innovation capability takes place in the computer and equipment industry and the smallest gap exists in the pharmaceutical manufacturing industry. The results of this study could play an important role in guiding the policies aiming to narrow regional gaps and promote coordinated development of different regions.

Key words: High-tech industry, innovation capability, theil entropy, gini coefficient

INTRODUCTION

High-tech industry which is strategic industry of national economy has become the important power of development and economic structure adjustment. Nelson (1984) considered that the high-tech industry was leading industry that led to general economic growth and strategic industry that enhanced national competitiveness. Since 1980s, the development of high technology industry becomes the major source that each country to gain competitive advantage and economic growth (Choi, 2003). During 11th Five-Year period, China's high-tech industry dimensions expanded ceaselessly. GDP grew at an average annual rate of 15%. By the end of 2011, total production value achieves 8.8434 trillion RMB which occupies GDP18.75%. But there are still many problems such as lack of core technology, low value-added exported products, under-investment of R and D. It still faces the demanding task of improving indigenous innovation urgently. The ability of indigenous innovation decides the development of an industry and influences national or regional industrial structure and competitiveness. The high-tech industry innovation ability has already caused the widespread concern of scholars home and abroad. They have discussed this issue from the different aspects and got many achievements.

From the point of abroad, Freeman (1987), Lundvall (1992), Nelson (1993), Freeman and Soete (1997), Malerba (2004) and Malerba and Brusoni (2007), studied on the concept of industrial innovation initially. Although there is no clear definition but it is believed that innovation is the concept of a system with its characteristics. According to the Malerba results, it generally consists of knowledge and technology, actors and network and system etc. On the industry innovation capability, Freeman and Soete (1997) discussed the cases from the United States, Japan and the Soviet Union. It is thought that industrial transformation efficiency depends on a country's innovation capability and innovation is the core of industrial innovation. Schramm (2008) thought that innovation was not just a great thought. The key is to increase the value to consumers and enterprises. While Peters (2008) studied German's enterprises innovation performance systematically and thought innovation really affects enterprise performance and competitiveness. As to the measurement of innovation capability, OECD (2005) released the OSLO Manual which focused on measurements of theoretical basis, framework and methods of industry innovation capability. It has been used as the survey book and guide to promote industry innovation activities in many countries. Schramm (2008) emphasizes not only the measure of innovation investment but also the measure of innovation output.

Adams *et al*. (2006) argued that the measure of innovation capability can not only pay attention to investment and output but also to processes. Benavente (2006), Griffith *et al*. (2006), Hall *et al*. (2009), Jefferson *et al*. (2006), Loof and Heshmati (2006), Polder *et al*. (2009) and other scholars used the CDM (Crepon *et al*., 1998) model to discuss the innovation input, innovation output and productivity relationship on the enterprise level. In China, Li *et al*. (2010) and Lu (2011) and other scholars discussed evaluation index system, method and model of high technology industry innovation capability from different perspectives. China's high-tech industry's innovation capability was analyzed and evaluated based on the qualitative or quantitative.

Reviewing the existed literature on innovation capability, the most concentrates on the construction of evaluation indices system. Most of them used qualitative or quantitative methods for absolute measurement and comparison. But the characteristics and tendency of spatial and temporal distribution are rarely involved. However, high-tech industry has become the important engine of economic growth. The big regional gap will affect the coordinated development of regional economy in China. Therefore, to research the characteristics and tendency of spatial and temporal distribution is of great importance, whether in theory or in practice. For that reason, Theil entropy and Gini coefficient are applied to answer this question, in order to better control the characteristics and trends of high-tech industry innovation capability, to better establish the policy to promote the development of high-tech industry in China.

MATERIALS AND METHODS

Innovation capability evaluation indices: The indices to measure high-tech industry innovation capability can be composed of many factors. From different perspectives researchers have designed evaluation indices system but the number of patents is very important. The amount of patent applications to measure an industry or a national scientific and technological progress and independent innovation ability is one of the key indexes. The patent is the only source to analyze the technology innovation process. As for data quality, availability and specific industry, organization and technical details, any other data are not comparable with it (Griliches, 1990). So using the patent applications or grants as innovation capability index is a widespread practice at home and abroad (Acs *et al*., 2002). Acs think that using the patent grants number to measure innovation ability exists certain one-sidedness. Because patents neither include all vital innovation, nor can indicate how important the innovation is. Though patent is imperfect to measure innovation, it is quite reliable and useful (Jaffe *et al*., 1993) which also has made a detailed explanation and description by Guan and Liu (2005). Jaffe (1989) Andersson *et al*. (1990) and Stern *et al*. (2000) that the patent is a measure of innovation is a good indicator. At the same time as the patent application grant amount has the versatility, consistency and availability which is still the researchers' commonly used measure of innovation ability index (Bode, 2004; Ceh, 2001). But there are some limitations to use the number of patent applications as innovation capability index in the study of Acs *et al*. (2002) Firstly, some innovators won't apply patents for the R and D outputs to avoid the risks of the disclosed information. Secondly, the number of patent applications can't exactly represent the quality and value of the innovation. To deal with the problems, new product sales are used to measure the innovation ability. Meanwhile, the sales may have potential statistic errors which are caused by the motivation to obtain extra government subsidies through telling lies about the sales.

In addition, the use of new product sales process innovation deficiency is not included and the amount of patent applications includes two parts processing and product innovation.

Therefore, in the absence of a better choice, use the patent as innovation capability index is a better choice. Then, this study will use patent applications as an evaluation index to explore the gap between the characteristics of spatial distribution and trend of high-tech industry innovation capability in mainland China (excluding Taiwan, Hong Kong and Macao).

Evaluation method of innovation capability: In general, the measurements of gaps include two methods which are absolute and relative indicators.

Absolute number has advantages of simple, popular and intuitive but it fails to depict the accurate relationships between internal structural characteristics and development tendency of high-tech industry innovation ability. In view of this, this research from the relative disparity proceed with, scientific choice, appropriate relative index to characterize the high-tech industry innovation ability temporal gap. The measure of relative difference measurement method, such as range, variation coefficient, standard deviation, Gini coefficient and Theil entropy, different research methods are to some extent in characterizing the differences that exist between. But according to the literature (Wan, 2008) study found, a good relative index should have the following properties: First, Anonymity; second, Homogeneity; third, Population Independence; fourth, Principle of Transfers

(Dalton, 1920); Fifth, Strongly Lorenz Consistent; sixth, Normalization etc. The methods of Theil entropy and Gini coefficient meet the requirements mentioned above and have its unique properties to describe the gaps. Consequently, both of them are used to measure the temporal gaps of high-tech industry innovation ability in China.

EVULATION MODEL OF INNOVATION CAPABILITY

Theil entropy decomposition model: Theil entropy was firstly proposed by Theil (1967). It is used to measure the regional income gap. Because of its prominent advantages that can reflect the regional disparity and its structure feature, the space gap can be decomposed into the independent group gap and within-group gap. Later it was widely used to measure the relative gap in economic development with strong scientific and adaptability on measuring relative difference gap. Shorrocks (1980), Duro and Padilla (2006) and other scholars put forward a more scientific calculation model by improvement and development. Theil entropy meets the above 6 standards at the same time, also has such features as Symmetry, Scale Invariance, Pigou Dalton Criterion and so on. In order to explore space and time gap of China's hi-tech industry innovation capability, Theil entropy model will be used and decomposed, i.e.,

$$I_c(y) = \frac{1}{N}\frac{1}{c(c-1)}\sum_{i}^{N}\left[\left(\frac{y_i}{\mu}\right)^c - 1\right],\ c \neq 0,1 \quad (1)$$

$$I_c(y) = \frac{1}{N}\sum_{i}^{N}\left(\frac{\mu}{y_i}\right)^c \log\frac{\mu}{y_i},\ c = 0 \text{ or } 1 \quad (2)$$

Among them, i = 1, 2......N, N is the number of regions or provinces, y_i is for the number patent applications of i areas, μ means the average value of y_i, namely the mean of regional patent applications. In equation (1), c is other values except 0 or 1 while in equation (2), c is 1 or 0. According to the Theil (1967) and Shorrocks (1980), early Theil entropy calculation of c was 1. But then as the model research unceasingly developed, Theil recommend c is 0 when computational model is used. Therefore the gap between groups and within-groups will be independent of each other and the overall gap will be completely decomposed into the independent group gap and within-group gap. Then the contribution to overall gap can be deduced from within-group gap and independent group gap. According to the documentary research (Shorrocks, 1980; Duro and Padilla, 2006), the overall N is divided into G group, Theil entropy can be decomposed into:

$$I_c\left(y^1, y^2, \ldots y^G; N\right) = \sum_{g=1}^{G} w_g^G(\mu, N) I\left(y^g; N_g\right) + I\left(\mu_1 u_{N_1}, \mu_2 u_{N_2}, \ldots \mu_G u_{N_G}; N\right) \quad (3)$$

Based on (3) Theil decomposition, the first on the right of the equal is within-group gap while second is the independent group gap.

Among them:

$$w_g^G(\mu, N) = \frac{N_g}{N}\left(\frac{\mu_g}{\mu}\right)^c$$

represents the group weight, when c = 0 it refers to the weight of the provinces and regions in group G of the total number of provinces and regions; $I(y^g; N_g)$ means the G group Theil entropy, I ($\mu_1 u_{N1}$, $\mu_2 u_{N2}$,....$\mu_G u_{NG}$;N)refers to the within-group gap which can be calculated by transposition, i.e.

$$I\left(\mu_1 u_{N_1}, \mu_2 u_{N_2}, \ldots \mu_G u_{N_G}; N\right) = I_c\left(y^1, y^2, \ldots y^G; N\right) - \sum_{g=1}^{G} w_g^G(\mu, N) I\left(y^g; N_g\right) \quad (4)$$

Meanwhile, contribution of different groups to nationwide Theil entropy calculation model can be deduced from equation (3), namely:

$$Con_g = \frac{w_g^G(\mu, N) I\left(y^g; N_g\right)}{I_c\left(y^1, y^2, \ldots y^G; N\right)} \times 100 \quad (5)$$

Innovation capability of gini coefficient model: Gini coefficient, proposed by the Italy economist named Gini, was evolved from a kind of inequality index. Since the index can reflect the overall state income gap it becomes very prevalent in the world and also becomes an important statistical analysis index to measure gap degree. Through the scholars' continuous transforming, developing and perfecting, the commonly used Gini coefficient equation is:

$$G = \frac{1}{NW_N}\sum_{i=2}^{N}\sum_{j=1}^{i-1}(y_i - y_j) \quad (6)$$

Among them, i = 1, 2,.....N, y_i is the patent quantity of i area among N regions or provinces which patent quantity are arranged from low to high while W_N is patent quantity of N regional area. For ease of calculation, according to the Gini Coefficient and Lorenz curve, simple equation of Gini Coefficient can be deduced, i.e.

$$G = 1 - \frac{1}{NW_N}(2\sum_{i=1}^{N} W_i - W_N \quad (7)$$

Among them:

$$W_i = \sum_{j=1}^{i} y_i$$

i = 1, 2,....N. Thus, Gini Coefficient can be calculated through STATA or EXCEL easily. Furthermore, according to documentary researches (Kakwani, 1977), Gini Coefficient can be decomposed, namely:

$$G = \frac{1}{\mu}\sum_{k=1}\mu_k C_{G_k}$$

G is total Gini coefficient. K is the source of partial patent. CI_{Gk} is Concentration Index, also can be expressed as partial patent Gini Coefficient. The calculation method is the same as the overall patent Gini Coefficient. μ, μ, respectively represents mean of all patent application quantity and partial mean. Let $V_k = \mu_k/\mu$, the representative partial patent mean total patent mean proportion, then $G = \sum_{k=1} V_k CI_{G_k}$ i.e.,

$$ConG_k = \frac{V_k CI_{G_k}}{G} \times 100\% \quad (8)$$

On the above, $ConG_k$ is the k patent's contribution rate to total patent Gini Coefficient.

EMPERICAL RESULTS AND ANALYSIS

Data selection and region division: The number of high-tech industry patent applications from 31 provinces, autonomous regions and municipalities will be chosen as the data for this study. Following the classification method which is mainly used in science and technology, all provinces (excluding Taiwan, Hong Kong and Macao) are divided into East region, Central region, West region as well as Northeast area. Moreover, because of space distribution characteristics of the Yangtze River Delta and the Bohai Rim, they are listed separately, in order to better measure innovation capability space gap of high-tech industry. The whole country is divided into six regions. And because Hainan and Tibet's high-tech industry patent data has serious missed, these two regions' will be eliminated to guarantee the analysis objective, reliable and valid. Therefore, high-tech industry innovation capability space-time gap of six regions in 29 provinces, autonomous regions and municipalities will be discussed. They are the Yangtze River Delta region (Shanghai, Jiangsu, Zhejiang), Bohai Rim region (Beijing, Hebei, Shandong and Tianjin), central region (Hubei, Hunan, Jiangxi, Henan, Shanxi and Anhui), Northeast region (Liaoning, Jilin, Heilongjiang), southern region (Fujian, Guangxi, Guangdong, Sichuan, Yunnan, Guizhou and Chongqing) and the northwest region (Shaanxi, Gansu, Qinghai, Xinjiang, Ningxia and Inner Mongolia). All data are derived from China's Statistics Yearbook on High-technology Industry and China's Statistical Yearbook on Science and Technology from 1995 to 2011.

Decomposition of innovation capability: According to Theil entropy decomposition model and patent data of different regions, high-tech industry innovation capability within-group gap and the gap between independent groups can be gained based on MATLAB 7.0, the results in Table 1. In Table 1,the larger the number is, the greater the gap of innovation ability is.

On the whole, space difference of China's high-tech industry innovation in different regions is large. Regional innovation capability gap is significant. From the time span, 1995-2010 innovation capability gaps have shown a trend to enlarge. During the 11th Five-Year Plan period, especially between 2007 and 2009, high-tech industry innovation capability gaps have narrowed. The result may be led by the plans and policies which relate to the improvement of independent innovation ability and the innovative country construction.

In regional terms, high-tech industry innovation capability gap in the Yangtze River Delta region, northeast region and the central region are smaller; innovation capability gap in northwest area and south area are the largest. Although the gap in the Yangtze River Delta region, northeast region and central region are very small, the absolute value difference is still very big. The innovation capability of Yangtze River Delta and Bohai Rim is much higher than the northeast region and the central region. The gap between groups is shown a trend to enlarge, the same as national high-tech industry innovation capability Theil entropy change trend. This point can also be examined from the contribution rate of innovation capability gap. According to equation (5), Table 2 can be drawn, in which contribution rate of innovation capability is shown. The meaning is degree within-group gap or gap between groups effects overall gap.

As can be seen from Table 2, the biggest factor of China's hi-tech overall gap is the gap between groups. This indicates that main reason for high-tech industry overall innovation capability gap is that the gap in different regions is bigger. Within-group gap has a bit influence. This result is an important reference to make

Table 1: Theil entropy decomposition of China's high-tech industry innovation capability (1995-2010)

Time	Nationwide	Yangtze river delta	Bohai Rim	Central	Northeast	South	Northwest	Group gap
1995	0.2079	0.0355	0.0960	0.0509	0.0824	0.1033	0.3494	0.0747
1996	0.2256	0.0227	0.1081	0.0270	0.0755	0.1269	0.3857	0.0845
1997	0.2585	0.0441	0.1287	0.1165	0.0622	0.1897	0.3078	0.0962
1998	0.3161	0.0324	0.0734	0.2537	0.0001	0.2619	0.3948	0.1052
1999	0.3949	0.0110	0.2853	0.2869	0.0203	0.2642	0.2278	0.1820
2000	0.4684	0.0370	0.2860	0.1560	0.0636	0.3372	0.4558	0.2105
2001	0.5216	0.0302	0.3198	0.1202	0.0030	0.2731	0.5821	0.2628
2002	0.5956	0.0098	0.3079	0.2212	0.0901	0.3242	0.8304	0.2470
2003	0.5959	0.0269	0.2279	0.0462	0.0059	0.3047	0.9303	0.2855
2004	0.6439	0.0591	0.1357	0.1517	0.0567	0.3441	0.8585	0.3212
2005	0.5942	0.0114	0.1175	0.1977	0.0900	0.4454	0.6023	0.2945
2006	0.7461	0.0202	0.0982	0.1494	0.0581	0.6091	0.5837	0.4258
2007	0.7797	0.0016	0.1359	0.1111	0.0230	0.5588	0.8196	0.4310
2008	0.7525	0.0105	0.1344	0.0969	0.0540	0.5558	0.8231	0.4028
2009	0.5603	0.0116	0.0971	0.1061	0.0850	0.4248	0.3641	0.3371
2010	0.6943	0.0324	0.1189	0.1029	0.1045	0.4959	0.7669	0.3641

Table 2: China's high-tech industry innovation capability contribution rate (%) (1995-2010)

Time	Yangtze river delta	Bohai Rim	Central	Northeast	South	Northwest	Group gap
1995	1.76	6.37	2.53	4.10	11.99	34.77	38.48
1996	1.04	6.61	1.24	3.46	13.58	35.37	38.70
1997	1.76	6.86	4.66	2.49	17.71	24.63	41.89
1998	1.06	3.20	8.30	0.00	20.00	25.84	41.60
1999	0.29	9.97	7.52	0.53	16.15	11.94	53.60
2000	0.82	8.42	3.44	1.40	17.38	20.14	48.40
2001	0.60	8.46	2.38	0.06	12.64	23.09	52.77
2002	0.17	7.13	3.84	1.57	13.14	28.84	45.31
2003	0.47	5.28	0.80	0.10	12.34	32.30	48.71
2004	0.95	2.91	2.44	0.91	12.90	27.58	52.31
2005	0.20	2.73	3.44	1.57	18.09	20.97	53.00
2006	0.28	1.81	2.07	0.81	19.71	16.18	59.14
2007	0.02	2.40	1.47	0.31	17.30	21.75	56.75
2008	0.14	2.46	1.33	0.74	17.83	22.63	54.87
2009	0.21	2.39	1.96	1.57	18.30	13.44	62.13
2010	0.48	2.36	1.53	1.56	17.24	22.85	53.98

policies promoting regional coordinated development of the high-tech industry. It is an alert that difference in different regional groups is shown a trend to enlarge. It has increased from 38.48% in 1995 to 53.98% in 2010, the same as the tendency shown in Table 2. This fully demonstrates regional gap of high-tech industry capability is still widening and uncoordinated or uneven trend of high-tech industry development is still expanding. Policymakers must be concerned about this. At the same time it indicates that the influences of several regions, such as the Yangtze River Delta region, the Bohai Rim region and the northeast region, on high-tech industry overall gap has a decreasing trend in Table 2. Especially, the effect of Yangtze River Delta region which has a better high-tech industry, has almost fallen down to zero. Its regional disparity in innovation capability of the high-tech industry has little effect which can be neglected. In contrast, the southern and northwest region is of greater impact on national high-tech industry innovation capability gap. And it shows the trend of expanding.

Therefore, for the Yangtze Delta, the Bohai Rim, Central and Northeast region whose innovation gap is smaller it is important to improve the overall innovation capability and competitiveness and promote the coordinated development of regional economy. For the bigger innovation gap regions it is important to make industry cluster effect and vigorously promote the development of high-tech industry, according to the local industrial advantages, resource endowments, as well as market demand and other conditions.

Analysis on innovation capability gap between different industries: For the further study of different high-tech industries' innovation capability gap and the effect different industries on the national high tech industry innovation capability gap, according to the equation (7) and (8), high-tech industry's Gini coefficient is computed through the STATA (Table 3). G_k is the Gini coefficient of the k patent. k indicates the high-tech industry which is derived from the current High-tech Industry Statistical Classification Catalogue. In Table 3, the larger the number is, the bigger the gap of innovation capability is.

In Table 3, the overall trend of innovation capability gap evaluated by Gini coefficient is highly consistent with trend estimated through Theil entropy. It demonstrates

Table 3: Gini coefficient of China's high-tech industry innovation capability (1995-2010)

Time	$G_{overall}$	$G_{Pharmaceutical}$	$G_{Aerospace}$	$G_{Electron\ and\ tel}$	$G_{Electronic\ computer}$	$G_{medical}$
1995	0.4964	0.6879	0.7484	0.6219	0.7341	0.5847
1996	0.5114	0.5829	0.6895	0.6673	0.7577	0.5942
1997	0.5401	0.5648	0.7177	0.7591	0.8685	0.6634
1998	0.5743	0.6123	0.7712	0.7999	0.8520	0.7304
1999	0.6508	0.5473	0.7684	0.7959	0.9193	0.6826
2000	0.6965	0.5570	0.7305	0.8718	0.9250	0.7205
2001	0.7249	0.6096	0.7790	0.8857	0.9078	0.7654
2002	0.7381	0.5952	0.8156	0.8883	0.8767	0.7123
2003	0.7259	0.6035	0.7716	0.8310	0.9048	0.6869
2004	0.7390	0.5971	0.8165	0.8549	0.8760	0.6954
2005	0.7616	0.5683	0.7213	0.8630	0.8785	0.6970
2006	0.8202	0.5624	0.7074	0.8974	0.9101	0.7266
2007	0.8186	0.5446	0.7131	0.8975	0.8598	0.7463
2008	0.7960	0.5881	0.7112	0.8836	0.8628	0.7456
2009	0.7438	0.4852	0.7101	0.8397	0.8650	0.6717
2010	0.7477	0.5521	0.6930	0.8427	0.8880	0.6589

Table 4: Gini coefficient contribution rate to high-tech industry innovation capability (%)

Time	Pharmaceutical manufacture	Aerospace manufacture	Electron and telecommunication manufacture	Electronic computer manufacture	Medical equipment and instrument manufacture
1995	42.04	13.45	18.00	11.48	15.03
1996	28.44	13.32	35.29	08.60	14.35
1997	26.82	10.04	35.69	14.20	13.25
1998	21.91	8.80	44.10	09.98	15.21
1999	12.94	5.08	38.54	32.30	11.14
2000	13.41	3.01	39.00	37.46	7.13
2001	13.11	2.33	47.74	29.60	7.21
2002	12.17	2.79	53.86	22.41	8.77
2003	11.62	3.21	61.54	17.83	5.80
2004	11.46	1.42	67.33	13.13	6.65
2005	11.36	1.75	70.18	12.08	4.64
2006	06.47	1.74	72.43	14.16	5.19
2007	05.71	1.98	75.94	09.63	6.75
2008	06.98	2.23	69.32	11.86	9.61
2009	07.59	2.08	61.88	14.45	14.00
2010	06.01	2.84	56.58	18.12	16.46

China's high-tech industry innovation capability gap presents a growing trend with time from different point. It has a strong correlation with China's high-tech industry spatial layout on one hand. On the other hand, is closely related with the local industrial base, industrial policy, resource endowments and the personnel structure. Meanwhile, Gini coefficient is larger than 0.48 in Table 3 which indicates that China's high-tech industry innovation capability overall gap is wide and five industries' gap is evident.

As for different industries, pharmaceutical manufacture industry innovation capability gap is relatively small and regional innovation capability is more balanced. Pharmaceutical manufacture industry space layout concentration is lower than other industries because of low-tech. It belongs to the resource-intensive industry. There are conditions for investment in production. On the other hand it also reflects overall layout of the pharmaceutical industry in China is more dispersed. While electronic computer and office equipment manufacture industry and electronic and communication equipment manufacture industry innovation capability gap is relatively large, mainly in coastal provinces of Guangdong, Jiangsu, Shanghai, Beijing and Tianjin and Fujian. This is decided by its peculiar life cycle and characteristics. Aerospace industry, medical equipment and instrument manufacture industry is in the middle position. Specifically, the gap of aerospace manufacture in the 1995-2003 was widening. From 2003 the disparity in innovation capability was greatly reduced and then a steady state. Aerospace manufacture is the smallest of the high-tech industry mainly because of high threshold market access, initial investment, closely related to national security and the great impact of the previous planned economy. In 1995-2002 it was mainly in Shaanxi. Since 2003 it has rapidly developed in Liaoning, Sichuan, Beijing, Heilongjiang and Guizhou. These provinces have become China's aerospace manufacture base. Regional gap in aerospace manufacture industry has been greatly reduced.

On five industries impact on overall gap it can be estimated by equation (8) that five industries' contribution to national high-tech industry innovation capability gap, see Table 4.

In Table 4 it can be seen in the Pharmaceutical manufacture industry, aviation and aerospace manufacture industry influence of hi-tech industry innovation capability overall gap has declined. And characteristic of medical equipment and instrument manufacture influence is a “U”. Electronic computer and office equipment manufacture industry is a reverse “U”. Electron and communication equipment manufacture industry impact on high-tech industry innovation capability overall gap has been great with upward trend year by year. It has risen from 18% (1995) to maximum value 75.94% (2007), thereafter remained in more than 60%.

DISCUSSION AND CONCLUSION

Using Theil entropy and Gini coefficient, this study has analyzed the gap of innovation capability based on the number of high-tech patent applications from 1995 to 2010 and drew some conclusions which previous researches did not find.

Through the Theil entropy model it measured China’s high-tech industry in the six regions’ variation tendency. During 1995-2010, space gap of China’s high-tech industry innovation capability in different regions is bigger, regional innovation capability gap of high-tech industry is significant. This finding is consistent with previous work in the literature (Zhang and Zhao, 2007; Pan *et al*., 2009; Zhao and Cheng, 2013). For instances, Zhang and Zhao, 2007) evaluate the innovation capability of high-tech industry in twenty-one areas and discover that there are significant differences among regions. Based on the evaluated model of regional high-tech industry competitiveness between 1996 and 2005, Pan *et al*. (2009) find that the competitiveness in China has distinct region difference which has the enlarged trend with the past time. Zhao and Cheng (2013) also find that the gap of high-tech industry capability among provinces is increasing larger in recent years. Unlike the explanations why the gap exists in previous studies, this study suggests and proves that within-group gap is the most important factor influences China’s high-tech innovation capability by Theil entropy. The main reason of China’s high-tech industry innovation capability gap is the gap in different regions while the within-group difference has less effect.

Time and space variation tendency of China five high-tech industries innovation capability has been calculated and evaluated through Gini Coefficient. From 1995 to 2010, China’s five high-tech industries innovation capability difference is generally large. Similarly, Li (2011) indicates that industries technology innovation ability has obvious differences in these five industries which are divided into 17 sub-industries, by using particle swarm optimization method. Gini coefficients are larger than 0.48 which reflects China’s five industries innovation capability difference in different regions is bigger. The gap between the electronic computer and office equipment manufacturing industry is the largest and the least is the medicine manufacturing industry.

It has compared the innovation capability gap measured by Theil entropy and Gini coefficient which are not used together in one study before. Through comparison it can be concluded the calculated overall innovation capability gap trend is highly consistent through Gini coefficient and Theil entropy model. From different perspectives, two different evaluation methods fully presents China’s high-tech industry innovation capability gap is tend to expand which is more credible than only one single method. It can provide realistic basis for government to make policies reducing regional disparities and promoting coordinated regional development.

ACKNOWLEDGMENT

The author thanks the anonymous reviewers of this Journal for their detailed and constructive comments. This work was partly funded by Henan Higher School Project of Philosophy and Social Sciences Innovation Team (2013-CXTD-08) and the MOE project of Humanities and Social Sciences (12YJC630056).

REFERENCES

Acs, Z.J., L. Anselin and A. Varga, 2002. Patents and innovation counts as measures of regional production of new knowledge. Res. Policy, 31: 1069-1085.

Adams, R., J. Bessant and R. Phelps, 2006. Innovation management measurement: A review. Int. J. Manage. Rev., 8: 21-47.

Andersson, A.E., C. Anderstig and B. Harsman, 1990. Knowledge and communications infrastructure and regional economic change. Regional Sci. Urban Econ., 20: 359-376.

Benavente, J.M., 2006. The role of research and innovation in promoting productivity in chile. Econ. Innovation New Technol., 15: 301-315.

Bode, E., 2004. The spatial pattern of localized R and D spillovers: An empirical investigation for Germany. J. Econ. Geography, 4: 43-64.

Ceh, B., 2001. Regional innovation potential in the United States: Evidence of spatial transformation. Paper Regional Sci., 80: 297-316.

Choi, B.R., 2003. High Technology Development in Regional Economic Growth: Policy Implications of Dynamic Externalities. Ashgate Publishing, Ltd., London, ISBN : 13-9780754632528, Pages: 119.

Crepon, B., E. Duguet and J. Mairessec, 1998. Research, innovation and productivity: An econometric analysis at the firm level. Econ. Innovation New Technol., 7: 115-158.

Dalton, H., 1920. The measurement of the inequality of incomes. Econ. J., 30: 348-361.

Duro, J.A. and E. Padilla, 2006. International inequalities in per capita CO_2 emissions: A decomposition methodology by Kaya factors. Energy Econ., 28: 170-187.

Freeman, C. and L. Soete, 1997. The Economics of Industrial Innovation. The MIT Press, London.

Freeman, C., 1987. Technology Policy and Economic Performance: Lessons from Japan. Pinter Publishers, London, UK., ISBN-13: 9780861879281, Pages: 155.

Griffith, R., E. Huergo, J. Mairesse and B. Peters, 2006. Innovation and productivity across four european countries. Oxf. Rev. Econ. Policy, 22: 483-498.

Griliches, Z., 1990. Patent statistics as economic indicators: A survey. J. Econ. Literature, 28: 1661-1707.

Guan, J. and S. Liu, 2005. Comparing regional innovative capacities of PR China based on data analysis of the national patents. Int. J. Technol. Manage., 32: 225-245.

Hall, B.H., F. Lotti and J. Mairesse, 2009. Innovation and productivity in SMEs: Empirical evidence for Italy. NBER Working Paper No. 14594, pp: 718. http://www.nber.org/papers/w14594.

Jaffe, A.B., 1989. The real effects of academic research. Am. Econ. Rev., 79: 957-970.

Jaffe, A.B., M. Trajtenberg and R. Henderson, 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. Q. J. Econ., 108: 577-598.

Jefferson, G.H., B. Huamao, G. Xiaojing and Y. Xiaoyun, 2006. R&D performance in Chinese industry. Econ. Innov. New Technol., 15: 345-366.

Kakwani, N.C., 1977. Applications of Lorenz curves in economic analysis. Econometrica, 45: 719-727.

Li, R.S., 2011. Comprehensive assessment of the technology innovation ability of China's high-tech industries: Based on particle swarm optimization method. Stat. Inform. Forum, 26: 59-66.

Li, X.C., S.W. Li and S.J. Zhang, 2010. Single factor efficiency analysis in high-tech and non-high-tech industry innovative activities. China Ind. Econ., 5: 68-77.

Loof, H. and A. Heshmati, 2006. On the relationship between innovation and performance: A sensitivity analysis. Econ. Innovation New Technol., 15: 317-344.

Lu, G., 2011. On the performance of the industrial innovation for the listed firms in Chinese SMEs stock market. Econ. Res., 2: 138-148.

Lundvall, B.A., 1992. National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter Publishers, London, UK., ISBN-13: 9781855670631, Pages: 342.

Malerba, F., 2004. Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe. Cambridge University Press, New York, USA., ISBN-13: 9781139454162, Pages: 519.

Malerba, F. and S. Brusoni, 2007. Perspectives on Innovation. Cambridge University Press, UK., ISBN: 13-9780521685610, Page: 498.

Nelson, R.R., 1984. High-Technology Policies: A Five-Nation Comparison. American Enterprise Institute for Public Policy Research, Washington, DC., ISBN:13-9780844735665, Pages: 94.

Nelson, R.R., 1993. National Innovation Systems: A Comparative Analisis. Oxford University Press, Oxford, New York.

OECD, 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. 3rd Edn., OECD., UK., ISBN:13-9789264013083 Pages: 163.

Pan, X.F., F.C., Liu and L. Yang, 2009. Analysis of evolutionary characteristics of space- time of regional high-tech industry competitiveness in China. Stud. Sci. Sci., 27: 52-58.

Peters, B., 2008. Innovation and Firm Performance: An Empirical Investigation for German Firms. A Springer Company, Mannheim, ISBN: 13-9783790820263, Pages: 238.

Polder, M., G. van Leeuwen, P. Mohnen and W. Raymond, 2009. Productivity effects of innovation modes. MPRA Paper No. 18893.

Schramm, C., 2008. Innovation measurement, tracking the state of innovation in the American economy. A Report to the Secretary of Commerce by the Advisory Committee on Measuring Innovation in the 21st Century Economy 2008.

Shorrocks, A.F., 1980. The class of additively decomposable inequality measures. Econometrica, 48: 613-625.

Stern, S., M.E. Porter and J.L. Furman, 2000. The determinants of national innovative capacity. National Bureau of Economic Research Working Paper, Cambridge, MA., pp: 7876.

Theil, H., 1967. Economics and Information Theory. North-Holland Published Co., Amsterdam.

Wan, G., 2008. Inequality measurement and decomposition: A survey. China Econ. Q., 8: 347-368.

Zhang, Q.N. and Y.L. Zhao, 2007. Comparation of regional high technology industry innovative ability. Inquiry Into Econ. Issues, 28: 60-65.

Zhao,Y.L. and P. Cheng, 2013. An empirical analysis on technological innovation capacity of high-tech industry on provincial scales in China. J. Bus. Econ., 33: 77-85.