A COMPARATIVE STUDY OF KNOWLEDGE-BASED ECONOMY DEVELOPMENT BETWEEN CHINA AND THE USA

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ABSTRACT

In this paper, the author analyzes the gap in knowledge-based economy development between China and the United States, explores its cause, and gives some constructive suggestions to promote Chinese knowledge-based economy development. The paper has three parts. The first is a brief literature review. The author concludes that at present the indicator model is more proper than the econometric model and statistical framework. In the second part, the author develops an indicator model with four dimensions: knowledge input, human capital, ICT application, and innovation performance. Each dimension has several different indicators. The Analytic Hierarchy Process (AHP) is used to give those indicators different weights and to compose them into a compound index in all hierarchies. On the basis of the above methodology, the third part calculates and compares the overall index and four dimension index differences of the development of Chinese and American. knowledge-based economies. There is a large gap between China and the United States. The dimension of innovation performance embodies this gap. The next dimensions are human capital, knowledge input, and ICT application in turn. The author then discusses reasons for such a great lag between China and the United States. The conclusion sums up the main challenges and puts forward some suggestions to promote the Chinese knowledge-based economy development.

Keywords: Knowledge-based economy, Knowledge input, Innovation performance, Knowledge technology system

1 INTRODUCTION

In the last stages of the 20th century, the knowledge-based economy proposed by OECD (1996) became a noticeably prominent event in the domain of economic theory. As one kind of new technical-economic paradigm, the knowledge-based economy emphasizes the role of knowledge, innovation, and information communication technology, which can help economists explore economic mechanisms hidden in economic growth, find new policies to promote economic development, and even help people understand why the poor and developing countries are poor and the rich and developed countries are rich (Word Bank, 1998). In recent years, China's fast growth has been facing more and more pressure from resource shortages and environmental pollution. To develop a knowledge-based economy becomes the inevitable choice. On the other hand, economic development demonstrates the same effect as one's consumer behavior. The United States has become the only political, military, and economic superpower, which is inseparable from formidable technological innovation. Since the 1990s, regarding the United States as one successful model of knowledge economic development, many countries including China are studying the United States' innovation policy and even copying its economic development model. Therefore, the purpose of this paper is to compare the Chinese and American knowledge-based economy developments, to discuss the reasons that the Chinese knowledge economy falls behind the American knowledge economy, and to give some polite suggestions to promote Chinese knowledge economic development.

2 A BRIEF LITERATURE REVIEW

The report that proposed a knowledge-based economy, OECD (1996), measured the knowledge-based economy in five interconnected areas: knowledge investment, knowledge stock and flow, knowledge output, knowledge networks, and knowledge and its study. In fact, it is only a measurement framework because it lacks concrete statistics and data indicators. In order to "analyse trends in the knowledge-based economy" with the latest internationally comparable data, to "capture the changing relationship between science, innovation and economic performance so that policy makers may make informed decisions, set priorities and address the challenges of the knowledge-based economy"(OECD 2001), OECD has designed an index system for knowledge-based economy measurement, including the influences that knowledge has on economic development, on economic globalization and technology, and on international competitive power, with 42 indexes together (OECD, 1999).

In the biennial report, "the OECD Science, Technology, and Industrial Scoreboard," indicators changed unceasingly, which also reflected that the OECD still was in the exploration phase of knowledge-based economy measure research. Influenced by the OECD, the World Bank (1998) has developed a knowledge appraisal matrix to analyze the validity of knowledge promotion development (Table 1). It indicated that to develop a knowledge-based economy, a country needs to strengthen its ability to acquire knowledge, create knowledge, communicate knowledge, and use knowledge. At the same time, it also needs to promote their interactivity with encouragement, mechanisms, human capital, and skills and information infrastructure. Compared with the above research, a new economy measurement project carried out by the Progressive Policy Institute (PPI), which is supported by the American Democratic Party, not only develops a new theoretical method but also gives some positive measurement to the knowledge-based economy development in American states and cities (PPI, 1998, 1999, 2002). Applying this method, Chinese scholars Li Jingwen (2000) and Hong Mingyong (2001) brought forward their own knowledge-based economy measurement index system. Meanwhile, Professor Yang Kaizhong (2004) at Peking University measured the knowledge-based economy development level in Chinese provinces.

Table 1. Knowledge-based economy development appraisal matrix

Functions variable	Interactive Functions			
	Encouragement	Mechanism	Human Capital and skills	Information infrastructure
Acquirement				
Creation				
Communication				
Utilization				

Source: Carl Dahlman (2001) Knowledge for Development: A Comprehensive Framework for Thinking about Knowledge for Development and a Primary Assess of China's Present Situation. In Ed. Hu AnGang *Knowledge and Development: A New Catch-up Strategy in the 21st Century.* Peiking University Press.

The Australian Bureau of Statistics (ABS) is another group launched by its government to carry out similar research, which applies statistical methods and emphasizes the cohesion between economic development and social development. Their measurement framework selects indicators from the existing statistical framework and combines them into five dimensions: background, innovation and entrepreneurship, human resources, ICT, as well as economic and societal influence (ABS, 2002). This research effort has only announced a rough draft at present and is inviting scholars from all over the world to participate in its discussions. Although the ABS has provided a new mentality and a general survey, the existing research demonstrates that the index system method is the dominant one. Just as the Bureau of Economic Analysis (BEA, 1999) pointed out, the present economic measurement system based on the NIPA has many flaws. However, it is more difficult to find a full-scale measurement for knowledge-based economic development. Therefore, the index system method perhaps is one of the best choices to measure knowledge economic development at present. In this paper, we also applied that method.

3 THE METHODOLOGY OF KNOWLEDGE-BASED ECONOMIC DEVELOPMENT MEASUREMENT

3.1 Index systems of measuring knowledge-based economic development

The OECD (1996) once stated that the knowledge-based economy is a kind of economy that is established on knowledge and information production, assignment, and utilization. For this somewhat confused description, there are different explanations in academic circles; it is too difficult to distinguish whether any is right or wrong. Similar to the description of industrial economy, perhaps knowledge-based economy does not need a strict definition. This article merely takes the knowledge-based economy as one kind of new technical-economic paradigm. Technological innovation is the driving factor for economical paradigm reformation and pushes a country's transformation from an industrial economy to a knowledge-based economy. Therefore, one ideal way to estimate and compare the knowledge-based economic development of different countries is based on the innovation process, to operate on the causal relation of two dimensions, that is, innovation input and output. Innovation input factors already include knowledge investment and non-knowledge investment. The latter often refers to labor and capital input. Obviously, knowledge investment plays the main role in affecting knowledge-based economic development. As for output, the counterpart of knowledge input is knowledge output. OECD once used R&D density and technical profit rates to characterize this. Because the conception of knowledge output is confused and difficult to define, this way is not satisfactory. Geisler (2000) stated, "It is difficult to measure the output of technology activities because it is difficult to give them clear definition." He has enumerated four major problems in measuring scientific and technological output activities: First, some kinds of outputs, especially those in the later part of the innovation process, are difficult to describe. Second, the process of scientific and technological activity is full of complexity and diversity. Third, science and technology output diffuse along many directions, with numerous potential receivers. Fourth, there are many output types, but some do not suit quantitative analysis, some cannot be measured directly, and some cannot be substituted for. In fact, these problems exist in the measurement of knowledge output. Compared with output, the connotation of innovation performance is narrower and has a large overlap with the connotation of output. Therefore, output and innovation could be put together to denote the changes of output dimension.

As one kind of new technical-economic paradigm that technological innovation promotes, knowledge-based economic development must inevitably give rise to a new knowledge-intensive technical system, an abbreviated knowledge technology system. Obviously, there are some corresponding relations between a technology system and technology. The knowledge technology system development also manifests itself in the knowledge-based economy development, and therefore in this paper, it is also taken as one dimension of measuring knowledge-based economic development. In order to further decompose the indictor system into a simple intelligible index, we use three dimensions to construct an index system to measure knowledge-based economic development (Table 2).

Table 2. A knowledge-based economic development measure system based on innovation process

Knowledge-based economy development level measurement	1st level Indicator	2nd level Indicator	3rd level Indicator	Explanatory Indicators	Notes
	Knowledge Innovation Input	R&D	R&D input	R&D Intensity	R&D Expenditure As a Percentage of GDP
				Non-official Public R&D Intensity	Non-official R&D Expenditure As a Percentage of GDP
			R&D Structure	R&D Expenditure Structure	Business R&D Expenditure as a Percentage of GDP
				R&D Executive Structure	R&D Expenditure by Sector of Performance
				R&D Category Structure	R&D Expenditure by Category
			R&D Personnel Furniture	R&D Population Intensity	
				R&D Expenditure Per Capita	Average R&D Expenditure of Researchers （USD）
		Human Capital	Stock of Human Capital	Average Schooling Years	
				College Students Rate Per Thousand	
			Human Capital Input	Education Expenditure As a Percentage of GDP	Educational Budget or public disbursement As a Percentage of GDP
			High Education Development	College Enrollment Ratio	Gross Enrollment Ratio for All Tertiary Schools
				High Education Expenditure Share	As a Percentage of Total Education Expenditure
	Knowledge Innovation Performance	Innovation Output	Patent Output	Invention Ratio	Invention Granted As a Percentage of Total Patents Granted
				Numbers of Invention Granted Per Capita	By Researchers
		Innovation Performan	Knowledge Productivity	Contribution For Economic Growth	Similar to TFP
			Productivity	Productivity	Labor Productivity

		ce	Technology Independence Degree	Technology Introduced Ratio	Substitute Indicator: Technology Introduced Expenditure As a Percentage of GDP
				Domestic Invention Granted Ratio	As a Percentage of Total Granted
			Competitiveness	Value Added of High-tech Industries As a Percentage of Value Added in Manufacturing Sector	
				Exports of High-tech As a Percentage of Manufacturing Sector	
		Structure Effect	Industrial Structure Change	Value of Knowledge Industries As a Percentage of GDP	
				Employment of Knowledge Industries As a Percentage of Total Work Force	
	Knowledge Technology System	ICT Development	Information Communication Technology Development	ICT Expenditure As a Percentage of GDP	
				ICT Invention Granted As a Percentage of Total Patents Granted	
			ICT Infrastructure Development	Communication Development	Lines Accessed Per Thousand Persons
				Internet Development	Internet User Per Thousand Persons
			ICT Applications	E-Commerce Development	E-Commerce Sales As a Percentage of Total Retails Volume

3.2 A method for a composite Knowledge-based Economic Development Index

Table 2 displays a hierarchical knowledge-base economic development measurement framework. In order to sort or compare easily different national knowledge-based economic developments, we need to express them in a composite index, that is, to synthesize the framework into knowledge-based economy development indices. The process is as follows in Figure 1.

Under-layer indicators or indices   Up-layer indicators or indices

X_1 and its weight W_1

……

} Y_1 and its weight Y_{w1}

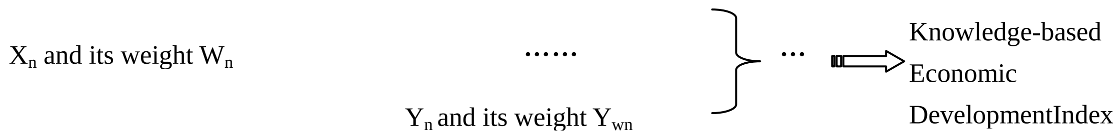

Figure 1. Knowledge-based economic development indices synthesis process

There are three types of indicator weights. First, when there is only one indicator under the next level, the corresponding indicator weight can be given naturally as 1. Second, when there are two indicators, their respective weights, the sum of which is 1, are evaluated according to their importance. Third, when there are three indicators or more, weighing can be evaluated according to their respective importance with the Analytic Hierarchy Process method (AHP), using equations 1-3.

$$y = \kappa_1 y^{(1)} + \kappa_2 y^{(2)} = \kappa_1 \sum_{i=1}^{n} w_i^{(1)} x_i + \kappa_2 \prod_{i=1}^{n} x_i^{w_i^{(2)}}, \quad (x_i \ge 1, \quad i = 1,2,...,n) \qquad (1)$$

$$\kappa_1 + \kappa_2 = 1, \qquad (\kappa_1 \ge 0, \quad \kappa_2 \ge 0) \qquad (2)$$

$$\sum_{i=1}^{n} w_i^{(1)} = 1, \quad \sum_{i=1}^{n} w_i^{(2)} = 1 \qquad (3)$$

Here, κ_1 & κ_2 are the corresponding weights for two indicators, and $w_i^{(1)}$ & $w_i^{(2)}$ separately are weights for the components in those two parts.

4 COMPARISON OF CHINESE AND AMERICAN KNOWLEDGE-BASED ECONOMIC DEVELOPMENT

4.1 Chinese and American knowledge-based economic development indices comparison results

On the basis of Table 2 and the above discussion, especially equations 1-3, we calculated the respective knowledge-based economic development indices of China and the United States. Because there are only two sample countries, in order to establish the reference system, we needed to give each explanatory indicator a valve value, consisting of a maximal value and a minimal value. The valve value referred to the knowledge-base economic development of America, Europe, Japan, Canada, Australia, New Zealand, Israel, and Singapore in 2000. The maximum value adopts a higher value, not necessarily always the highest value. On the other hand, there is an effect in different countries' economic development similar to the demonstrated effect in consumer behaviors. All the countries listed above are relatively in the lead in knowledge-based economic development. Since the 1990s, the United States has been the knowledge-based economic development model. The United States became the only political, military, and economic superpower in the world. This fact is inseparable from its formidable technological innovation ability. Including China, other countries are studying the United States' innovation policy in order to learn its economic development pattern. Therefore, the selection of a valve value referring to the above countries is scientific and logical. Taking R&D intensity as an example, this index's highest value in the above countries was 4.0 (Sweden) in 2000; the next was 3.40 (Denmark). The same indicator value in the second group of countries lay between 2.6-3.0, including Japan (2.98), the US (2.72), South Korea (2.65), Iceland (2.77), and Switzerland (2.63). Therefore the maximum value of the R&D intensity indicator is taken as 3, and the minimum value is taken as zero. Other indicators' valve value selections are made in a variety of ways.

Based on the above discussion, the knowledge-based economic development indices of China and the United States in 2003 are calculated as follows (Table 3).

Table 3. Knowledge-based economic development indices of China and the United States in 2003

	China	USA	1st level index	China	USA	2nd level index	China	USA	3rd level index	China	USA
Knowledge-based economic development index	36.07	91.40	Knowledge innovation input index	43.82	95.20	R&D index	33.70	95.00	R&D input	41.00	88.33
									R&D structure	88.95	99.69
									R&D personnel furniture	12.51	100.8
						Human capital index	53.07	95.34	Stock of Human Capital	55.21	96.43
									Human Capital input	52.18	98.48
									High education development	49.31	88.43
			Knowledge innovation performance index	30.12	84.77	Innovation output index	27.18	94.12	Patent output	27.18	94.12
						Innovation performance index	27.6	80.80	Knowledge productivity	36.36	63.64
									Productivity	2.72	109.8
									Technology independence degree	47.94	85.28
									Competitiveness	51.39	81.01
						Structure effect index	36.9	81.05	Industrial structure change	36.90	81.05
			Knowledge technology system development index	24.25	91.52	ICT development index	24.25	91.52	ICT development	62.47	78.77
									ICT infrastructure development	16.49	113.8
									ICT application	3.70	91.33

4.2 Sino-American knowledge-based economic development analysis

From Table 3, it can be seen that there is a large gap in knowledge-based economic development between China and the United States. The knowledge-based economic development index of the United States reaches as high as 91.4. Based on the explanation of the indicator valve value selection principles, this is also sufficiently explained even if it is a developed country. The United States is also the leading country in knowledge-based economic development. Compared with the US, obviously China's 36.07 index is very low. According to the knowledge-based economic development index score, each national knowledge-based economic development can be divided into six different levels: The dormancy stage (0-15), the germination stage (15-30), the start-up stage (30-45), the under-developed stage (45-65), the pursuing stage (65-85), and the leading stage (above 85). In this case, China's knowledge-based economic development is still in the start-up stage.

Looking at the 2nd level index, the biggest disparity between Chinese and American knowledge-based economic developments lies in the knowledge technology system development index, respectively 24.25 and 91.52, a difference of 67.27. The reason for this is that China's ICT infrastructure is also very weak, and ICT applications are not popular and are at a quite low level in particular. From Table 4, the disparity in ICT infrastructure and ICT applications between China and America is easily seen. For example, in 2002, American computer intensity (computer numbers per thousand persons) and telephone intensity (household telephones and mobile numbers per thousand persons) were respectively 23.8 times and 3.5 times those of China's. B2C, which is involved in computers, networks, communication, finance, enterprise, and individuals, is a typical comprehensive commercial application. America's B2C share accounts for 1 percent of the whole American merchandise retail value, but the Chinese B2C can almost be ignored. According to a survey made by the China Network Information Center (CNNIC), over 30% of Chinese enterprises do not know how to deal with e-commerce or are even aware of e-commerce. The disparity in ICT between China and the United States can be seen throughout Table 4. Here more detail is needed to explain why Chinese ICT expenditure as a percentage of GDP is relatively higher than in the United States. On the one hand, China's low-income level drives up the relative ICT expenditure share. On the other hand, the number of ICT original innovations in the United States is much greater than in China. ICT expenditure is mainly spent for the United States' own technology, which underestimates their ICT expenditure share of GDP. Because of its low technical innovation level, China spends a large surcharge for its internal ICT consumption, thus overestimating its ICT expenditure share in the GDP. That said, there is a great disparity of original technical innovation between China's and the United States' knowledge-based economic development.

Table 4. Comparison of certain Sino- American ICT applications

	Telephone and mobile number per thousand persons		Computer number per thousand persons		ICT expenditure as a percent of GDP		ICT expenditure per capita (USD)		B2C transaction value (hundred million USD)	
	China	America	China	America	China	America	China	America	China	America
1999	119.99	969.81	12.24	507.27	4.8	8.2	38.2	2792	NA	NA
2000	177.63	1053.51	15.9	572.1	5.4	8.1	46	2926.2	NA	272
2001	247.72	1121.39	19.04	625.01	5.7	7.9	52.7	2923.8	0.6	342
2002	327.78	1133.96	27.64	658.88	5.81	6.49	57.54	2357.92	1.9	447

Data from: Xinhua online, economy data system.

The second reason for the knowledge-based economic development disparity between China and the United States lies in technical innovation input and innovation performance. Those two indices are respectively 54.65 and 51.38. Looking at 2nd level and 3rd level indices, the main cause of the lower Chinese knowledge innovation investment index is the low level of research and investment ability. Compared with the same index of 95.00 for the United States, China's research development index only reaches 33.70. Another big disparity between the two countries lies in the human capital index. From Table 5, Chinese knowledge innovation investment appears low. The American GDP is much more than China's, but in 2003, American R&D intensity and Chinese R&D intensity, total R&D expenditure as a percentage of GDP, reached 2.6% and 1.31% respectively. In 2000, American research intensity was seven times that of China's. Chinese deficient investment excessively favors higher education. However, China's gross tertiary enrollment ratio is only 16%, far less than America's 83% in 2002. On the other hand, the expenditure ratio per student among Chinese college students, secondary students, and primary students is 13.6:1.9:1, while America's is 1.3:1.2:1. The lopsided input structure seen in China's expenditures is rare in the world.

Table 5. Comparison of certain knowledge innovation investment indicators between China and USA

	R&D researchers per million persons （1）		R&D expenditure as a percentage of GDP（%） （2）		Expenditure ratio per student among different level （3）		Gross tertiary enrollment ratio （4）	
	China	America	China	America	China	America	China	America
2000	550.54	NA	1.00	2.72	13.6:1.9:1[c]	1.3:1.2:1	12.68	70.67
2001	583.93	4099.39[a]	1.07	2.74	NA	NA	13[d]	81[d]
2002	NA	NA	1.23	2.67	NA	NA	16[d]	83[d]
2003	NA	NA	1.31	2.62	NA	NA	NA	NA

Note: NA is lack of data. a) 1997 data, (b) American data do not include most or all capital expenditure, c) 1999 data

Data from: (1) Xinhua online, economy data special system; (2)-(3) OECD (2004) and the International Bank, World Development Indicators; (4) the United Nations Educational, Scientific, and Cultural Organization (UNESCO), referring to gross matriculation.

Compared with the innovation investment in China, America’s knowledge innovation performance dimension is much greater. First, Chinese innovation performance is very weak. For example, the Chinese patent output index only reaches 27.18. Of the patents granted by the State Intellectual Property Office of the People’s Republic of China, only 16.2% were granted to native citizens and enterprises. Most of these are for utilities and design. Obviously there are few valuable and original innovations in China. Second, China's innovation contribution is also weak. The related index only reaches 27.6 and the productivity index is only 2.72 compared to the 109.8 of the United States. Even discounting the exchange rate factor on Chinese productivity that underestimates influence, the lack of innovation might still explain why China's productivity is extremely low. There is no innovation or even innovative application in many manufacturing sectors. On the other hand, because China has a massive inexpensive labor force, the labor-intensive industry and high-tech manufacturing industry had a chance for speedy growth. Thus the Chinese competitiveness index and structure effect would still show good performance. This indicates that China’s strategy of attracting advanced technology and promoting industrial reformation has been successful.

5 CONCLUSIONS AND SUGGESTIONS

Looking at the above results and analyzing according to the disparity size, the disparity between Chinese and American knowledge-based economic development manifests itself in three dimensions: knowledge technology system development, knowledge innovation performance, and knowledge innovation input.

Looking at the innovation angle, the dimension of knowledge technology system development involves innovation diffusion and application. The dimension of knowledge innovation performance involves innovation output and efficiency. It is indicated that, besides the difference in input, the main reason for the large differences between China’s and America’s knowledge-based economic developments lies in China’s slow innovation diffusion and weak innovation performance. These two causes are the weakest links, I think, in Chinese knowledge-based economic development.

Looking at the policy-making angle, what should be done to promote Chinese knowledge-based economic development in those three dimensions? Accelerating the capacity for innovation involves enterprises, government, and individuals. Whether the enterprise applies a new technology or not is decided not only by market competition and the enterprise itself but also by government policy. As a “referee” in the market, the government should maintain a suitable balance between regulation policies and competition policies to create an open competitive environment. Taking the diffusion of communication and network technology as an example, because of the regulation reform driven by the government, there are five limited-competition companies, that is, China Telecommunication, China Netcom, China Mobile, China Unicom, and the China Tietong. Otherwise, communication and network markets would still maintain soaring prices and unendurable service, and most enterprises and individuals wouldn’t benefit from the convenience of information communication technology. At the same time, the government also could take measures in finance and tax policy to stimulate enterprises to adopt new technologies, including permitting fixed asset accelerating depreciation. In addition, China should make full use of national science service stations to spur innovative technology diffusion.

As for innovation performance, the key is to enhance further enterprise’s main role. Because enterprises face the market directly, the demand for technological innovation has a more direct characteristic. It is easy to realize that commercial value reduces the distance between innovations and innovation diffusion. In China, a great many researchers are in those institutions financed by the government, and the main R&D expenditures of the government are supplied to those government and university researchers. Because of different value targets, commercialized technological innovation receives only a small share of those funds. Therefore, it is crucial to raise the technological innovation performance and to reform present scientific research management systems. At the same time, both government and enterprise need to increase their innovation input. In addition, there are many ways that the government can support enterprise, including financial support to its R&D activities, just as support is given to the American defense industry and the European aerospace industry by the United States and the European Union respectively, such as adopting a policy to compensate for R&D expenditure or to help enterprises attract talented persons by creating an attractive environment.

In actual policy operation, many measures in the above link are actually interwoven. For example, technological innovation diffusion is restrained by both supply and demand factors. First, the supply factor in China is insufficient. From Table 3, China's R&D index is only 33.70, and its human capital index is only 53.07. The ratio between these two indices is no more than 0.64. However in the United States, the R&D index and the human capital index respectively are 95.00 and 95.34; the same ratio is approximately 1. Obviously, China's knowledge innovation input is short; moreover its structure is unreasonable. Because of low R&D investment, many researchers lack sufficient research funds. Technological innovation driven by supply factors lacks enough impetus. The demand factors are also insufficient. It is evident that the ICT commercial application index falls behind the ICT development index and the ICT infrastructure index. It is the demand factor that really decides innovation direction, diffusion pace, and performance, and it is necessary to promote demand and enhance a demand-base management in the future.

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