Construction on Theoretical Model and Indicator System of Competitiveness of Human Resources in Science and Technology at Metropolitan Level

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Abstract: This paper proposes the definition of competitiveness of Human Resources in Science and Technology (HRST), analyzes the factors affecting the competitiveness of HRST, and puts forward the "One Body Two Wings" theoretical model of competitiveness of HRST. “One Body” refers to the “competitiveness of HRST”, and “two wings” refers to the “realistic competitiveness” and “potential competitiveness” of competitiveness of HRST. The “realistic competitiveness” wing includes the quantity, quality and creativity of competitiveness of HRST, the “potential competitiveness” wing includes the cultivation ability, investment intensity and external environment of competitiveness of HRST. Based on this, a set of evaluation indicator system of competitiveness of HRST was constructed, which consists of two first-level indicators, six second-level indicators and 20 third-level indicators.

Key words: human resources in science and technology (HRST); competitiveness; theoretical model; indicator system

The concept of Human Resources in Science and Technology (HRST) and its corresponding statistical analysis were born and developed after the 1960s. In 1995, the Organization for Economic Cooperation and Development (OECD) and the European Union Statistics Bureau (EUROSTAT) published《Manual on the Measurement of Human Resource Devoted to S&T-- Canberra Manual 1995》, comprehensively analyzed and systematically explained the basic definition, classification, related factors and data sources of HRST, clearly proposed the statistical standards and specifications of HRST for the first time in the world.

HRST are the core of science and technology resources of one country or region. They are also important carriers for supporting the production, diffusion and application of scientific knowledge in one country or region, and play an important role in promoting local economic and social development. Although the academic research on HRST has accumulated a lot of research literatures, some scholars

generally only evaluate some aspects on HRST while lack of comprehensive evaluation research from the perspective of “competitiveness”. This paper intends to explore the connotation of the competitiveness of HRST, explore the theoretical model, indicator system construction and quantitative evaluation at the metropolitan level. The so-called Metropolis refers to a city that is politically, economically and culturally important in one country or region.

1. Conceptual Connotation of Competitiveness of HRST

There is a clear definition on the concept of HRST. The definition of HRST given by the Ministry of Science and Technology (MOST) is generally adopted in China: “HRST refer to human resources that actually engages in or has the potential to engage in the production, promotion, dissemination and application of systematic science and technology. HRST include both the labor force actually engaged in scientific and technological activities and the labor force capable of engaging in scientific and technological activities." So, what is the definition of competitiveness of HRST? Du Qian (2006) believes that "the competitiveness of HRST is an objective performance of the ability and level of development and utilization of HRST in one country or region." "The core issue of the competitiveness of HRST is the efficiency of the development and utilization of HRST." This paper believes that the development and utilization of HRST is indeed the "core" of the competitiveness of HRST, but not all of it. This paper gives the definition of “competitiveness of HRST” is as follows: The competitiveness of HRST is a dynamic force manifested by various factors such as the quantity, quality, creativity , cultivation ability, investment intensity and external environment of HRST in one country or region ,compares with other countries or regions.

2. The Components of Competitiveness of HRST

To evaluate the competitiveness of HRST in one region, we must first define the components of the competitiveness of HRST. According to the definition of competitiveness of HRST, this paper divides the components that affect the competitiveness of HRST into two types: realistic competitiveness and potential competitiveness.

2.1 Influencing Factors of Realistic Competitiveness of HRST

The realistic competitiveness refers to the competitiveness that has existed in reality and can be measured immediately. The realistic competitiveness of HRST is more reflected in the inherent competitiveness of HRST, that is, the quantity, quality and creativity of HRST in one region.

2.1.1 The Quantity of HRST

The quantity of HTST refers to the scale and number of HTST in one region in a certain period of time. The scale and number of HTST is the basic factor affecting the realistic competitiveness of HTST, and it is also the most fundamental indicator for comparing the competitiveness of HTST in different regions from a quantitative

perspective. In today's economic and technological globalization, the reserve and development of human resources, especially the human resources in science and technology, have an important role in promoting the comprehensive strength of one country and even the advancement of global science and technology; the competition of science and technology, especially the competition of the human resources in science and technology, has become the focus of international competition. The country which has a large scale and sufficient number of HRST can gain a competitive advantage in knowledge and technological innovation, and can take the initiative in economic and social development. Therefore, the competition for HTST in various regions is foremost the competition for the scale and number of HRST.

2.1.2 The Quality of HRST

The quality of HRST refers to the proportion of high-quality HRST in one regional HRST team, which reflects the quality level of HRST in one region. So how do we measure the "high-quality" HRST? As we all know, "high quality" is a highly subjective fuzzy concept, which is not easy to quantify. But for research needs, it is still necessary to set some standards that can be quantified. Can we find an indicator that includes the qualifications and titles of HRST, so that it is easier to measure the quality of HRST? In fact, “scientists and engineers” is an indicator that meet such requirements. According to the interpretation of the China Science and Technology Statistical Yearbook, “scientists and engineers” refer to those who have high and intermediate professional technical titles (jobs) and those have the quantification of undergraduate or above but do not have high or intermediate professional technical titles (jobs). Therefore, it can be said that “scientists and engineers” are the higher quality of HRST and the core strength of scientific and technological activities. For one region, the number of scientists and engineers and their proportion in scientific and technological personnel and R&D personnel not only reflects the quality of scientific and technological activities, but also reflects the quality of HRST, which are important indicators reflecting the quality of HTST in one country or region.

2.1.3 The Creativity of HRST

The creativity of HRST refers to the total ability of HRST in one region in production and dissemination of scientific knowledge and technological innovation, as shown in the overall output level of scientific and technological activities in one certain period of time. In today's world, with the acceleration of the pace of globalization of the science and technology, innovation has become the dominant force in economic and social development, and has become an important foundation and symbol of the liberation and development of productive forces in today's society. Innovative ability has become a decisive factor in the competitiveness of one country or region. Its strength is an important measure to measure the competitiveness of one country or region. The innovative ability of one region ultimately depends on the region's HRST to implement and promote. Therefore, in a sense, the innovative ability of one region is the creativity of HRST in this region.

2.2 Influencing Factors of Potential Competitiveness of HRST

The potential competitiveness refers to certain basic factors that contain competitiveness, and there is a trend of transforming into realistic competitiveness. The potential competitiveness of HRST is more reflected in the external competitiveness of HRST, that is, the cultivation ability, the investment intensity and the external environment of HRST.

2.2.1 The Cultivation Ability of HRST

The cultivation ability of HRST is embodied in the number of HRST that one country or region can cultivate in a certain period of time. For any country or region, having a large scale and great number of HTST is the basic prerequisite and necessary condition for its economic development and technological progress. In addition to the existing number of HRST, the amount of HRST in one region depends to a large extent on the cultivation ability of HRST. Because the amount of existing HRST is not fixed, it is dynamically changing. The existing HRST of one country or region may either withdraw from the science and technology field because of reaching the retirement age, or may flow to other countries or regions, which will result in the reduction of existing HRST. Therefore, only one country or region with strong cultivation ability of HRST can continuously cultivate the high-quality HTST needed for economic and social development, thereby enhancing the potential competitiveness of HRST.

2.2.2 The Investment Intensity of HRST

Schultz believes that there are five sources of investment in human capital: nutrition and health care costs, school education costs, on-the-job training costs, personnel costs incurred during career selection, and migration costs. Li Tao (2006) attributed human capital investment to six aspects: education, training, research and development, medical and health care, labor migration and social security. This paper believes that the most important investment in HRST is reflected in two aspects: science and technology investment and education investment. Firstly, science and technology investment is a strategic investment. The cultivation and growth of scientific and technical personnel require a large amount of research and development activities, and the research and development activities themselves require a large amount of investment. Therefore, the intensity of investment in science and technology in one region is closely related to the potential competitiveness of HRST. Secondly, education investment is a long-term investment. It does not necessarily obtain immediate returns, but gradually reveals its inherent value and significance in future social activities. Moreover, unlike material investment, the human capital that has been raised through education investment is always in the human body, and under the necessary circumstances and conditions, it can play a role and pay off. For investors, the return on investment in education is not one-off, but a long-term, life-long benefit.

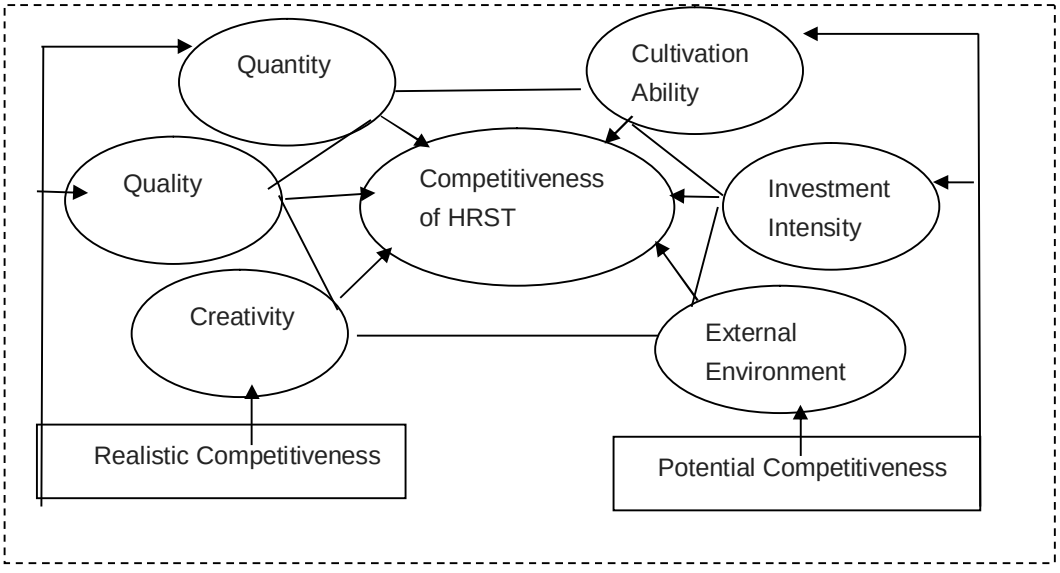
2.2.3 The External Environment of HRST

The external environment of HRST refers to the combination of social and material conditions on which one region's HRST depend for survival and development, including the sum of various external factors that affect the growth of HRST. The external environment of HRST is a complex system, it can be divided into two parts: hard environment and soft environment. The hard environment refers to the tangible hardware conditions that affect the development of HRST, including economic environment, working environment, living environment, etc., which are embodied in the regional advantages, economic strength, infrastructure, natural ecology, technology and education development in the region. The soft environment refers to the intangible software conditions that affect the development of HRST, including the institutional environment, legal environment, institutional environment, policy environment, humanistic environment, etc., embodied in the cultural heritage, market economic order, and legal policy system, the degree of completeness and the intrinsic functions of citizens' ideas and quality of life. The external environment of HRST in one region can not only attract the inflow of a large number of high-quality HRST to form agglomeration, but also enhance the innovation performance of HRST in the region.

3. The "One Body Two Wings" Theoretical Model of Competitiveness of HRST

Based on the above analysis, this paper believes that the connotation of competitiveness of HRST is composed of two parts: the realistic competitiveness and the potential competitiveness. The specific components include six elements as follows: the quantity, quality, creativity, cultivation ability, investment intensity and external environment of HRST. These two parts and six elements constitute the "one body two wings" theoretical analysis model of competitiveness of HRST, as shown in Figure 1.

FIGURE 1: "One Body Two Wings" Theoretical Model of Competitiveness of HRST



competitiveness” of HRST The “realistic competitiveness” wing includes three elements: the quantity, quality and creativity of HRST; the "potential competitiveness" wing also includes three elements: cultivation ability ,investment intensity and external environment of HRST The interaction of six elements constitutes the "one body and two wings" theoretical model of the competitiveness of HRST.

The model has three characteristics. Firstly, the model not only emphasizes the realistic competitiveness of HRST, but also emphasizes the potential competitiveness of HRST. It embodies the characteristics of the combination of internal and external, static and dynamic, realistic and future, and it embodies the concept of sustainable development. Secondly, the model embodies the structure and level of the connotation of the competitiveness of HRST. It has a good analytical effect and can meet the needs of the evaluation and analysis of the competitiveness of HRST in various regions. Thirdly, the model is also the theoretical basis for the design of the evaluation index system for competitiveness of HRST.

4. Construction of Evaluation Indicator System for Competitiveness of HRST

How to construct a scientific and reasonable evaluation indicator system is the basis and key to the evaluation of competitiveness of HRST. When evaluating the competitiveness of HRST, the quality of indicator selection and the number of indicators play a decisive role. Therefore, in the construction of the indicator system, we must follow certain principles, methods and steps to build a more scientific and reasonable evaluation indicator system.

4.1 Principles for Construction of Indicator System

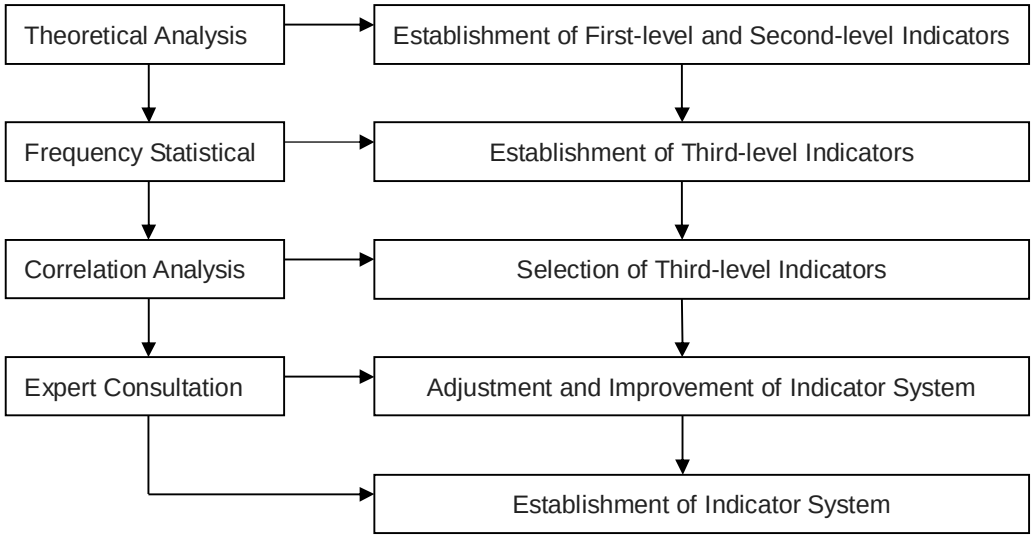
This paper follows the following principles in the process of indicator system construction: (1) The principle of objectivity. When selecting indicators, try to select quantitative indicators, and at the same time ensure the accuracy and credibility of the indicator data; and qualitative indicators should be used as little as possible to ensure the objectivity of the evaluation. (2) The principle of simplicity. The evaluation indicators are not good as many as possible, the design indicator system should be as small and precise as possible in quantity and level. (3) The principle of comparability. The purpose of constructing the indicator system is to evaluate and compare the competitiveness of HRST in different region. (4) The principle of indicator independence. Each indicator should be clearly defined and relatively independent; the indicators at the same level should not overlap each other.

4.2 Methods and Steps for Construction of Indicator System

Any indicator system has certain subjectivity. This requires that in the establishment of the evaluation indicator system of the competitiveness of HRST, we should try our best to improve the objectivity of the evaluation indicator system based on objectivity, adopt certain methods and steps. The construction of the indicator system of the competitiveness of HRST is mainly based on the empirical determination method, but at the same time, the theoretical analysis method, the

frequency statistical method, the correlation analysis method and the expert consultation method are adopted. These methods are used throughout the establishment of the indicator system. The specific methods and steps are shown in Figure 2:

FIGURE 2: Methods and Steps for Establishment of Indicator System for Competitiveness of HRST



4.3 Establishment of Indicator System

According to the above principles, methods and steps，this paper constructs a set of indicator system of the competitiveness of HRST, consisting of two first-level indicators, six second-level indicators and 20 third-level indicators, as shown in Table 1. The indicator system is rich in content and simple in form, embodying the principles of objectivity, systemicity and simplicity. The indicator data are derived from the domestic authoritative yearbooks such as China Science and Technology Statistical Yearbook, China Education Statistical Yearbook and China Statistical Yearbook. The indicators are comparable and operability, and the indicator data is reliable, accurate, and highly reliable.

TABLE 1: Evaluation Indicator System for Competitiveness of HRST

First-level Indicators	Second-level Indicators	Third-level Indicators
Realistic Competitiveness（A_1）	Quantity（B_1）	Research and development (R&D) personnel full-time equivalent（C_1）
		population with College degree and above（C_2）
	Quality（B_2）	The proportion of scientists and engineers in R&D personnel（C_3）
		The proportion of scientists and engineers in personnel in scientific and technological activities（C_4）
	Creativity（B_3）	Per capita national industrialization plan projects（C_5）
		Per capita domestic patent grants（C_6）
		Per capita number of scientific papers collected by major foreign search tools（C_7）
		Per capita technology market contract amount（C_8）
		Per capita number of research projects in research and development institutions（C_9）
		Per capita number of R&D topics in colleges and universities（C_{10}）
Potential Competitiveness（A_2）	Cultivation Ability（B_4）	Number of students in colleges and universities（C_{11}）
		Number of graduate students in colleges, universities and institutions（C_{12}）
	Investment Intensity（B_5）	Per capita expenditure on science and technology funds（C_{13}）
		Per capita national financial education funding（C_{14}）
	External Environment（B_6）	Per capita GDP（C_{15}）
		Average labor compensation for urban employees（C_{16}）
		Number of institutions in research and development（C_{17}）
		Number of enterprises with scientific and technological institutions in large and medium-sized industrial enterprises（C_{18}）
		Number of colleges and universities（C_{19}）
		Number of public libraries（C_{20}）

4.4 Determination of Indicator Weight

Using Analytical Hierarchy Process (AHP) to determine weights, subjective judgments and quantitative methods can be organically combined to make the determination of weights more scientific and credible. Therefore, in the indicator system of competitiveness of HRST, this paper uses AHP to determine the weight of each indicator. According to the basic principles and steps of AHP, the weights of all levels of indicators in the indicator system of competitiveness of HRST shown in Table 1 are calculated. The calculation results are shown in Table 2. With the indicator system and weight table, we can choose appropriate evaluation methods and evaluation models to empirically evaluate the competitiveness of HRST in different metropolitan areas.

TABLE 2: Weights of Evaluation Indicator System for Competitiveness of HRST

First-level Indicators		Second-level Indicators			Third-level Indicators		
Indicator Number	Weight (WA_i)	Indicator Number	Relative weight (WB_i)	Total weight (WB_j)	Indicator Number	Relative weight (WC_i)	Total weight (WC_j)
A_1	0.5	B_1	0.1095	0.0548	C_1	0.5	0.0274
					C_2	0.5	0.0274
		B_2	0.3090	0.1545	C_3	0.5	0.0773
					C_4	0.5	0.0773
		B_3	0.5815	0.2907	C_5	0.4426	0.1286
					C_6	0.1820	0.0529
					C_7	0.0938	0.0273
					C_8	0.1820	0.0529
					C_9	0.0498	0.0145
					C_{10}	0.0498	0.0145
A_2	0.5	B_4	0.1005	0.0503	C_{11}	0.6667	0.0335
					C_{12}	0.3333	0.0168
		B_5	0.4330	0.2165	C_{13}	0.6667	0.1443
					C_{14}	0.3333	0.0721
		B_6	0.4665	0.2332	C_{15}	0.0842	0.0196
					C_{16}	0.1363	0.0318
					C_{17}	0.2401	0.0560
					C_{18}	0.2401	0.0560
					C_{19}	0.2401	0.0560
					C_{20}	0.0592	0.0138

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