RESEARCH ON THE MEASUREMENT OF THE INVESTMENT BALANCE OF INDUSTRY INNOVATION BASED ON THE IMPROVEMENT OF THE GINI COEFFICIENT

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ABSTRACT

Innovation ability is the first element to promote social development. The enterprise's investment in innovation will affect its core competitiveness to a large extent. From the perspective of industry, based on the analysis of the applicability of Gini coefficient in the measurement of investment balance of industry innovation, the calculation method with the comprehensive equilibrium of industry innovation investment that can comprehensively consider the number of R&D funds and personnel was proposed. And it can determine the investment balance of industry innovation by defining standards. The feasibility of theoretical research has been verified by relevant data of a listed company in a certain industry. The study will provide effective support for industry authorities to formulate relevant policies for promoting innovation investment.

Keywords: Innovation Investment Balance, Gini Coefficient, Comprehensive Equilibrium, Index System, Measurement Model.

1. Introduction

The report of the 19th CPC National Congress clearly stated that innovation is the primary force guiding development and the strategic support for building a modernized economic system. In 1912, Schumpeter first put forward the concept of innovation in The Theory of Economic Development, and proposed that innovation is endogenous in the production process, not imposed from the outside[1]. Over the past 40 years of reform and opening up, China's enterprise development has shifted from the mode of an extensive development which simply aimed at increasing material investment and expanding reproduction, to the mode of intensive

development with technology and human capital investment as the main line as well as the innovation driven. Implementing the innovation-driven development strategy is a major movement determined by the central government in the new development stage. In the Outline of the National Strategy of Innovation-Driven Development, the central government has formulated the strategic objectives of becoming an innovative nation in 2020, becoming an international leader in innovation in 2030 and becoming a world powerhouse of scientific and technological innovation in 2050[2]. The realization of the strategic goal of innovation-driven development requires the joint efforts from all parts of society. As the main body of innovation, enterprise innovation will be realized through investment in human and material resources. However, there is a certain imbalance in enterprise innovation investment in China. Even within the same industry, there is a certain gap in innovation investment between enterprises [3-4]. In this background, it is necessary to analyze the balance of innovation investment of companies in the industry to provide effective support for the industry authorities and enterprises to make policies and investment mechanisms related to innovation investment.

At present, the research on enterprise innovation mainly focuses on the analysis of enterprise innovation driving factors, the calculation of enterprise innovation efficiency, the development mode driven by enterprise innovation, etc. the starting point of the existing study is mainly the research on enterprise innovation mechanism, an on how to evaluate and improve it on the basis of mechanism exploration. The foothold of existing study is mainly based on the enterprise itself, while there is a relative lack on exploring enterprise innovation from the industry or government level [5-10]. Among them, the relevant study on the balance of innovation investment of enterprises in the industry is basically not involved by scholars.

The research on the balance of innovation investment of enterprises in the industry is helpful to analyze the difference degree of innovation investment of enterprises in the industry so as to provide effective support for the industry authorities to promote the innovation investment of enterprises in the industry, On the other hand, for enterprises, they can find the gap between themselves and other enterprises in the industry in all aspects of innovation investment through comparison, providing effective support for improving the path of innovation investment [11]. When measuring the balance of industrial innovation investment, this article took a listed company in a certain industry as the analysis object, trying to introduce the Gini coefficient into it. Aiming at the problem that the Gini coefficient can only measure the balance of a single index, thearticle tried to introduce the concept of comprehensive equilibrium of innovation investment and combine the entropy method with the group-decision analytic hierarchy process, so as to determine the weight of each index in the equilibrium degree of innovation investment.

2. The Adaptability and Improvement Strategy of Gini Coefficient in the Measurement of Industrial Innovation Investment Balance

2.1. Applicability analysis

As a internationally accepted index in the world to measure the gap between the rich and the poor in a country or region, the Gini coefficient was proposed by the famous American economist Hirschman on the basis of the Lorenz curve. The smaller the Gini coefficient, the more equal the income distribution tends to be, and the smaller the arc of the Lorenz curve. On the contrary, the larger the Gini coefficient, the more unequal the income distribution is, and the greater the arc of the Lorenz curve [12].

There is a certain similarity between the equilibrium of industrial innovation investment and the equilibrium of national income distribution. Based on this, we can borrow the relevant content and methods from the Gini coefficient to build a scientific and reasonable system of industrial innovation investment balance evaluation index and evaluation methods, so that the industrial innovation investment balance can be measured.

Drawing on the concept of Gini coefficient, the research proposed the concept of Gini coefficient of industrial innovation investment: the equilibrium of industrial innovation investment can be measured by multiple indexes. The coefficient of the relationship between the cumulative operating income ratio and the cumulative innovation investment ratio of each enterprise in the industry calculated by using one of the index is called the Gini coefficient of industrial innovation investment under a certain index.

2.2. Improvement strategy

Considering that industry innovation investment can be measured from many aspects, it is necessary to comprehensively consider all aspects of industrial innovation investment when discussing the balance of it, that is, multiple indexes should be used to examine the situation of industrial innovation investment. And considering that the importance of various aspects of innovation investment to enterprise development is different, it is also necessary to put forward the concept of comprehensive equilibrium degree of industrial innovation investment on the basis of calculating the Gini coefficient of each index of industrial innovation investment equilibrium.

The concept of comprehensive equilibrium degree of industrial innovation investment is as follows: the equilibrium degree of industrial innovation investment can be measured by multiple

indexes, and the importance of each index in reflecting the equilibrium degree of industrial innovation investment is different. On the basis of calculating the Gini coefficient of industrial innovation investment reflected by each index, a comprehensive measure of the equilibrium of innovation investment in a certain industry is formed according to the weight of each index, which is the comprehensive equilibrium degree of industrial innovation investment.

2.3. Defining standard

The comprehensive equilibrium degree of industrial innovation investment is realized by using the basic principle of Gini coefficient. Therefore, when using the it to measure the equilibrium of industrial innovation investment, the relevant definition standards also refer to the related standards of Gini coefficient commonly used in the world. The definition criteria of industrial innovation investment balance is shown in Table 1 as follows.

Table1The definition criteria of industrial innovation investment balance

Level of industrial innovation investment balance	Hierarchical meaning	Range of comprehensive equilibrium degree of industrial innovation investment
Level 1	Absolutely balanced	< 0.2
Level 2	Well balanced	0.2-0.3
Level 3	Relatively balanced	0.3-0.4
Level 4	Relatively unbalanced	0.4-0.5
Level 5	Unbalanced	≥0.5

3. Measurement Index and Model of the Industrial Innovation Investment Balance

3.1. Selection of measurement index of the industrial innovation investment balance

As an important theory in economics, human capital theory integrates the two analysis dimensions of human management and return on capital investment, and proposes that human capital management should focus on both quantitative and qualitative management, integrating physical capital and human resources to achieve a higher level of value realization. As an important internal driving force for enterprise development, enterprise innovation not only needs

the support of material capital investment (mainly monetary input), but also requires the core driven power of enterprise R&D human resources investment. The Nobel Prize winner in economics Thodore W. Schults who is known as the builder of the human capital theory, also believes that the human factor is the most important one among the many influencing factors in economic development, which means that, when measuring enterprise innovation investment, it is necessary to measure not only the currency performance of enterprise innovation investment, but also the human capital investment related to enterprise innovation.

Enterprise innovation investment can be characterized from two dimensions: the first is enterprise R&D investment. If expressed in absolute value, it is the amount of R&D investment, and if expressed in relative value, it is the ratio of R&D investment to operating income. The second is the investment of enterprise R&D personnel. If it is expressed as an absolute value, it is the number of R&D personnel, and it is the proportion of the number of R&D personnel when expressed as a relative value.

Based on the above analysis, combined with the calculation of Gini coefficient, two indexes, the amount of R&D investment (ZB1) and the number of R&D personnel (ZB2), were selected as the measurement index of the investment balance of industry innovation.

3.2. Construction of measurement model of industrial innovation investment balance

(1) Calculation method of Gini coefficient of industrial innovation investment

According to the definition of Gini coefficient of industrial innovation investment listed above, combined with the determined measurement indexes of industrial innovation investment balance, the calculation method of Gini coefficient of industrial innovation investment is proposed as follows:

For an certain industry, assuming that the number of the enterprises in the industry is n, the n enterprises in the industry were ranked according to the magnitude of the determined industrial innovation investment balance measurement index. Assuming that the proportion of the index value of the first enterprise in the whole industry is a_1, and the proportion of the enterprise's operating revenue in the whole industry is b_1, and so on, the proportion of the index value of the ith enterprise in the whole industry is a_i, and the proportion of the ith enterprise's operating revenue in the whole industry is b_i. Then the corresponding data (b_1, a_1), (b_2, a_2),..., (b_i, a_i),..., (b_n, a_n) can be connected in sequence on the rectangular coordinate system to obtain the Lorentz

curve.

Based on this, the Gini coefficient of industrial innovation investment under the index can be calculated

$$G = -(1 + \sum_{i=1}^{n} a_i b_i - 2 \sum_{i=1}^{n} (\sum b_i) a_i) \, (1)$$

Among them, $\sum b_i$ -- Accumulated to the cumulative proportion of the ith enterprise in the industry. (2)

(2) Determination of index weight of industrial innovation investment

Since the measurement index of the innovation investment balance in two industries shares different degree of importance, it is necessary to determine the weight of the two index when calculating the comprehensive balance of industrial innovation investment.

At present, the methods for determining the index weight can be roughly divided into two categories: one is the subjective weighting method, which is determined by the subjective judgment of experts, commonly including AHP(Analytic Hierarchy Process), Delphi method, DARE(Decision Alternative Ratia Evaluation system), etc. The other is objective weighting method, commonly including entropy method, PCA(Principal Component Analysis method), multi-objective programming approach and so on. Considering that both subjective evaluation method and objective weighting method have their own advantages and disadvantages, this article attempted to combine the subjective weighting method and objective weighting method to determine the index weight by using the subjective and objective comprehensive weighting method [13].

After comparative analysis, the IGAHP(Improved Group-decision Analytical Hierarchy Process) was selected as the subjective weighting method. The objective weighting method adopted entropy weight method.

① Method of determining weight by IGAHP

Aiming at the problem that the traditional AHP method can only make decisions by one person and unable to be evaluated by interval numbers, corresponding improvements were made.

Suppose there are K experts participate in the determination of the index weight of the industrial

innovation investment balance measurement. In the process of determining the index system weight, determined by the jth ($j=1,2,\ldots,J$) expert, the comparative interval value of the relative importance of the two index $ZB1$ as well as $ZB2$ is $[d_1^{(j)}, d_2^{(j)}]$ ($d_2^{(j)} \geq d_1^{(j)}$) , and the weight of each expert is c_j ($j=1,2,\ldots,J$)respectively, then the comparative value of the relative importance of the two index $ZB1$ and $ZB2$ is as follows.

$$p_{ZB1,ZB2} = \frac{1}{2} \bullet \frac{\sum_{j=1}^{J}\{[d_2^{(j)}]^2 - [d_1^{(j)}]^2\} \bullet c_j}{\sum_{j=1}^{J}[d_2^{(j)} - d_1^{(j)}] \bullet c_j} \quad (3)$$

On the basis of determining the comparative value of the relative importance of the two indexes, the determination of the weight will be carried out according to the steps and requirements of the AHP method [14].

② Method of determining weight by entropy method

The study of entropy method has been relatively mature and due to the limited space, this article will not discuss it too much [15-16].

③Method of determining comprehensive weight

Assuming that the subjective weight of the kth index determined by the IGAHP is e_k ($k=1,2$), and the objective weight of the kth index determined by the entropy method is f_k ($k=1,2$), then the final weight of each index W_k is

$$W_k = e_k f_k / \sum_{k=1}^{2} e_k f_k \quad k=1,2 \quad (4)$$

(3) Calculation method of comprehensive equilibrium degree of industrial innovation investment

There are two indexes to measure the balance of industrial innovation investment, namely, the amount of R&D investment ($ZB1$) and the number of R&D personnel ($ZB2$). According to the definition of the comprehensive equilibrium degree of industrial innovation investment, it is necessary to calculate the Gini coefficient of industrial innovation investment under the two

indexes, as well as calculate the comprehensive equilibrium degree of industrial innovation investment according to the weight of the index.

Based on this, the calculation method of comprehensive equilibrium degree of industrial innovation investment is as follows:

The set formed by the Gini coefficient of industrial innovation investment under the two indexes is G_k ($k = 1, 2$), and the set formed by the weights of the two indexes is W_k ($k = 1, 2$).

The comprehensive equilibrium degree of innovation investment in a certain industry is C, then

$$C = G_k \otimes W_k \quad (5)$$

According to the calculated comprehensive equilibrium degree of industrial innovation investment, combined with the definition standard of industrial innovation investment equilibrium in Table 1, it is possible to judge the industrial innovation investment equilibrium.

4. Case Analysis -- Taking Listed Companies in Environmental Protection Industry as an Example

4.1. Data sources

There are 11 companies in the environmental protection industry listed on the Shenzhen and Shanghai main boards. According to the 2019 annual financial report data of the listed companies, the basic data on innovation investment was sorted out, which is shown in Table 2.

Table 2 Basic data of 2019 annual financial report of Listed Companies in environmental protection industry

Serial number	Company code	Operating revenue in 2019（billion yuan）	Number of R & D personnel in 2019（unit）	Proportion of R & D personnel in 2019（%）	Amount of R&D investment in 2019 (million yuan）	Proportion of R & D investment in operating revenue in 2019（%）
1	AD1	3.731	188	5.30	10.7602	0.29
2	AD2	1.663	101	6.87	32.2496	1.94

3	AD3	1.614	0	0.00	0.00	0.00
4	AD4	12251	33	3.06	0.4278	0.03
5	AD5	0.440	15	1.40	1.9687	0.45
6	AD6	0.981	0	0.00	0.00	0.00
7	AD7	4.202	219	5.07	63.6631	1.52
8	AD8	3.544	214	11.00	23.1985	0.65
9	AD9	4.472	21	0.40	0.9855	0.02
10	AD10	1.101	0	0.00	0.00	0.00
11	AD11	1.244	0	0.00	0.00	0.00

4.2. Determination of index weights

According to the research, the amount of R&D investment (ZB1) and the number of R&D personnel (ZB2) were selected as the measurement index of the balance of industrial innovation investment. Since these two index play different roles in measuring the balance of industrial innovation investment, it is necessary to determine their respective weights.

(1) Determination of subjective weights

The determination of the subjective weight adopted the IGAHP. Seven experts respectively determined the relative importance comparison interval value of the two indexes, and the weight of each expert was determined respectively according to the professional and technical level of each expert as well as their authority in the industry, qualifications, education and other aspects. On this basis, the comparative value of the relative importance of the two indexes is calculated according to formula (3). Based on this, according to the steps and requirements of the AHP method, the subjective weights of the two indexes, the amount of R&D investment (ZB1) and the number of R&D personnel (ZB2), were determined. The results are shown in Table 3.

Table 3Subjective weight determination results

Index	Index Weight

The amount of R&D investment（ZB1）	0.426
The number of R&D personnel（ZB2）	0.574

(2) Determination of objective weight

The determination of the objective weight adopted the entropy method. According to the calculation steps of the method and the content of this article, the objective weights of the two indexes of R&D investment (ZB1) and R&D personnel (ZB2) were calculated, which are shown in Table 4.

Table 4 Objective weight determination results

Index	Index Weight
The amount of R&D investment（ZB1）	0.580
The number of R&D personnel（ZB2）	0.420

(3) Determination of comprehensive weight

According to formula (4), determine the comprehensive weight of two indexes: R&D investment amount(ZB1) and R&D personnel number (ZB2) and the results are shown in Table 5.

Table 5 Comprehensive weight determination result

Index	Index Weight
The amount of R&D investment（ZB1）	0.506
The number of R&D personnel（ZB2）	0.494

4.3. Calculation of Gini coefficient and comprehensive equilibrium degree of industrial

innovation investment

According to the calculation method of Gini coefficient of industrial innovation investment proposed above and formula (1), the Gini coefficient of innovation investment in environmental protection industry corresponding to the two indexes of R & D investment amount (ZB1) and the number of R & D personnel (ZB2) can be calculated. The results are shown in Table 6.

Table 6 Calculation results of Gini coefficient of innovation investment in environmental protection industry under each index

Index	Gini coefficien
The amount of R&D investment（ZB1）	0.601
The number of R&D personnel（ZB2）	0.460

According to the calculation results in Table 6 and the weight determination results in Table 5, the comprehensive equilibrium degree of innovation investment in environmental protection industry was calculated, which is 0.531.

4.4. Result analysis

From the above calculation, it can be concluded that the comprehensive equilibrium degree of innovation investment in the environmental protection industry is 0.531. Combined with the criteria for defining the equilibrium of industrial innovation investment given in Table 1, the equilibrium level of innovation investment in the environmental protection industry is in level 5, which is unbalanced. Judging from the amount of R&D investment, its Gini coefficient is 0.601, which is also in level 5, referring to unbalanced, and from the perspective of the number of R&D personnel, its Gini coefficient is 0.460, which is in level 4, referring to relatively unbalanced. In general, the environmental protection industry presents an unbalanced state on innovation investment, which means that the listed companies in the industry vary greatly in innovation investment.

4.5. Case analysts

Although the innovation input of an enterprise does not represent its final innovation output, it

will affect the future core competitiveness of the enterprise to a great extent. From the industry level, to realize the upgrading and transformation from manufacturing to innovation, it is not enough to rely on only one or two enterprises, the innovation capacity of the whole industry have to be improved. In recent years, benefiting from the support of national policies and the large demand of the environmental governance market, the environmental protection industry has maintained a rapid development trend. However, at least for now, there is still a large gap in the independent innovation ability of our environmental protection enterprises compared with the developed countries all around the world. Moreover, there are great differences in innovation investment among listed Companies in China's environmental protection industry according to the above calculation, and the comprehensive equilibrium degree of innovation investment is 0.531, showing an obvious imbalance. How to improve the initiative of independent innovation of China's environmental protection enterprises, enhance the intensity of innovation investment, promote the normalization of enterprise innovation investment as well as shape and strengthen the innovation competitiveness of the industry is an urgent problem to be solved.

Throughout the existing research literature, the intensity of innovation investment and its imbalance are mainly affected by internal factors such as firm scale, financing constraints, and corporate governance, as well as external factors such as market structure, government policy intervention, and social environment. In addition, the long-term nature of innovation and R&D process and the uncertainty of innovation output and its final benefits also reduce the enthusiasm of enterprises to innovate to a certain extent. For example, some enterprises reduce R&D investment in order to effectively control business risks. Even if some enterprises are willing to bear the uncertainty of innovation and R&D subjectively, they may objectively reduce R&D investment because of the risk assessment which affects the external financing. The comprehensive consideration of various factors inside and outside the enterprise leads to a relatively low level of innovation input intensity and normalization of innovation input in the industry. Facing such a circumstance, the government, industry authorities and enterprises need to work together to build an innovation-driven development state.

According to the external theory, due to the strong knowledge spillover of R&D investment, the private income obtained by enterprises is often lower than the social benefits created by them, and enterprises engaged in R&D unable to get their expected benefits, which leads a lower innovation intention of enterprises[17]. In addition, affected by the characteristics of long investment payback period, uncertain investment benefits and information asymmetry, enterprise often has large innovation risk. If only relying on market mechanism, it can easily lead to insufficient investment in enterprise innovation [18]. In this case, active fiscal and taxation

policies can reduce the R&D cost and innovation investment risk of enterprises, stimulate the innovation enthusiasm of enterprises, thus to enable enterprises to increase R&D investment. Furthermore, policy dividends (such as R&D subsidies, innovation funds, science and technology awards and other government subsidies) are a positive signal for beneficiary enterprises and have certification effect, which transmits the information of enterprise innovation ability to external investors, making it easier to win the trust of external investors, broaden financing channels and effectively alleviate the financial pressure compared with other competitive enterprises in the industry, further promote the innovation investment of enterprises[19]. Therefore, the government should implement active national intervention policies (such as government R&D subsidy policy, favorable tax policy, green credit, public-private partnership, etc.) to stimulate the innovation enthusiasm of enterprises, so as to improve the innovation investment of enterprises and realize the normalization of industry innovation investment.

Market competition is the external driving force to promote enterprise innovation. The more intense the market competition, the stronger the sense of oppression on enterprises, the more enterprises will be urged to innovate and increase innovation investment. Therefore, the industry authority should carry out dynamic monitoring of industrial development, clarify innovative reward and punishment measures, standardize the market order, form a unified and open market system with equal access and orderly competition, and give full play to the decisive role of the market in the resource allocation of energy conservation and environmental protection industry.

As mentioned above, due to the long innovation investment cycle, the large amount of capital investment, and the high uncertainty of innovation output and benefits, there are high risks when investing in innovation. Enterprise innovation investment includes capital investment and human capital investment. From the perspective of human capital, R&D personnel, as an important supporting force for enterprise innovation activities, who play a key role in the quantity and quality of innovation output, are the executors to improve the innovation performance of enterprises [20], greatly reducing risk of innovation investment to a certain extend. Therefore, for the enterprise itself, it is necessary to strengthen the training and introduction of top innovative talents in environmental protection, especially the innovative talents urgently needed for enterprise development, establish a talent incentive mechanism, such as implementing options, technology shares, equity and other incentives for scientific and technological personnel and management personnel who have made outstanding contributions, strengthen the relationship with the government, universities and scientific research institutions, accurately connecting the required technical and R&D talents, and improve salaries to attract more fresh blood for the

company, etc.

5. Conclusion

In an era of knowledge economy, innovation investment has become an important focus related to the driving force of social development. As far as the micro subject is concerned, the innovation investment of enterprises will affect the future core competitiveness of them to a great extent. From the perspective of industry management, this article proposes to use the principle of Gini coefficient to calculate the comprehensive balance of industrial innovation investment by comprehensively considering the amount of R&D investment and R&D investment personnel, and judge the balance of industrial innovation investment by defining standards. The research provides effective support for the industry authorities to formulate policies related to innovation investment.

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