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Study on Measurement of Collaborative Innovation Development of Electronic and Communication Equipment Manufacturing Industry and Its Influencing Factors in Yangtze River Delta

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Abstract

Collaborative innovation is a new paradigm of innovation and development. It promotes the integration of complementary resources and improves the innovation ability by playing the national will. Electronic and communication equipment manufacturing industry is the foundation and core industry of modern information technology, which is the pillar industry of our country. It plays the role of economic multiplier in every application field by supporting the development of other industries. Among them, the Yangtze River Delta is the leader of China's electronic and communication equipment manufacturing industry, accounting for half of the country's industrial scale. Therefore, this research takes the electronic and communication equipment manufacturing industry in the Yangtze River Delta region as the research object, based on the research results of domestic and foreign scholars, and the shortcomings of previous studies as the breakthrough point, and uses the literature analysis method and empirical analysis method to analyze its collaborative innovation. First of all, this research makes a quantitative analysis of the innovation status of the electronic and communication equipment manufacturing industry in the Yangtze River Delta from the perspective of innovation input and output. Then, according to the relevant data of the Yangtze River Delta's electronic and communication equipment manufacturing industry from 2011 to 2019, the order degree of the innovation subsystem and the coordination degree of the whole innovation system of the Yangtze River Delta's electronic and communication equipment manufacturing industry are

calculated by using the composite system coordination degree model, and these are taken as the explained variables; This research analyzes the influence of government, market, innovation and economy on the development of collaborative innovation, uses unit root test, co-integration test and other methods to test the index data, and makes regression analysis. Finally, the research summarizes the current situation, the measurement of synergy degree and the analysis of the influencing factors, and puts forward some countermeasures and suggestions.

Keywords

Yangtze River Delta, Electronic and Communication Equipment Manufacturing Industry, Measurement of Synergy, Influencing Factors

1. Background

Innovation ability is the core of national competitiveness. China has put scientific and technological innovation in the first place. It is 2020 the final year for China to enter an innovative country. According to *The 2020 Global Innovation Index Report* (World Intellectual Property Organization, 2020), China has increased by 20 places from 2012 to 2020 so that China has established a position as an innovation leader. But the current innovation system in China has some problems, such as low conversion rate of scientific and technological achievements, scattered, closed and lack of integration of innovation resources. Because individuals all pursue their own interest's maximization, and there are restrictions and barriers between departments and regions so that resources cannot be shared and complementary, which seriously hinder the development of innovation in China. Collaborative innovation is a new paradigm to give full play to the will of the national government to realize organized innovation. It can become a new trend to improve innovation efficiency and lead innovation by promoting the close combination and deep integration of government, industry, universities and research institutes.

Electronic and communication equipment manufacturing is a pillar and strategic industry of Chinese national economy, which is encouraged and supported by The State Council, the Ministry of Industry and Information Technology, the National Development and Reform Commission and local governments. Driven by market demand, the scale of China's electronic and communication equipment manufacturing industry has grown with sales rising year by year. Nowadays it is far ahead of other countries in the world. The Yangtze River Delta is an important region for the development of electronic and communication equipment manufacturing industry. In November 2018, the development of regional integration in the Yangtze River Delta became a national strategy. *The Outline of the Development Plan for Regional Integration in the Yangtze River Delta* (National Development and Reform Commission, 2019) pointed out that the

planning scope of regional integration in the Yangtze River Delta includes Shanghai, Jiangsu Province, Zhejiang Province and Anhui Province. Taking 27 cities such as Shanghai, Nanjing in Jiangsu Province, Hangzhou in Zhejiang Province and Hefei in Anhui Province as the central area, it radiates and drives the high-quality development of the Yangtze River Delta. Due to its strong importance in economy, finance and science and technology in China, it has been the focus of academic research, and the research results under the proposition of the integration of the Yangtze River Delta have been very rich.

There is still little research on Collaborative Innovation in electronic and communication equipment manufacturing industry in China. Therefore, this research starts from the Yangtze River Delta, which is at the forefront of China's development, and collects, screens and arranges the relevant data, Using the empirical research methods of DEA and composite system synergy model, this research makes a quantitative analysis on the efficiency of innovation and development of electronic and communication equipment manufacturing industry in the Yangtze River Delta and the synergy of innovation system of electronic and communication equipment manufacturing industry in the Yangtze River Delta, so as to put forward appropriate development path suggestions, which not only enriches the relevant theories of collaborative innovation of electronic and communication equipment manufacturing industry, It also provides a reference for the research of other scholars, has a certain theoretical significance, and also provides a certain reference for the development of China's electronic and communication equipment manufacturing industry.

2. Literature Review

Collaborative innovation of industrial clusters has been studied by many scholars at home and abroad, and remarkable research results have been achieved. This chapter summarizes the research results of collaborative innovation of industrial clusters from two aspects: mechanism and evaluation.

2.1. Research on Collaborative Innovation Mechanism of Industrial Clusters

Katarzyna Szkuta et al. (2014) studied the quantity and quality of innovation collaboration in the public sector and the private sector respectively, indicating that the differences of collaborative innovation subjects may lead to different ways and effects of collaborative innovation.

Tongtong Wang (2014) believes that the main body of collaborative innovation in industrial clusters is enterprises, while the government, financial institutions, intermediaries and scientific research institutions are the support system in industrial clusters, providing policy support, financial guarantee and technical support for collaborative innovation activities in clusters. The main content of industrial cluster collaborative innovation is composed of the main innovation ability of enterprises in the cluster, the support ability of the support system and

the performance ability reflecting the output effect of collaborative innovation.

Yinwei Li (2014) believes that collaborative innovation of industrial clusters is a new paradigm of open innovation, which can not only share resources and complement each other's advantages, but also improve production efficiency and increase competitive advantage. Finally, leapfrog development can be realized.

Min Yan (2014) believes that enterprises in industrial clusters realize the sharing of knowledge, technology and other resources by integrating individual internal and external resources. And the efficiency of collaborative innovation is much higher than that of single enterprise.

Tingting Lu (2017) studied the collaborative innovation of emergency industrial clusters and proposed seven collaborative relationship innovation chains. In general, it is a process in which enterprises, universities and scientific research institutions carry out technical cooperation, at the same time, and rely on the financial support of financial and intermediary service institutions, so as to improve the innovation ability of industrial clusters.

Ronghua Fu (2019) believes that collaborative innovation of industrial clusters is related enterprises in the industrial chain gathered in a specific region. By breaking the boundaries within the system, the resource elements can flow freely, and then the whole system can operate efficiently and harmoniously.

2.2. Research on the Evaluation of Collaborative Innovation Ability of Industrial Clusters

Kim and Park (2010) took Korean small and medium-sized enterprises as the research object and used multiple regression analysis to draw the conclusion that there are differences in the impact of open innovation activities of small and medium-sized enterprises on their innovation output.

Hao and Jiang (2015) used principal component analysis and questionnaire survey to determine the evaluation indicators, designed 57 three-level indicators from collaborative innovation environment, input, process, output and effect. He used AHP method to determine the weight of each indicator and to form the evaluation index system. Finally, TOPSIS method was adopted to evaluate the performance of collaborative innovation in Higher Education.

From the perspective of patents, Kun Wang (2017) selected the patent data of pharmaceutical manufacturing industry in the Beijing-Tianjin-Hebei region from 1995 to 2015 and established the coordination degree model of composite system. He studied the coordination degree of biomedical industry in Beijing, Tianjin and Hebei, and analyzed the patent distribution and Patent Cooperation Innovation in the region by using Social Network Analysis and Patent Map Methods.

From the two core elements of knowledge spillover capacity and technology absorption capacity, Xing Zeng (2018) used Principal Component Analysis to collect the questionnaire survey data of pharmaceutical enterprises of Jiangsu pharmaceutical business association from 2012 to 2015, including the R & D and

output of enterprises, and established an evaluation system for the collaborative innovation ability of Jiangsu pharmaceutical manufacturing industry. The panel data regression method is used to analyze the influencing factors in the process of industry university research collaborative innovation.

Based on the perspective of industrial chain cooperation, Zhihua Wang (2018) selected the influencing factors of collaborative innovation of industrial clusters from five levels of industrial chain. He collected data by questionnaire, constructed an evaluation system by using structural equation model and quantitatively analyzed the influencing factors of collaborative innovation of Shanxi semiconductor industrial clusters.

Cai and Zhao (2019) collected the panel data of 29 provinces from 2011 to 2015 and constructed a triple helix strength model to analyze the efficiency and influencing factors of University-Enterprise-Government collaborative innovation. Then he found that R & D human investment and capital investment play positive roles in promoting the efficiency of collaborative innovation. But relatively speaking, human investment has a stronger driving effect on Collaborative Innovation.

Hou Guangwen (2019), based on the perspective of complex network adaptability, used Evolutionary Game Analysis and Social Network Analysis to explore the network structure characteristics of collaborative innovation of aerospace industry clusters and the stability conditions of cooperative relations. The theoretical model of the impact of enterprise network on the collaborative innovation performance of aerospace industry cluster was established by using Mathematical Analysis and Statistical Analysis.

Zheng Zhenqiang (2020) evaluated the collaborative innovation capability of nuclear power enterprises through catastrophe progression method and entropy weight method based on the third-level indicators such as the growth rate of total assets in the last three years and the proportion of the number of patents disclosed under the second-level indicators such as independent innovation capability, knowledge sharing capability and knowledge integration capability.

Liu and Chen (2020) used the data envelopment method to measure the regional collaborative innovation efficiency of 30 provinces in China from two aspects of input and output, and made an empirical analysis on the impact effects of key influencing factors by using static and dynamic spatial panel model.

Sun Zhengqing et al. (2020) used the Three-stage DEA method and labor input, capital input and project input are selected as input indicators, economic benefit and innovation results are taken as output indicators. Taking research and development support, industrial structure, regional economic development level, degree of opening up and government financial support as environmental variables, he calculated the collaborative innovation efficiency of China's four major urban agglomerations and Tobit regression model was used to analyze the key influencing factors of collaborative innovation efficiency among them. And it is concluded that R & D support and regional economic development level

play a positive role in improving collaborative innovation efficiency.

Liu and Wu (2021) used the super efficiency DEA model based on the input-oriented model to measure the collaborative innovation efficiency of marine high-tech industries in 11 Marine Provinces of China and concluded that the overall efficiency of collaborative innovation of marine high-tech industries in China is not high, and there is a large room for improvement.

2.3. Commentary

By combing the literature of relevant research fields of domestic and foreign scholars, it can be found that, as a new paradigm of innovation, the importance of collaborative innovation has been paid more and more attention by many scholars. Therefore, the connotation of collaborative innovation is constantly improving. Scholars at home and abroad have conducted research on collaborative innovation activities of industrial clusters from different angles and achieved certain research results, but there are still areas to be explored and worthy of improvement:

Firstly, previous scholars' research on collaborative innovation was mainly general research focusing on manufacturing or specific pharmaceutical manufacturing and high-tech industries. However, there is less research on electronic and communication equipment manufacturing industry.

Secondly, industrial cluster is a phenomenon of industrial layout. The electronic and communication equipment manufacturing industry has formed an obvious industrial agglomeration area in China, but there is less research on the electronic and communication equipment manufacturing industry in specific areas.

Thirdly, for the relevant research on Collaborative Innovation of specific regions or industries, most of the research is mainly in the stage of qualitative or simple quantitative analysis, and the quantitative test research and analysis is lack of persuasion, while the research on in-depth quantitative analysis of collaborative innovation of specific industries in specific regions is very lack.

3. Research Structure and Methods and Theoretical Basis

3.1. Research Structure

The research content of this paper is mainly carried out from the following seven parts:

Part 1 is background. This chapter mainly expounds the research background and significance of this paper, and explains that collaborative innovation is of great significance to the development of electronic and communication equipment manufacturing industry in the Yangtze River Delta.

Part 2 is literature review. Sort out the relevant literature on industrial clusters, collaborative innovation and collaborative innovation evaluation at home and abroad, so as to provide a theoretical basis for this research. At the same time, it is the starting point of this paper the shortcomings of previous scholars'

research.

Part 3 is the investigation contents and methods and theoretical basis. This chapter first defines the two concepts of the Yangtze River Delta region and the electronic and communication equipment manufacturing industry, explains the investigation contents and methods, and then introduces the theoretical basis of this paper.

Part 4 summarizes and analyzes the current situation of the innovation and development of the electronic and communication equipment manufacturing industry in the Yangtze River Delta from two aspects: the current situation and innovation status of the electronic and communication equipment manufacturing industry in the Yangtze River Delta.

Part 5 is the measurement of collaborative innovation development of electronic and communication equipment manufacturing industry in the Yangtze River Delta. This chapter uses the composite system synergy model to study the synergy of the innovation system of electronic and communication equipment manufacturing industry in the Yangtze River Delta, and finally analyzes the results.

Part 6 is the empirical analysis of the influencing factors of collaborative innovation development of electronic and communication equipment manufacturing industry in the Yangtze River Delta. This chapter uses panel data to empirically analyze the influencing factors of innovation and development of electronic and communication equipment manufacturing industry in the Yangtze River Delta, in which the degree of synergy is the explanatory variable, and the explanations of innovation, government, market and economy are the explanatory variables.

Part 7 is the conclusion and countermeasures. Summarize the conclusions of the above chapters, combined with the reality, put forward the countermeasures and suggestions for the collaborative innovation and development of electronic and communication equipment manufacturing industry in the Yangtze River Delta.

3.2. Research Methods

Through qualitative analysis, this research defines the related concepts of Yangtze River Delta, electronic and communication equipment manufacturing industry, and combs the synergetic theory, synergetic innovation theory and technological innovation theory to provide a basis for quantitative analysis. Use quantitative analysis method to analyze the current situation of the electronic and communication equipment manufacturing industry on the basis of finishing the relevant data. And use DEA to calculate the Yangtze River delta regional innovation efficiency of electron and communication equipment manufacturing industry. The coordination degree model of complex system is used to calculate and analyze the order degree of the innovation system of electronic communication equipment manufacturing industry in the Yangtze River Delta and the synergy

degree of the whole innovation system. Finally, a regression model is established to analyze the relationship between them.

Based on the review of existing research results, this research introduces the theoretical basis of synergetic science and synergetic innovation. On this basis, DEA and synergetic degree model of composite system are used for empirical analysis. According to the empirical analysis results and combined with the reality, the corresponding development path is obtained.

3.3. Theoretical Basis

The Synergetics theory was put forward by Haken (1984). He believes that after complex coordination and cooperation, each subsystem in a system can produce the utility that cannot be realized by a single subsystem and the realized utility is greater than the sum of the utility of a single subsystem, which is said to the synergy effect. Synergetics includes many basic and key principles, such as order parameter principle, dominance principle and self-organization principle.

Collaborative innovation is a concept based on collaborative theory and innovation theory. The concept of innovation comes from the innovation theory put forward by Schumpeter (1912). It is a conceptual process characterized by new thinking, new invention and new description. It includes three meanings: updating, creating new things and changing.

Based on the synergy and innovation, Gluesing et al. (2011) give such a definition: collaborative innovation is a network group composed of self-motivated personnel to form a collective vision, exchange ideas, information and work conditions through the network and cooperate to achieve common goals.

This research mainly studies the collaborative innovation of electronic and communication equipment manufacturing industry in the Yangtze River Delta. Its connotation needs to be acknowledged. According to the above connotation of collaborative innovation and combined with the research purpose of this research, Yangtze River Delta electronics and communications equipment manufacturing collaborative innovation refers that electronic and communication equipment manufacturing industry innovation systems of Shanghai, Jiangsu, Zhejiang and Anhui under the condition of the interior of the various factors, through the complicated nonlinear interaction between subsystems, realize the whole system from disorderly state to orderly state, and ultimately to achieve the overall coordination effect.

The operation mechanism of collaborative innovation includes coupling mechanism, which refers to the interdependent mechanism between subsystems. And demand-driven mechanism, that is, the benefits gained by the subjects through collaborative innovation are greater than the benefits obtained by the independent production of each subject. The starting point of collaborative innovation among subjects with different identities, backgrounds and interests is the pursuit of maximum benefits.

On the basis of innovation theory, Solow first put forward the concept of

technological innovation, which includes innovation in thought and actual production needs. Enos (1962) further defined technological innovation in a more specific way believing that technological innovation is mostly an economic concept and can only be produced by the interaction of technological factors with other factors, such as the choice of invention, capital investment guarantee, employment of workers and market opening. Dosi (1982) distinguished the concept of technological innovation from the connotation of innovation at different levels. He believed that technological innovation at the economic level should be defined from the perspective of products, starting from the conception and design of new products, and focusing on the consumption of new products. However, in China, the definition of technological innovation includes that the results of innovation have been applied to practice achieving a certain degree of success in business and emphasizing that enterprises are the main body of technological innovation.

Regional technological innovation ability emphasizes the interaction and connection between the regional environment and all internal industries, which is manifested in the innovation ability of the regional socio-economic system. It is characterized by highlighting the knowledge diffusion ability of technological innovation of enterprises in the region. Knowledge diffusion is the transmission of knowledge in time and space after knowledge creation.

4. Current Situation

Innovation is a complex process of multi-input and multi-output. This chapter analyzes the current situation of innovation development of electronic and communication equipment manufacturing industry in Yangtze River Delta from two aspects of input and output of innovation.
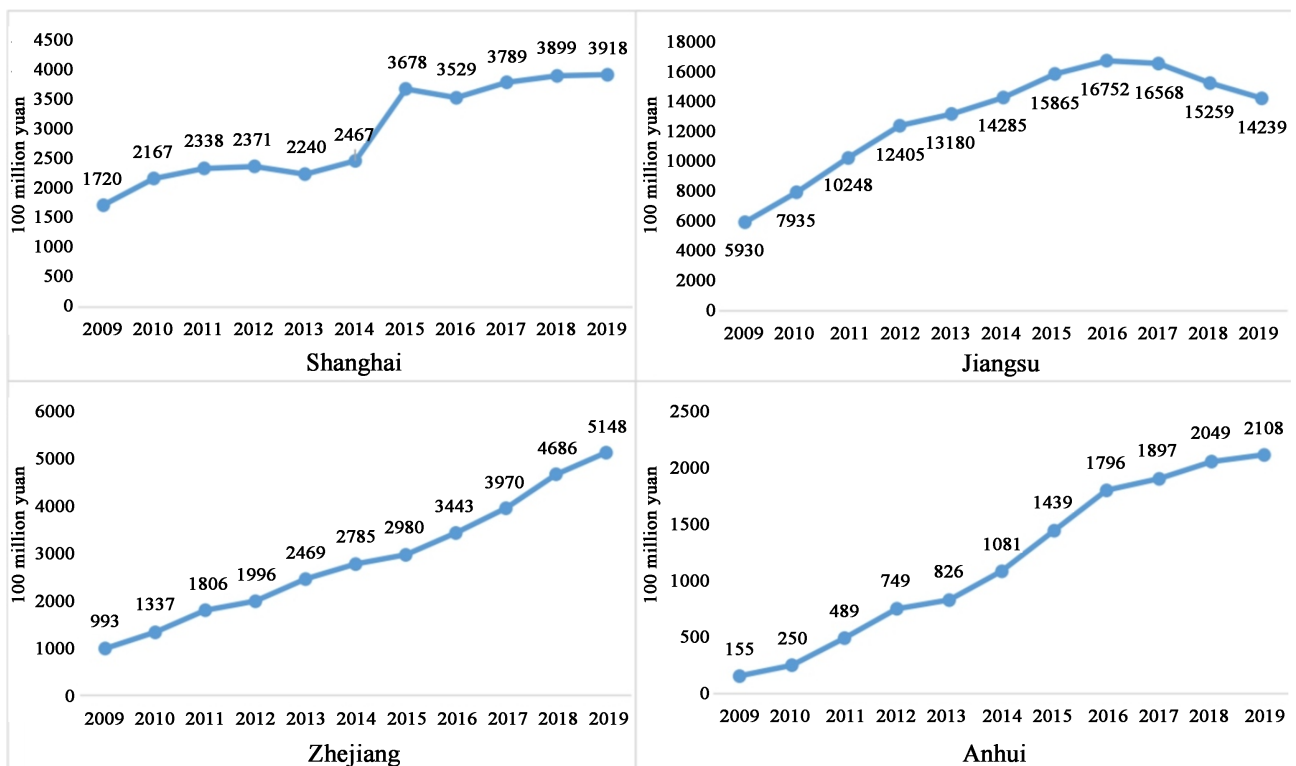
4.1. Current Situation of Electronic and Communication Equipment Manufacturing in Yangtze River Delta

Among three provinces and one city in the Yangtze River Delta region, everyone has its own characteristics. Shanghai has numerous scientific research institutions and abundant talent reserve and enjoys huge advantages in technological innovation. The electronic and communication equipment manufacturing industry develops rapidly. Jiangsu has a large economic volume, rich scientific and technological innovation resources and numerous electronic and communication equipment manufacturing enterprises. Zhejiang is rich in scientific and technological innovation resources. Well-known universities represented by Zhejiang University actively carry out innovation activities. Meanwhile, scientific research institutions and enterprises actively carry out cooperation, realizing the transformation of a large number of scientific research achievements. The development of electronic and communication equipment manufacturing industry in Anhui started late, so the foundation of industrial innovation ability is low. And the innovation ability of industry, university and research institute is

insufficient. In recent years, the electronic and communication equipment manufacturing industry in the four regions has been developing, expanding and enhancing profitability.

As can be seen from Figure 1, in terms of main business income, the electronic and communication equipment manufacturing industry in each region of the Yangtze River Delta showed an overall upward trend except for a slight decline in some years. The main business income of Jiangsu has always been the highest in the Yangtze River Delta, and the main business income of Shanghai is following, but in 2013, Zhejiang surpassed Shanghai. The income gap between the two main business incomes is small indicating that the electronic and communication equipment system of Zhejiang has made great progress in recent years. In addition, we can also know that Anhui's main business income is far behind Jiangsu, and there is a big gap with Zhejiang and Shanghai. By 2019, the proportion of main business income of electronic and communication equipment manufacturing in The Yangtze River Delta region is 56.03% in Jiangsu, 20.26% in Zhejiang, 15.42% in Shanghai and 8.29% in Anhui.

As can be seen from Figure 2, in terms of profit, the electronic and communication equipment manufacturing industry in all regions of the Yangtze River Delta presents an overall upward trend. Jiangsu is still the most profitable province

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 1. Main business income of electronic and communication equipment manufacturing in major provinces (cities) in Yangtze River Delta region from 2009 to 2019.
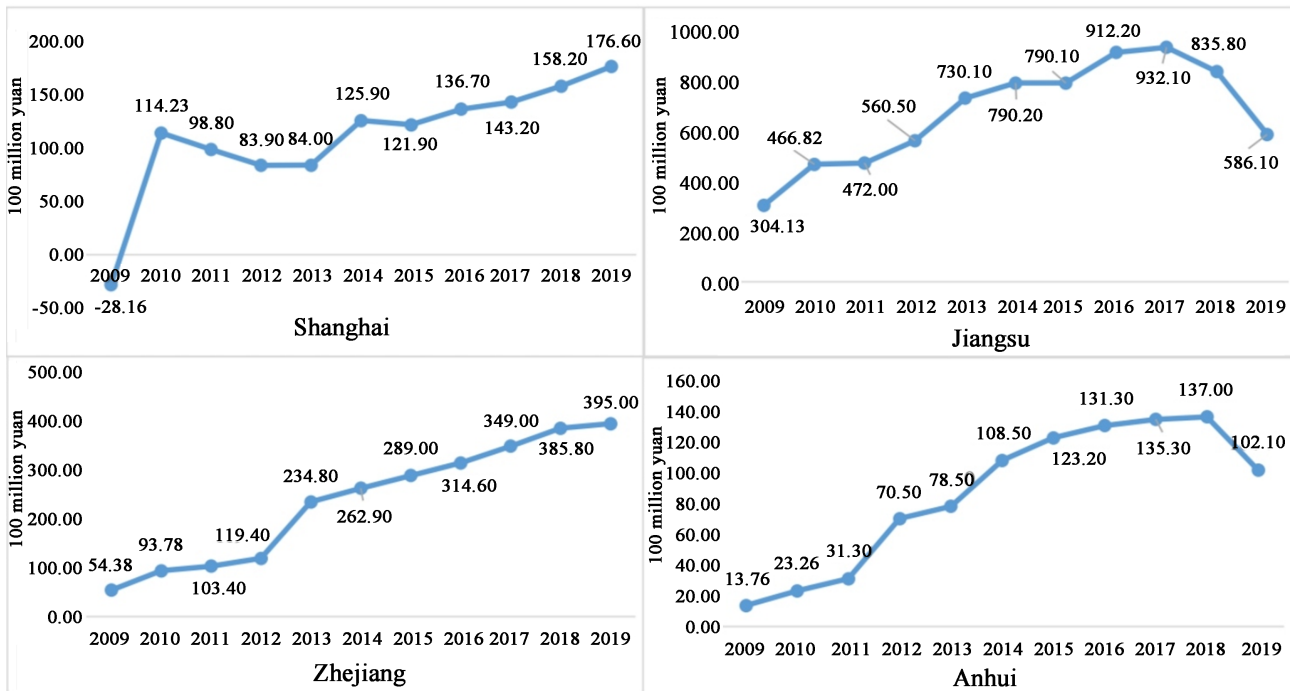
Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 2. Profits of electronic and communication equipment manufacturing of major provinces (cities) in Yangtze River Delta region from 2009 to 2019.
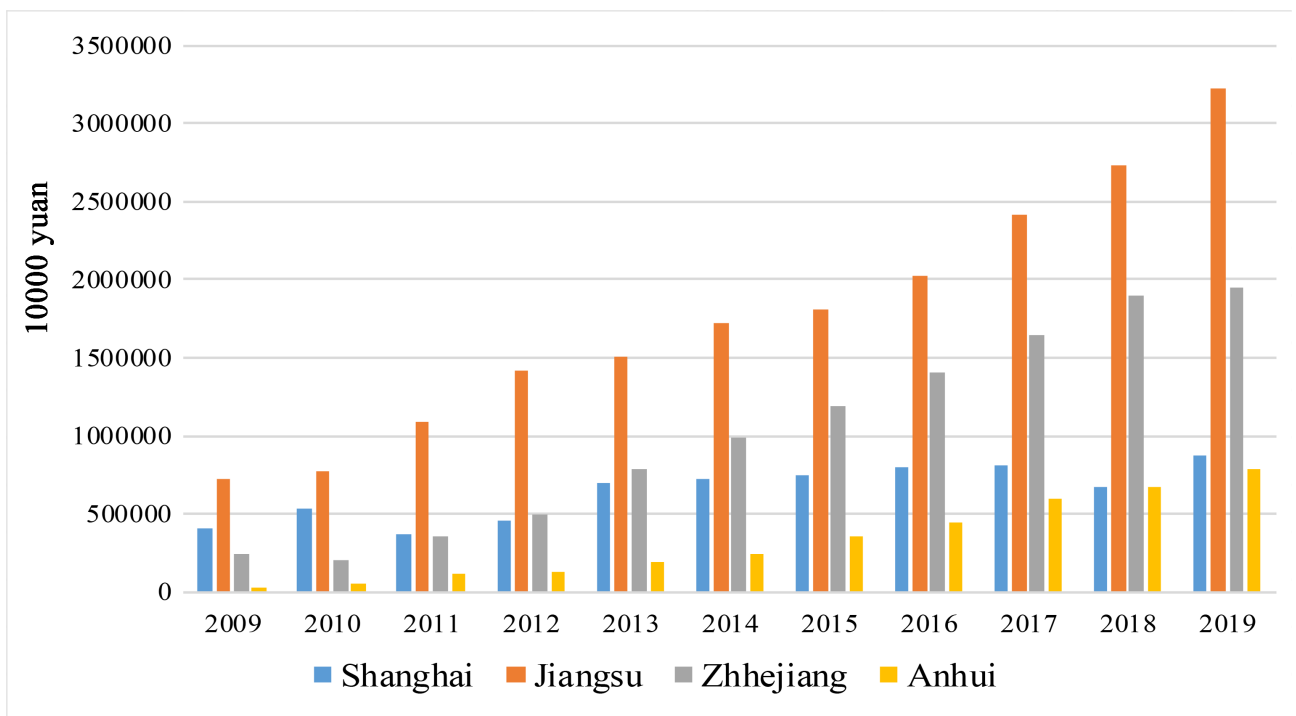

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 3. Research and development investment of three provinces and one city in Yangtze River Delta.

in the Yangtze River Delta region, followed by Zhejiang, Shanghai and Anhui. But the gap with Shanghai is narrowing. In addition, it can be seen that Jiangsu's profits are significantly higher than other areas. By 2019, the profit of electronic and communication equipment manufacturing in the Yangtze River Delta will account for 46.52% in Jiangsu, 31.35 % in Zhejiang, 14.02% in Shanghai and 8.10% in Anhui.

4.2. Innovation and Development Status of Electronic and Communication Equipment Manufacturing Industry in Yangtze River Delta

As an important part of innovation investment, to a certain extent, the more R & D investment, the stronger the innovation ability. As can be seen from Figure 3, the three provinces and one city in the Yangtze River Delta as a whole show an upward trend year by year. Jiangsu always ranks first in R & D investment of electronic and communication equipment manufacturing industry, followed by Zhejiang, Shanghai and Anhui. Shanghai and Anhui have a large gap in R & D investment with Jiangsu. In 2019, Jiangsu's R & D investment in electronics and communication equipment manufacturing was 4.1 times that of Anhui.

As a high-tech industry, R & D activities are the core and foundation of the development of electronic and communication equipment manufacturing industry. As the main carrier of technology, R & D personnel are the main body of innovation activities. The quantity and quality of R & D personnel play an important role in the innovation and development of electronic and communication equipment manufacturing industry. To a certain extent, the more R & D personnel, the stronger the innovation ability. As can be seen from Figure 4, the R & D personnel investment in Jiangsu, Zhejiang and Anhui shows an upward trend year by year, while the R & D personnel investment in Shanghai has decreased slightly in individual years. Similar to the R & D capital investment, the R & D personnel investment in Jiangsu is the highest among the four regions, followed by Zhejiang. Shanghai was higher than Anhui before 2016 and ranked third. After 2016, Anhui overtook Shanghai.

The number of invention patent applications refers to the number of patents applied by the electronic and communication equipment manufacturing industry to the national patent agency every year. As the most direct knowledge output of innovation, the number of invention patents can reflect the level of innovation ability.

According to Figure 5, it can be seen that the number of invention patent applications for electronic and communication equipment manufacturing industry in three provinces and one city decreased slightly in some regions and years, and generally showed an upward trend year by year. It shows that the innovation ability of the four regions is improving. Among them, the number of invention patent applications in Jiangsu's electronic and communication equipment manufacturing industry is the largest among the four regions, followed by Zhejiang,
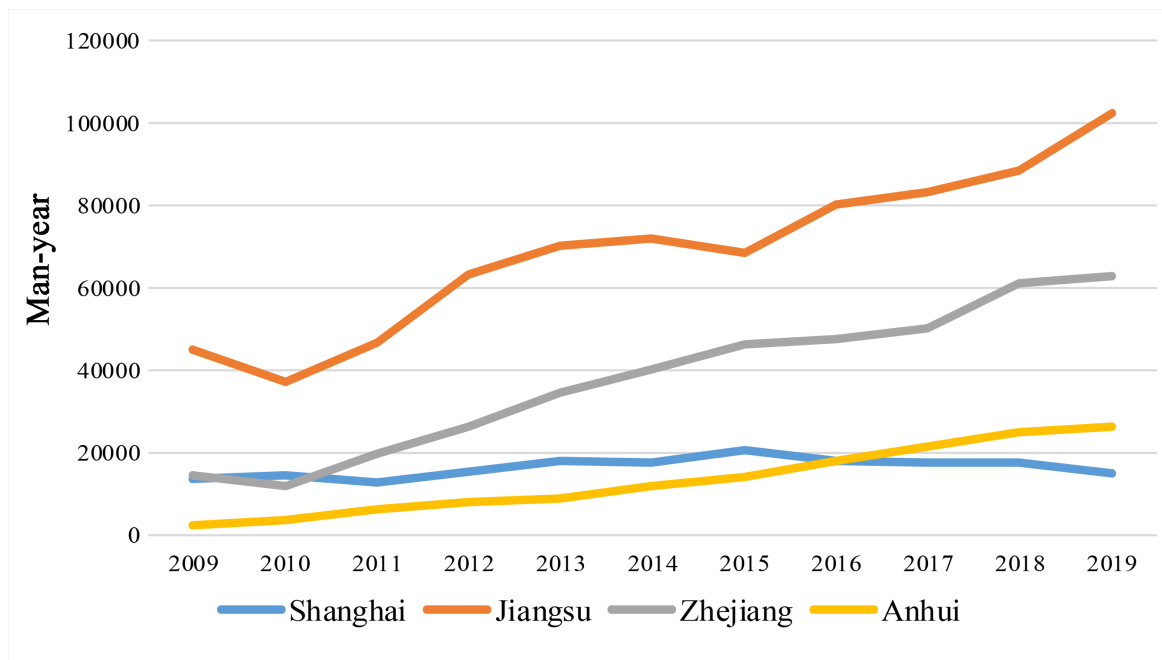
Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 4. Investment of R & D personnel in three provinces and one city in Yangtze River Delta.
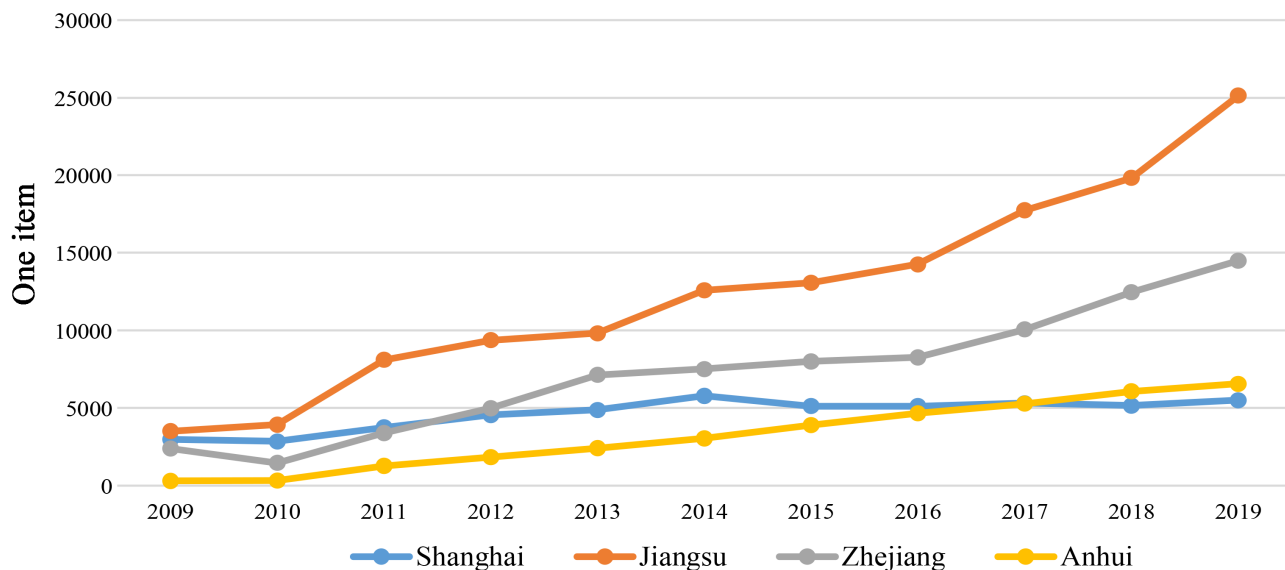
Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 5. Number of invention patent applications for electronic and communication equipment manufacturing in three provinces and one city in Yangtze River Delta.

Shanghai and Anhui. There is a large gap between Jiangsu and others. In 2019, the number of invention patent applications in Jiangsu was 25,140, The number of invention patent applications in Anhui is 7.8 times that of 3239.

Industrialization is the most important link of technological innovation. The transformation of scientific research achievements into sales products through industrialization is not only an important step for new technologies to realize market value but also the key for scientific and technological progress to promote economic development. New product sales revenue refers to the revenue obtained from the sales of products developed by the electronic and communication equipment manufacturing industry in the market, which can reflect the innovation achievements of scientific and technological innovation subjects and the collaborative innovation activity of scientific and technological innovation subjects.

According to Figure 6, from 2009 to 2019, the sales revenue of new products in electronic and communication equipment manufacturing industry in Jiangsu, Zhejiang, Shanghai and Anhui increased year by year. Among them, the sales revenue of new products in Jiangsu is much higher than that of others, close to 500 billion yuan in 2018. The sales revenue of new products in Zhejiang surpassed Shanghai to become the second in 2012, which is gradually narrowing the gap with Jiangsu. The sales revenue of new products in Anhui grew slowly, while the sales revenue of new products in Shanghai decreased in 2011 and 2012 and increased in 2013, which is close to Anhui.
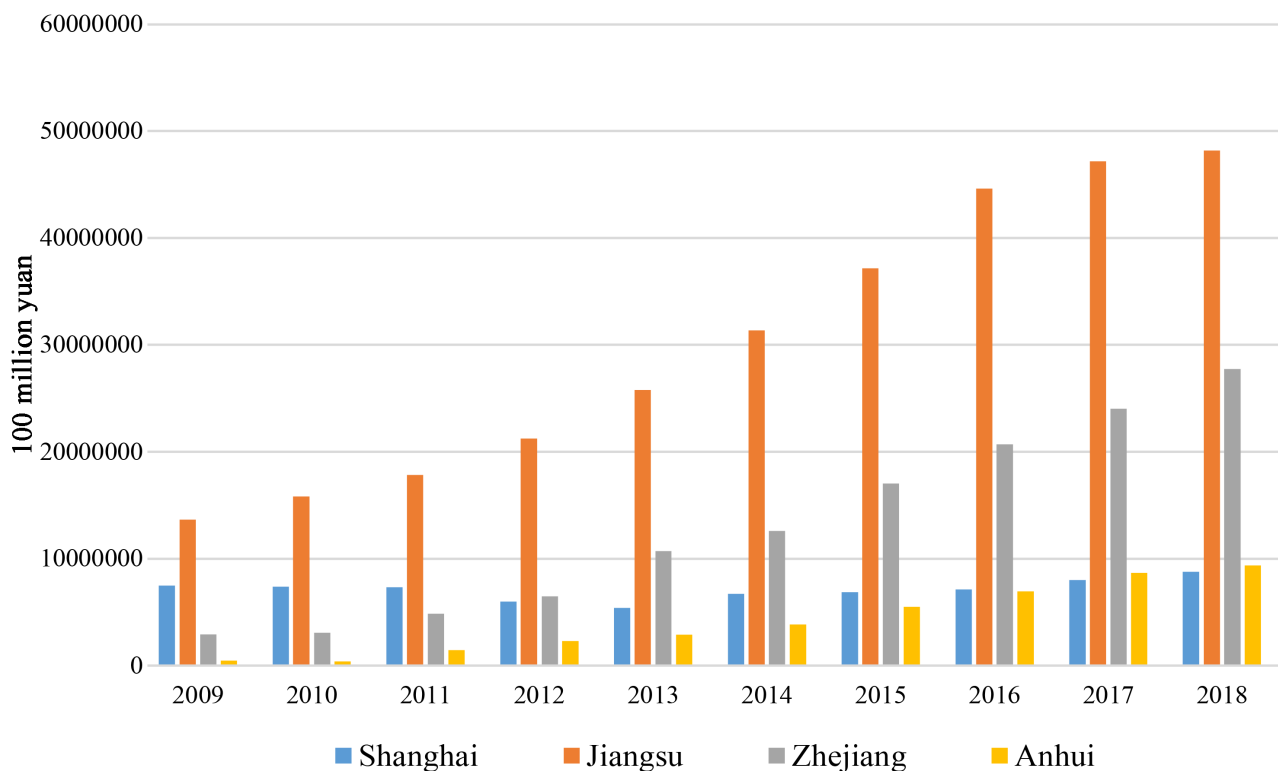

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 6. Sales revenue of new products of electronic and communication equipment manufacturing in three provinces and one city in Yangtze River Delta.

5. Measurement

5.1. Evaluation Method

In this research, the collaborative degree model of composite system is used to quantitatively analyze the development of collaborative innovation in electronic and communication equipment manufacturing industry in the Yangtze River Delta. According to its evolution path, it can be divided into the following four steps:

The model of coordination degree of complex system with complex system, subsystem and order parameter is constructed.

According to the information entropy of order parameters, the weight of order parameters is determined by selecting entropy value method. The smaller the entropy value of the order parameter index is, the more information it contains, and the larger the weight of the index should be. Generally, there are large differences in order parameters, so the normalization method is firstly used to conduct dimensionless processing on the data of order parameters, which makes the collaborative evaluation more reasonable and effective.

Calculate subsystem order degree. The calculation formula is

$$\mu_i\left(e_{ij}\right) = \begin{cases} \dfrac{e_{ij} - \beta_{ij}}{\partial_{ij} - \beta_{ij}} & j \in [1, k] \\[2mm] \dfrac{\partial_{ij} - e_{ij}}{\partial_{ij} - \beta_i} & j \in [k+1, n] \end{cases} \tag{1}$$

The complex system is $S = \{S_i\}$ ($i = 1, 2, 3, 4$), and the order parameter variable is defined as e_{ij} ($i = 1, 2, 3, 4; j > 1$), the maximum value of the order parameter is set as α_{ij}, the minimum value is set as β_{ij}, then $\beta_{ij} \leq E_{ij} \leq \alpha_{ij}$, $\mu_i\left(e_{ij}\right) \in [0,1]$ represents the contribution of e_{ij} in the orderly development of subsystems. The larger the $\mu_i(e_{ij})$ value is, the higher the contribution of e_{ij} is; the smaller the $\mu_i(e_{ij})$ value is, the lower the contribution of e_{ij} is.

The order degree of subsystem is determined by the order degree of order parameters. Its calculation formula is as follows:

$$\mu_i\left(e_i\right) = \sum_{i=1}^{n}\left[\lambda_{ij} * \mu_i\left(e_{ij}\right)\right] \tag{2}$$

$i = 1, 2, 3, 4$, $\mu_i\left(e_i\right) \in [0,1]$, μ_1, μ_2, μ_3 and μ_4 correspond to the order degree of subsystems in Shanghai, Jiangsu, Zhejiang and Anhui respectively. λ_{ij} is the index weight calculated in Step 2. The synergy degree of composite system was calculated.

After calculating the order degree of all subsystems, the synergy degree of the composite system can be obtained by bringing the value into the formula. Assuming that the initial time is t_0, the order degree of the subsystem is respectively $\mu_i^0\left(e_i\right), i \in [1,4]$, and when it evolves to a certain time t_1, the order degree of each subsystem is respectively $\mu_i^1\left(e_i\right), i \in [1,4]$. Then the calculation formula of synergy degree of composite system from t_0 to t_1 is

$$\text{DGS} = \theta \sum_{i=1}^{4} \left[\mu_i^1(e_i) - \mu_i^0(e_i) \right]$$

$$\theta = \begin{cases} 1, \min\left[\mu_i^1(e_i) - \mu_i^0(e_i)\right] > 0 \\ -1, \min\left[\mu_i^1(e_i) - \mu_i^0(e_i)\right] < 0 \end{cases} \tag{3}$$

5.2. Construction of Evaluation Index System

In this research, the collaborative innovation system of electronic and communication equipment manufacturing in Yangtze River Delta can be divided into four subsystems: Shanghai, Jiangsu, Zhejiang and Anhui. They evolve the whole system from disorder to order and finally achieve coordination through nonlinear interaction. The four innovation subsystems include innovation resources, innovation absorption, innovation output and innovation environment. According to scientific, systematic and operable principles, the following indicators are selected:

Innovation resources: full-time equivalent of R & D personnel, new product development expenditure and enterprise funds in internal expenditure of R & D expenditure.

Absorption of innovation: expenditure for technology introduction, expenditure for technological transformation, expenditure for digestion and absorption, and expenditure for purchasing domestic technology.

Innovation output: revenue from new product sales and patent applications.

Innovation environment: number of government funds and R & D institutions in internal expenditure of R & D funds.

As shown in **Table 1**, these variables of each indicator correspond to each other one by one.

Table 1. Evaluation index of collaborative innovation in electronic and communication equipment manufacturing industry.

Order parameter	Identification	Unit
Government funds in internal expenditure of R & D funds	X_1	Ten thousand yuan
Number of R & D institutions	X_2	One
Full time equivalent of R & D personnel	X_3	Person-year
New product development expenditure	X_4	Ten thousand yuan
Enterprise funds in internal expenditure of R & D funds	X_5	Ten thousand yuan
Technology introduction expenditure	X_6	Ten thousand yuan
Digestion and absorption expenditure	X_7	Ten thousand yuan
Expenditure for purchasing domestic technology	X_8	Ten thousand yuan
Expenditure for technological transformation	X_9	Ten thousand yuan
New product sales revenue	X_{10}	Ten thousand yuan
Number of patent applications	X_{11}	Item

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

5.3. Data Collection and Result Analysis

This research selects the data from 2011 to 2019, that is, since the 13th and 14th five year plans. Detailed data can be shown in Tables 2-5. The data sources are *the Statistical Yearbook of China's High-Tech Industry*, *the Statistical Yearbook of China* and *the Statistical Yearbook* of three provinces and one city in the Yangtze River Delta. The data are collected from the statistical yearbook of China's

Table 2. Shanghai Electronic and communication equipment manufacturing subsystem index data.

Index	2011	2012	2013	2014	2015	2016	2017	2018	2019
X_1	49,232	46,449	74,929	59,734	94,792	84,594	89,045	121,084	78,222
X_2	91	144	89	75	79	72	70	67	73
X_3	10,700	12,636	14,911	13,812	15,673	15,241	13,890	12,524	10,444
X_4	730,837	755,605	884,185	956,828	988,858	1,094,108	1,108,219	1,003,536	1,178,576
X_5	295,579	369,087	555,009	621,256	624,395	673,479	628,392	520,905	784,960
X_6	52,235	43,657	29,772	19,421	6926	10,395	4566	3872	5257
X_7	5591	952	7871	32,454	30,589	16,088	16,739	26,323	35,423
X_8	6480	5195	5973	25,480	13,887	5408	5532	1747	7072
X_9	71,909	41,773	37,382	18,841	33,559	13,348	45,664	35,767	109,971
X_{10}	7,355,255	6,004,552	5,416,429	6,707,755	6,879,185	7,129,442	8,002,364	8,784,254	10,654,699
X_{11}	3744	4546	4873	5784	5120	5121	5307	5151	5502

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Table 3. Jiangsu Electronic and communication equipment manufacturing subsystem index data.

Index	2011	2012	2013	2014	2015	2016	2017	2018	2019
X_1	24,836	44,556	33,495	29,462	53,988	34,932	46,890	50,024	50,133
X_2	528	1557	1573	1776	1757	1985	1809	1944	1822
X_3	39,922	49,590	54,251	56,681	55,380	63,483	64,019	64,963	78,227
X_4	155,8775	2,147,922	2,174,916	2,327,876	2,228,050	2,549,418	3,021,769	3,408,731	4,070,745
X_5	942,150	1,286,208	1,359,790	1,580,831	1,620,486	1,897,204	1,998,632	2,547,321	3,009,074
X_6	162,629	134,050	111,588	145,026	101,718	75,091	65,430	36,914	45,643
X_7	42,899	15,980	23,986	9538	8853	10,971	9930	13,345	2762
X_8	8359	12,709	7652	12,693	9404	13,953	14,820	24,303	14,885
X_9	399,181	537,555	633,239	420,925	530,409	583,153	493,213	496,918	378,235
X_{10}	17,843,670	21,226,185	25,782,123	31,365,535	37,172,162	44,624,664	47,189,709	48,176,239	44,621,630
X_{11}	8101	9373	9817	12580	13,068	14,258	17,734	19,830	25,140

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Table 4. Zhejiang Electronic and communication equipment manufacturing subsystem index data.

Index	2011	2012	2013	2014	2015	2016	2017	2018	2019
X_1	16,397	20,258	23,284	27,024	28,537	20,556	21,908	27,926	30,610
X_2	392	491	518	552	608	637	681	746	904
X_3	16,404	20,792	28,495	34,641	39,326	39,729	46,621	50,917	53,001
X_4	435,663	546,785	938,457	1,083,053	1,247,016	1,583,803	1,729,602	1,958,464	2,295,152
X_5	330,990	461,089	738,885	928,122	1,121,684	1,342,376	1,450,891	1,711,206	1,844,578
X_6	7925	6427	6256	8220	5380	1483	1820	1390	551
X_7	2195	3800	3208	4747	1187	832	2019	2361	700
X_8	5800	7092	10,903	9941	7610	3981	4489	14,283	13,943
X_9	90,205	70,305	73,048	153,631	126,916	129,619	142,228	163,161	121,345
X_{10}	4,884,413	6,504,798	10,713,301	12,601,312	17,025,107	20,695,791	24,030,980	27,760,493	31,883,810
X_{11}	3384	4982	7132	7508	8002	8262	10,065	12,466	14,496

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Table 5. Anhui Electronic and communication equipment manufacturing subsystem index data.

Index	2011	2012	2013	2014	2015	2016	2017	2018	2019
X_1	14,518	10,370	16,901	22,860	21,746	44,858	33,345	30,063	20,480
X_2	88	171	161	205	277	318	346	394	420
X_3	3542	5219	6173	7703	10,212	12,994	13,974	14,773	19,182
X_4	141,371	216,324	240,109	337,225	510,303	559,472	604,291	766,258	854,134
X_5	77,882	110,695	153,073	196,191	305,237	378,831	457,893	617,020	700,581
X_6	12,538	714	7687	1042	121	210	709	2702	1084
X_7	1831	197	2730	528	281	132	310	300	638
X_8	1661	644	726	527	779	552	709	15,663	1931
X_9	11,376	21,448	29,044	50,873	34,829	36,646	86,421	74,792	82,305
X_{10}	1,446,543	2,296,360	2,886,078	3,843,528	5,502,686	6,958,837	8,672,105	9,377,311	10,156,071
X_{11}	1258	1832	2405	3042	3897	4663	5278	6075	6555

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

high-tech industry, the statistical yearbook of China and the statistical yearbook of three provinces and one city in the Yangtze River Delta. The missing data is calculated by SPSS to replace the corresponding missing value, and the linear interpolation method is used to estimate the missing data according to the existing data. After sorting out the panels of Shanghai, Jiangsu, Zhejiang and Anhui provinces and cities from 2011 to 2019, the index data are sorted and ana-

lyzed according to a single subsystem. Because the dimensions of the collected original data of each index are inconsistent and cannot be calculated directly, dimensionless standardization processing is required, and then the standardized data is used for calculation.

It can be seen from Table 6 and Figure 7 that the order degree of innovation system of electronic and communication equipment manufacturing industry in Shanghai, Jiangsu, Zhejiang and Anhui has a certain fluctuation, but on the whole presents a rising trend. By transverse comparison can be seen, electron and communication equipment manufacturing industry in Jiangsu innovation

Table 6. Order degree of four innovation subsystems in Yangtze River Delta.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
$\mu_1(e_1)$	0.24	0.31	0.36	0.40	0.42	0.34	0.45	0.50	0.51
$\mu_2(e_2)$	0.23	0.36	0.37	0.41	0.45	0.48	0.52	0.57	0.62
$\mu_3(e_3)$	0.19	0.28	0.40	0.41	0.42	0.39	0.50	0.54	0.55
$\mu_4(e_4)$	0.11	0.06	0.21	0.18	0.21	0.28	0.36	0.38	0.41

Data sources: calculated according to the Statistical Yearbook of China's High-tech Industry, the Statistical Yearbook of China and the Statistical Yearbook of three provinces and one city in the Yangtze River Delta.
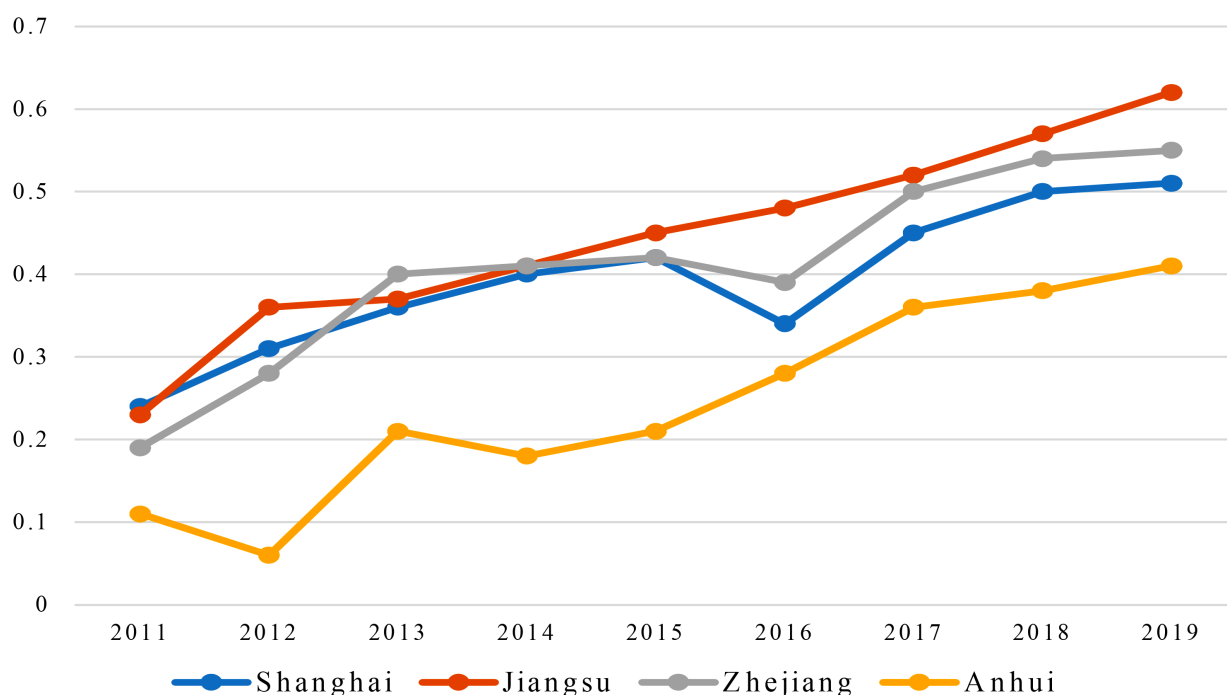
Data sources: calculated according to the Statistical Yearbook of China's High-tech Industry, the Statistical Yearbook of China and the Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 7. Order degree of four innovation subsystems in Yangtze River Delta.

system order degree of the vast majority are among the highest in the four sub-systems, electron and communication equipment manufacturing industry innovation system in Anhui minimum order degree, Shanghai and Zhejiang electronic and communication equipment manufacturing industry innovation system order degree is located in the middle position of four subsystems. The four electronic and communication equipment manufacturing innovation subsystems have different order degrees.

It can be seen from Table 7 and Figure 8 that the synergy degree of the collaborative innovation system of the electronic and communication equipment manufacturing industry in the Yangtze River Delta shows an increasing trend

Table 7. Synergy degree of electronic and communication equipment manufacturing synergetic innovation system in Yangtze River Delta.

Year	2012	2013	2014	2015	2016	2017	2018	2019
Synergy degree	−0.0985	0.1504	0.1723	0.1999	0.2018	0.2772	0.3204	0.3487

Data sources: calculated according to the Statistical Yearbook of China's High-tech Industry, the Statistical Yearbook of China and the Statistical Yearbook of three provinces and one city in the Yangtze River Delta.
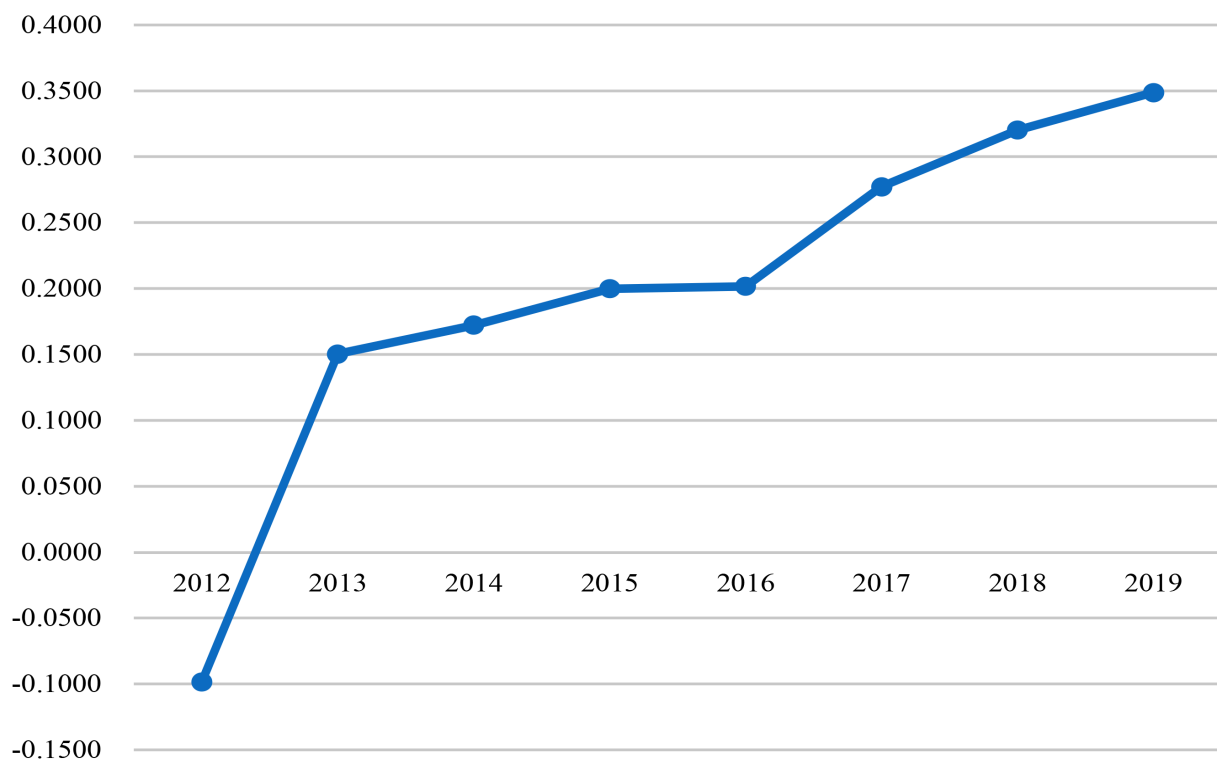
Data sources: calculated according to the Statistical Yearbook of China's High-tech Industry, the Statistical Yearbook of China and the Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

Figure 8. Synergy degree of electronic and communication equipment manufacturing synergetic innovation system in Yangtze River Delta.

year by year. In 2012, the synergy degree is -0.0985, and in the following years, it is in the synergy state, and the synergy degree gradually increases. At the same time, it can be found that the growth rate is different in different time periods. As can be seen from the broken line chart, the electronic and communication equipment manufacturing industry in Yangtze River Delta is relatively flat from 2013 to 2016 with a slow growth rate, and it has been growing rapidly since 2016.

Synergy degree has certain evaluation standard, according to the Yangtze River Delta electronics and communication equipment manufacturing industry in the process of collaborative innovation system evolution characteristics. Reference Chen Feichao, based on super efficiency DEA Beijing-Tianjin-Hebei effect research scholars research, collaborative innovation could be divided into five synergy degree of numerical interval, corresponding system on the synergy development level, specific criteria as shown in Table 8.

Table 9 shows that the synergetic degree of electronic and communication equipment manufacturing synergetic innovation system in Yangtze River Delta is increasing year by year. The synergetic level has experienced the process of non-synergetic, low effect synergetic and basic synergetic and is developing towards the direction of good synergetic and high quality synergetic. However, it is true that the overall level of collaborative innovation system coordination in the electronic and communication equipment manufacturing industry in the Yangtze River Delta is not too high.

6. Empirical Analysis

This chapter will select the order degree of the innovation subsystem of the electronic and communication equipment manufacturing industry in the Yangtze River Delta as the explanatory variable, because collaborative innovation is a complex process and is affected by many factors. Referring to the research of Yin Han (2018), Wang Xue (2018), He Yi (2014) and other scholars, combined with the operability of relevant theories and index selection, this research believes that the collaborative innovation development of regional electronic and communication

Table 8. Collaborative evaluation standard of collaborative innovation system for electronic and communication equipment manufacturing in Yangtze River Delta

Synergy degree	DGS < 0	0 < DGS ≤ 0.2	0.2 < DGS ≤ 0.5	0.5 < DGS ≤ 0.8	0.8 < DGS ≤ 1
Synergy level	Non-synergy	Low effect	Basic synergy	Good	High quality

Table 9. Collaborative level of electronic and communication equipment manufacturing collaborative innovation system in Yangtze River Delta.

Synergy level	Non-synergy	Low effect	Basic synergy
Year	2012	2013, 2014, 2015	2016, 2017, 2018, 2019

equipment manufacturing industry is affected by four factors: government, innovation, economy and market. And this research adopts DEA model to empirically analyze the technological innovation efficiency of electronic and communication equipment manufacturing industry in Yangtze River Delta.

The evaluation system is shown in Table 10.

DEAP2.1 software is used to conduct DEA analysis on the input-output data of the three provinces and one city in the Yangtze River Delta from 2011 to 2019. And the comprehensive technological innovation efficiency of Shanghai, Jiangsu, Zhejiang and Anhui is calculated. The results are shown in Table 11.

After obtaining the data of innovation efficiency, in order to remove the influence of the data itself, the variables are logarithmicized. Table 12 describes the variables.

It can be seen from the above description that the model construction of this research is as follows:

$$\ln CD_{it} = \beta_0 + \beta_1 \ln PGDP_{it} + \beta_2 \ln GS_{it} + \beta_3 \ln TMT_{it} + \beta_4 \ln IE_{it} + \varepsilon_{it}$$

i = 1, 2, 3, 4 represents four regions in the Yangtze River Delta, t represents the year, and the value is (1, 2, ..., 9), $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ is the parameter to be evaluated and ε_{it} is the random error term.

Before analyzing the factors influencing the collaborative innovation

Table 10. Evaluation index system of collaborative innovation efficiency in electronic and communication equipment manufacturing industry.

Dimension	Serial number	Index	Unit
Input	X1	Full time equivalent of R & D personnel	annual work done per capita
	X2	Internal expenditure of R & D funds	Ten thousand yuan
	X3	Expenditure for new products	Ten thousand yuan
Output	Y1	New product sales revenue	Ten thousand yuan
	Y2	Number of invention patent applications	a
	Y3	Main business income	million yuan

Table 11. The comprehensive technology innovation efficiency of Shanghai, Jiangsu, Zhejiang and Anhui.

region \ year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Shanghai	0.865	0.874	0.896	0.889	0.912	0.921	0.935	0.946	0.951
Jiangsu	0.893	0.902	0.91	0.921	0.913	0.925	0.942	0.951	0.964
Zhejiang	0.841	0.863	0.889	0.895	0.91	0.919	0.895	0.918	0.926
Anhui	0.789	0.81	0.829	0.843	0.889	0.895	0.906	0.9	0.916
Mean value	0.847	0.862	0.881	0.887	0.906	0.915	0.920	0.923	0.940

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

development of electronic and communication equipment manufacturing industry in the Yangtze River Delta, ADF test is used to conduct unit root test on panel data in order to prevent data pseudo regression. According to Table 13, the results show that the existence probability P of unit root of second-order difference sequence is less than 0.05, which can be co-integration test. In this research, Kao test is selected for co-integration test, the results are shown in Table 14. The null hypothesis is that there is no co-integration relationship, and the alternative hypothesis is that there is a co-integration relationship. If the P value is less than 0.05, the null hypothesis is rejected, indicating that there is a co-integration relationship.

Table 12. Description of each variable.

	Index	Variable description	Sign
Explained variable	Collaborative order	Order degree of electronic and communication equipment manufacturing subsystem and synergy degree of composite system	Ln CD
Explanatory variable	Economic development level	Per capita GDP	Ln PGDP
	Government support	Government funds in internal expenditure of R & D funds	Ln GS
	Market activity	Technology market turnover	Ln TMT
	Innovation ability	Innovation efficiency	Ln IE

Table 13. Unit root test results.

Variable	Yangtze River Delta		Shanghai		Jiangsu		Zhejiang		Anhui	
	Statistic	P value	Statistic	P value	Statistic	P value	Statistic	P value	Statistic	P value
LnCD	3.3114	0.0307	2.5196	0.0012	3.0146	0.0312	2.4380	0.0452	2.0317	0.0319
Δ^2LnCD	19.2156	0.0000	21.1536	0.0000	28.4901	0.0000	27.3573	0.0000	30.1013	0.0000
Ln PGDP	3.4981	0.879	2.3613	0.7021	2.3083	0.913	1.0527	0.8130	2.1002	0.7813
Δ^2LnPGDP	36.1680	0.0000	23.71222	0.0001	29.8217	0.0001	41.3243	0.0010	26.4173	0.0005
LnGS	2.3417	0.9176	1.7981	0.7915	2.3141	0.3475	2.8376	0.4717	3.4389	0.8823
Δ^2LnGS	29.3771	0.0013	30.0197	0.0010	28.0795	0.0000	27.778	0.0000	29.4546	0.0000
LnTMT	2.3116	0.8811	2.0301	0.7351	4.1384	0.8331	3.8619	0.8912	2.0309	0.9751
Δ^2LnTMT	31.4773	0.0001	28.4090	0.0000	27.6071	0.0003	35.7721	0.0000	29.4350	0.0001
LnTE	3.3016	0.9021	2.0171	0.8743	2.9123	0.6371	1.9375	0.7025	2.1243	0.6350
Δ^2LnTE	17.8143	0.0002	40.8101	0.0000	31.1111	0.0001	16.3575	0.0000	30.8391	0.0002

Table 14. Kao test results.

ADF	Yangtze River Delta		Shanghai		Jiangsu		Zhejiang		Anhui	
	Statistic	P value	Statistic	P value	Statistic	P value	Statistic	P value	Statistic	P value
	−2.3663	0.0002	−3.4771	0.00031	−2.6342	0.0001	−5.7173	0.0000	−4.3701	0.0001

Hausman Test is selected to determine whether panel data should be based on individual fixed effect model or individual random effect model. The original hypothesis is to establish a random effect model, and the alternative hypothesis is to use a fixed effect model. According to Table 15, the P values of Yangtze River Delta, Shanghai, Jiangsu, Zhejiang and Anhui are all less than 0.05, so the original hypothesis is rejected and the fixed effect model is used.

Based on the panel data of three provinces and one city in the Yangtze River Delta from 2011 to 2019, mainly referring to Tables 2-5, Table 11 and Table 16, this research uses the fixed effect model to regress the Yangtze River Delta, Shanghai, Jiangsu, Zhejiang and Anhui.

According to Table 17, in the model regression results of the Yangtze River Delta, the government support (government funds in the internal expenditure of R & D funds) is significant at the level of 1% and is positively correlated with the synergy of collaborative innovation and development of electronic and communication equipment manufacturing industry in the Yangtze River Delta, indicating that the more government investment, the higher the synergy of electronic and communication equipment manufacturing industry in the Yangtze River

Table 15. Hausman test results.

Region	P value	Model selection
Yangtze River Delta	0.0000	FE
Shanghai	0.0013	FE
Jiangsu	0.0004	FE
Zhejiang	0.0015	FE
Anhui	0.0031	FE

Table 16. Main business income of Yangtze River Delta from 2011 to 2019 (hundred million).

Year	Shanghai	Jiangsu	Zhejiang	Anhui
2011	98.8	472.0	103.4	31.3
2012	83.9	560.5	119.4	70.5
2013	84.0	730.1	234.8	78.5
2014	125.9	790.2	262.9	108.5
2015	121.9	790.1	289.0	123.2
2016	136.7	912.2	314.6	131.3
2017	143.2	932.1	349.0	135.3
2018	158.2	835.8	385.8	137.0
2019	176.6	586.1	395.0	102.1

Data sources: Statistical Yearbook of China's High-tech Industry, Statistical Yearbook of China and Statistical Yearbook of three provinces and one city in the Yangtze River Delta.

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Table 17. Model regression results.

Variable	Yangtze river delta	Shanghai	Jiangsu	Zhejiang	Anhui
Ln PGDP	0.0631**	0.0357**	0.0320***	0.0401**	0.0780*
	(0.43)	(0.32)	(0.31)	(4.23)	(3.12)
Ln TMT	0.1035**	0.0689***	0.0125**	0.0471***	0.1301**
	(1.19)	(1.24)	(1.09)	(0.90)	(2.06)
Ln IE	0.0072*	0.0412***	0.0067***	0.0013**	0.1011*
	(3.12)	(1.81)	(3.69)	(2.47)	(3.15)
R^2	0.3649	0.4782	0.4192	0.6024	0.5921
F-Measure	17.8923	19.9891	13.9663	19.7632	14.3860

Note: *Means significant at the level of 10%, **Means significant at the level of 5%, ***Means significant at the level of 1%.

Delta. Government factors have a great impact on the development of electronic and communication equipment manufacturing industry in the Yangtze River Delta indicating that the electronic and communication equipment manufacturing industry in the Yangtze River Delta is still in the stage of growth and development and still needs the strong support of the government.

Market factors (technology market transaction volume) and economic factors (per capita GDP) are significant at the level of 5%, and are positively correlated with the degree of synergy, which indicates that market factors and economic factors have played an important role in the collaborative innovation and development of electronic and communication equipment manufacturing industry in the Yangtze River Delta. The innovation factor (innovation efficiency) is significant at the level of 10%, which is positively correlated with the degree of synergy, indicating that the improvement of innovation efficiency can promote the coordinated and orderly development of electronic and communication equipment manufacturing industry in the Yangtze River Delta but the impact is not significant, indicating that the overall innovation efficiency of electronic and communication equipment manufacturing industry in the Yangtze River Delta is not high.

For the horizontal comparison of the four models of Shanghai, Jiangsu, Zhejiang and Anhui in the Yangtze River Delta, the synergistic impact of government factors on Anhui and Jiangsu is more significant indicating that the electronic and communication equipment manufacturing industry in Anhui and Jiangsu depends more on government support, especially for the electronic and communication equipment manufacturing industry in Anhui. For Shanghai and Zhejiang, the significance of market factors is higher than that of Anhui and Jiangsu, because the market mechanism of Shanghai and Zhejiang is relatively perfect and the market force is relatively strong. At the same time, the collaborative impact of innovation efficiency on Shanghai and Jiangsu is also significant, which is due to the large number of innovation resources and strong innovation

ability of Shanghai and Jiangsu. For the impact of economic factors, Anhui has the weakest significance. Due to the high economic level, Shanghai and Jiangsu have promoted the collaborative innovation and development of electronic and communication equipment manufacturing industry.

Considering that there may be endogenous problems due to the two-way causal relationship between variables or the omission of variables, which leads to the unstable regression results, the Robustness Test was performed using the substitution variable method: The two-stage input-output index is constructed and the DEA model is used to calculate the efficiency of scientific and technological innovation in Colleges and universities. In order to further test the factors affecting the collaborative innovation development of electronic and communication equipment manufacturing industry in the Yangtze River Delta, based on the two-stage input-output indicators, the entropy method is used to calculate the collaborative innovation ability of electronic and communication equipment manufacturing industry in the Yangtze River Delta. And the comprehensive level value of collaborative innovation of electronic and communication equipment manufacturing industry in the Yangtze River Delta is used to replace the explanatory variables for Robustness Test. The regression results show that the regression results of replacement variables and control variables are significant, and the symbols of regression coefficients are consistent with the baseline regression, indicating that the regression results of this paper are relatively robust.

7. Conclusion and Suggestion

7.1. Conclusion

The current situation analysis shows that the R & D input and output levels of electronic and communication equipment in the Yangtze River Delta are Jiangsu, Zhejiang, Shanghai and Anhui from high to low.

From the measurement results of subsystem order, from 2011 to 2019, the innovation order of electronic and communication equipment manufacturing industry in Shanghai, Jiangsu, Tianjin and Anhui has been continuously improved. Among them, the innovation and development order level of electronic and communication equipment manufacturing industry in Jiangsu is the highest, Zhejiang ranks second and Shanghai ranks third, there is a big gap between Anhui and the other three regions. From the whole collaborative innovation system of electronic and communication equipment manufacturing industry in the Yangtze River Delta, its degree of synergy has experienced the process from non-synergy, low effect synergy to basic synergy, showing an upward trend year by year.

From the perspective of the influencing factors of collaborative innovation development, the four factors of government, market, innovation and economic development can promote the collaborative innovation development of electronic and communication equipment manufacturing industry in the Yangtze

River Delta. Among them, for Jiangsu, the impact of economy and innovation is more significant. For Shanghai, innovation and market factors have a significant impact. For Zhejiang, the impact of market and economy is more significant. Anhui has the most significant government influence.

7.2. Suggestion

In the context of double circulation, as the main gathering place of innovation elements, in order to achieve high-quality integrated development, the Yangtze River Delta urban agglomeration should not only enhance the regional economic coordination of the innovation ecosystem, but also give full play to the role of innovation as the first driving force, break the island phenomenon of innovation and strive to build a regional scientific and technological innovation community.

The construction of the Yangtze River Delta should be strengthened. In the innovation system of electronic communication equipment manufacturing industry in Shanghai, Jiangsu, Zhejiang and Anhui, there is a certain degree of order volatility and an upward trend, which is not high on the whole. However, the degree of order should be the key factor affecting the innovation system of electronic communication equipment manufacturing industry in three provinces and one city. Therefore, we should give full play to our own advantages, strengthen our own construction and further improve the degree of order.

Strengthen coordination and cooperation among the three provinces and one city in the Yangtze River Delta. Through complex system coordination degree model of the evaluation results can be found that in three provinces and one city electron and communication equipment manufacturing industry innovation and development orderly level there is a gap, and the overall electron and communication equipment manufacturing coordination degree is low. Yangtze River Delta electronics and communication equipment manufacturing industry innovation development is out of step. In the Yangtze River Delta, the innovation system of electronic and communication equipment manufacturing industry can realize the coordination of the whole system through the interaction of resources and market factors. Therefore, the electronic communication equipment manufacturing industry in the Yangtze River Delta should strengthen the cooperation between resources and market, and do a good job in the overall planning of collaborative innovation and development of electronic communication equipment manufacturing industry. And by strengthening the sharing of innovation resources, talent exchange and cooperation and information interconnection, we can realize the coordinated development of electronic communication equipment manufacturing industry in the Yangtze River Delta.

Give full play to government functions. We should increase investment in the collaborative innovation development of electronic communication equipment manufacturing industry and create a good collaborative innovation environment. Improve the legal protection mechanism and the patent protection mechanism. Earnestly safeguard the legitimate rights and interests of enterprises

and scientific researchers and promote the coordinated innovation and healthy development of electronic communication equipment manufacturing industry in the Yangtze River Delta.

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Project Name

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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