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Research Article

Research on Dynamic Comprehensive Evaluation of Resource Allocation Efficiency of Technology Innovation in the Aerospace Industry

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From the perspective of input and output, this paper constructs an evaluation index system for the status quo of technology innovation resource allocation in China's aerospace industry. Taking the industrial panel data of 20 provincial regions from 2007 to 2016 in China as samples, this paper uses the stochastic frontier method, which is improved by the projection pursuit model based on accelerated genetic algorithm, to analyze the factors influencing the allocation efficiency of technology innovation resource in the aerospace industry and then make a static evaluation for the current situation. In addition, based on the perspective of velocity characteristics, this study uses the dynamic comprehensive evaluation model to evaluate the resource allocation of technology innovation in the aerospace industry. The empirical research shows that the resource allocation efficiency of technology innovation in the aerospace industry is generally at the lower middle level, indicating an unbalanced trend of "reverse" allocation with the level of regional economic development. It is also found that the efficiency improvement effect in recent years is not obvious. At last, based on the study's findings, some countermeasures and suggestions are put forward to improve the current situation.

1. Introduction

The 19th National Congress of the Communist Party of China was proposed to strengthen strategic and scientific forces and accelerate the construction of innovation-oriented country. The aerospace industry is a typical high-tech industry, and as the leading force in the creation of space power, it plays a vital role in promoting the upgrading of industrial quality and efficiency. Its technical level and industrial strength are not only the necessary conditions for the improvement of comprehensive national strength but also the comprehensive reflection of the modernization level of China's defense-related science and technology industry, which is an essential part of national defense security construction. Unlike other technological powers such as Britain and the United States, China, as an emerging economy, started its aerospace industry late, with a small scale and a relative lack of talent and infrastructure construction. In the past 70 years, the achievements of China's aerospace industry have mainly benefited from the support of national policies, but government policies are by no means omnipotent, especially under the impact of the wave of internationalization and marketization. China's aerospace industry has shown specific deep-rooted economic problems such as "unbalanced structure" and "insufficient innovation," which are particularly prominent in the new normal of China's economy. There are no more than two solutions to these problems: one is to promote industrial development by increasing factor input; the other is to improve the efficiency of factor resource allocation through policy guidance. As we all know, the extensive economic growth model that relies solely on factor input has become unsustainable. In contrast, the latter may be a more reasonable way which is also the main issue discussed in this study.

The key to the development of the aerospace industry lies in technology innovation. Moreover, effective utilization and rational allocation of innovation resource are of practical significance for improving technology innovation ability [1].

As efficiency is the core index for evaluating industrial technology innovation capability, the study on the efficiency of resource allocation of technology innovation is conducive to comprehensively investigating the process of resource input and innovation output in technology innovation activities and then finding out the existing institutional constraints and institutional barriers [2, 3]. However, there are few papers to evaluate the resource allocation efficiency of technology innovation with the aerospace industry as the research object. Therefore, it is necessary to explore the technology innovation resource allocation situation of China's aerospace industry and to reveal the key factors influencing the allocation efficiency and mechanism, which are of theoretical significance to enrich the evaluation of innovation efficiency and of practical relevance to both coordinate the optimal allocation of the aerospace industry resources and realize the development pattern of aerospace industry power.

2. Literature Review

At present, there is no authoritative definition of the connotation of resource allocation efficiency in academic circles [1]. Instead, relevant research results mainly focus on the efficiency of technology innovation and the allocation of scientific and technical resources.

The concept of technology innovation efficiency was first proposed by Afriat, referring to the input-output variable of effective technology in R&D innovation activities [4]. The measurement of technology innovation efficiency includes mostly two methods: the parametric method and the nonparametric method. One of the nonparametric techniques which are commonly used is the data envelopment analysis (DEA) [5]. Scholars have carried out a lot of studies on regional innovation efficiency [5–7], industrial technology innovation efficiency [8, 9], and other issues based on different research perspectives, building different indicator systems and selecting various sample data. In addition, one of the parametric methods which are commonly used is the stochastic frontier analysis (SFA) [10]. At present, the SFA method has been widely applied to evaluate innovation efficiency at many levels such as regional level [11], industrial level [12–14], and research structure [15, 16]. Besides, scholars have also carried out some research on the influencing factors of technology innovation efficiency, mainly involving some traditional industrial organization factors, such as ownership structure [17–19], enterprise scale [20–23], and market competition degree [24, 25].

Regarding the allocation of technological resources, the research priorities by domestic and foreign scholars are different. International scholars paid more attention to the optimization effect of the implementation of technology policies and plans on the allocation of national technology resources from the national level. Campolina et al. [26], Chaminade and Plechero [27], and other scholars proposed the key factors to optimize the allocation path of science and technology resources by comparing the allocation methods and expenditure on science and technology of various countries. Meantime, because enterprises play an indispensable role in the market economy of developed countries and basically represent the science and technology innovation ability of the whole society, many scholars started to study the allocation of science and technology resources from the perspective of enterprises. Pelinand [28], Endo [29], and other scholars verified the mechanism of the impact of government R&D subsidies, corporate strategy, and cost advantages on R&D resource allocation. However, domestic scholars mostly paid more attention on the science and technology resource allocation system, mechanism, and the ability from the regional level, which is based on the facts of China's unbalanced local economic development. Fan et al. [30], Li and Wen [31], and Chen et al. [32] evaluated the regional science and technology resource allocation efficiency in different periods, as well as analyzed the main factors affecting the improvement of the local science and technology resource allocation efficiency. In addition, Chen et al. [32] and Huang and Zhang [33], respectively, analyzed the allocation efficiency of science and technological resources in China's strategic emerging industries, agricultural colleges, and universities. A brief presentation of previous studies and their findings is presented in Table 1.

In summary, scholars have conducted in-depth research on technology innovation efficiency and technology resource allocation from the enterprise, regional, and national levels. However, there are few relevant analyses on the efficiency of resource allocation of technology innovation and technology innovation in the aerospace industry; in the literature on the factors influencing the effectiveness of technology innovation, scholars hold different views on the same influencing variable. The influencing mechanism of resource allocation efficiency in the aerospace industry is more like a "black box." Accordingly, this study comprehensively considers both the technology innovation and the efficiency of science and technology resource allocation. Based on the sample data of 20 provinces and cities, this paper uses the RAGA-PP-SFA model and the dynamic comprehensive evaluation model to evaluate the resource allocation efficiency of technology innovation in the aerospace industry from the regional level, as well as to assess the extensive dynamic development trend during the whole evaluation period, so as to enrich the relevant studies.

3. Research Model

3.1. Static Evaluation Model. DEA and SFA are two effective methods of efficiency evaluation, which are constantly improved in the application process. For example, PDEA solves the problem of inaccurate and ambiguous data in the traditional DEA model [34]. However, the DEA method sets a deterministic boundary in the efficiency measurement, so that measurement errors are not allowed, that is, all deviations from the production boundary or cost boundary are attributed to low efficiency, which is not in line with the actual situation [23]. Compared with the DEA method lacking risk considerations and statistical characteristics, the SFA has the following two advantages in empirical analysis. On the one hand, the SFA divides the actual output into three parts, production function, random perturbation, and technical inefficiency, and divides the error term into two

Table 1: Existing literatures on measurement of technology innovation efficiency.

Study	Research method	Research context	Period	Findings
Zemtsov and Kotsemir [5]	DEA	Measurement of the efficiency of Russia's regional technology system (RIS)	2009–2012	RIS efficiency in Russia increased during the period, especially in the least developed territories, RIS efficiency was higher in technologically more developed regions with the oldest universities and larger patent stock
Chen and Fu [6]	Dynamic DEA	Evaluation on efficiency of R&D input-output systems in China's provinces	2006–2010	All regions had deficiencies in the overall operation of the R&D and production system, the overall efficiency of the economically developed eastern coastal areas is significantly higher than that of inland provinces
Liang et al. [7]	SBM model	Evaluation on the efficiency of regional green technology innovation in 30 regions of China	2006–2017	The efficiency of regional green technology innovation is generally low, and technology inefficiency is more serious than scale inefficiency
Sueyoshi and Goto [8]	An improved DEA model	Discussion on the green technology innovation efficiency of Japanese industries	2013–2015	In the current business environment, production limits are likely to occur in most industries, with manufacturing outperforming nonmanufacturing in operating efficiency
Martinez and Pina [9]	Two Malmquist DEA	Regional energy efficiency across Colombian departments in the manufacturing industries	2005–2013	Various manufacturing industries across Colombian departments have a high potential to increase energy efficiency
Zhang and Zhang [11]	SFA	Measurement of the efficiency of technology innovation in the Beijing-Tianjin-Hebei region	2011–2015	The overall innovation efficiency of Beijing-Tianjin-Hebei is relatively low, but the innovation efficiency of Hebei province is basically higher than the average of Beijing-Tianjin-Hebei
Wang et al. [12]	SFA	Measurement of the technology innovation efficiency of Xinjiang's equipment manufacturing industry	2000–2014	The technology innovation efficiency of Xinjiang's equipment manufacturing industry and its subsectors is not high, but the efficiency has improved significantly in recent years; there is not much difference between the subsectors, and there is still much room for improvement
Yi et al. [13]	SFA	Calculation and analysis of the technology innovation efficiency of China's high-tech industries	2000–2015	The overall level of high-tech industry`s innovation efficiency is not high, the innovation efficiency of the high-tech industry among regions generally shows a fluctuating increase, and the regional distribution of its growth rate is different
Yin and Chen [14]	Two-phase SFA	Innovation efficiency of 103 Shanghai-Shenzhen pharmaceutical listed companies in China	2009–2013	The efficiency of technology innovation in enterprises is characterized by stages, resource utilization in innovation generation phase is between 39% and 46%, efficiency loss in innovation transformation stage is less than 35%, innovation generation promotes the transformation of innovative output
Yu [15]	PP-SFA	Measurement of the innovation efficiency of 27 regions in China	2008–2015	The average innovation efficiency of Chinese universities is 0.509, which is at a medium level as a whole; and the innovation efficiency of universities in different regions is quite different, and their development is uneven
Li and Dong [16]	PP-SFA	Measurement of value creation efficiency in 12 branches of Chinese Academy of Sciences	2009–2014	The overall value creation efficiency of CAS is low and the mean is 0.58, which could be improved significantly
Fan et al. [30]	SBM model	The analysis of regional science and technology resource allocation efficiency in China	2001–2014	The spatial distribution pattern of regional science and technology resource allocation efficiency is obvious. The efficiency of science and technological resource allocation without considering the nonexpected output is more than that of the nonexpected output

Table 1: Continued.

Study	Research method	Research context	Period	Findings
Li and Wen [31]	SBM-Tobit	Estimation of the allocation efficiency of science and technology financial resources in 27 provinces of China	2009–2016	The overall status of resource allocation has not been reached, there are differences among regions and there is still much room for improvement
Chen et al. [32]	Catastrophe series method	The regional differences in the allocation capacity of agricultural technology resource in China	1999–2011	There is a significant difference in the allocation of agricultural science and technology resource by region, and the fairness of allocation has generally declined
Huang and Zhang [33]	DEA model	Analysis on the resource allocation efficiency of the strategic emerging industries	2009–2011	Analysis on the resource allocation efficiency of the strategic emerging industries

parts, the first part $V \sim N(0, \sigma_V^2)$ is used to reflect the statistical noise (error) and the second part is $U \geq 0$, which is used to reflect the part that is controllable but not optimal [21]. By these ways, the SFA has advantages in measurement error and statistical interference processing. On the other hand, based on robust economic theory, the SFA method can quantitatively analyze the impact of related factors including input variables and environmental variables on innovation efficiency while measuring the efficiency of technology innovation [34].

However, the SFA method also has an obvious shortcoming that it can only explain the efficiency of a single output rather than dealing with the multioutput efficiency. Consequently, this study uses the RAGA-PP (real-coded accelerating genetic algorithm-projection pursuit) model to improve the SFA method, that is, to reduce the multidimensional output data by optimizing the projection direction with the purpose of reflecting the original high-dimensional data structure and characteristics to the greatest extent. Finally, by means of optimizing the projection direction of the original high-dimensional data globally, the one-dimensional optimal output projection value is obtained [15, 16]. In the case of random errors, this paper calculates the resource allocation efficiency of technology innovation in the aerospace industry and further analyzes the influence of five factors, including government support and enterprise scale, in order to provide decision support for the policy formulation of technology innovation in the aerospace industry. In summary, the detailed steps of the static evaluation model of the technical innovation resource allocation efficiency in the aerospace industry are as follows.

Step 1: determine the projection value of innovation output:

$$z(i)_t = \sum_{j=1}^{p} a(j)_t y(i, j)_t, \quad (1)$$

where $a(j)_t$ represents the projection direction of the variable j ($j = 1, 2, 3$) of 20 provinces and municipalities in the year of t and j is the projection value of innovation output.

Step 2: construct the projection index function:

$$Q(a) = S_z D_z, \quad (2)$$

where S_z is the standard deviation of $z(i)_t$ and D_Z represents the local density of $z(i)_t$.

Step 3: optimize the projection index function:

According to the dispersion characteristics of projection values, the local projection points are required to be as dense as possible, and it is preferable to form several point clusters, while the overall projection point clusters are as dispersed as possible; therefore, this article constructs an optimization function so as to make sure the product of the variance of projection values and the local density is the largest. Because the function is a complex nonlinear function, this paper adopts RAGA to conduct global optimization of the optimal projection direction and maximum function value of the projection index function. The function is constructed as follows:

$$\begin{cases} \max \quad Q(a_t) = S_z D_z, \\ \text{s.t.} \quad \sum_{j=1}^{3} a^2(j)_t = 1. \end{cases} \quad (3)$$

Step 4: calculate the technology innovation output index:

Combined with Step (3), the projection value of the technology innovation output $z(i)_t$ for 10 years is calculated, which is regarded as the technology innovation output index.

Step 5: calculate the resource allocation efficiency of technology innovation in the aerospace industry:

The stochastic frontier model is a stochastic boundary model based on parameters with compound perturbation terms. Different from the data enveloping analysis method, this model can not only measure the technical efficiency but also analyze the nonefficiency factors of innovation.

$$y_{it} = f(x_{it}, t)\exp(v_{it} - u_{it}). \quad (4)$$

Taking the logarithm of both sides of formula (4), we obtain the following equation:

$$\ln y_{it} = \ln f(x_{it}, t) + v_{it} - u_{it}, \quad (5)$$

where y_{it} represents the innovation output of region i in year t, x_{it} represents the R&D input of region i in the year of t, $v_{it} - u_{it}$ serves the error term, and v_{it} is a random variable, assuming that $v_{it} \sim N(0, \sigma^2)$ is independent of u_{it} which is a nonnegative random variable. It is expected that the positive half of the distribution of $u_{it} \sim N(m_{it}, \sigma^2)$ reflects the inefficiency of production technology, namely, the loss of technology innovation efficiency in the t year in the region of i. In order to systematically reflect the statistical characteristics of the variation of resource allocation efficiency, we can set the variance parameter γ; the expression is

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2} + \sigma_v^2, \quad (6)$$

where $\gamma \in (0, 1)$ reflects the different characteristics of innovation efficiency in statistics. $\gamma \longrightarrow 0$, the input-output points in all regions are on the production frontier, and then the least square method can be used. When $\gamma \longrightarrow 1$, it indicates that u accounts for the main component in the deviation between the actual production unit and the production front in each region, and the SFA method should be adopted. This study uses the translog production function, which is more flexible than the Cobb–Douglas production function, and can effectively avoid the deviation of efficiency estimation caused by improper model setting [21]. The establishment of the translog-random stochastic frontier model is as follows:

$$\begin{aligned} \ln y_{it} = {} & \beta_0 + \beta_1 \ln l_{it} + \beta_2 \ln k_{it} + \beta_3 (\ln l_{it})^2 + \beta_4 (\ln k_{it})^2 \\ & + \beta_5 \ln l_{it} \ln k_{it} + v_{it} - u_{it}, \end{aligned} \quad (7)$$

where y_{it} represents the overall output of technology innovation in region i of the t year, l_{it} represents the full-time equivalent of R&D personnel, k_{it} represents the R&D capital stock, and β is the parameter to be estimated.

On the basis of the stochastic frontier production model, the nonefficiency function of technology is introduced to further analyze the impact of five factors, including government support, enterprise scale, market concentration, regional development level, and labor quality on the allocation efficiency of technology innovation resource in the aerospace industry; the model is set to

$$m_{it} = \delta_0 + \delta_1 \mathrm{GS} + \delta_2 \mathrm{ES} + \delta_3 \mathrm{MC} + \delta_4 \mathrm{RDL} + \delta_5 \mathrm{EDS}, \quad (8)$$

where m_{it} represents the mean value of the distribution function of technical inefficiency in technology innovation output; GS, ES, MC, RDL, and EDS represent government support, enterprise size, market concentration, regional development level, and labor quality, respectively; δ is a parameter to be estimated, reflecting the degree of influence factors on technical inefficiency. When $\delta < 0$, it means that it has a positive impact on the allocation efficiency of technology innovation resource, and $\delta > 0$ means that it has a negative effect on the allocation efficiency of technology innovation resource.

3.2. Dynamic Comprehensive Evaluation Model. The dynamic comprehensive evaluation of the resource allocation efficiency of technology innovation in the aerospace industry is based on the static evaluation index. In this paper, the dynamic evaluation model constructed by Liu et al. [35] is used for reference to measure the integration significance. The purpose of the dynamic evaluation is to analyze the development speed, acceleration, and overall development trend of the allocation efficiency of technology innovation resource in the aerospace industry, so as to make up for the time-point stagnation of static evaluation and to be more comprehensive. The specific steps of thorough dynamic assessment are as follows.

Step 1: calculate the dynamic change speed v_{ij}:

The static evaluation timing sequence matrix R is constituted by the static evaluation value (in which the evaluated object $i \in [1, m]$ and the time point $j = [1, n+1]$), and the dynamic change degree v_{ij} is calculated to form the dynamic change speed matrix V. The model is set as follows:

$$R = [r_{ij}]_{m(n+1)} = \begin{bmatrix} r_{11} & \cdots & r_{1(n+1)} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{m(n+1)} \end{bmatrix},$$

$$V_{ij} = \frac{r_{i(j+1)} - r_{ij}}{t_{j+1} - t_j} \begin{cases} > 0 \text{ increasing trend}, \\ = 0 \text{ relatively stable}, \\ < 0 \text{ decreasing trend}, \end{cases} \quad (9)$$

$$V = [v_{ij}]_{mn} = \begin{bmatrix} v_{11} & \cdots & v_{1n} \\ \vdots & \ddots & \vdots \\ v_{m1} & \cdots & v_{mn} \end{bmatrix}.$$

Step 2: calculate the dynamic change rate state S_v^i:

According to the definition of definite integral, the integral calculation is carried out at different moments of dynamic change velocity and the comprehensive area is the state of active change rate, obtaining the state information matrix S of dynamic change rate and the evaluation object's linear change of pace a_{ij} in a certain period of time; the formula is as follows:

$$S_v^i(t_j, t_{j+1}) = \int_{t_j}^{t_{j+1}} \left[v_{ij} + (t - t_j) \cdot \frac{v_{i(j+1)-v_{ij}}}{t_{j+1-t_j}} \right] \mathrm{d}t,$$

$$a_{ij} = \begin{cases} 0, & t_{j+1} = 1, \\ \dfrac{v_{i(j+1)-v_{ij}}}{t_{j+1-t_j}}, & t_{j+1} > 1. \end{cases} \quad (10)$$

Step 3: calculate the dynamic change speed trend $\omega(a_{ij})$:

The formula of the function $\omega(a_{ij})$ is constructed as follows. The dynamic trend value increases with the growth of a_{ij}. When a_{ij} approaches positive infinity, the value of the function is θ; as a_{ij} approaches minus infinity, the value of the function is 0; if θ is assigned to 2, then when $a_{ij} = 0$, the function value is 1 and the range is (0, 2). Before the inflection points of $a_{ij} = 0$ and $\omega(a_{ij}) = 1$, the growth speed of the trend function of dynamic change rate is in increasing state; after the inflection point, the situation is reversed and the change rate of both sides is getting larger and larger, which represents the incentive effect of the change rate trend of the evaluated object on the comprehensive dynamic change evaluation. The evaluation result is set as follows: when $\omega(a_{ij}) \in (1, 2)$, it can positively stimulate the changing speed state; when $\omega(a_{ij}) = 1$, the change speed is relatively stable and no incentive or punishment measures are taken. When $\omega(a_{ij}) \in (0, 1)$, negative correction measures are made for the changing rate state.

$$\omega\left(a_{ij}\right) = \frac{\theta}{1 + e^{-a_{ij}}}. \tag{11}$$

Step 4: calculate the dynamic comprehensive evaluation of value F_i:

Referring to Newton's second law $\sum F = kma$, where the coefficient k is a set term, it does not affect the analysis of the evaluation results, so it is set to 1; m is represented by the dynamic change rate state S_v^i, and the acceleration a is represented by the dynamic change rate trend $\omega(a_{ij})$. Newton's second law formula is used to obtain the dynamic comprehensive evaluation value F_i of the object i at the time point of j. Finally, the dynamic complete evaluation value F_i of the object to be evaluated is obtained by summing up the comprehensive evaluation values at each time point. The formula is as follows:

$$\begin{aligned} f_{ij} &= S_v^i\left(t_j, t_{j+1}\right) \cdot \omega\left(a_{ij}\right), \\ F_i &= \sum_{j=1}^{j=n-1} f_{ij}. \end{aligned} \tag{12}$$

The numerical value of the dynamic comprehensive evaluation and its positive and negative performance indicate the development trend of the evaluated object intuitively. When $F_i > 0$, the progressive development of aerospace technology innovation resource allocation efficiency in the evaluated area is on the rise, and the larger the value is, the better the development situation is. When $F_i < 0$, the development trend of the evaluated objects showed a downward trend. When $F_i = 0$, the subject was relatively stable throughout the empirical period.

4. Indicator System and Data Selection

4.1. Indicator System. The input of technology innovation resource allocation in the aerospace industry includes R&D personnel input and R&D expenditure input, of which R&D personnel input is expressed by R&D personnel full-time equivalent and R&D funding input is selected by R&D internal expenditure. Because the expenditure of R&D expenditure is a flow index, which reflects the input of current R&D expenditure, it is unable to reflect the cumulative effect of R&D activities and also has a time-lag effect; the R&D capital stock with a lag of one period is carefully chosen as the index of R&D expenditure [36]. The initial capital stock is estimated by dividing the internal support of R&D funds in 2007 by 10% [35], and the capital stock of other years is $K_{i\cdot t} = K_{i\cdot t-1}(1-\delta) + C_{i\cdot t}$, where $K_{i\cdot t}$ and $K_{i\cdot(t-1)}$ are actual R&D expenditures for the t and $t-1$ years in the region of i, δ is the depreciation rate ($\delta = 9.600\%$), and C is the net value of the new capital stock. Based on these indicators, we calculate the actual value of R&D expenditure on the allocation of technology innovation resource in the aerospace industry.

The technology innovation output of the aerospace industry includes knowledge benefit output and economic benefit output. The patented invention is a direct output of the aerospace industry R&D activities, which can objectively reflect the technology innovation capability and comprehensive science and technological strength of the aerospace industry. In this paper, the number of patent applications and effective invention patents of the aerospace industry in various regions [8] is selected to represent the knowledge benefit output of its technology innovation efficiency. This paper regards the sales revenue of new products of the aerospace industry in various regions as economic benefit output in that the ultimate value of scientific and technology innovation is its commercial value. This study processes the RAGA-PP model to reduce the number of patent applications, effective inventions, and sales revenue of new products of the aerospace industry in various regions and years.

The efficiency of resource allocation of technology innovation in the aerospace industry is influenced by many factors, such as its own industrial characteristics (enterprise scale and so on), regional environment (market concentration, regional development level, labor quality, and so on), and relevant policies and guidelines of government departments. The control variables selected in this paper are as follows: the government funds raised by the R&D activities represent government support (GS); the ratio of the primary business income to the number of enterprises is taken as the measurement index of the average size of enterprises, which is named as enterprise scale (ES); market concentration degree (MC) is represented by the proportion of the number of enterprises in each region in the total number of enterprises in the area; the logarithm of current GDP of each region is selected as the representative variable of regional development level (RDL); EDS is the labor quality represented by the logarithm of the number of college students per 100,000 population.

4.2. Data Selection. Aerospace manufacturing is a typical representative of China's high-tech industry, which is a landmark industry in China's construction and high-tech level [35]. Fortunately, the aerospace industry sector has authoritative public data. Consequently, based on the aviation and aerospace manufacturing industry from 2007 to 2016 in China Science and Technology Statistical Yearbook, Statistical Yearbook of High-tech Industry and China Statistical Yearbook, this article selects 20 provincial regions including Beijing, Shaanxi, and Liaoning as samples (data of Xizang, Hainan, and other rural local are seriously missing and do not include examples).

5. Empirical Analysis

5.1. Calculation of the Aerospace Industry Innovation Output Index. The science and technology innovation output data of provincial regions from 2007 to 2016 in China are substituted into the projection pursuit model, applying the accelerated genetic algorithm RAGA based on real coding, to optimize the optimal projection direction and to obtain the optimal projection value. The RAGA program is compiled by the software MATLAB2014a, and the relevant parameters are set as follows: population size $n = 400$, crossover probability $P_c = 0.8$, the mutation probability $P_m = 0.1$, and the acceleration times are set to 7. The calculation results are shown in Table 2.

5.2. Analysis of the Factors Affecting Resource Allocation Efficiency of Technology Innovation in the Aerospace Industry. Based on the provincial-level panel data of China in 2007–2016, the transcendental logarithmic stochastic frontier model is used to calculate both the allocation efficiency of technology innovation resource and the influence of various factors on the efficiency in China's aerospace industry.

As shown in Table 3, $\gamma = 0.99$ is significant at the 1% level, indicating that the SFA method can adequately estimate the output function. The log-likelihood function value is 7.0446, and the maximum likelihood estimation works well; the unilateral LR test value is 50.9555, which indicates that the technical inefficiency term has a significant impact on the allocation efficiency of science and technology resources in various regions. According to the above numerical analysis, the establishment of the model has a higher rationality. Combined with the evaluation results, the output elasticity of resource input factors in the aerospace industry can be obtained. We find that the output elasticity of R&D personnel resource elements is rising, while the output elasticity of R&D expenditure resource elements is declining, which indicates that the effectiveness of China's aerospace industry technology innovation resource allocation is more dependent on the input of R&D personnel resource elements. This is exactly consistent with the current situation that human resource input is relatively insufficient, while financial resource input is comparatively excessive, and the per capita R&D expenditure is relatively high, while the high-level professional labor resources are inadequate in the resource allocation of technology innovation in China's aerospace industry.

It can be seen from the estimation of the efficiency function that the regression coefficient supported by the government is significantly positive, showing that the government's financial support has not met the expectations in improving the efficiency of resource allocation for technology innovation. Because of severe information asymmetry between the government and the production and management of the aerospace industry, there are subjective one-sidedness and time lag in the judgment and capital investment of technology innovation and development. At the same time, merely intervening in innovation activities of the aerospace industry in the form of financial support will enable some enterprises profit from rent-seeking behaviors and undermine fair competition in the market environment, causing the crowding-out effect. This is consistent with the declining elasticity of the cost factor output shown in the production function.

The regression coefficient of the enterprise scale is significantly negative, indicating that the expansion of the enterprise scale has a significant positive impact on the improvement of the resource allocation efficiency of technology innovation in the aerospace industry. Because of the risk and difficulty of technology innovation activities in the aerospace industry, small enterprises with weak financial strength are in a disadvantaged position in terms of cost-sharing and financing channels, while large enterprises with high capital intensity have remarkable economies of scale with the strong antirisk ability and easy access to effective venture capital support.

The regression coefficient of market concentration is significantly negative, indicating that market concentration has a significant positive impact on the improvement of the allocation efficiency of technology innovation resource in the aerospace industry. As a reverse index, the greater the market concentration degree, the lower the monopolistic degree and the higher the efficiency. The aerospace industry inevitably faces the international competitive environment, and it is absolutely necessary for enterprises to joint research and innovation in both vertical and horizontal directions under the strict innovation condition. However, the lack of technology innovation impetus in the monopolized market and the emergence of innovation inertia are not conducive to the improvement of the overall efficiency of technology innovation resource allocation.

The regression coefficient of regional development level is significantly negative, indicating that the improvement of local development level has a significant positive impact on the growth of allocation efficiency of technology innovation resource in the aerospace industry. The region's precious material resources and solid technology innovation foundation promote the two-way flow of technology innovation resource and contribute to the enlargement of the linkage effect of industrial structure optimization and economic development.

The regression coefficient of labor force quality is significantly positive, which indicates that the optimization of labor quality has not achieved the expected improvement in the efficiency of the technology innovation resource allocation of the aerospace industry. Consistent with the previous analysis, in the context of the new economic development, the demand for talents is reflected not only in quantity but also in high quality and professionalism. On a

Table 2: Science and technology innovation output index.

Region	Year									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Beijing	0.02104	0.33554	0.36382	0.23165	0.39360	0.50790	0.39257	0.71672	0.89806	0.78669
Tianjin	0.01901	0.02071	0.01842	0.02772	0.03264	0.00487	0.02993	0.48416	1.25213	0.76408
Hebei	0.01953	0.02762	0.05012	0.04791	0.06278	0.05322	0.03497	0.09318	0.06020	0.06772
Liaoning	0.67467	1.61304	1.23579	1.24324	1.46332	1.31262	1.26758	1.41745	1.48870	0.93925
Heilongjiang	0.70421	0.66442	0.75872	0.59320	0.67589	0.70146	0.40862	0.70079	0.51927	0.59848
Shanghai	0.11031	0.10875	0.39683	0.23632	0.39369	0.36550	0.23890	0.33659	0.40025	0.35112
Jiangsu	0.00793	0.51274	0.35772	0.42501	0.89435	0.70191	0.67421	0.47556	0.38504	0.36386
Zhejiang	0.02009	0.16311	0.20596	0.03679	0.04718	0.01021	0.02709	0.03498	0.02025	0.01979
Anhui	0.05746	0.15133	0.36925	0.33788	0.17136	0.23344	0.03097	0.02112	0.01066	0.00543
Jiangxi	0.18693	0.41326	0.38096	0.43630	0.42030	0.71651	0.58609	0.71118	0.51186	0.14581
Shandong	0.00106	0.02060	0.01462	0.03374	0.03847	0.04504	0.08408	0.07887	0.08787	0.05106
Henan	0.00697	0.52921	0.89083	0.99860	0.81981	0.54966	0.27651	0.47007	0.47729	0.58225
Hubei	0.02501	0.31245	0.22087	0.21765	0.33180	0.17968	0.17823	0.40303	0.38504	0.34647
Hunan	0.80578	0.41331	0.48816	0.43629	0.42030	0.32825	0.41800	0.48428	0.24799	0.25501
Guangdong	1.00116	0.51274	0.36343	0.02757	0.03696	0.06530	0.05220	0.75404	0.10467	0.76418
Chongqing	0.00102	0.00492	0.02251	0.02644	0.03883	0.02599	0.01869	0.03059	0.02182	0.00811
Sichuan	0.13815	1.20089	0.89080	0.62134	0.41640	0.50456	0.58447	0.89865	0.72947	0.80944
Guizhou	0.67189	1.03452	1.01573	0.75322	0.61933	0.71710	0.58609	0.99355	0.89806	0.76408
Shaanxi	0.32877	1.39863	1.44296	1.24324	1.46291	1.38368	1.66540	1.63987	1.59181	1.64133
Gansu	0.00131	0.02006	0.02578	0.00950	0.03964	0.04801	0.03686	0.03945	0.03435	0.01806
Total	0.24011	0.47289	0.47566	0.39918	0.43898	0.42275	0.37957	0.53920	0.50624	0.46411
East region	0.15002	0.21273	0.22137	0.13334	0.23746	0.21924	0.19174	0.37176	0.40106	0.39606
Northeast region	0.68944	1.13873	0.99725	0.91822	1.06961	1.00704	0.83810	1.05912	1.00398	0.76887
Central region	0.21643	0.36391	0.47001	0.48534	0.43271	0.40151	0.29796	0.41793	0.32657	0.26699
West region	0.22823	0.73180	0.67956	0.53075	0.51542	0.53587	0.57830	0.72042	0.65510	0.64820

Table 3: The estimation results of stochastic frontier function and efficiency function.

Variable	Estimated coefficient	T-value
The constant terms of efficiency function	4.91200***	3.89404
$\ln l_{it}\,(\beta_1)$	0.31119*	1.17270
$\ln k_{it}\,(\beta_2)$	−0.98319***	5.86939
$(\ln l_{it})^2\,(\beta_3)$	0.02073	0.43071
$(\ln k_{it})^2\,(\beta_4)$	0.06298***	3.73092
$\ln l_{it}\ln k_{it}\,(\beta_5)$	−0.04978	0.72683
σ^2	0.05548***	11.87127
γ	0.99997***	38.28302
The constant terms of efficiency function	0.11597	0.54325
$GS\,(\sigma_1)$	0.35956*	1.77509
$ES\,(\sigma_2)$	−0.01611***	5.50768
$MC\,(\sigma_3)$	−3.13288***	13.14202
$RDL\,(\sigma_4)$	−0.0771***	2.75388
$EDS\,(\sigma_5)$	0.20847***	3.41828
Log-likelihood function value	7.0446	
Unilateral LR test	50.9555	

***, **, and * represent significance at the levels of 1%, 5%, and 10%, respectively.

national scale, high-tech talents are mainly concentrated in the eastern region, but the aerospace industry is concentrated in the western and northeastern regions, which often does not match the career plans of high-quality talents, resulting in a serious mismatch of human resources. Hence, the optimization of labor quality has no beneficial effect on the allocation of technology innovation resource in the aerospace industry.

5.3. Static Comprehensive Evaluation of Resource Allocation Efficiency of Technology Innovation in the Aerospace Industry. According to the output of the model, firstly, we calculate the average efficiency of resource allocation efficiency of the aerospace industry in each province (see Table 4), and then we carry out the simple arithmetic average calculation of the data. Finally, we obtain the resource innovation resource allocation of the aerospace industry in each region (see Table 5). Accordingly, we draw a radar map (see Figure 1). On the whole, there are significant differences in the allocation efficiency of technology innovation resource among different regions, which reflects the imbalance of regional development. Also, on the space, there is a pattern of “low east and high west,” which is opposite to the local economic development.

From the national perspective, the mean value of the evaluation of efficiency in China’s aerospace industry technology innovation resource allocation is 0.4571, which is between the average cost of the central and western regions, generally at the lower middle level and in urgent need of improvement. There are 9 regions higher than the national average and 11 areas lower than the national average, indicating that more than half of the areas are still at a low level of allocation of technology innovation resource in the aerospace industry, and there is an excellent room for improvement. Among them, the average evaluation values of technology innovation resource allocation in the northeast

Table 4: Evaluation results of the allocation of interprovincial technology innovation resource in the aerospace industry.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean	Rank
Beijing	0.2614	0.3460	0.3354	0.2841	0.3420	0.3587	0.3022	0.3942	0.4629	0.4033	0.3490	19
Tianjin	0.3866	0.3855	0.3854	0.3908	0.3888	0.3868	0.3951	0.6226	0.9054	0.6885	0.4936	7
Hebei	0.3835	0.3810	0.3577	0.3584	0.4005	0.3709	0.3617	0.3747	0.3517	0.3492	0.3689	16
Liaoning	0.4076	0.9891	0.6700	0.6328	0.7464	0.6259	0.5727	0.6409	0.6554	0.3690	0.6310	2
Heilongjiang	0.4975	0.4770	0.5118	0.4160	0.4395	0.4367	0.3150	0.4048	0.3358	0.3491	0.4183	11
Shanghai	0.3028	0.3027	0.3985	0.3480	0.3790	0.3327	0.2867	0.2812	0.2968	0.2727	0.3201	20
Jiangsu	0.3665	0.6076	0.5147	0.5358	0.8346	0.6711	0.5974	0.4930	0.4332	0.4053	0.5459	5
Zhejiang	0.3954	0.4602	0.4745	0.4006	0.4065	0.3952	0.3924	0.3914	0.3899	0.3891	0.4095	12
Anhui	0.3948	0.4403	0.5575	0.4943	0.4077	0.4743	0.3857	0.3790	0.3690	0.3632	0.4266	10
Jiangxi	0.3255	0.4111	0.3937	0.4071	0.3868	0.5077	0.4378	0.4698	0.3855	0.2437	0.3969	13
Shandong	0.3702	0.3766	0.3734	0.3889	0.3713	0.3226	0.3774	0.4036	0.3950	0.3757	0.3755	14
Henan	0.3236	0.5474	0.7581	0.8489	0.7121	0.5387	0.4014	0.4879	0.4723	0.5056	0.5596	4
Hubei	0.2951	0.3976	0.3631	0.3621	0.4001	0.3365	0.3239	0.4037	0.3916	0.3686	0.3642	17
Hunan	0.7627	0.5169	0.5625	0.5056	0.4787	0.4352	0.4565	0.4744	0.3647	0.3548	0.4912	8
Guangdong	0.9423	0.5846	0.5065	0.3638	0.3447	0.3583	0.3570	0.6983	0.3607	0.6504	0.5167	6
Chongqing	0.3719	0.3600	0.3679	0.3558	0.3626	0.3620	0.3626	0.3675	0.3649	0.3613	0.3636	18
Sichuan	0.3095	0.8856	0.6417	0.4645	0.3644	0.3742	0.3847	0.5030	0.3949	0.4268	0.4749	9
Guizhou	0.5793	0.8361	0.7961	0.5740	0.4972	0.5186	0.4341	0.6312	0.5597	0.4732	0.5899	3
Shaanxi	0.2557	0.7401	0.7663	0.6202	0.7336	0.6422	0.8136	0.7598	0.6978	0.7116	0.6741	1
Gansu	0.3828	0.3906	0.3915	0.3815	0.3877	0.3782	0.3670	0.3606	0.3518	0.3400	0.3732	15

The evaluation results in Table 4 are reserved for four decimal places, the same as below.

Table 5: Evaluation results of resource allocation of regional aerospace industry technology innovation.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean	Rank
Total	0.4157	0.5218	0.5063	0.4567	0.4692	0.4413	0.4162	0.4771	0.4469	0.4201	0.4571	
East region	0.4261	0.4305	0.4183	0.3838	0.4334	0.3995	0.3837	0.4574	0.4494	0.4418	0.4224	4
Northeast region	0.4526	0.7330	0.5909	0.5244	0.5929	0.5313	0.4439	0.5229	0.4956	0.3590	0.5247	1
Central region	0.4203	0.4626	0.5270	0.5236	0.4771	0.4585	0.4011	0.4430	0.3966	0.3672	0.4477	3
West region	0.3798	0.6425	0.5927	0.4792	0.4691	0.4550	0.4724	0.5244	0.4738	0.4626	0.4952	2

The eastern regions in Table 4 include Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Shandong, and Guangdong; the central areas include Anhui, Jiangxi, Henan, Hubei, and Hunan; the western areas include Chongqing, Sichuan, Guizhou, Shaanxi, and Gansu. Northeast region includes Heilongjiang and Liaoning; other regions were not included in the sample due to serious data missing.

region and the western region are 0.5247 and 0.4952, respectively, which are at a high level; also, the average values of the central region and the eastern region are 0.4477 and 0.4224, respectively, which are at a low level and slightly higher in the central part.

From the perspective of the provincial level, there are considerable differences in the allocation of technology innovation resource in China. The provinces with the top 5 evaluation rankings are Shaanxi, Liaoning, Guizhou, Henan, and Jiangsu, and the bottom 5 provinces are Hebei, Hubei, Chongqing, Beijing, and Shanghai. Shaanxi province is a vital force in China's national defense construction. During the period of "1st Five-Year Plan," the military construction projects in Shaanxi province accounted for 23.9% of the total number of military projects in the country. Moreover, in the course of the "2nd Five-Year Plan" period, the state built 14 military projects in Shaanxi province based on national defense security and regional economic development. For a long time, Shaanxi province has maintained a strong development momentum in the national defense science and technology industry, aerospace industry, and other domestic defense industries. The three areas with the highest efficiency in resource allocation for technology innovation in China's aerospace industry are located in the economically underdeveloped regions of the northwest, northeast, and southwest, while most of the provinces in the economically developed regions are inefficient in resource allocation at large, such as the Beijing-Tianjin-Hebei region and the Yangtze River Delta and other provinces with the highest level of economy. The aerospace industry can neither effectively absorb the spillover effect of technology innovation nor timely acquire the advance technology in developed regions. In addition, under the condition of the market economy, it is difficult for the central and western regions to attract and retain high-level science and technological talents, which is in line with the preliminary analysis.

From the perspective of the four regions, as shown in Figure 2, in terms of the northeast region, the allocation efficiency of technology innovation resource in the aviation and aerospace industry is in the leading position in most years, with the highest value of allocation efficiency in 2008 being 0.733 and the lowest amount of allocation efficiency in 2016 being 0.359. The allocation efficiency of the technology innovation resource in the aerospace industry in the eastern region showed a rising trend. In 2014, the allocation efficiency was the highest with a value

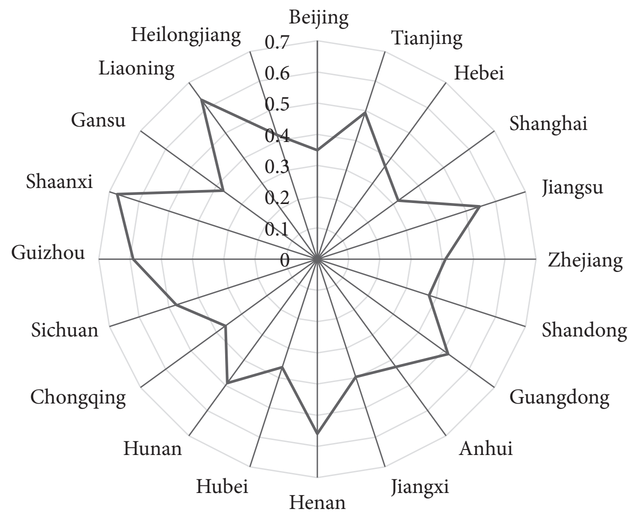

Figure 1: The efficiency of resource allocation for technology innovation in China's aerospace industry.

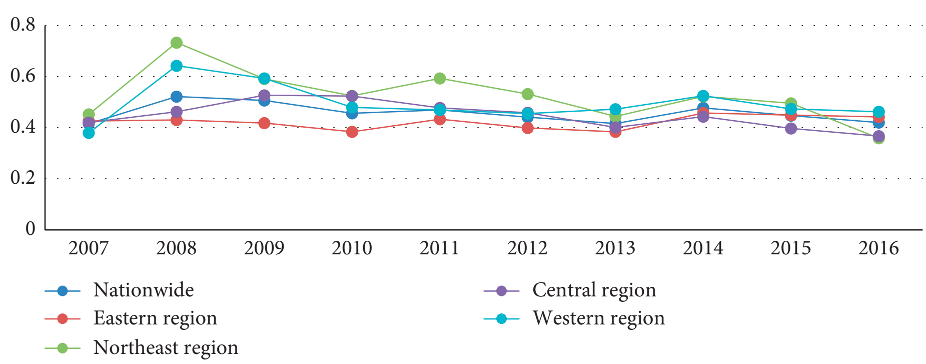

Figure 2: Regional technology innovation resource allocation efficiency in the aerospace industry.

of 0.4574, and the allocation efficiency in 2013 was the lowest with a value of 0.3837. The allocative ability of technology innovation resource in the aviation and aerospace industry in the central region showed a trend of decline with fluctuation. The allocative efficiency was the highest with a value 0.527 in 2009 and the lowest with a value 0.3672 in 2016. In the western region, the efficiency value showed a fluctuating upward trend, with the highest amount of 0.6425 in 2008 and the lowest value of 0.3798 in 2007.

Generally speaking, the allocation of technology innovation resource in China's aerospace industry presents a stable and fluctuating trend with limited efficiency improvement. The reasons are as follows: firstly, the "boundary conflict" between resource sharing and safety management of technology innovation subjects may be an eternal obstacle to the development of China's space industry. Secondly, the aerospace industry itself fails to effectively integrate with the market economy and absorb the spillover effect of high and new technology in the process of development. Thirdly, the regions with high-quality development of the aerospace industry are mostly the central and western regions with poor economic growth, unable to attract and retain high and new technology talents, resulting in a lack of development momentum.

5.4. Dynamic Comprehensive Evaluation of Resource Allocation Efficiency of Technology Innovation in the Aerospace Industry. Based on the static evaluation index, the dynamic change speed state index is analyzed from the acceleration angle of the resource allocation efficiency change (see Table 6). From the perspective of the change speed data of the aerospace industry's innovation resource allocation, the shift in innovation speed in different regions is quite different. With the time-lapse, the development process of different areas is totally different in which the data vary considerably. By horizontal comparison of the change speed of different regions in the same period, it shows that the change speed of Beijing and Tianjin is higher than the average of all regions. Besides, the positive overall change speed indicates that the innovation speed of the two regions is constantly increasing. By longitudinal comparison of the changing speed state in the different areas of the same region, it shows that the speed changes in Henan, Liaoning, Guizhou, Sichuan, Tianjin, and Jiangsu fluctuate considerably, while the speed states in other

Table 6: Change speed state of the aerospace industry's technology innovation resource allocation efficiency.

Region	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016
Beijing	0.0370	−0.0309	0.0033	0.0373	−0.0199	0.0177	0.0803	0.0046
Tianjin	−0.0006	0.0026	0.0017	−0.0020	0.0032	0.1179	0.2551	0.0329
Hebei	−0.0129	−0.0113	0.0214	0.0063	−0.0194	0.0019	−0.0050	−0.0127
Liaoning	0.1312	−0.1782	0.0382	−0.0034	−0.0868	0.0075	0.0413	−0.1360
Heilongjiang	0.0071	−0.0305	−0.0361	0.0104	−0.0622	−0.0160	0.0104	−0.0279
Shanghai	0.0479	0.0227	−0.0098	−0.0077	−0.0461	−0.0258	0.0051	−0.0042
Jiangsu	0.0741	−0.0359	0.1600	0.0676	−0.1186	−0.0890	−0.0821	−0.0439
Zhejiang	0.0395	−0.0298	−0.0340	−0.0027	−0.0070	−0.0019	−0.0013	−0.0011
Anhui	0.0814	0.0270	−0.0749	−0.0100	−0.0110	−0.0477	−0.0083	−0.0079
Jiangxi	0.0341	−0.0020	−0.0034	0.0503	0.0255	−0.0190	−0.0261	−0.1130
Shandong	0.0016	0.0062	−0.0010	−0.0332	0.0030	0.0405	0.0088	−0.0140
Henan	0.2172	0.1508	−0.0230	−0.1551	−0.1553	−0.0254	0.0354	0.0089
Hubei	0.0340	−0.0178	0.0185	−0.0128	−0.0381	0.0336	0.0339	−0.0176
Hunan	−0.1001	−0.0056	−0.0419	−0.0352	−0.0111	0.0196	−0.0459	−0.0598
Guangdong	−0.2179	−0.1104	−0.0809	−0.0028	0.0061	0.1700	0.0019	−0.0239
Chongqing	−0.0020	−0.0021	−0.0027	0.0031	0.0000	0.0028	0.0012	−0.0031
Sichuan	0.1661	−0.2106	−0.1387	−0.0452	0.0102	0.0644	0.0051	−0.0381
Guizhou	0.1084	−0.1310	−0.1495	−0.0277	−0.0315	0.0563	0.0628	−0.0790
Shaanxi	0.2553	−0.0600	−0.0163	0.0110	0.0400	0.0588	−0.0579	−0.0241
Gansu	0.0043	−0.0045	−0.0019	−0.0016	−0.0104	−0.0088	−0.0076	−0.0103

regions are relatively stable. From the perspective of the dimensionality distribution of the four regions, the mean value comparison shows that the velocity change state of the western region is at the highest value in each year, while that of the central region is at the negative value in recent years.

Through the measurement of the change speed trend value (as shown in Table 7), the change of the efficiency of the innovation resource allocation in the aerospace industry is further explored and the "incentive" or "punishment" mechanism is given for the evaluation of the state of the speed change. Most of the values fluctuated around the value of 1, and the revision of the changing velocity state in each region was continually changing. Beijing, Shandong, Gansu, Liaoning, and Heilongjiang are mainly in the correction result of "punishment," while Zhejiang and Shanghai are mostly in the correction result of "incentive."

According to the sum of the product of changing velocity state and changing velocity trend, the dynamic comprehensive evaluation index is calculated. In general, Table 8 shows that 70% of the data are negative and only a few dynamic comprehensive evaluation indicators are positive. From the year 2007 to 2016, the allocation efficiency of technology innovation resource in the aerospace industry in most regions of China showed a decreasing trend, among which only Beijing, Tianjin, Shanghai, Jiangsu, Anhui, and Guizhou showed an upward trend in the overall dynamic changes. In the ranking of 20 regions, Shaanxi province ranks first, while Guangdong province ranks last. As a major province of China's aerospace industry, Shaanxi province has a large number of professionals and sophisticated equipment. Sufficient exclusive industrial resources, sophisticated equipment, high-end talent flow, and other fundamental factors combined with the social policy support have prompted Xian to take the aerospace industry as the leading industry and lead the innovation and development of the domestic aerospace industry. Relatively, Guangdong's aerospace industry developed late with a weak foundation. In the past decade, China's "12th Five-Year Plan" and "13th Five-Year Plan" have all promoted the relevant aerospace industry in Guangdong province. However, because of the small scale of the aerospace industry and the insignificant industrial agglomeration effect in Guangdong Province, the overall development situation is still relatively weak.

Dividing the provinces and cities into four regions, it can be observed intuitively that the polarization is more obvious in the regions except northeast China where the dynamic comprehensive evaluation index generally lags behind. In the eastern region, for example, Beijing, Tianjin, and Jiangsu rank higher, while other provinces and cities lag behind, especially the Guangdong province.

By combining static evaluation with dynamic evaluation, this paper makes a more comprehensive analysis of the resource allocation efficiency of technology innovation in the aerospace industry in 20 regions. By comparing the static ranking and dynamic ranking of the same region, as shown in Figure 3 and Table 9, two extreme phenomena can be found: the static ranking of Beijing and Shanghai is behind while their dynamic rankings are at the front; the static ranking of Liaoning, Guangdong, and Guizhou is at the front while the dynamic ranking is behind. The difference between the two extreme phenomena lies in the necessary status quo and development trend of efficiency under the allocation of technology innovation resource. With relatively developed economic development, Beijing and Shanghai continue to attract the introduction of domestic and foreign talents and technologies, rapidly improving their core capabilities in the process of development and gradually professionalizing the allocation of space resources. In these regions, the initial weak essential capacity is continually rising, and the high-end R&D

Table 7: The trend of changing speed of resource allocation efficiency in the aerospace industry.

Year	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016
Beijing	0.9525	0.9796	1.0546	0.9794	0.9634	1.0741	0.9883	0.9360
Tianjin	1.0005	1.0027	0.9964	0.9999	1.0052	1.1091	1.0277	0.7552
Hebei	0.9897	1.0120	1.0208	0.9641	1.0102	1.0111	0.9820	1.0102
Liaoning	0.5779	1.1400	1.0753	0.8835	1.0336	1.0606	0.9731	0.8507
Heilongjiang	1.0277	0.9348	1.0596	0.9869	0.9406	1.1053	0.9208	1.0411
Shanghai	1.0479	0.9270	1.0407	0.9614	1.0001	1.0203	1.0106	0.9801
Jiangsu	0.8345	1.0570	1.1379	0.7729	1.0449	0.9846	1.0223	1.0160
Zhejiang	0.9747	0.9559	1.0399	0.9914	1.0043	1.0009	0.9997	1.0004
Anhui	1.0359	0.9100	0.9883	1.0764	0.9225	1.0410	0.9983	1.0021
Jiangxi	0.9486	1.0154	0.9832	1.0704	0.9049	1.0509	0.9420	0.9712
Shandong	0.9952	1.0094	0.9834	0.9845	1.0517	0.9858	0.9825	0.9947
Henan	0.9934	0.9402	0.8866	0.9817	1.0180	1.1114	0.9490	1.0245
Hubei	0.9316	1.0167	1.0196	0.9492	1.0255	1.0461	0.9541	0.9945
Hunan	1.1447	0.9488	1.0150	0.9917	1.0324	0.9983	0.9363	1.0499
Guangdong	1.1390	0.9677	1.0617	1.0164	0.9925	1.1697	0.6730	1.3037
Chongqing	1.0099	0.9900	1.0094	0.9964	1.0006	1.0022	0.9962	0.9995
Sichuan	0.6115	1.0334	1.0385	1.0549	1.0003	1.0538	0.8872	1.0699
Guizhou	0.8527	0.9092	1.0725	1.0491	0.9471	1.1399	0.8664	0.9926
Shaanxi	0.7748	0.9141	1.1290	0.8979	1.1307	0.8879	0.9959	1.0378
Gansu	0.9966	0.9946	1.0081	0.9922	0.9991	1.0024	0.9988	0.9985

Table 8: Dynamic comprehensive evaluation of resource allocation efficiency in the aerospace industry.

	Evaluation value	Rank
East region		
Beijing	0.0316	5
Tianjin	0.0641	3
Hebei	−0.0288	11
Shanghai	0.0032	7
Jiangsu	0.0971	2
Zhejiang	−0.0362	14
Shandong	−0.0362	13
Guangdong	−0.4685	20
Central region		
Anhui	0.0064	6
Jiangxi	−0.0054	8
Henan	0.0349	4
Hubei	−0.0350	12
Hunan	−0.2725	16
West region		
Chongqing	−0.0068	9
Sichuan	−0.3380	19
Guizhou	−0.3209	18
Shaanxi	0.1515	1
Gansu	−0.0243	10
Northeast region		
Liaoning	−0.2944	17
Heilongjiang	−0.1370	15

capacity is continuously concentrated. The layout of the aerospace industry has constantly been adjusted so that the aerospace industry technology innovation resource allocation efficiency has a relatively rapid development potential. In contrast, Liaoning province, as the cradle of China's aerospace industry, is the most concentrated area of the aerospace industry in China's planned economy, with solid strength and development opportunities. Nevertheless, the lack of integration of industry with systematic, professional knowledge aging makes it less optimistic for Liaoning province to advance a profound development of the aerospace industry.

In a nutshell, the allocation efficiency of technology innovation resource in China's aerospace industry is unbalanced, and in most regions, the allocation efficiency of technology innovation resource is in a dynamic declining

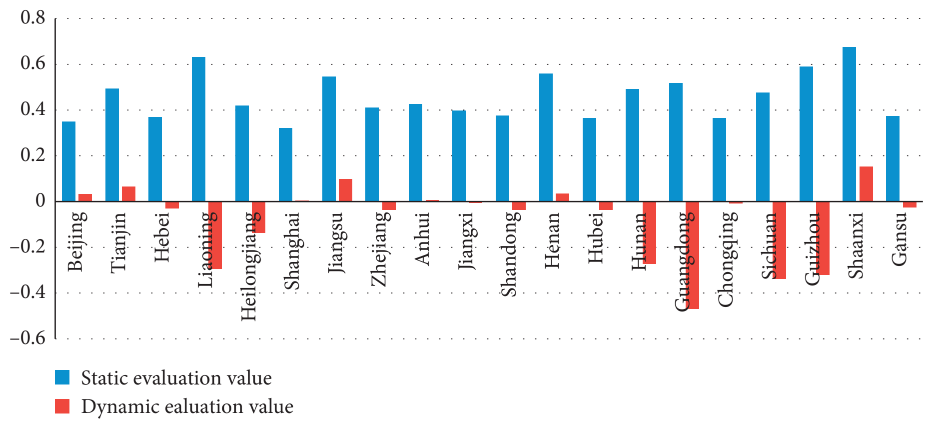

FIGURE 3: Static and dynamic evaluation of resource allocation efficiency in the aerospace industry.

TABLE 9: Static and dynamic evaluation of resource allocation efficiency in the aerospace industry.

Region	Static evaluation value	Dynamic evaluation value	Static rank	Dynamic rank
Beijing	0.3490	0.0316	19	5
Tianjin	0.4936	0.0641	7	3
Hebei	0.3689	−0.0288	16	11
Liaoning	0.6310	−0.2944	2	17
Heilongjiang	0.4183	−0.1370	11	15
Shanghai	0.3201	0.0032	20	7
Jiangsu	0.5459	0.0971	5	2
Zhejiang	0.4095	−0.0362	12	14
Anhui	0.4266	0.0064	10	6
Jiangxi	0.3969	−0.0054	13	8
Shandong	0.3755	−0.0362	14	13
Henan	0.5596	0.0349	4	4
Hubei	0.3642	−0.0350	17	12
Hunan	0.4912	−0.2725	8	16
Guangdong	0.5167	−0.4685	6	20
Chongqing	0.3636	−0.0068	18	9
Sichuan	0.4749	−0.3380	9	19
Guizhou	0.5899	−0.3209	3	18
Shaanxi	0.6741	0.1515	1	1
Gansu	0.3732	−0.0243	15	10

trend. The main reason lies in the discontinuity of the industrial chain in some regions, the unreasonable distribution of the industrial structure, and the urgent demand of professional personnel and technology.

6. Conclusions

This paper selects the panel data of 20 provinces from 2007 to 2016, constructs a static and dynamic evaluation model to measure the efficiency of resource allocation of China's aerospace industry technology innovation, and then effectively identifies and empirically analyzes its critical influencing factors. The conclusions and policy implications are summarized as follows.

The overall efficiency of the technical innovation resource allocation of the aerospace industry is at a medium-to-lower level, and there are problems such as resource redundancy and waste, as well as resource mismatch and imbalance. The efficiency of resource allocation of technology innovation in the aerospace industry is obviously different among regions and has little coordination with the level of regional economic development Therefore, it is unable to effectively absorb the technology spillover effect from the high-tech industry and the new economic form. In the past ten years, China's aerospace industry technology innovation resource allocation efficiency has been improved to some extent, but the improvement effect is not visible. According to the above analysis, we find that the development of China's aerospace industry is still in its infancy, and the problem of technical innovation resource allocation is prominent. At the same time, the input-output ratio has not yet reached the ideal level, which needs to be improved progressively.

Government support and labor quality have adverse effects on the allocation efficiency of technology innovation resource in the aerospace industry, while enterprise scale, market concentration, and regional development levels all have positive impact on the allocation efficiency of technology innovation resource in the aerospace industry. Hence, in terms of funds and policies, the government ought to give full play to the primary role of the market and help the aerospace industry to realize its "hematopoietic" function in a more effective way in combination with the development of the aerospace industry. Secondly, it is necessary to encourage full cooperation within the aerospace industry and strengthen synergy with institutions of higher learning and scientific research institutions to maximize the flow of technology innovation elements. In the end, based on the overall situation of the country, we should promote the balanced development of the aviation and aerospace industry in the east, central, and western regions and strengthen the aviation and aerospace industry in the west and northeast regions to impart experience to the east and central areas. At the same time, it is indispensable to guide the outflow of high-quality talents from the eastern region and lead the development of the aerospace industry in other regions.

Data Availability

The development data of China's aerospace industry used to support the results of this study have been published in the China high-tech statistics yearbook 2017 published by the National Bureau of Statistics of China in 2017. The data can be downloaded from the national bureau of statistics website.

Conflicts of Interest

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

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