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# A Study on the Efficiency of China's Express Industry Based on Three-Stage SBM Model

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## Abstract

This article focuses on the spatiotemporal evolution characteristics of the efficiency of the express delivery industry in 31 provinces in China from 2011 to 2019. Since the express delivery business contributes significantly to the improvement of industrial structure and economic competitiveness, the temporal and spatial characteristics of its efficiency are crucial. In this paper, a three-stage SBM model is adopted to analyze the efficiency. The following are the findings: First, the express delivery industry is significantly affected by the external environment and also by random factors. The optimization of the industrial structure will reduce the input redundancy, and the improvement of the Internet level will lead to input redundancy. Second, China's eastern, central, and western regions have the same overall efficiency change trend in the express delivery industry, with the highest in the central region, followed by the eastern region, and the lowest in the western region. Third, the technical efficiency of the express delivery industry is mainly affected by its scale efficiency. Our research results provide an empirical basis for government policies and social-related investments.

**Keywords:** Express industry, Efficiency, Three-stage SBM model.

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**Ethical:** This study followed all ethical practices during writing.
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## 1. Introduction

The logistics industry is the basic industry of modern economic development. The efficient and high-quality development of the logistics industry plays a vital role in economic development. The improvement in the efficiency of the logistics industry will help to improve the industrial structure of the region or country and change the economic growth model of the region [1-4]. There is no doubt that the logistics industry has an effect on the development of the modern economy. As a new transportation service mode of the logistics industry, the express industry is to quickly and safely complete the point-to-point third-party transportation service mode through its own or independent joint venture networks such as railway and aviation. Under the influence of COVID-19, the efficient operation of the express delivery industry can significantly affect

the low cost of goods. The high efficiency of the express industry will effectively promote the development of commodity circulation. On the contrary, the low efficiency of the express industry will bring a waste of time, resources, and costs to enterprises and regions. To effectively study the efficiency of the express industry, the author takes the development of the express industry in 31 regions of China as the research sample to make an empirical study on its efficiency.

## 2. Research Review

The growth of China's express business from 1993 to 2019 may be separated into three stages: support and satisfaction, leading and enabling, and financing reform [5].

When studying the efficiency of the express industry, different scholars adopt different theoretical methods. Chan, et al. [6] used the analytic hierarchy process to study the efficiency of the express industry through index weight Chan, et al. [6]. Kozłowska [7] used the super-efficiency DEA model to calculate the efficiency of the Polish express industry, and evaluated the efficiency state of its express industry through the Mamquist model Kozłowska [7]. Meschi, et al. [8] used the data envelopment analysis method to define the efficiency level of the express industry by calculating the DEA relative efficiency of the express industry Meschi, et al. [8]. Chodakowska and Nazarko [9] measured and evaluated the express efficiency of an express company in different stages through the network DNA model Chodakowska and Nazarko [9]. Among them, there are abundant studies on the efficiency of China's express industry. Wang and Tan [10] used the DEA Tobit model to study the efficiency of China's express industry at the municipal level Wang and Tan [10]. Wu and Huang [11] investigated and measured the efficiency development level of China's private enterprise express industry Wu and Huang [11]. Xu, et al. [12] studied China's provincial and express efficiency levels through data envelopment analysis. The results show that most express enterprises in Anhui Province have input redundancy Xu, et al. [12]. Qin, et al. [13] calculated the express efficiency level of Guangxi Province Qin, et al. [13]. Ding [14] conducted an empirical study on the efficiency of the express industry in 31 provinces and cities in China Ding [14]. Liu and Qi [15] focused on the efficiency level of cooperation in the express industry in different regions Liu and Qi [15].

The research on the efficiency of the express industry and its influencing factors started relatively late, which is mainly due to the rapid evolution of the express industry under the influence of emerging technologies in the last 20 years. Among these, research on express industry efficiency frequently focuses on the express industry in a region or country, or on the express industry and enterprise efficiency in a region or country. There are relatively few studies on the temporal and spatial evolution of the efficiency of the express industry, ignoring the differences in the efficiency of the express industry in different provincial regions. At the same time, there are relatively few studies on the influencing factors of the efficiency of the express industry. To conduct an in-depth study on the efficiency of the express industry, the author used express industry data from 31 Chinese provincial regions from 2011 to 2019 as the research sample and conducted an empirical study on the temporal and spatial evolution of the efficiency of China's express industry using the three-stage SBM model and investigated the main factors influencing the efficiency of its express industry using the Stochastic Frontier Analysis (SFA) method. This study has three advantages. First, it can complete the regional and time comparative analysis of the efficiency of the express industry. Second, it focuses on the socio-economic environmental variables that affect the efficiency of the express industry. Third, the accuracy and reliability of the efficiency of the express industry are guaranteed by eliminating the influence of environmental factors and random interference.

## 3. Model Theory and Index Selection

### *3.1. Three-stage SBM Model Theory*

Data envelopment analysis (DEA) was proposed in 1978. It is a mature operational research method to measure the efficiency of decision-making units. The traditional DEA model is a radial model, which cannot consider the influence of relaxation variables. The Slacks-Based Measure (SBM) model considers the input and output relaxation variables of each decision-making unit, and directly introduces them into the objective function, which can measure the non-efficiency caused by the relaxation variables compared with the efficiency frontier and can effectively deal with the input and output relaxation problem.

This paper only performed SFA regression decomposition on the input relaxation variables of the express industry and adjusted the input variables. In the second decision, this paper stacked all relaxation variables to estimate only a single SFA regression. This method can ensure that the degree of freedom of model processing is higher. The adjusted input-output variables were used to measure the efficiency of China's express industry of each decision-making unit again. This time, the efficiency has eliminated the influence of environmental factors and random factors, which is relatively true and accurate.

### *3.2. Index Selection and Data Description*

The three-stage SBM model needed to select DEA input-output indicators and environmental variable indicators. According to previous studies, the efficiency input of the express industry was mainly considered from three aspects: human, financial and material resources and the output were only considered from the aspects of business volume and business income. This research chose the measures based on the application of scientific methods and principles, representativeness, and availability: the number of workers, fixed assets, and business outlets indicated the express industry's human, financial, and material investment indicators, respectively. As the fixed assets of the express industry depend on the whole logistics industry, the whole of society's fixed assets investment in transportation, warehousing, and postal industry was selected to represent the fixed investment in the express industry. As it is difficult to ascertain the number of employees and outlets in the express industry in each province, the number of postal industry employees and postal business outlets was chosen instead. In terms of output, the express business income and express volume were selected, and increase in the average service

population of each business outlet was chosen to represent the service capacity level of the express industry in each province.

Environmental variables mainly include per capita Gross Domestic Product (GDP), industrial structure, urbanization rate, local financial transportation expenditure, and Internet penetration. The per capita GDP reflects the economic development level of each province. The more economically developed regions will provide strong material support for the development of the express industry. At the same time, the stronger the consumption ability and online shopping ability of residents in economically developed regions will promote the development of the express industry. The proportion of secondary and tertiary industries in GDP was selected as the industrial structure. The higher the level of industrial structure; the higher the level of industrial manufacturing and service industries. The goods transported by the express industry are mainly industrially manufactured goods. The express industry belongs to the modern service industry. Therefore, the development of the express industry is closely related to the level of industrial structure. The urbanization rate is the proportion of the urban population in the total population and measures the level of regional social development. Urbanization means a series of changes from township to cities, such as regional employment mode, living environment, and social security. As a result, residents' consumption habits, consumption ideas, and consumption modes have also changed. Since the entire consumption scale of e-commerce in cities and towns is now higher than that in rural areas, the express industry is concentrated in cities and towns, which is unfavorable for coordinated regional development. The urbanization rate of different provinces has different degrees of effect on the express industry. Local financial transportation expenditure measures the support of local governments to the express industry. The higher the local government attaches importance, the more conducive it is to the development of the express industry. Internet penetration measures the level of Internet development. The rapid development of the Internet has spawned e-commerce. The express industry is closely related to the development of e-commerce. Internet penetration in different regions will have different effects on the express industry.

The input-output indicators and environmental variable indicators are shown in the Table 1.

**Table 1.**
Input-output indicators and environmental variable indicators.

| Classify | Primary index | Secondary index |
|---|---|---|
| Input index | Manpower input | Number of employed persons in postal industry (person) |
| | Financial input | Postal business outlets (offices) |
| | Material input | Investment in fixed assets of the whole society in transportation, warehousing and postal industry (RMB100mn)<br>※"RMB" means the Chinese currency "Renminbi". |
| Output indicators | Business level | Express business income (Ten thousand yuan) |
| | | Express volume (10000 pieces) |
| | service level | Average service population of each business outlet (ten thousand people) |
| environment variable | Economic development level | Per capita GDP = GDP / total population (RMB100mn) |
| | Industrial structure level | Industrial structure = total value of secondary and tertiary industries / GDP (%) |
| | Social development level | Urbanization rate = urban population / total population (%) |
| | Government support | Local financial transportation expenditure (RMB100mn) |
| | Internet level | Internet penetration (%) |

This paper selected the panel data of 31 provinces in China from 2011 to 2019 for analysis. The Internet penetration rate mainly comes from China's National Bureau of Statistics and the statistical report on the development of China's Internet. Other indicators are from the National Bureau of Statistics of China. Some missing values are filled by linear interpolation.

## 4 Efficiency Analysis of China's Express Industry

### *4.1. Analysis of the Current Situation of China's Express Industry*

The express business entered China following the establishment of reform and opening up in 1978. In 1980, China Post opened the international express mail service (EMS), which was the beginning of the development of China's express industry. The establishment of China express industry in 1985 marked the rise of the express industry in China. In the subsequent period, China express company occupied most of the market share in the international and domestic express business market, but it was difficult to meet the social needs due to its high price, rigid system, and other disadvantages. In the 1990s, private express companies appeared, and state-owned and private companies were interdependent and competitive. China joined the World Trade Organization (WTO) in 2001 and fully opened the express market to foreign capital in 2006. Since then, the express industry has gradually formed three main bodies: private, state-owned, and foreign capital.

With the rapid development of China's economy, the total business volume and revenue of China's express industry are expanding.

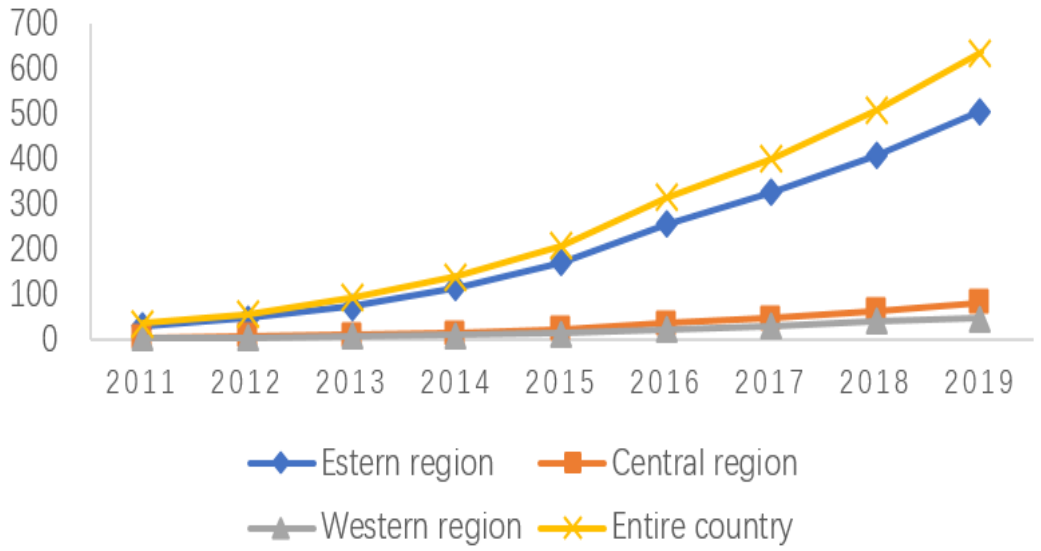


**Figure 1.**
Express business volume (100 million pieces).

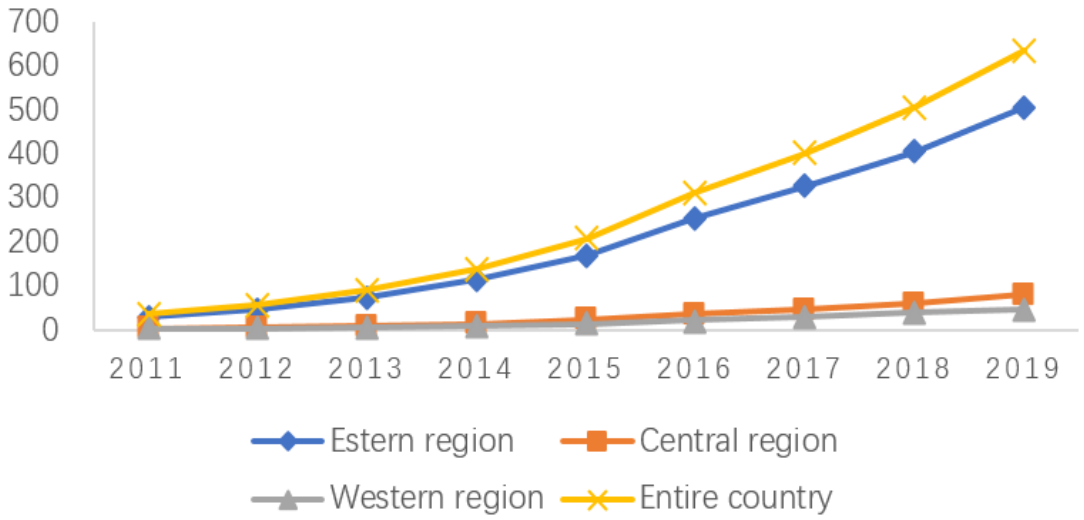


**Figure 2.**
Express business revenue (RMB100mn).

According to the data of the state post administration of the People's Republic of China and the State Bureau of Statistics, the total amount of express business in China in 2011 was 3.7 billion pieces, and the express business revenue reached 75.8 billion yuan. The express business revenue accounts for 48.5% of the total revenue of the postal industry. The regional distribution shows a pattern of high in the East and low in the West. The express business volume in the eastern region was 2.94 billion pieces, with business revenue of 61.4 billion yuan. The total volume of express business in the central region was 410 million pieces, and the business revenue reached 7.53 billion yuan. The amount of express business in the western region was 330 million pieces, and the business income was 6.84 billion yuan. Figure 1 shows the changes in regional volume of the express business in China from 2011 to 2019.

Subsequently, the express business volume and income increased year after year. After 2014, the growth curve was gradually steep. The total amount of express business in China exceeded 14 billion pieces and the business revenue exceeded 200 billion yuan. The gap between the central and western regions began to widen gradually. In 2019, the total volume of express business in China reached 63.5 billion pieces, a year-on-year increase of 25.3%, and the total business revenue reached 749.8 billion yuan, a year-on-year increase of 24.2%, accounting for 77.8% of the total revenue of the postal industry. There are great regional differences, among which the eastern region is far ahead, with the total amount of express business reaching 50.6 billion pieces, a year-on-year increase of 25%, and the total revenue reaching 601.6 billion yuan, a year-on-year increase of 24.5%.

The growth trend in the central and western regions is stable. The central region continued to speed up, with a total business volume of 8.2 billion pieces, a year-on-year increase of 30.9%, and total revenue of 84.4 billion yuan, a year-on-year increase of 24.5%. The western region is relatively backward, with a total business volume of 4.7 billion pieces, a year-on-year increase of 19.4%, and total revenue of 63.8 billion yuan, a year-on-year increase of 20.4%. Figure 2 shows the changes in regional revenue of the express business in China from 2011 to 2019.

It can be seen that China's express industry presents a high-speed and stable development trend as a whole, but the regional differences are obvious and continue to expand. To promote the regional coordinated development of the express industry, it is necessary to further study the efficiency of the express industry in different provinces and regions.

*4.2. Empirical Analysis of the Efficiency of China's Express Industry*

*4.2.1. Phase I Efficiency Analysis*

Firstly, the SBM model was used to calculate the efficiency value of the express industry in the first stage of 31 provinces in China, and the mean value was obtained for different regions, and the standard deviation and coefficient of variation of each year were calculated. The efficiency values of the first stage are shown in the Table 2.

**Table 2.**
Efficiency values of express industry in the first stage in different regions of China.

| Year | Eastern mean | Central mean | Western mean | National average | standard deviation | Coefficient of variation |
|---|---|---|---|---|---|---|
| 2011 | 0.471 | 0.547 | 0.358 | 0.447 | 0.305 | 0.683 |
| 2012 | 0.470 | 0.431 | 0.326 | 0.404 | 0.264 | 0.654 |
| 2013 | 0.487 | 0.466 | 0.262 | 0.395 | 0.273 | 0.693 |
| 2014 | 0.527 | 0.479 | 0.311 | 0.431 | 0.261 | 0.606 |
| 2015 | 0.561 | 0.581 | 0.392 | 0.501 | 0.281 | 0.560 |
| 2016 | 0.379 | 0.492 | 0.362 | 0.401 | 0.284 | 0.707 |
| 2017 | 0.552 | 0.518 | 0.408 | 0.487 | 0.310 | 0.635 |
| 2018 | 0.593 | 0.454 | 0.440 | 0.498 | 0.287 | 0.576 |
| 2019 | 0.579 | 0.506 | 0.502 | 0.531 | 0.296 | 0.557 |
| Mean | 0.513 | 0.497 | 0.374 | 0.455 | 0.285 | 0.626 |

From 2011 to 2019, the average technical efficiency of the express industry in China showed a fluctuating growth trend. It showed that it decreased year by year from 2011 to 2013, increased to 0.501 in 2015, decreased to 0.401 in 2016, and returned to the trend of increasing year by year from 2017 to 2019.

From the perspective of the three regions in the east, central and west, the eastern region is higher than the central and western regions during the period, showing a "growth-decline-growth" trend as a whole. From 2011 to 2014, it increased steadily from 0.471 to 0.5612016 to 0.37920, rebounded to 0.552 after 2017, and continued to maintain the growth trend. The central region as a whole showed a "decline - growth - decline" trend. It reached its highest value of 0.581 in 2015, showing a downward trend in 2016 and stabilizing at 0.506 in 2019. The efficiency value of the express industry in the western region is the lowest, showing a trend of "falling first and then rising" as a whole.

From 2011 to 2013, it decreased from 0.358 to 0.262. After 2014, it showed an overall growth trend year by year, reaching the highest value of 0.502 in 2019, gradually leveling with the central region. From the standard deviation and coefficient of variation, the efficiency value of the express industry in 31 provinces in China decreased year by year from 2011 to 2015.

The efficiency difference between provinces was the largest in 2016 and narrowed again after 2017. In 2016, the business income, express volume, and average service population of each express industry business outlet improved in comparison to 2015, but the efficiency was the lowest. The reason is that the investment growth rate of that year was too high, the fixed asset investment increased by 15% year-on-year and the growth rate ranked second in the investigation year. Business outlets increased by 37.13% year-on-year, ranking first in the investigation year. The growth rate of its output level ranks third. It failed to achieve a high output level, resulting in low utilization of input and possible waste of input resources.

The eastern region has a high economic level, strong consumption capacity, and obvious location advantages, which is conducive to the rapid development of the express industry. One belt, one road, Middle East countries with low economic level, which has a relatively low economic level. The development of the express industry here is lagging behind. So, the efficiency is low.

But with the development of the western region and the strategy of "Central China's rise" and the "one belt and one road" initiative, the development in recent years has been increasing continuously and has great potential for development. The efficiency of the express industry in different regions may be affected by its external environment or random factors, which needs further analysis.

*4.2.2. Second stage SFA Regression Analysis*

This stage took account of industrial structure, urbanization rate, per capita GDP, local fiscal expenditure, and internet penetration as explanatory variables and five environmental variables such as fixed asset investment relaxation variable, employee relaxation variable, and business outlet relaxation variable as explanatory variables for SFA regression analysis to eliminate the influence of external environmental differences and to realize the objectivity and impartiality of efficiency evaluation in different provinces. The regression results are shown in the Table 3.

**Table 3.**
Second stage SFA regression.

| Classify | Model 1 Slack variable of fixed asset investment | | Model 2 Employee relaxation variable | | Model 3 Outlet relaxation variable | |
|---|---|---|---|---|---|---|
| | coefficient | T value | coefficient | T value | coefficient | T value |
| Constant Term | -8844.53*** | -9.56 | -10792.4*** | -101.58 | -22654.91*** | -144.59 |
| Industrial Structure | -2108.03*** | -3.01 | -22408.54*** | -242.77 | -9834.13*** | -51.86 |
| Urbanization Rate | -710.09** | -2.58 | 16273.98*** | 77.92 | 91.82 | 0.11 |
| Per Capita GDP | 171.41* | 1.96 | 1114.31 | 1.66 | -1250.94*** | -2.76 |
| Local Financial expenditure | 94.19 | 1.07 | 10052.33*** | 5.44 | -642.9*** | -2.62 |
| Internet Penetration | 1470.62*** | 6.04 | -11251.15*** | -16.01 | 9534.46* | 7.93 |
| $\sigma^2$ | 915255*** | 24707 | 244784860*** | 244743190 | 13426847* | 9539684 |
| $\gamma$ | 0.84*** | 56.29 | 0.55*** | 13.53 | 0.84*** | 76.10 |
| Log Likelihood | -2117.54 | | -3005.89 | | -2521.96 | |
| Unilateral inspection value | 205.41*** | | 51.59*** | | 178*** | |

**Note:** *, * *, * * * respectively indicate the significance at the level of 10%, 5% and 1%.

The following three characteristics were obtained from the regression results. First, model 1 to model 3 shows the values of Y, which are 0.84, 0.55, and 0.84 respectively that were than 0.5. At the same time, they passed the significance test at the 1% level, indicating that there was a joint influence of management factors and the random error term, which was suitable for SFA regression. Second, the unilateral test values passed the significance test at the 1% level, indicating that the significance of the model was good. Third, the regression coefficients of multiple environmental variables on the relaxation variables passed the significance test, indicating that the environmental variables had a significant effect on the relaxation variables, which in turn affected the efficiency of the express industry.

Further analyze the coefficient of environmental variables to input relaxation variables. If the coefficient is positive, it indicates that environmental variables will increase input redundancy and waste resources. If the coefficient is negative, it indicates that the environmental variable will reduce the input redundancy and is conducive to the rational utilization of resources. From different environmental variables, the industrial structure had a significant negative impact on the fixed asset investment, employees and business outlets of the express industry; the urbanization rate had a significant negative effect on the relaxation variable of fixed asset investment and a significant positive effect on the relaxation variable of employees; Per capita GDP had a significant positive effect on the relaxation variable of fixed asset investment and a negative effect on the relaxation variable of business outlets; local fiscal expenditure had a significant positive effect on fixed-asset investment and employee relaxation variables, and a significant negative effect on business outlet relaxation variables; Internet penetration has a significant positive effect on the relaxation variables of fixed asset investment and business outlets, and a significant negative effect on the relaxation variables of employees. Therefore, the increase in the proportion of secondary and tertiary industries in the national economy is conducive to reducing the redundancy of various inputs in China's express industry and improving its efficiency. Therefore, it is necessary to further optimize the level of China's industrial structure. Urbanization rate, per capita GDP, and local fiscal expenditure have significant effects on only two input relaxation variables, and the impact directions are different, which needs to be determined according to the specific situation. The Internet level has a significant positive effect on unwanted, indicating that it will lead to increased investment redundancy in the express industry. In recent years, the rapid development of China's Internet level has spawned a large number of online transactions. To improve the transportation capacity of goods, the express industry has invested a lot in infrastructure construction and increased the number of business outlets that will, inevitably, lead to the blind expansion of investment scale and waste of resources. Therefore, in the period of rapid development of the Internet, the development of the express industry should be more rational.

*4.2.3. Phase III Adjusted Efficiency Analysis*

The adjusted input and original output were again evaluated by the SBM model to obtain the efficiency of the express industry in the third stage. The results are shown in the Table 4.

On the whole, the efficiency of the adjusted express industry presents the following different characteristics compared with that before the adjustment. First, the total average efficiency after adjustment is 0.685, which is higher than that before adjustment. It showed that the first stage without excluding environmental variables underestimates the efficiency of China's express industry. Second, the efficiency growth trend of the express industry in various regions and the whole country has changed. After adjustment, the changing trend of the East, middle and West was consistent as a whole, showing the characteristics of "growth-decline-growth-decline", and the lowest value appeared in 2016. It showed that after eliminating the interference of external environmental variables, the express industry in various regions presents similar development characteristics under the same development environmental conditions. Third, the ranking among regions has changed. Before the adjustment, the efficiency value of the express industry in the East was the highest, the middle was the second and the west was the lowest. After adjustment, the efficiency value of the express industry in the central region was the highest, followed by the East and the West.

**Table 4.**
Efficiency values of express industry in the third stage in different regions of China.

| Year | Eastern mean | Central mean | Western mean | National average | standard deviation | Coefficient of variation |
|---|---|---|---|---|---|---|
| 2011 | 0.652 | 0.640 | 0.653 | 0.650 | 0.186 | 0.286 |
| 2012 | 0.677 | 0.729 | 0.705 | 0.701 | 0.163 | 0.232 |
| 2013 | 0.718 | 0.711 | 0.656 | 0.692 | 0.175 | 0.253 |
| 2014 | 0.768 | 0.777 | 0.723 | 0.753 | 0.159 | 0.211 |
| 2015 | 0.730 | 0.782 | 0.693 | 0.729 | 0.162 | 0.223 |
| 2016 | 0.396 | 0.542 | 0.459 | 0.458 | 0.264 | 0.577 |
| 2017 | 0.692 | 0.647 | 0.642 | 0.661 | 0.195 | 0.295 |
| 2018 | 0.778 | 0.750 | 0.789 | 0.775 | 0.177 | 0.229 |
| 2019 | 0.746 | 0.741 | 0.743 | 0.744 | 0.171 | 0.231 |
| Mean | 0.684 | 0.702 | 0.674 | 0.685 | 0.204 | 0.298 |

**Table 5.**
Efficiency value and ranking change of express industry in China's provinces before and after adjustment.

| Region | Before Adjustment | | | After Adjustment | | | Ranking Change | | |
|---|---|---|---|---|---|---|---|---|---|
| | TE | PTE | SE | TE | PTE | SE | TE | PTE | SE |
| Beijing | 0.820 | 0.870 | 0.945 | 0.734 | 0.991 | 0.742 | -4 | 2 | -16 |
| Tianjin | 0.767 | 0.847 | 0.902 | 0.770 | 0.987 | 0.778 | 0 | 2 | -6 |
| HeBei | 0.402 | 0.897 | 0.493 | 0.930 | 0.969 | 0.953 | 9 | -2 | 28 |
| ShanXi | 0.358 | 0.404 | 0.856 | 0.630 | 0.863 | 0.726 | -7 | 4 | -9 |
| NeiMengGu | 0.208 | 0.240 | 0.860 | 0.544 | 0.877 | 0.624 | 3 | 12 | -19 |
| LiaoNing | 0.365 | 0.440 | 0.825 | 0.704 | 0.930 | 0.755 | 2 | 10 | -2 |
| JiLin | 0.301 | 0.415 | 0.788 | 0.679 | 0.890 | 0.759 | 4 | 8 | 3 |
| HeiLongJiang | 0.281 | 0.479 | 0.706 | 0.770 | 0.916 | 0.833 | 17 | 3 | 20 |
| ShangHai | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0 | 0 | 0 |
| Jiangsu | 0.543 | 0.609 | 0.898 | 0.746 | 0.853 | 0.876 | 2 | -10 | 2 |
| Zhejiang | 0.943 | 1.000 | 0.943 | 0.977 | 1.000 | 0.977 | -1 | 0 | 1 |
| Anhui | 0.336 | 0.566 | 0.715 | 0.689 | 0.833 | 0.819 | 2 | -10 | 17 |
| Fujian | 0.435 | 0.463 | 0.938 | 0.648 | 0.881 | 0.733 | -8 | 2 | -15 |
| Jiangxi | 0.362 | 0.562 | 0.723 | 0.638 | 0.843 | 0.751 | -7 | -8 | 9 |
| Shandong | 0.320 | 0.457 | 0.749 | 0.693 | 0.767 | 0.898 | 6 | -8 | 17 |
| Henan | 0.324 | 0.575 | 0.642 | 0.716 | 0.819 | 0.871 | 8 | -12 | 24 |
| Hubei | 0.222 | 0.256 | 0.873 | 0.515 | 0.712 | 0.715 | 0 | -1 | -12 |
| Hunan | 0.254 | 0.361 | 0.746 | 0.640 | 0.762 | 0.834 | 3 | -4 | 14 |
| Guangdong | 0.811 | 1.000 | 0.811 | 1.000 | 1.000 | 1.000 | 5 | 0 | 15 |
| Guangxi | 0.248 | 0.459 | 0.715 | 0.732 | 0.851 | 0.853 | 15 | -2 | 21 |
| Hainan | 0.611 | 0.731 | 0.849 | 0.694 | 1.000 | 0.694 | -4 | 9 | -11 |
| Chongqing | 0.214 | 0.256 | 0.843 | 0.469 | 0.779 | 0.601 | -2 | 1 | -17 |
| Sichuan | 0.159 | 0.172 | 0.929 | 0.374 | 0.588 | 0.635 | 0 | 0 | -23 |
| Guizhou | 0.204 | 0.271 | 0.774 | 0.508 | 0.793 | 0.639 | 2 | 1 | -8 |
| Yunnan | 0.234 | 0.392 | 0.733 | 0.591 | 0.916 | 0.658 | 2 | 12 | -1 |
| Xizang | 0.742 | 1.000 | 0.742 | 0.474 | 0.974 | 0.488 | -22 | -7 | -7 |
| Shanxi | 0.235 | 0.320 | 0.789 | 0.569 | 0.811 | 0.695 | 0 | 1 | -5 |
| Gansu | 0.327 | 0.499 | 0.746 | 0.686 | 0.879 | 0.774 | 2 | -2 | 10 |
| Qinghai | 0.882 | 0.910 | 0.951 | 0.810 | 1.000 | 0.810 | -1 | 5 | -10 |
| Ningxia | 0.889 | 1.000 | 0.889 | 0.629 | 0.949 | 0.659 | -21 | -10 | -17 |
| Xinjiang | 0.310 | 0.471 | 0.755 | 0.670 | 0.964 | 0.693 | 2 | 8 | -4 |
| mean value | 0.455 | 0.578 | 0.811 | 0.685 | 0.884 | 0.769 | -6 | -4 | 2 |

It showed that the eastern region had a good external environment or the influence of random factors, and its own development level of express industry was overestimated. The external environment or random factors in the central region had a negative impact on the development of its express industry, thus its actual efficiency value was better than its results.

Both before and after the adjustment, the western region was lower than the national average level, indicating that the resource allocation efficiency of the express industry was low, which needs to be further optimized and the resource allocation structure. Fourth, the difference in efficiency between regions has changed. The adjusted standard deviation was between 0.159 ~ 0.264, and the coefficient of variation was between 0.211 ~ 0.577, which was lower than that before the adjustment, indicating that after excluding the influence of external environmental variables and random factors, the difference between the express industry in each province was smaller, and the stability of the national express industry as a whole has improved.

To further study the efficiency differences and ranking changes of provinces before and after adjustment, the comprehensive efficiency values of the express industry before and after adjustment were decomposed into pure technical efficiency and scale efficiency values from the perspective of variable returns to scale, and the average efficiency of provinces from 2011 to 2019 was obtained to get the efficiency ranking changes of different provinces. The pure technical efficiency value represents the management and institutional level of the express industry in each province, whereas the scale efficiency value represents the difference between the existing industry scale and the optimal scale of the express industry. Table 5 shows the efficiency and ranking changes of the express industry in China's provinces before and after the adjustment.

Overall, the efficiency of the express industry in most provinces improved after adjustment, and the ranking changed to varying degrees. In terms of technical efficiency, the top five before adjustment were Shanghai, Zhejiang Province, Ningxia, Qinghai Province, and Beijing, of which the average value of Shanghai was 1, reaching the technical frontier. After adjustment, the number of provinces with effective technical efficiency increased to include Guangdong Province. After adjustment, Ningxia ranks 30 in the national ranks. The last five provinces, both before and after the adjustment, included Guizhou, Sichuan, Inner Mongolia, and Chongqing. It showed that the express efficiency of Ningxia Province performed well from 2011 to 2019 due to the good external environment and random factors.

The distribution characteristics and numerical value of pure technical efficiency before adjustment were not different from that of technical efficiency. After adjustment, the ranking changed greatly. Qinghai Province and Hainan Province joined the ranks of pure technical efficiency, Tibet and Ningxia ranked 26th and 30th respectively. It showed that before the adjustment, the efficiency value of the express industry in all provinces was mainly subject to its management and system level, and the external environment and random factors had an adverse effect on this level. The distribution characteristics and value of scale efficiency after adjustment were not different from that of technical efficiency, and the ranking changes were comparable with that before adjustment. For example, Hebei, Henan and Guangxi have 28, 24 and 21 SE respectively in the ranking change, and Sichuan Province, Inner Mongolia, and Chongqing decreased by 23, 19, and 17 respectively, indicating that the efficiency value of the express industry of each province after adjustment was mainly subject to its scale efficiency level, and the real scale efficiency level is highly recognized.

## 5. Conclusions and Policy Recommendations

The temporal and spatial evolution of China's express industry efficiency was studied in accordance with the three-stage SBM model. Specific conclusions were made as follows:

1. From the regression analysis of the second stage, the overall environmental variables had a significant effect on each input relaxation, indicating that China's express industry was affected by the external environment and random factors, which interfere with the efficiency measurement to a certain extent. The increase in the proportion of secondary and tertiary industries in the national economy is conducive to reducing the redundancy of various inputs in China's express industry and improving its efficiency. The Internet level had a significant positive effect on unwanted, indicating that it will lead to an increase in investment redundancy in the express industry. Urbanization rate, per capita GDP, and local fiscal expenditure significantly affected two input relaxation variables, and the directions of their effect were different, which need to be determined according to the specific situation.

2. From the DEA results of the third stage, among different provinces, the express industry efficiency of Shanghai, Zhejiang, Qinghai, Guangdong, and Beijing was higher. The express industry in Guizhou, Sichuan, Inner Mongolia, and Chongqing was inefficient. In different regions, the change trends of the East, Middle, and West were the same on the whole, showing the characteristics of "growth-decline-growth-decline". The central part is most efficient, the eastern part is the second, and the western part is the lowest. It showed that there were obvious differences in the efficiency of the express industry between different provinces and regions.

3. From the comparative analysis of the first stage and third stages, and before the adjustment, the efficiency value of the express industry in the East was the highest, the middle was the second, and the west was the lowest. After adjustment, the efficiency value of the express industry in the middle area is most efficient, followed by the East and the West. It shows that the eastern region had a good external environment or the influence of random factors, and its own development level of express industry was overestimated. The external environment or random factors in the middle area had a negative effect on the development of its express industry, so its actual efficiency value was better than its results.

4. Before the adjustment, the efficiency value of the express industry in all provinces in China was mainly subject to its management and system level, and the external environment and random factors had an adverse effect on this level. After adjustment, the efficiency value of the express industry in each province was mainly subject to its scale efficiency level, and the real scale efficiency level was overestimated. We should further optimize the input and output structure, optimize the input-output ratio, and promote the efficiency of the express industry.

Based on the above research results, the following policy suggestions are put forward:

First, continue to improve the development environment of the express industry. External socio-economic environment variables will have an important effect on the improvement of the overall efficiency of the express industry. Therefore, different regions should formulate express industry policies in line with the basic conditions of the region, improve the

industrial planning of the express industry in the region, formulate relevant industrial policies, and provide a good external environment for the efficient development of the express industry.

Second, improve resource allocation efficiency and scale efficiency. There are obvious differences in the efficiency of the express industry in different regions, and the overall scale efficiency of China's express industry is not high. Therefore, all provinces and regions should do a good job in the top-level design of the express industry, introduce relevant policies, and improve the management level, avoid repeated construction, integrate existing resources, avoid resource waste, and realize input-output optimization to improve the efficiency of the express industry.

Third, actively carry out regional cooperation and build cross-provincial regional express industry coordination. There are obvious differences in express efficiency among provincial regions. We should reduce the differences in the efficiency of the express industry in middle and West region of China and improve the collaborative efficiency of the express industry in different regions by improving the reasonable division of labor within the industry in different regions. We should build a trans-regional express industry system, form express industry clusters, and improve the development level of the regional express industry.

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