Research Article

Research on the Operating Efficiency of Chinese Listed Pharmaceutical Companies Based on Two-Stage Network DEA and Malmquist

Tsung-Xian Lin ¹, Zhong-huan Wu ¹, Xiao-xia Ji ², and Jia-jia Yang ³

¹Department of Business Administration, Guangzhou Huashang College, Guangzhou 511300, China

²School of Business, Guangdong University of Foreign Studies, Guangzhou 510000, China

³Department of Public Policy, King's College London, London WC2R 2LS, UK

Correspondence should be addressed to Xiao-xia Ji; 976224056@qq.com

Received 20 May 2021; Accepted 16 June 2021; Published 23 June 2021

Academic Editor: Yiwen Zhang

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The development of pharmaceutical companies, which is an important part of the national economy and industry, is closely related to people's livelihood issues. With the era of big data, this paper uses the two-stage DEA and Malmquist method to evaluate the efficiency of listed Chinese pharmaceutical companies. From a static and dynamic perspective, it analyses the total factor productivity index, pure efficiency change index, scale efficiency index, and so on. The results show that government subsidies have not had a positive impact on most Chinese pharmaceutical companies, and for firms, diseconomies of scale caused by rapid expansion should be avoided.

1. Introduction

Since the outbreak of the COVID-19, medical health has become the primary topic of concern for the government and the public. The operation of pharmaceutical companies has become the focus of discussion. At present, China's pharmaceutical manufacturing industry has long been in a state of low industry concentration, high product homogeneity, and weak technological innovation capabilities. It has a large gap with the international advanced level. In recent years, China's various medical reform policies and regulations have been promulgated one after another. It has brought many uncertain factors to the development of the pharmaceutical industry. How to adapt to changes in the external environment and further improve operating efficiency has become an

important issue facing the government and enterprises. Based on the above background, this article focuses on the research on the operating efficiency of pharmaceutical companies, innovatively combining the DEA method with Malmquist, taking 164 listed companies in China as a sample, and studying their operating conditions during the five-year period from 2015 to 2019.

The structure of the following parts of this article is as follows. Section 2 collects current scholars' research on the efficiency evaluation of pharmaceutical companies; Section 3 introduces the related content of the two-stage network DEA and Malmquist index method in this article; Section 4 outlines the research of this article process, sample selection, and two-stage DEA data analysis. Section 5 uses Malmquist to analyse the dynamic effects of the data and finally summarizes the research results of this article.

2. Literature Review

At present, many scholars use the DEA method to measure the actual situation of the operating efficiency of pharmaceutical companies and provide suggestions for improvement of the company's operations. For example, Wang [1] selected Chinese biopharmaceutical companies from 2017 to 2019 as a research sample and established a static DEA model to measure their financing efficiency. The results show that although the overall financing efficiency of Chinese biotech companies is not high, the level of it is increasing year by year. And Zhang Zicheng [2] innovatively combined the AHP method with the DEA method, finding that, compared with the scale factor, the deficiency of technology hinders the operating performance of companies such as Lunan Pharmaceutical firm. Meanwhile, Li et al. [3] used a two-step method of factor analysis and SE-DEA model to calculate the financial data of 58 listed pharmaceutical companies in China from 2009 to 2013 and concluded that the overall inefficiency of the pharmaceutical industry is also due to insufficient investment on scale and technology.

Among them, some scholars even divide medical companies into groups to study their operational status in different regions [4, 5]. The research found that there are indeed differences in the operating efficiency as well as in terms of technological innovation of pharmaceutical companies in different regions [6, 7]. For example, Xiong [8] used the panel data of technological innovation of medical companies listed in Guangdong, Shandong, Zhejiang, and Jiangsu as samples to study the allocation of technological innovation resources of pharmaceutical manufacturers in four provinces in China from 2015 to 2017 and finally came to the following conclusions: in the province, Jiangsu pharmaceutical companies have the advantage of pure technical efficiency in innovation activities, while Guangdong pharmaceutical companies performed better in scale efficiency with regard to technological innovation. However, the traditional DEA model cannot study the influencing factors in the process. Therefore, the research studies on the two-stage network DEA model and the Malmquist index method have received widespread attention from many scholars.

Regarding the two-stage network DEA, such method has been applied to plenty of fields. For example, Lewis et al. applied the undirected network DEA method to the efficiency evaluation of Major League Baseball [9]. Additionally, Liang et al. used a two-stage network DEA model to analyse the input-output efficiency of 50 universities in China [10], while Li et al. applied the DEA model under the two-stage expansion structure to the research on the efficiency of R&D in China's provincial regions [11]. At the same time, some researchers also combine two-stage network DEA with other methods. For instance, Chen et al. [12] and Kao [13] combined it with the two-stage additive efficiency decomposition DEA method to study the relative efficiency of 24 non-life insurance companies in Taiwan. Lee and Johnson combined Malmquist under the network DEA structure to study the performance of the semiconductor manufacturing industry [14]. It can be seen that the two-stage network DEA

has been widely used in insurance companies, universities, and other industry research. However, research in the pharmaceutical industry is still relatively rare.

Regarding the Malmquist index method, scholars have also made great achievements. In the field of sustainable e-agriculture, Pan and others used the 31 provinces as the research objects and explored the sustainable development efficiency of agriculture in mainland China through DEA and Malmquist productivity index models [15]. In the medical industry, Hashimoto and Haneda [16] used the conventional DEA method and the Malmquist productivity index method to measure the R&D efficiency of the Japanese pharmaceutical industry from the enterprise level and the industry level, respectively. Empirical evidence shows that the total factor productivity of Japan's pharmaceutical industry is declining, and the main reason for the decline is the sharp decrease in technological changes. What is more, Pannu et al. [17] used the output-oriented VRS model and the Malmquist productivity index method to measure the increase in efficiency and productivity of the Indian pharmaceutical industry over a 10-year period, finding that the increase was mainly due to the growths in technical efficiency. Furthermore, Zhiyue and Qiu [18] also used the Malmquist index method to conduct an empirical analysis of the operating efficiency of China's biopharmaceutical industry from both horizontal and vertical aspects. The results show that the overall operating efficiency of the biopharmaceutical industry is not ideal, and there is a large difference in efficiency between provinces and cities.

In summary, it can be seen that scholars have used many different methods to study the operating efficiency of pharmaceutical manufacturing enterprises, but the research still has the following shortcomings. Firstly, most research studies on the efficiency of pharmaceutical manufacturing enterprises use nonparametric methods. When measuring enterprise efficiency, some scholars only consider a certain aspect of static or dynamic and thus cannot comprehensively analyse the efficiency level and development trend of pharmaceutical manufacturing enterprises. Secondly, there are few literatures on the research of listed pharmaceutical companies using the two-stage network DEA and Malmquist index method, most of which focus on the traditional DEA method. Finally, in the literature on efficiency influencing factors, the selection of variables is relatively limited, and there are few literatures that consider the R&D capabilities of enterprises. For pharmaceutical manufacturing companies, environmental variables are very important and have a very large impact on the efficiency of the company. Therefore, the external environment of the company should be considered when studying the efficiency of the company. Based on the above deficiencies, this paper uses the two-stage network DEA and Malmquist index method to study the operating efficiency of enterprises from both static and dynamic perspectives. When studying the factors affecting the operating efficiency of enterprises, environmental variables have been added and considered from multiple angles in the article, striving for a more comprehensive selection of influencing factors.

3. Research Method

3.1. Two-Stage Network DEA. In the traditional DEA model, we only know the final efficiency values of the entire process, but the specific situation in the whole process is unknown. The information provided by the traditional DEA model is not enough, and the guidance to managers is limited. The two-stage network DEA model can open the “black box” of the production system, which can effectively measure the complex production network. Therefore, this paper also adopts the two-stage network DEA model for performance evaluation and pays more attention to the progressive relationship between the two stages based on the research results of other scholars. Its internal structure is shown in Figure 1.

Among them, X_{ij}^1 ($i = 1, 2, \dots, I$) represents the i -th input of DMU _{j} in the first stage; Z_{dj} ($d = 1, 2, \dots, D$) represents the intermediate variable, namely, it is not only the d -th output of DMU _{j} in the first stage, but also the d -th input of DMU _{j} in the second stage; X_{kj}^2 ($k = 1, 2, \dots, K$) represents the k -th input of the newly added DMU _{j} in the second stage; and y_{rj} ($r = 1, 2, \dots, R$) represents the r -th output of DMU _{j} in the second stage. First of all, calculate the efficiency of the first stage and then calculate the efficiency of the second stage on this basis, which means keeping the efficiency of the first stage unchanged. Finally, the product of the efficiency of the two stages is regarded as the total efficiency of the system. At this point, the model can be established as follows:

The first-stage model (model 1) is given by

$$\text{Max} \quad \frac{\sum_{d=1}^D W_d Z_{d0}}{\sum_{i=1}^I V_i X_{i0}^1}, \quad (1)$$

$$\text{s.t.} \quad \frac{\sum_{d=1}^D W_d Z_{dj}}{\sum_{i=1}^I V_i X_{ij}^1} \leq 1, \quad j = 1, 2, \dots, n, \quad (2)$$

$$\frac{\sum_{r=1}^R U_r Y_{rj}}{\sum_{d=1}^D Z_{dj} + \sum_{k=1}^K t_k X_{kj}^2} \leq 1, \quad j = 1, 2, \dots, n, \quad (3)$$

$$U_r, V_i, W_d, t_k \geq 0, \quad \forall r, i, d, k. \quad (4)$$

Model 1 adds a constraint on the basis of the traditional CCR model, that is, the last constraint. Its purpose is to ensure that the optimal solution of the first stage makes the efficiency value of the second stage not more than 1, so as to ensure that the second stage model must have a feasible solution; otherwise, there may be no feasible solution. Therefore, this constraint is necessary, which was not considered in the previous two-stage DEA model. In model 1, U_r, V_i, W_d, t_k , respectively, represent the weights of the corresponding variables, after considering the study conducted by Cheng and Zheng [19]. The efficiency of each DMU can be obtained by model 1. Record the efficiency of the DMU₀ as θ_1^{0*} .

Then second-stage model (model 2) is given by

$$\text{Max} \quad \frac{\sum_{r=1}^R U_r Y_{r0}}{\sum_{d=1}^D W_d Z_{d0} + \sum_{k=1}^K t_k X_{k0}^2}, \quad (5)$$

$$\text{s.t.} \quad \frac{\sum_{d=1}^D W_d Z_{dj}}{\sum_{i=1}^I V_i X_{ij}^1} \leq 1, \quad j = 1, 2, \dots, n, \quad (6)$$

$$\frac{\sum_{r=1}^R U_r Y_{rj}}{\sum_{d=1}^D W_d Z_{dj} + \sum_{k=1}^K t_k X_{kj}^2} \leq 1, \quad j = 1, 2, \dots, n, \quad (7)$$

$$\frac{\sum_{d=1}^D W_d Z_{d0}}{\sum_{i=1}^I V_i X_{i0}^1} = \theta_1^{0*}, \quad (8)$$

$$U_r, V_i, W_d, t_k \geq 0, \quad \forall r, i, d, k. \quad (9)$$

Solving (5)–(9) can get the efficiency of the second-stage DMU, noting θ_2^{0*} as the efficiency of the second stage. So far, it can be concluded that the total efficiency of the two-stage system DMU₀ is $\theta^{0*} = \theta_1^{0*} \theta_2^{0*}$ (10).

3.2. Malmquist Index. The two-stage network DEA model just horizontally compared the efficiency of listed pharmaceutical enterprises. So we will build the Malmquist index model to make a longitudinal analysis of efficiency and dynamically analyse the change of efficiency.

TFP is total factor productivity index:

$$\begin{aligned} \text{TFP} &= \frac{D_t^u(x_t, y_t)}{D_{t-1}^u(x_{t-1}, y_{t-1})} \times \left[\frac{(D_t(x_t, y_t)/D_{t-1}^C(x_{t-1}, y_{t-1}))}{(D_t^u(x_t, y_t)/D_{t-1}^u(x_{t-1}, y_{t-1}))} \right] \\ &\times \left[\frac{D_{t-1}^C(x_{t-1}, y_{t-1})}{D_t^C(x_{t-1}, y_{t-1})} \times \frac{D_{t-1}^C(x_t, y_t)}{D_t^C(x_t, y_t)} \right]^{(1/2)}. \end{aligned} \quad (10)$$

PEC is pure efficiency change index:

$$\text{PEC} = \frac{D_t^u(x_t, y_t)}{D_{t-1}^u(x_{t-1}, y_{t-1})}, \quad (11)$$

SE is scale efficiency index:

$$\text{SE} = \frac{(D_t^C(x_t, y_t)/D_{t-1}^C(x_{t-1}, y_{t-1}))}{(D_t^A(x_t, y_t)/D_{t-1}^A(x_{t-1}, y_{t-1}))}, \quad (12)$$

TC is technical change index:

$$\text{TC} = \left[\frac{D_{t-1}^C(x_{t-1}, y_{t-1})}{D_t^C(x_{t-1}, y_{t-1})} \times \frac{D_{t-1}^C(x_t, y_t)}{D_t^C(x_t, y_t)} \right]^{(1/2)}, \quad (13)$$

The formula of total factor productivity is

$$\text{TFP} = \text{PEC} \times \text{SE} \times \text{TC}. \quad (14)$$

FIGURE 1: The two-stage network DEA model.

TABLE 1: Variable selection and measurement.

	Variable type	Variable name	Measure
The first stage	Output	Gross costs	Gross costs in corporate annual reports
		Total number of employees	Total number of in-service staff
	Input	Net value of fixed assets	Net value of fixed assets in corporate annual reports
		Gross revenue	Gross revenue in corporate annual reports
The second stage	Output	Net profit	Total profit – income tax
		Gross costs	—
	Input	Government subsidies	Government subsidies that are included in the current profit and loss

4. Empirical Analysis

4.1. Sample Selection. With reference to the definition of pharmaceutical companies, combined with the description of the main business in the annual report of the A-share listed pharmaceutical company and the proportion of the main business in operating income, the study sample is determined. At the same time, to ensure the validity of the analysis results, ST, PT, and ST* companies were excluded, and 164 listed pharmaceutical companies were finally identified as the research samples. The data of inputs and outputs comes from Cathay Pacific database and the annual public report of enterprise.

4.2. Variable Selection

4.2.1. The First Stage of Input and Output Variables. The selection of variables is based on character of listed pharmaceutical companies, and we fully inspect the business characteristics and operation of listed pharmaceutical companies. The inputs selected are gross costs (X_1), total number of employees (X_2), and net value of fixed assets (X_3), and the output is gross revenue (Y_1).

4.2.2. The Second Phase of Input and Output Variables. This paper comprehensively examines the business characteristics and operation of listed pharmaceutical companies. Government subsidies (X_5) as a new input are added to the second stage, and the other input is the gross revenue (X_4) that is the output of first stage, and the final output is net profit (Y_2). More details are shown in Table 1.

4.3. DEA Efficiency Analysis in the First Stage. In first stage (shown in Table 2), no listed pharmaceutical company's technical efficiency reached 1 during 2015–2019. There are 119 companies with technical efficiency between 0.6 and 1.0,

accounting for 73%, indicating that the technical efficiency of these companies is good. The efficiency values of the eight securities companies (Chongqing Taiji Industry, Baiyunshan, Kelun, Huabei, Hisun, Harbin, China Medicine, and Renfu) are below 0.4, indicating that the technical efficiency level of these companies is relatively low, and they need to increase investment.

Five securities companies, Adisseo, Changchun High-Tech, Hualan Biological Engineering, Hengrui, and Zhifei, have achieved technology effectiveness in some years. Adisseo's technical efficiency is effective in 2016 and has dropped significantly after 2016, and the technical efficiency can be improved by referring to the operation method of 2016 when the technology is effective (see Table 3 for specific annual data).

4.4. DEA Efficiency Analysis in the Second Stage. In the second stage (shown in Table 2), there is no company that has reached technical efficiency of 1 during 2015–2019, indicating that all the companies were not effective. There are 97 companies with a technical efficiency value of 0.6–1.0, accounting for 59.5%, which is significantly lower than the first stage. Only 3 companies had technical efficiency below 0.4 (Sinopharm, Xinbang, and Baiyunshan). The technical efficiency in second stage is generally low, but companies with lower efficiency have been promoted, which may be correlated with government subsidies.

Adisseo, Dezhan Health, Jiao, Hengrui, Livzon Group, Shanghai RAAS, and Zhifei Biotechnology have achieved technical efficiency of 1 in some years. And Adisseo is the same as the first stage, the technical efficiency is effective in 2016 and has dropped dramatically after 2016. The technical efficiency of Dezhan Health and Jiao pharmaceutical companies in the second stage has increased; we believe that the first stage is relevant to the second stage in these companies. However, the average technical efficiency of Hualan

TABLE 2: Summary of means of technical efficiency.

Company name	The first stage	The second stage	Total
Adisseo	0.731807447	0.70427645	0.718041949
Anke Bio	0.701258545	0.65681619	0.679037367
Osaikon	0.77517144	0.677756486	0.726463963
Baiyunshan	0.383760611	0.329568568	0.35666459
Bdy	0.621063253	0.668172657	0.644617955
Beilu	0.755456729	0.662521895	0.708989312
Porton	0.626443198	0.653894142	0.64016867
None	0.708205489	0.644792119	0.676498804
Changchun High-Tech	0.754140117	0.760920762	0.757530439
Changjiang Runfa Medicine	0.622444299	0.581956694	0.602200497
Changshan Pharma	0.705379957	0.663215003	0.68429748
DAJY	0.611416622	0.570090491	0.590753556
Dezhan	0.800138709	0.776221753	0.788180231
Jiao	0.68813071	0.761262056	0.724696383
DBBT	0.715738024	0.641593159	0.678665591
VC	0.463121349	0.46703195	0.465076649
Dongcheng	0.67384118	0.680702372	0.677271776
Nhwa Pharm	0.655734649	0.667349718	0.661542183
Ekzy	0.679041427	0.578708106	0.628874767
Fangsheng	0.700194471	0.656633368	0.678413919
Fengyuan	0.58132929	0.49193138	0.536630335
Fczy	0.678039919	0.651980945	0.665010432
Fayy	0.64776847	0.593446924	0.620607697
Fosun Pharm	0.469682442	0.744647296	0.607164869
Fuxiang	0.699215567	0.600348021	0.649781794
Guangji	0.686416693	0.640838606	0.66362765
Kwong Sang Hong	0.739991067	0.650835677	0.695413372
Guang Yuyuan	0.697803931	0.643573172	0.670688552
Lark	0.630381464	0.657746723	0.644064093
Glsj	0.677120987	0.682796241	0.679958614
Sinopharm Hyundai	0.496221436	0.397513751	0.446867593
Harbin Pharm	0.34428928	0.475791143	0.410040211
Haili Bio	0.727883095	0.652682123	0.690282609
Hnhy	0.609983775	0.528580996	0.569282386
Hepalink	0.64389566	0.594403859	0.619149759
Haishun New Pharma	0.750928424	0.661675715	0.706302069
Haisco	0.720451696	0.487743987	0.604097841
Hisoar	0.645544623	0.65460421	0.650074417
Haixin	0.627599087	0.672097746	0.649848417
Hisun	0.353460494	0.409015554	0.381238024
Han Sen Pharm	0.668777752	0.663899646	0.666338699
Hybio	0.636033086	0.580810237	0.608421662
Hengrui	0.837490527	0.961302739	0.899396633
Chase Sun	0.547733919	0.410016	0.478874959
NCPC	0.36259657	0.447801928	0.405199249
Huahai	0.543995409	0.553533665	0.548764537
Hualan Bio	0.807931213	0.595846914	0.701889064
Huaren	0.595328472	0.659644838	0.627486655
HRSJ	0.541774861	0.574425738	0.558100299
China Resources Double-Crane	0.568038828	0.54622275	0.557130789
Huashen Technology	0.719199418	0.674035569	0.696617493
Walter Dyne	0.664596536	0.687196219	0.675896377
Yanbian FC	0.778142258	0.63590963	0.707025944
Kyrgyzstan	0.601616926	0.496027976	0.548822451
Jichuan	0.683807204	0.487854907	0.585831056
Jimin	0.681185309	0.657322504	0.669253906
JYPC	0.685562921	0.649641211	0.667602066
Joincare pharm	0.610082457	0.454142296	0.532112376
Jiangzhong	0.642567847	0.736567664	0.689567756
Jincheng	0.639785389	0.569178368	0.604481878

TABLE 2: Continued.

Company name	The first stage	The second stage	Total
Jinhe Bio	0.623354577	0.649028661	0.636191619
Jinling	0.546235719	0.635576844	0.590906281
Jinshiya	0.715796667	0.644757882	0.680277274
Jingxin	0.68571291	0.570388142	0.628050526
Jinghua	0.636944978	0.641649287	0.639297132
Jingfeng	0.606488959	0.543530495	0.575009727
Jiuqiang	0.786956228	0.700046207	0.743501218
Jiuzhitang	0.645201026	0.516603024	0.580902025
Jiuzhou	0.628567115	0.584155422	0.606361268
CONBA	0.543861375	0.481004348	0.512432862
Kanghong	0.665245011	0.527460836	0.596352924
Kangyuan	0.61414204	0.577926992	0.596034516
Kangzhi	0.684816087	0.656415871	0.670615979
KHB	0.727976507	0.591841298	0.659908903
Kelun	0.378799441	0.493231698	0.43601557
Sunflower	0.556170097	0.511400244	0.533785171
Kunming Pharm	0.534324416	0.551964191	0.543144303
Lummy	0.625056228	0.628112755	0.626584491
LAYN	0.721614484	0.661566479	0.691590481
Lisheng Pharma	0.657353855	0.679177139	0.668265497
Livzon Pharm	0.71738134	0.628871094	0.673126217
LEADMAN	0.714944289	0.624498345	0.669721317
Lianhuan pharm	0.698888411	0.670367118	0.684627765
Lingkang	0.725743874	0.584694518	0.655219196
Lingrui Pharm	0.666997747	0.677070779	0.672034263
Long jin Pharm	0.753570272	0.647133166	0.700351719
Lukang Pharm	0.509027638	0.460965245	0.484996442
Mike Bio	0.742422513	0.650407694	0.696415103
M.k.	0.654220437	0.562356283	0.60828836
Palin Bio	0.703269836	0.65109186	0.677180848
PIEN TZE HUANG	0.763824558	0.726005071	0.744914814
Julie Plec	0.709624166	0.469789228	0.589706697
plyy	0.489613809	0.53054052	0.510077164
CHEEZHENGTTM	0.714689814	0.613582646	0.66413623
Qidi	0.691053939	0.654977334	0.673015636
Qianhong Biopharma	0.70228214	0.679203457	0.690742799
Qianjin Pharm	0.612647181	0.607590824	0.610119003
Qianyuan	0.664973414	0.556845497	0.610909455
Renfu	0.322406425	0.42016555	0.371285988
Renhe Pharmacy	0.596351472	0.672679619	0.634515546
rpsw	0.651166925	0.5912946	0.621230762
Saisheng	0.761947778	0.701836844	0.731892311
SAM	0.671926336	0.659700513	0.665813424
Shanhe Pharmacy	0.734791349	0.650221186	0.692506268
Shkb	0.698069521	0.680387876	0.689228698
Shanghai RAAS Blood Products	0.676407378	0.605561928	0.640984653
Shenqi	0.646589105	0.581969742	0.614279423
Biological Stock	0.760202981	0.756042924	0.758122952
Salvage Pharm	0.463144872	0.502413614	0.482779243
Sts	0.739781567	0.689149244	0.714465406
Scyy	0.699966811	0.603380282	0.651673546
Beijing SL Pharm	0.773760654	0.68883442	0.731297537
Stellite	0.667760149	0.642702048	0.655231099
Shsw	0.73692057	0.657203864	0.697062217
Tat	0.60265023	0.544697259	0.573673745
Taiji Group	0.399279671	0.498518625	0.448899148
Taloph Pharm	0.61924255	0.644434623	0.631838587
Teyi	0.698667383	0.66716684	0.682917112
Tasly	0.41666853	0.630275487	0.523472009
Tiantan Biological	0.733010668	0.657600328	0.695305498

TABLE 2: Continued.

Company name	The first stage	The second stage	Total
Tianyao Pharm	0.646240088	0.613143357	0.629691722
Thdb	0.77883326	0.706539764	0.742686512
Thjm	0.567809163	0.564386742	0.566097953
TRT	0.499628521	0.691621404	0.595624963
Wanbangde	0.427406852	0.537992679	0.482699766
Wondfo	0.715009555	0.631798868	0.673404211
WEDGE INDUSTRIAL	0.736184308	0.643355439	0.689769873
Weiming	0.711826016	0.650321829	0.681073922
Wowu	0.770567021	0.675840362	0.723203692
Wohua	0.703903392	0.661188132	0.682545762
Wosen	0.671912477	0.552904143	0.61240831
AMD	0.750945781	0.61052309	0.680734436
Xianju Pharm	0.609803878	0.607517262	0.60866057
Xiangxue Pharm	0.56837251	0.537740093	0.553056301
Sunflower	0.55841059	0.566683692	0.562547141
NHU	0.632654979	0.4122508	0.52245289
Xinhua	0.488947377	0.556767052	0.522857214
Xinbang	0.440203247	0.395079286	0.417641267
SALUBRIS	0.715240078	0.63026292	0.672751499
BROTHER	0.697594871	0.621553604	0.659574237
Yabao	0.558060463	0.567098443	0.562579453
Yatai	0.59468608	0.568673089	0.581679584
Yananbikang	0.585080092	0.503340182	0.544210137
Yiling Pharm	0.591814993	0.635212897	0.613513945
Yifan	0.659880029	0.609050879	0.634465454
Yibai	0.564093323	0.437330699	0.500712011
Yisheng	0.661646927	0.603737031	0.632691979
Yiduoli	0.648099384	0.597623845	0.622861614
Chinataurine	0.692881108	0.647370414	0.670125761
Gloria Pharm	0.479739963	0.433218753	0.456479358
Baiyao	0.50362558	0.819177469	0.661401524
Zhejiang Medicine	0.500873109	0.515343568	0.508108338
Zhenbao Island	0.66468048	0.494783002	0.579731741
zdzy	0.568909321	0.561712443	0.565310882
Zhifei	0.821043844	0.783585599	0.802314721
Zhongguancun	0.603226518	0.546917339	0.575071929
China Medicine	0.326022175	0.619902235	0.472962205
Zhongheng Group	0.699336493	0.716431982	0.707884238
Zhongmu	0.534061049	0.625219552	0.579640301
Zhongxin	0.523656226	0.64705675	0.585356488
Zsyy	0.728308394	0.611906374	0.670107384
JLZX	0.70032643	0.554290101	0.627308266
Zuoli	0.658487779	0.492143686	0.575315732

Biological is below 0.6 in the two stages, for the resources cannot be well utilized (see Table 4 for specific annual data).

4.5. Overall Efficiency Analysis. In the overall efficiency analysis (shown in Table 2), there are 109 companies with efficiency between 0.6 and 1.0, accounting for 66.9%, and it shows that the technical efficiency of the second stage is less than that of the first stage.

Comparing Hengrui (the highest efficiency) and Baiyunshan (the lowest efficiency), we found that Hengrui did not receive government subsidies in the 2018 and 2019, but the technical efficiency reached 1, and Baiyunshan has received government subsidies, but the technical efficiency rises first and then decreases.

For Zhifei Bio with the second highest efficiency, its efficiency in 2018 and 2019 was significantly higher than in 2016 and 2017, and the government subsidies received by Zhifei Bio in 2018 and 2019 were significantly lower than before. The second-to-last-ranked company, Medicare, reached a low point in 2018, followed by a significant rebound next year, when it was not subsidized by the government in 2019.

It can be concluded that government subsidies have no obvious effect for most companies, but it has a positive impact on enterprises with low efficiency in a short term. The government may need to reconsider the way of subsidies to pharmaceutical companies, such as the capital subsidies to equipment upgrades and talent introduction (see Table 5 for specific annual data).

TABLE 3: Analysis of DEA efficiency in the first stage of Chinese pharmaceutical companies.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Adisseo	1	0.538826377	0.748769622	0.639633789
Anke Bio	0.69893892	0.731620495	0.671113197	0.703361568
Osaikon	0.713077361	0.75673785	0.813339088	0.817531461
Baiyunshan	0.328542111	0.356320523	0.546507045	0.303672764
Bdyy	0.589761232	0.62883886	0.592320492	0.673332429
Beilu	0.701152973	0.769964623	0.718534493	0.832174827
Porton	0.617509415	0.622015319	0.606350945	0.659897114
None	0.709527587	0.749839674	0.680641517	0.692813179
Changchun High-Tech	0.644238901	0.693875856	0.678445711	1
Changjiang Runfa Medicine	0.661073921	0.633858532	0.577628241	0.617216502
Changshan Pharma	0.702574435	0.737444456	0.654896914	0.726604025
DAJY	0.608034181	0.612562673	0.565649446	0.659420187
Dezhan	0.778248014	0.8859713	0.801172953	0.735162569
Jiao	0.695876014	0.752555196	0.784627533	0.519464099
DBBT	0.698427402	0.732910456	0.683799871	0.747814366
VC	0.356746951	0.369605175	0.596620054	0.529513216
Dongcheng	0.685298529	0.713356357	0.65224054	0.644469293
Nhwa Pharm	0.566050744	0.595888879	0.559629612	0.90136936
Ekzy	0.695893135	0.642142688	0.56111062	0.817019263
Fangsheng	0.690430635	0.7072366	0.668234842	0.734875807
Fengyuan	0.507954055	0.513382048	0.500312529	0.803668528
Fczy	0.673318722	0.706559734	0.637287549	0.694993671
Fayy	0.640199162	0.622882581	0.47487985	0.853112289
Fosun Pharm	0.440829161	0.453177832	0.491647136	0.49307564
Fuxiang	0.69509172	0.713319861	0.655317677	0.733133012
Guangji	0.665875845	0.685465131	0.666509377	0.727816419
Kwong Sang Hong	0.731211949	0.758118876	0.703598927	0.767034517
Guang Yuyuan	0.705727447	0.728802756	0.672683165	0.684002357
Lark	0.592069879	0.607690808	0.548144601	0.77362057
Glsj	0.646076312	0.70291605	0.642642634	0.716848951
Sinopharm Hyundai	0.550500314	0.31927442	0.586702033	0.528408978
Harbin Pharm	0.232904004	0.239750504	0.452243584	0.452259029
Haili Bio	0.720958825	0.755724092	0.683383826	0.751465636
Hnhy	0.593723249	0.615663681	0.533902785	0.696645384
Hepalink	0.613624689	0.594913319	0.565038631	0.802005999
Haishun New Pharma	0.730858479	0.770599806	0.71368573	0.788569679
Haisco	0.694950719	0.689640795	0.627724818	0.86949045
Hisoar	0.536160514	0.598345145	0.58053481	0.867138023
Haixin	0.598921852	0.651676624	0.60413451	0.655663364
Hisun	0.279462381	0.291252982	0.396970805	0.446155807
Han Sen Pharm	0.622641145	0.670338249	0.638264052	0.743867561
Hybio	0.706990021	0.762095736	0.569815841	0.505230747
Hengrui	0.659908876	0.690053233	1	1
Chase Sun	0.590616729	0.546391865	0.485056058	0.568871023
NCPC	0.261478601	0.273294764	0.476531644	0.439081271
Huahai	0.510939772	0.532978902	0.422450272	0.70961269
Hualan Bio	0.724489053	0.75903868	0.74819712	1
Huaren	0.547811923	0.60655341	0.573018429	0.653930126
HRSJ	0.421806748	0.424780128	0.642346121	0.678166446
China Resources Double-Crane	0.396338204	0.412017952	0.746295359	0.717503796
Huashen Technology	0.692282897	0.748644224	0.673121394	0.762749156
Walter Dyne	0.64905781	0.687320156	0.604331968	0.717676209
Yanbian FC	0.728434735	0.796358227	0.622973596	0.964802474
Kyrgyzstan	0.690648563	0.723721435	0.676558269	0.315539437
Jichuan	0.654593403	0.687752464	0.658917181	0.733965769
Jimin	0.667207312	0.715203145	0.639062034	0.703268743
JYPC	0.676163429	0.660551878	0.674564338	0.730972038
Joincare Pharm	0.42609937	0.779556709	0.42013106	0.814542688
Jiangzhong	0.577983092	0.660234497	0.621771461	0.710282338

TABLE 3: Continued.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Jincheng	0.604349975	0.635628024	0.540328079	0.778835478
Jinhe Bio	0.620488457	0.622315827	0.593163862	0.657450163
Jinling	0.457693647	0.464485434	0.485300003	0.77746379
Jinshiya	0.739579461	0.794884842	0.642073972	0.686648392
Jingxin	0.615013047	0.645371162	0.600849303	0.881618128
Jinghua	0.654292046	0.695723085	0.644925134	0.552839647
Jingfeng	0.655470879	0.625155781	0.56168705	0.583642128
Jiuqiang	0.775537026	0.80576769	0.741353597	0.825166597
Jiuzhitang	0.638432251	0.632345693	0.526816311	0.783209851
Jiuzhou	0.531129929	0.563082683	0.553227164	0.866828683
CONBA	0.424959572	0.448091924	0.76318362	0.539210385
Kanghong	0.649678902	0.676913482	0.617801313	0.716586348
Kangyuan	0.547173659	0.538412405	0.521974436	0.84900766
Kangzhi	0.681459875	0.718856205	0.658583409	0.68036486
KHB	0.679909201	0.70601526	0.646219781	0.879761787
Kelun	0.309440068	0.306632161	0.481370093	0.417755441
Sunflower	0.503468625	0.542712714	0.541164765	0.637334286
Kunming Pharm	0.487752766	0.494592469	0.456784207	0.698168222
Lummy	0.59477378	0.650148325	0.620139476	0.63516333
LAYN	0.706666281	0.764250345	0.658484063	0.757057246
Lisheng Pharma	0.652358213	0.658225585	0.633802648	0.685028972
Livzon Pharm	0.483127888	0.90147395	0.765854345	0.719069177
LEADMAN	0.685277868	0.739693609	0.685479669	0.749326011
Lianhuan Pharm	0.672599294	0.711757269	0.670159541	0.741037539
Lingkang	0.698902905	0.743402231	0.696586279	0.764084079
Lingrui Pharm	0.674401636	0.672389024	0.614906134	0.706294196
Long Jin Pharm	0.731845112	0.770452444	0.718767022	0.793216512
Lukang Pharm	0.427468486	0.46570682	0.460332769	0.682602477
Mike Bio	0.708027483	0.72319852	0.645149742	0.893314305
M.k.	0.708395924	0.726482926	0.56873759	0.613265307
Palin Bio	0.671391314	0.718181986	0.666425242	0.757080803
PIEN TZE HUANG	0.684930611	0.750405659	0.661039196	0.958922766
Julie Plec	0.707704329	0.723714045	0.673462726	0.733615566
Plyy	0.406959748	0.414853778	0.427735839	0.708905869
CHEEZHENGTMM	0.686682951	0.725135357	0.678237865	0.768703082
Qidi	0.666806547	0.68236924	0.64498398	0.770055989
Qianhong Biopharma	0.71938682	0.719385025	0.656560098	0.713796618
Qianjin Pharm	0.530656791	0.548629069	0.522713754	0.848589111
Qianyuan	0.638506467	0.671543368	0.62791026	0.721933561
Renfu	0.334218803	0.413272744	0.149231487	0.392902669
Renhe Pharmacy	0.533268479	0.506914813	0.519999497	0.8252231
Rpsw	0.638039028	0.654974398	0.617845497	0.693808777
Saisheng	0.754473392	0.796748489	0.72770648	0.76886275
SAM	0.680909431	0.689598358	0.594020614	0.72317694
Shanhe Pharmacy	0.713262981	0.747755843	0.701291618	0.776854953
Shkb	0.690613654	0.721026937	0.655361928	0.725275566
Shanghai RAAS Blood Products	0.815937216	0.711632966	0.29512233	0.882937
Shenqi	0.646515892	0.665122901	0.604905717	0.669811909
Biological Stock	0.776300364	0.857731961	0.733310511	0.673469086
Salvage Pharm	0.405423981	0.471147411	0.570580408	0.405427689
Sts	0.745342868	0.789809576	0.695943443	0.728030381
Scyy	0.621324992	0.736624764	0.67014276	0.771774728
Beijing SL Pharm	0.754959569	0.822479251	0.739066637	0.778537157
Stellite	0.64699861	0.679791002	0.648708242	0.695542742
Shsw	0.706490688	0.749047972	0.701812101	0.790331518
Tat	0.583302035	0.579802833	0.530612746	0.716883304
Taiji Group	0.368697953	0.288373447	0.505506669	0.434540617
Taloph Pharm	0.60505421	0.644707882	0.569453781	0.657754327
Teyi	0.685639388	0.710137044	0.667309716	0.731583384

TABLE 3: Continued.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Tasly	0.344736323	0.364398246	0.547507961	0.410031592
Tiantan Biological	0.56685493	0.735139685	0.705597237	0.924450822
Tianyao Pharm	0.567784075	0.640100799	0.568366328	0.808709151
Thdb	0.690420152	0.76073724	0.692058634	0.972117015
Thjm	0.700759308	0.682066065	0.62099078	0.2674205
TRT	0.449941637	0.452561856	0.578565313	0.517445278
Wanbangde	0.350398153	0.410898312	0.464547495	0.483783447
Wondfo	0.706033933	0.749163259	0.666377487	0.738463539
WEDGE INDUSTRIAL	0.718041181	0.768397698	0.690260111	0.76803824
Weiming	0.748177009	0.769128321	0.619853486	0.710145248
Wowu	0.739298451	0.784243922	0.7386125	0.820113211
Wohua	0.674322938	0.710157045	0.659012071	0.772121516
Wosen	0.619303412	0.571491875	0.797393821	0.699460802
AMD	0.689966569	0.789941263	0.71329527	0.810580022
Xianju Pharm	0.514464857	0.566490622	0.540109586	0.818150446
Xiangxue Pharm	0.537483667	0.540068623	0.481275233	0.714362519
Sunflower	0.540029523	0.598998632	0.388532054	0.706082152
NHU	0.517692055	0.603883517	0.66053792	0.748506424
Xinhua	0.402109863	0.430156322	0.437174929	0.686348395
Xinbang	0.43011624	0.428808192	0.361237255	0.540651302
SALUBRIS	0.744881615	0.779294136	0.697651488	0.639133074
BROTHER	0.663383853	0.719528977	0.583598178	0.823868476
Yabao	0.453418706	0.507914392	0.515088977	0.755819777
Yatai	0.687624616	0.723497946	0.658661044	0.308960713
Yananbikang	0.615088274	0.598667978	0.63509745	0.491466664
Yiling Pharm	0.535399897	0.54629301	0.521004694	0.764562368
Yifan	0.62137248	0.706145232	0.543427556	0.768574846
Yibai	0.601819983	0.583245952	0.344474902	0.726832453
Yisheng	0.640708057	0.679203014	0.623539381	0.703137255
Yiduoli	0.61878647	0.601097854	0.566968291	0.80554492
Chinataurine	0.65392248	0.715865276	0.674513572	0.727223103
Gloria Pharm	0.619802462	0.583161465	0.534749776	0.181246147
Baiyao	0.407703292	0.415325832	0.598683278	0.592789916
Zhejiang Medicine	0.39694149	0.393998731	0.627437898	0.585114319
Zhenbao Island	0.615637011	0.630467145	0.565464187	0.847153576
Zdzy	0.53930568	0.541502435	0.447281659	0.74754751
Zhifei	0.659011263	0.779383924	0.84578019	1
Zhongguancun	0.607984942	0.597661057	0.559189938	0.648070137
China Medicine	0.298293719	0.284321785	0.389396559	0.332076638
Zhongheng Group	0.6583369	0.730823738	0.660884453	0.747300882
Zhongmu	0.46697542	0.505701728	0.480753041	0.682814008
Zhongxin	0.425869997	0.478604566	0.475336345	0.714813998
Zsyy	0.672284742	0.721839471	0.64125814	0.877851223
JLZX	0.658045275	0.724715509	0.596666189	0.821878746
Zuoli	0.647050689	0.667106722	0.616372459	0.703421246

TABLE 4: Analysis of DEA efficiency in the second stage of Chinese pharmaceutical companies.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Adisseo	1	0.649837545	0.625737431	0.541530825
Anke Bio	0.765162026	0.476189062	0.772255149	0.613658522
Osaikon	0.843778066	0.441445985	0.850780731	0.575021161
Baiyunshan	0.128029731	0.338472809	0.44681541	0.404956323
Bdyy	0.890834395	0.445222754	0.727676509	0.608956969
Beilu	0.808544991	0.447781474	0.735202266	0.658558851
Porton	0.790606856	0.452864356	0.741151893	0.630953461
None	0.899553352	0.412224769	0.692164738	0.575225616
Changchun High-Tech	0.697331634	0.534086802	0.974210731	0.83805388
Changjiang Runfa Medicine	0.758278202	0.457208597	0.757178228	0.355161748
Changshan Pharma	0.839430913	0.452268392	0.722949426	0.63821128
DAJY	0.498749812	0.453046771	0.736062102	0.592503277
Dezhan	1	0.540144516	0.907325608	0.65741689
Jiao	1	0.695657355	1	0.349390869
DBBT	0.79160979	0.443887279	0.725436161	0.605439407
VC	0.52176685	0.452560475	0.4923262	0.401474275
Dongcheng	0.875632334	0.456954862	0.768638857	0.621583435
Nhwa Pharm	0.902685534	0.481101741	0.812506347	0.47310525
Ekzy	0.663965694	0.492139653	0.741589175	0.417137904
Fangsheng	0.83728348	0.445912668	0.729448377	0.613888946
Fengyuan	0.381700772	0.448248178	0.729255255	0.408521314
Fczy	0.810829455	0.450323096	0.733612414	0.613158813
Fayy	0.853851088	0.462652138	0.626676033	0.430608438
Fosun Pharm	0.405879589	0.887608474	0.863039604	0.822061518
Fuxiang	0.686147937	0.40302621	0.65968793	0.652530008
Guangji	0.781783744	0.438862422	0.728105584	0.614602675
Kwong Sang Hong	0.833600898	0.445235421	0.721873605	0.602632782
Guang Yuyuan	0.873544633	0.467173716	0.78987118	0.443703159
Lark	0.856359723	0.507355275	0.834541643	0.432730249
Glsj	0.762864498	0.498932775	0.802401553	0.666986138
Sinopharm Hyundai	0.304326441	0.467872765	0.522609903	0.295245894
Harbin Pharm	0.471907832	0.498927974	0.51892983	0.413398936
Haili Bio	0.845981594	0.452963586	0.715761969	0.596021344
Hnhy	0.546132286	0.451209071	0.73929906	0.377683569
Hepalink	0.570692829	0.455773586	0.833748227	0.517400795
Haishun New Pharma	0.875191121	0.441283929	0.718583719	0.61164409
Haisco	0.265247759	0.462094574	0.770404638	0.453228976
Hisoar	0.806777693	0.483733043	0.841284576	0.486621529
Haixin	0.869599312	0.45122025	0.748838002	0.618733421
Hisun	0.295330677	0.469935051	0.434672128	0.436124359
Han Sen Pharm	0.842792274	0.449054927	0.739269782	0.624481603
Hybio	0.741190863	0.482159427	0.64940653	0.450484128
Hengrui	0.994006619	0.851204335	1	1
Chase Sun	0.510934768	0.252963632	0.388183145	0.487982456
NCPC	0.446958138	0.442893623	0.485019512	0.416336438
Huahai	0.483631419	0.517819876	0.744562547	0.468120819
Hualan Bio	0.488018688	0.463275133	0.825155867	0.606937968
Huaren	0.858322442	0.445957989	0.72614299	0.608155932
HRSJ	0.39055996	0.606296731	0.659827456	0.641018804
China Resources Double-Crane	0.532023886	0.544202986	0.588679129	0.519985
Huashen Technology	0.899423723	0.461862909	0.723906959	0.610948685
Walter Dyne	0.842502696	0.497242721	0.767143201	0.641896259
Yanbian FC	0.442623386	0.657329408	0.887815963	0.555869763
Kyrgyzstan	0.455180857	0.466836149	0.763056261	0.299038639
Jichuan	0.692456078	0.269019483	0.480891191	0.509052877
Jimin	0.843175982	0.447230193	0.72593401	0.612949828
JYPC	0.902264504	0.405752965	0.710764503	0.579782874
Joincare Pharm	0.320679344	0.446019187	0.442365325	0.607505328
Jiangzhong	0.968578156	0.488910163	0.806995681	0.681786657

TABLE 4: Continued.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Jincheng	0.680587626	0.446883725	0.726463433	0.422778688
Jinhe Bio	0.767555971	0.454800853	0.751896726	0.621861095
Jinling	0.882151804	0.462632532	0.777149818	0.420373223
Jinshiya	0.818824975	0.430337738	0.708029409	0.621839405
Jingxin	0.754271786	0.3997261	0.669011225	0.458543459
Jinghua	0.818896414	0.46479897	0.771305173	0.511596589
Jingfeng	0.659628837	0.462586912	0.756245434	0.295660795
Jiuqiang	0.888800059	0.475114126	0.779541159	0.656729486
Jiuzhitang	0.682939594	0.388385296	0.576221175	0.418866032
Jiuzhou	0.70068303	0.459376494	0.75017596	0.426386203
CONBA	0.450840367	0.532007534	0.572159801	0.36900969
Kanghong	0.630861917	0.383874254	0.632910424	0.462196751
Kangyuan	0.569889462	0.483812562	0.800075831	0.457930115
Kangzhi	0.860448512	0.447077729	0.722807424	0.595329819
KHB	0.75874045	0.446262253	0.731865553	0.430496937
Kelun	0.392192554	0.491878068	0.573939315	0.514916857
Sunflower	0.397069408	0.402221867	0.677747189	0.568562512
Kunming Pharm	0.484712539	0.482852557	0.787863272	0.452428396
Lummy	0.757591911	0.446024294	0.735699424	0.57313539
LAYN	0.82616477	0.46673708	0.735088104	0.618275961
Lisheng Pharma	0.892289898	0.44823865	0.743782606	0.632397402
Livzon Pharm	0.330476519	1	0.621269109	0.563738749
LEADMAN	0.744491132	0.439674197	0.708587278	0.605240773
Lianhuan Pharm	0.883381664	0.449882686	0.733590338	0.614613785
Lingkang	0.487342648	0.461147315	0.755609423	0.634678684
Lingrui Pharm	0.820570294	0.469108287	0.768403276	0.650201258
Long Jin Pharm	0.825269505	0.445474296	0.7213483	0.596440566
Lukang Pharm	0.709307544	0.271967764	0.448405964	0.41417971
Mike Bio	0.829672491	0.491963544	0.816516452	0.463478288
M.k.	0.702540171	0.461798568	0.750504723	0.334581671
Palin Bio	0.800366688	0.44299407	0.733746558	0.627260125
PIEN TZE HUANG	0.9045343	0.538290845	0.947536174	0.513658965
Julie Plec	0.549521085	0.305111815	0.499939327	0.524584684
Plyy	0.533402894	0.421972728	0.708018213	0.458768245
CHEEZHENGTMM	0.565148659	0.465429448	0.761471867	0.662280612
Qidi	0.86117892	0.441527153	0.709508207	0.607695056
Qianhong Biopharma	0.874606048	0.456315537	0.750563573	0.635328671
Qianjin Pharm	0.739246108	0.471814504	0.779924867	0.439377818
Qianyuan	0.831338985	0.404575277	0.655154668	0.336313058
Renfu	0.334414205	0.618045999	0.176055483	0.552146513
Renhe Pharmacy	0.888111873	0.496037076	0.837040815	0.469528713
Rpsw	0.594394568	0.433880869	0.709930487	0.626972475
Saisheng	0.929682934	0.476157778	0.77599003	0.625516632
SAM	0.905264682	0.451150287	0.680555861	0.60183122
Shanhe Pharmacy	0.847924844	0.432928146	0.710008765	0.610022991
Shkb	0.848089711	0.471499157	0.758909287	0.643053348
Shanghai RAAS Blood Products	1	0.54470828	0.409520354	0.468019077
Shenqi	0.714762096	0.381344561	0.617613041	0.61415927
Biological Stock	0.965359357	0.549223179	0.870620483	0.638968678
Salvage Pharm	0.689364433	0.415308201	0.706749477	0.198232344
Sts	0.935757517	0.472141333	0.74357052	0.605127606
Scyy	0.739153533	0.426485993	0.676414771	0.571466831
Beijing SL Pharm	0.733749939	0.506947781	0.832842848	0.681797114
Stellite	0.803378896	0.437370993	0.715251262	0.614807042
Shsw	0.890410616	0.434761769	0.700177597	0.603465476
Tat	0.842586294	0.360807923	0.584823244	0.390571577
Taiji Group	0.67919953	0.452980777	0.474001541	0.387892653
Taloph Pharm	0.842636824	0.438224781	0.689161525	0.607715363
Teyi	0.836358694	0.453682077	0.749014352	0.629612238

TABLE 4: Continued.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Tasly	0.717299163	0.615735065	0.675224149	0.512843572
Tiantan Biological	0.678613559	0.591061254	0.860246774	0.500479724
Tianyao Pharm	0.857677116	0.448393948	0.737240947	0.409261416
Thdb	0.900688131	0.545722415	0.888741777	0.491006733
Thjm	0.744976147	0.47311369	0.785334315	0.254122817
TRT	0.836177972	0.656151609	0.703560723	0.570595311
Wanbangde	0.792851861	0.453600664	0.482306406	0.423211786
Wondfo	0.718234154	0.423654128	0.712394655	0.672912535
WEDGE INDUSTRIAL	0.78623338	0.450705667	0.727173666	0.609309043
Weiming	0.801846721	0.489019559	0.697530662	0.612890373
Wowu	0.915178281	0.444228865	0.732530156	0.611424148
Wohua	0.849951067	0.451158165	0.726657243	0.616986053
Wosen	0.293538834	0.36896297	0.927581915	0.621532855
AMD	0.565789697	0.46605309	0.755941006	0.654308568
Xianju Pharm	0.722129826	0.46975224	0.788610822	0.449576159
Xiangxue Pharm	0.56594413	0.450246609	0.728601595	0.400865973
Sunflower	0.775727247	0.435119495	0.472627581	0.583260445
NHU	0.744446192	0.084792409	0.174517515	0.645247085
Xinhua	0.686150026	0.418580131	0.691475644	0.430862405
Xinbang	0.37146641	0.482379256	0.29706599	0.42940549
SALUBRIS	0.828950689	0.45514634	0.744067755	0.492886897
BROTHER	0.867361567	0.491290966	0.722969193	0.404592688
Yabao	0.62538223	0.465981424	0.776164146	0.400865973
Yatai	0.791869911	0.458579905	0.749488501	0.274754037
Yananbikang	0.609592291	0.525754839	0.495889903	0.382123694
Yiling Pharm	0.732199742	0.505748671	0.83520904	0.467694136
Yifan	0.895380366	0.428163195	0.614491215	0.498168738
Yibai	0.622820274	0.32775112	0.386250987	0.412500415
Yisheng	0.615818561	0.450233859	0.733856106	0.615039599
Yiduoli	0.768370215	0.454151698	0.749092834	0.418880633
Chinataurine	0.790572254	0.445496958	0.734787151	0.618625291
Gloria Pharm	0.425375138	0.473021826	0.735198757	0.099279291
Baiyao	0.676420897	0.831225519	0.898534261	0.870529199
Zhejiang Medicine	0.648977621	0.470928238	0.508877262	0.43259115
Zhenbao Island	0.366714214	0.44796952	0.719005835	0.445442437
Zdzy	0.666462777	0.477272075	0.688004343	0.415110578
Zhifei	0.794312561	0.48858374	1	0.851446092
Zhongguancun	0.638431487	0.361048475	0.600829723	0.58735967
China Medicine	0.600385661	0.632935767	0.705012728	0.541274783
Zhongheng Group	0.779488337	0.516431725	0.842980772	0.726827094
Zhongmu	0.891791426	0.461595881	0.758629587	0.388861314
Zhongxin	0.784299166	0.500035996	0.833734288	0.470157549
Zsyy	0.712236556	0.493776655	0.805881833	0.435730452
JLZX	0.56839467	0.487351822	0.7538412	0.407572713
Zuoli	0.506830635	0.327842837	0.530045226	0.603856046

TABLE 5: Analysis of the overall efficiency of Chinese pharmaceutical companies.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Adisseo	1	0.594331961	0.687253527	0.590582307
Anke Bio	0.732050473	0.603904778	0.721684173	0.658510045
Osaikon	0.778427713	0.599091917	0.832059909	0.696276311
Baiyunshan	0.228285921	0.347396666	0.496661228	0.354314544
Bdyy	0.740297813	0.537030807	0.6599985	0.641144699
Beilu	0.754848982	0.608873049	0.726868379	0.745366839
Porton	0.704058135	0.537439838	0.673751419	0.645425288
None	0.804540469	0.581032222	0.686403127	0.634019398
Changchun High-Tech	0.670785268	0.613981329	0.826328221	0.91902694
Changjiang Runfa Medicine	0.709676062	0.545533564	0.667403235	0.486189125
Changshan Pharma	0.771002674	0.594856424	0.68892317	0.682407653
DAJY	0.553391996	0.532804722	0.650855774	0.625961732
Dezhan	0.889124007	0.713057908	0.85424928	0.696289729
Jiao	0.847938007	0.724106276	0.892313767	0.434427484
DBBT	0.745018596	0.588398867	0.704618016	0.676626886
VC	0.4392569	0.411082825	0.544473127	0.465493745
Dongcheng	0.780465431	0.58515561	0.710439698	0.633026364
Nhwa Pharm	0.734368139	0.53849531	0.686067979	0.687237305
Ekzy	0.679929415	0.567141171	0.651349898	0.617078583
Fangsheng	0.763857057	0.576574634	0.69884161	0.674382377
Fengyuan	0.444827414	0.480815113	0.614783892	0.606094921
Fczy	0.742074088	0.578441415	0.685449982	0.654076242
Fayy	0.747025125	0.542767359	0.550777941	0.641860364
Fosun Pharm	0.423354375	0.670393153	0.67734337	0.657568579
Fuxiang	0.690619828	0.558173035	0.657502803	0.69283151
Guangji	0.723829795	0.562163776	0.697307481	0.671209547
Kwong Sang Hong	0.782406423	0.601677149	0.712736266	0.684833649
Guang Yuyuan	0.78963604	0.597988236	0.731277172	0.563852758
Lark	0.724214801	0.557523041	0.691343122	0.603175409
Glsj	0.704470405	0.600924412	0.722522094	0.691917544
Sinopharm Hyundai	0.427413377	0.393573592	0.554655968	0.411827436
Harbin Pharm	0.352405918	0.369339239	0.485586707	0.432828982
Haili Bio	0.783470209	0.604343839	0.699572898	0.67374349
Hnhy	0.569927767	0.533436376	0.636600922	0.537164476
Hepalink	0.592158759	0.525343452	0.699393429	0.659703397
Haishun New Pharma	0.8030248	0.605941868	0.716134725	0.700106885
Haisco	0.480099239	0.575867685	0.699064728	0.661359713
Hisoar	0.671469103	0.541039094	0.710909693	0.676879776
Haixin	0.734260582	0.551448437	0.676486256	0.637198392
Hisun	0.287396529	0.380594016	0.415821467	0.441140083
Han Sen Pharm	0.732716709	0.559696588	0.688766917	0.684174582
Hybio	0.724090442	0.622127582	0.609611185	0.477857438
Hengrui	0.826957748	0.770628784	1	1
Chase Sun	0.550775748	0.399677749	0.436619602	0.528426739
NCPC	0.354218369	0.358094194	0.480775578	0.427708854
Huahai	0.497285595	0.525399389	0.58350641	0.588866754
Hualan Bio	0.606253871	0.611156906	0.786676493	0.803468984
Huaren	0.703067183	0.5262557	0.649580709	0.631043029
HRSJ	0.406183354	0.51553843	0.651086789	0.659592625
China Resources Double-Crane	0.464181045	0.478110469	0.667487244	0.618744398
Huashen Technology	0.79585331	0.605253566	0.698514176	0.686848921
Walter Dyne	0.745780253	0.592281438	0.685737585	0.679786234
Yanbian FC	0.58552906	0.726843818	0.75539478	0.760336119
Kyrgyzstan	0.57291471	0.595278792	0.719807265	0.307289038
Jichuan	0.673524741	0.478385974	0.569904186	0.621509323
Jimin	0.755191647	0.581216669	0.682498022	0.658109286
JYPC	0.789213967	0.533152421	0.692664421	0.655377456
Joincare Pharm	0.373389357	0.612787948	0.431248192	0.711024008
Jiangzhong	0.773280624	0.57457233	0.714383571	0.696034497

TABLE 5: Continued.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Jincheng	0.6424688	0.541255874	0.633395756	0.600807083
Jinhe Bio	0.694022214	0.53855834	0.672530294	0.639655629
Jinling	0.669922726	0.463558983	0.63122491	0.598918507
Jinshiya	0.779202218	0.61261129	0.67505169	0.654243898
Jingxin	0.684642416	0.522548631	0.634930264	0.670080794
Jinghua	0.73659423	0.580261028	0.708115153	0.532218118
Jingfeng	0.657549858	0.543871346	0.658966242	0.439651462
Jiuqiang	0.832168543	0.640440908	0.760447378	0.740948042
Jiuzhitang	0.660685922	0.510365495	0.551518743	0.601037942
Jiuzhou	0.615906479	0.511229588	0.651701562	0.646607443
CONBA	0.43789997	0.490049729	0.667671711	0.454110037
Kanghong	0.640270409	0.530393868	0.625355868	0.589391549
Kangyuan	0.558531561	0.511112483	0.661025134	0.653468887
Kangzhi	0.770954193	0.582966967	0.690695416	0.63784734
KHB	0.719324825	0.576138757	0.689042667	0.655129362
Kelun	0.350816311	0.399255114	0.527654704	0.466336149
Sunflower	0.450269017	0.47246729	0.609455977	0.602948399
Kunming Pharm	0.486232652	0.488722513	0.622323739	0.575298309
Lummy	0.676182846	0.548086309	0.67791945	0.60414936
LAYN	0.766415526	0.615493713	0.696786083	0.687666604
Lisheng Pharma	0.772324056	0.553232118	0.688792627	0.658713187
Livzon Pharm	0.406802204	0.950736975	0.693561727	0.641403963
LEADMAN	0.7148845	0.589683903	0.697033474	0.677283392
Lianhuan Pharm	0.777990479	0.580819977	0.70187494	0.677825662
Lingkang	0.593122777	0.602274773	0.726097851	0.699381382
Lingrui Pharm	0.747485965	0.570748655	0.691654705	0.678247727
Long Jin Pharm	0.778557308	0.60796337	0.720057661	0.694828539
Lukang Pharm	0.568388015	0.368837292	0.454369366	0.548391093
Mike Bio	0.768849987	0.607581032	0.730833097	0.678396297
M.k.	0.705468047	0.594140747	0.659621157	0.473923489
Palin Bio	0.735879001	0.580588028	0.7000859	0.692170464
PIEN TZE HUANG	0.794732455	0.644348252	0.804287685	0.736290866
Julie Plec	0.628612707	0.51441293	0.586701026	0.629100125
Plyy	0.470181321	0.418413253	0.567877026	0.583837057
CHEEZHENGTMM	0.625915805	0.595282402	0.719854866	0.715491847
Qidi	0.763992733	0.561948196	0.677246094	0.688875522
Qianhong Biopharma	0.796996434	0.587850281	0.703561836	0.674562645
Qianjin Pharm	0.634951449	0.510221787	0.651319311	0.643983464
Qianyuan	0.734922726	0.538059322	0.641532464	0.529123309
Renfu	0.334316504	0.515659371	0.162643485	0.472524591
Renhe Pharmacy	0.710690176	0.501475944	0.678520156	0.647375907
Rpsw	0.616216798	0.544427634	0.663887992	0.660390626
Saisheng	0.842078163	0.636453134	0.751848255	0.697189691
SAM	0.793087056	0.570374323	0.637288238	0.66250408
Shanhe Pharmacy	0.780593912	0.590341994	0.705650192	0.693438972
Shkb	0.769351682	0.596263047	0.707135607	0.684164457
Shanghai RAAS Blood Products	0.907968608	0.628170623	0.352321342	0.675478039
Shenqi	0.680638994	0.523233731	0.611259379	0.641985589
Biological Stock	0.870829861	0.70347757	0.801965497	0.656218882
Salvage Pharm	0.547394207	0.443227806	0.638664943	0.301830016
Sts	0.840550192	0.630975455	0.719756982	0.666578994
Scyy	0.680239263	0.581555378	0.673278766	0.671620779
Beijing SL Pharm	0.744354754	0.664713516	0.785954743	0.730167136
Stellite	0.725188753	0.558580997	0.681979752	0.655174892
Shsw	0.798450652	0.591904871	0.700994849	0.696898497
Tat	0.712944165	0.470305378	0.557717995	0.553727441
Taiji Group	0.523948741	0.370677112	0.489754105	0.411216635
Taloph Pharm	0.723845517	0.541466331	0.629307653	0.632734845
Teyi	0.760999041	0.581909561	0.708162034	0.680597811

TABLE 5: Continued.

Company name	Year			
	2015-2016	2016-2017	2017-2018	2018-2019
Tasly	0.531017743	0.490066656	0.611366055	0.461437582
Tiantan Biological	0.622734244	0.66310047	0.782922006	0.712465273
Tianyao Pharm	0.712730596	0.544247373	0.652803637	0.608985283
Thdb	0.795554142	0.653229828	0.790400206	0.731561874
Thjm	0.722867728	0.577589877	0.703162547	0.260771659
TRT	0.643059805	0.554356733	0.641063018	0.544020294
Wanbangde	0.571625007	0.432249488	0.473426951	0.453497617
Wondfo	0.712134043	0.586408694	0.689386071	0.705688037
WEDGE INDUSTRIAL	0.75213728	0.609551683	0.708716889	0.688673642
Weiming	0.775011865	0.62907394	0.658692074	0.661517811
Wowu	0.827238366	0.614236394	0.735571328	0.715768679
Wohua	0.762137003	0.580657605	0.692834657	0.694553785
Wosen	0.456421123	0.470227422	0.862487868	0.660496829
AMD	0.627878133	0.627997177	0.734618138	0.732444295
Xianju Pharm	0.618297341	0.518121431	0.664360204	0.633863302
Xiangxue Pharm	0.551863899	0.495157616	0.604938414	0.560265277
Sunflower	0.657878385	0.517059063	0.430579818	0.644671298
NHU	0.631069124	0.344337963	0.417527717	0.696876755
Xinhua	0.544129945	0.424368226	0.564325286	0.5586054
Xinbang	0.400791325	0.455593724	0.329151623	0.485028396
SALUBRIS	0.786916152	0.617220238	0.720859622	0.566009985
BROTHER	0.76537271	0.605409971	0.653283686	0.614230582
Yabao	0.539400468	0.486947908	0.645626561	0.578342875
Yatai	0.739747264	0.591038926	0.704074772	0.291857375
Yananbikang	0.612340283	0.562211409	0.565493676	0.436795179
Yiling Pharm	0.633799819	0.526020841	0.678106867	0.616128252
Yifan	0.758376423	0.567154214	0.578959385	0.633371792
Yibai	0.612320129	0.455498536	0.365362945	0.569666434
Yisheng	0.628263309	0.564718437	0.678697744	0.659088427
Yiduoli	0.693578342	0.527624776	0.658030562	0.612212776
Chinataurine	0.722247367	0.580681117	0.704650362	0.672924197
Gloria Pharm	0.5225888	0.528091646	0.634974266	0.140262719
Baiyao	0.542062095	0.623275676	0.74860877	0.731659557
Zhejiang Medicine	0.522959555	0.432463484	0.56815758	0.508852734
Zhenbao Island	0.491175612	0.539218332	0.642235011	0.646298006
Zdzy	0.602884228	0.509387255	0.567643001	0.581329044
Zhifei	0.726661912	0.633983832	0.922890095	0.925723046
Zhongguancun	0.623208215	0.479354766	0.58000983	0.617714904
China Medicine	0.44933969	0.458628776	0.547204643	0.43667571
Zhongheng Group	0.718912618	0.623627731	0.751932612	0.737063988
Zhongmu	0.679383423	0.483648804	0.619691314	0.535837661
Zhongxin	0.605084581	0.489320281	0.654535316	0.592485773
Zsyy	0.692260649	0.607808063	0.723569987	0.656790838
JLZX	0.613219972	0.606033666	0.675253694	0.61472573
Zuoli	0.576940662	0.497474779	0.573208842	0.653638646

TABLE 6: Annual Malmquist index and its decomposition indexes.

	EC	SC	TC	PC	TFP
2015-2016	1.1841	2.7910	1.0109	0.4242	1.1970
2016-2017	0.5162	1.4472	1.1211	0.3567	0.5787
2017-2018	0.9815	2.4676	1.0018	0.3978	0.9833
2018-2019	0.5188	1.2176	1.0034	0.4260	0.5205
Mean	0.8001	1.9808	1.0343	0.4012	0.8219

5. Dynamic Effect Analysis

The efficiency of the two-stage network DEA model varies from year to year, and the efficiency value of different years is not comparable, so time series analysis cannot be carried out. To make up for the shortcomings of the traditional two-stage network DEA, this paper adds the Malmquist index to study the total factor productivity of listed pharmaceutical companies in 2015–2019 and quantify its decomposition limit. The results are shown in Table 6.

The average total factor productivity (TFP) is 0.8219 that has fallen by an average 17.81%. Viewed from the decomposition index, the mean of EC is 0.8001; that is, EC has decreased by an average of 19.99%. The mean of PC is 0.4012, with the rate of decline in each averaging over 59.88% a year. SC is 1.9808, with an average annual growth rate of 98.08%. It shows that the operating efficiency of listed pharmaceutical enterprises depends on the scale expansion and makes up for low management efficiency. The average technology change (TC) is 1.0343, and it has risen by nearly 3.43% per year. The technology change has been improved between 2015 and 2019.

The listed pharmaceutical companies rely on product development and can be combined with innovative technologies. For the pharmaceutical industry, the level of research and development of products indirectly affects the level of industry development. The drugs or pharmaceutical equipment is very important; if the level of medical technology research and development is not advanced enough, the progress of medical level will be affected. Therefore, the listed pharmaceutical enterprises should rely on the existing advanced technology achievements, improving their own technology, to improve operating efficiency.

6. Conclusion

This paper firstly divides the two subsystems by using the two-stage network DEA and analyses the operating efficiency of 1,63 listed pharmaceutical companies in China from 2015 to 2019. Secondly, Malmquist index is used for dynamic analysis; the total factor productivity and decomposition limit were obtained. Finally, we make some suggestions based on the results of the study.

From the results, the technical efficiency of the second phase is less than that of the first stage; government subsidies have no positive impact on most companies. It is possible that enterprises move government subsidies elsewhere rather than pharmaceutical companies. It is also possible that government subsidies have increased, enterprises are more willing to invest in product development and enterprises expansion, and it is difficult to see the improvement of operational efficiency in the short term. However, the government subsidies have a positive impact on enterprises with low efficiency in a short term. To ensure the efficiency of investment and avoid waste of resources, government needs to choose the object of subsidies carefully and reformulate policies that encourage pharmaceutical listed companies. And according to the Malmquist index results, enterprises should pay attention to risk prevention and avoid rapid

expansion bringing in diseconomies of scale. All in all, enterprises should improve management level and technological capabilities and shift scale growth to total factor productivity.

However, there are also some limitations. Regarding the data resources, the data we chose cannot exactly predict the operational situations among current Chinese medical firms, since there is more uncertainty in the market, especially during the COVID-19 period, which is likely to be a potential direction that other scholars can study further in the future. Concerning variables, this article analyses the operational efficiency of 164 firms; researchers can only choose several companies to make an in-depth analysis instead of the whole industrial analysis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

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

Acknowledgments

This research was financially supported by Guangdong Planning Office of Philosophy and Social Sciences Project (Youth): Research on cross-border social responsibility of private foreign trade enterprises in Guangdong and the reconstruction of legitimacy—Perspective of the organization to piece together. (Project number: GD20YGL09). And it also supported by Department of Education of Guangdong Province “Innovative projects with characteristics of ordinary universities” project: Research on Sustainable Development of Foreign Trade in Guangdong Province Based on Energy Footprint (Project no. 2019WTSCX158). Moreover, it is also supported by Key Discipline-International Business Construction and Development Project (Project no. HS2019CXQX17).

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