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The Evolution of Economies of Scale and Natural Monopoly of Airline Industry in China

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Abstract: *Air transport industry has been considered as a traditional natural monopoly industry in China for a long time. The judgment of whether the natural monopoly attribute of airline industry (passenger and cargo transport business) has weakened with the decrease of economies of scale will affect the regulatory policy of China's airline industry. Firstly, this paper explains the relationship between economies of scale and natural monopoly, and then analyzes the theoretical mechanism of demand and technology influencing the evolution of natural monopoly attribute of the industry. Also the paper shows the actual performance of demand and technology in China's airline industry as evidence. Then, by using the improved Cobb-Douglas function, the paper establishes the logarithmic multiple regression equation between the air transport turnover and the number of airline pilots, the number of transport aircrafts and the air fuel consumption. By calculating the sum of the regression coefficients for ten consecutive cycles, we find that the returns to scale continue to decline. The result supports the conclusion that the economies of scale in Chinese airline industry are reduced, that is, the natural monopoly attribute is weakened.*

Keywords: *airline industry, returns to scale, economies of scale, natural monopoly*

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I. Introduction

Air transport industry has been considered as a traditional natural monopoly industry in China for a long time. However, some studies show that the natural monopoly of the airline industry which is one of the businesses of the air transport industry, i.e. air passenger and cargo transport business, has weakened. There are similar problems in other business of air transport industry, which seems to be verified by the practice of air transport in China in recent years. The understanding of this problem affects the industrial policy of air transport industry in China.

This paper expects to prove the fact that the economies of scale and the nature monopoly attribute of China's airline industry are weakened through the analysis of the factors affecting the natural monopoly and the empirical analysis of returns to scale of China's airline industry, so as to provide the theoretical and empirical basis for the airline industry to further relax the regulatory policy.

II. Literature review

Scholars have paid attention to this problem: Bailey & panzar (1981) thought that the air transport of most domestic trunk markets in the United States met the hypothesis of competitive market [1]. Kahn (1988) believes that air transport industry is not a natural monopoly industry, and it is more efficient to introduce competition [2]. Charles & Seabright (2001) used the relevant data of European and American Airlines to conduct an empirical study on the effect of introducing competition in the air transport industry. The results show that the introduction of competition can greatly improve production efficiency [3]. Yu et al (2008), a Chinese scholar, pointed out that, at present, the air transport industry is no longer considered as a natural monopoly industry, but the monopoly of routes and airports needs further study [4]. Wang et al. (2007) believed that air transport services in the air transport industry are (potential) competitive businesses [5]. Wang (2006) demonstrated the dynamic characteristics of natural monopoly in air transport industry, and proposed the dynamic regulation and the establishment of a market structure compatible with economies of scale and market competition [6]. Pan (2002) believes that the monopoly of China's air transport industry is administrative monopoly, but the air transport enterprises do not have the power of decision-making in the monopoly market, which is directly related to China's civil aviation management system [7]. Sun (2017) presents a structural model of the Korean airline industry, examines the effects of Korea's Airline Deregulation Act and believes the legacy carriers' post-deregulation competitive behavior is far from collusive [8]. In summary, few scholars have made empirical analysis on the evolution of scale economy and natural monopoly attribute of Chinese airline industry.

III. Theoretical Analysis on Economies of Scale and Natural Monopoly

3.1 Economies of Scale and Natural Monopoly

The so-called economies of scale usually refer to the benefits brought by the continuous decline of average cost with the expansion of production scale. Railway, air transport and other industries with large investment, long return cycle, strong asset specificity and large precipitation cost, high fixed cost and low marginal cost, show very obvious economies of scale. Such industries are often called natural monopoly industries.

The traditional theory holds that the natural monopoly is determined by economies of scale, which makes the average cost of one firm lower than that of several firms, so monopoly is reasonable in economy. However, Sharkey (1982) and Baumol, panzar & Willig (1982) believe that the definition or the most significant feature of natural monopoly should be its subadditivity [9] [10]. That is:

$$C(Q) < \sum_{i=1}^{m} C(Q_i), \quad \sum_{i=1}^{m} Q_i = Q \qquad (1)$$

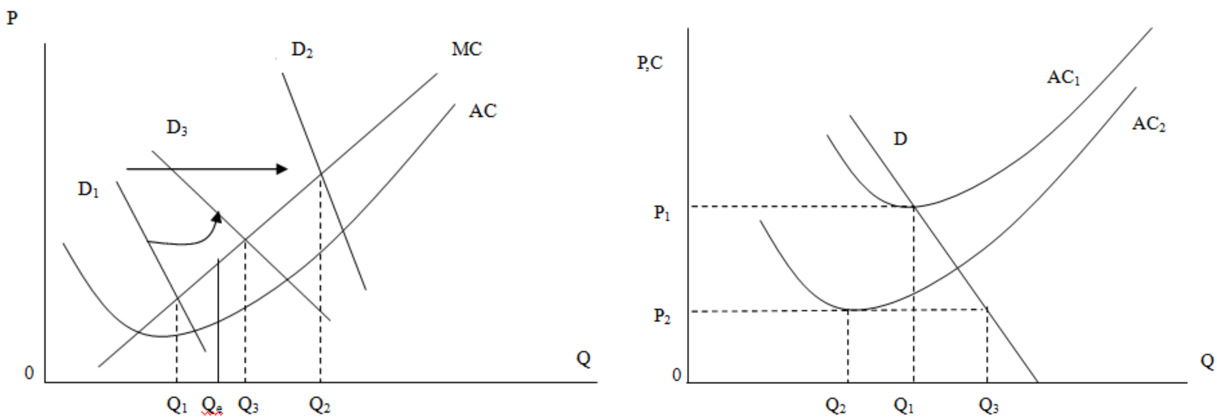
Where, $C(Q)$ is cost function, Q is the total output of the industry, Q_i is the output of each firm.

Now, most of scholars think that for natural monopoly with a single product, economies of scale is the sufficient condition rather than the necessary condition. For multi-product natural monopoly, economies of scale are neither the sufficient condition nor the necessary condition. The sufficient and necessary condition of natural monopoly is subadditivity.

3.2 Factors Influencing the Evolution of Natural Monopoly

Since Watson put forward that technology and demand can change the nature of natural monopoly industry in the late 1980s, more and more evidences show that natural monopoly of the industry is not eternal.

Fig. 1 is the economic model of demand and technology influencing the attribute of natural monopoly of the industry.



a. Evolution of natural monopoly caused by the change of demand

b. Evolution of natural monopoly caused by the change of technology and cost

Fig.1 Demand and Technology Influencing the Attribute of Natural Monopoly

Fig. 1 a shows that the shift of demand curve D to the right causes market capacity Q_2 and Q_3 to be larger than natural monopoly boundary output Q_e. Fig. 1 b shows that technical advancement leads to the average cost curve AC to move downward and to make the minimum economic scale smaller. Both make natural monopoly unnecessary, and the market can contain more than one firm.

3.3 Demand and Technical Factors in China's Airline Industry

In the past few decades, the market demand of Chinese airlines has grown rapidly (See Fig. 2).

The growth of demand makes the market capacity expand, the market can accommodate more airlines to provide products and services, and the natural monopoly market structure of the airline industry tends to weaken or even transform to competitive market structure.

On the other hand, technological advancement in the airline industry has led to lower costs. The development of aircraft design and manufacturing technology leads to the aircraft with better safety and economy, which can reduce operation costs. Management technology innovations such as e-ticket, revenue management, code sharing, low-cost carrier and aircraft leasing also reduce the cost of airlines. Both make the natural monopoly of airline industry tend to weaken.

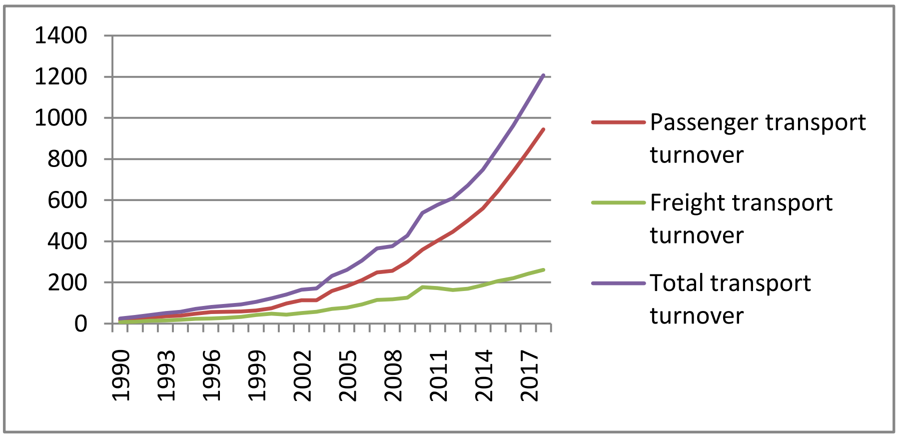


Fig. 2 Air transport turnover in China: 1990-2018 (hundred million revenue ton kilometers)

Note: For comparison purposes, passenger transport turnover is converted to revenue ton kilometers according to official standards.

IV. Empirical Analysis on the Economies of Scale and the Weakening of Natural Monopoly in the Airline Industry

For a long time, the debate about whether there are economies of scale in the airline industry has been affecting people's understanding of its natural monopoly attribute. Some scholars think that the airline industry no longer has the effect of scale economy, but others think that the airline industry has the effect of network scale. Whether the airline industry has the effect of economies of scale or not, these qualitative studies can not give an accurate answer. This part will make an empirical analysis by estimating the returns to scale of *C-D* production function.

4.1 Cobb-Douglas Production Function

C-D production function, also known as Cobb-Douglas production function, was proposed by mathematician Cobb and economist Douglas. Its general form is as follows:

$$Q = AL^{\alpha}K^{\beta} \qquad (2)$$

Where, Q is output; α, β, A are parameters; and usually $0 < \alpha < 1$, $0 < \beta < 1$, L is input of labor, K is input of capital.

The meaning of parameter is very important. $\alpha + \beta > 1$ means increasing returns to scale, $\alpha + \beta < 1$ means decreasing returns to scale, and $\alpha + \beta = 1$ means constant returns to scale. A stands for technology.

The increasing returns to scale of production function is a special case of economies of scale, that is to say, the increasing returns to scale is a sufficient but unnecessary condition of economies of scale, and economies of scale is a sufficient but unnecessary condition of natural monopoly, so the increasing returns to scale is a sufficient but unnecessary condition of natural monopoly. The airline industry can be considered as a natural monopoly, if we can prove that the returns to scale of production function of the airline industry in China increase.

Here, the total turnover of passenger and freight transport is adopted as the output of airlines. In terms of investment factors, aircraft is the largest capital investment of airlines. In terms of labor input, pilots are the most critical labor input for air transport due to the particularity of technical requirements for flight. As the cost of air fuel occupies the first place of all cost projects of Chinese airlines, fuel consumption is also an important factor affecting output. In addition, the progress of aircraft performance, air transport organization and management technology reflect the impact of technological progress on the output of the airline industry. According to these, combined with the *C-D* production function, we construct the production function of the airline industry as follows:

$$Q = AL^{\alpha}K^{\beta}M^{\gamma} \qquad (3)$$

Where, Q is total turnover of airline industry (hundred million revenue ton kilometers); α, β, A are parameters; L is the number of airline transportation pilots, K is the number of aircrafts (excluding general aviation and other aircrafts), and M is the amount of air fuel consumption (ten thousand tons).

4.2 Empirical Analysis of Airline Industry

In order to realize linear regression analysis, the nonlinear *C-D* function is transformed into linear form by taking logarithm:

$$\ln Q = \ln A + \alpha \ln L + \beta \ln K + \gamma \ln M + \varepsilon \qquad (4)$$

The model uses relevant data of civil aviation of China from 1990 to 2018 (see Table 1 and Fig. 3):

Table 1 Relevant Data of China's Airline Industry from 1990 to 2018

Variable	Sample	Max.	Min.	Mean	Std. Dev.
Q	29	1206.5	25.0	360.8	344.6
L	29	21021	1153	6633.3	5840.2
K	29	3639	204	1209.6	991.3
M	29	3462.7	118.6	1109.9	971.8

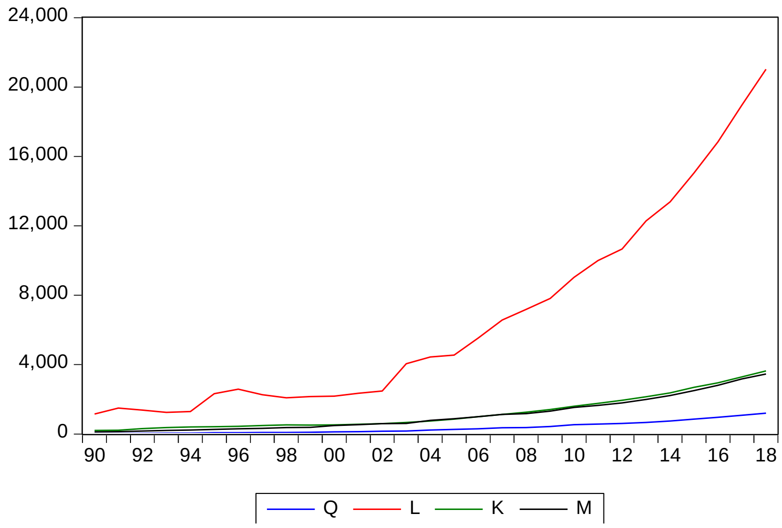


Fig. 3 Relevant Data of China's Airline Industry from 1990 to 2018
Source: *A Survey of Civil Aviation of China from Statistical Data: 1992-2019*

In order to reflect the dynamic trend of economies of scale in airline industry, first, we prefer to build a regression model with 20 consecutive years of data from 1990, and then build another regression model with 20 consecutive years of data from 1991, and so on, to establish a total of 10 regression models. After that, we test the hypothesis of the model and calculate the sum of regression coefficients $\alpha + \beta + \gamma$ in order to investigate the trend of economies of scale and natural monopoly attribute of airline industry.

For example, based on the above model and data, we calculated the regression equation between 1990 and 2009 as follows:

$$\widehat{LNQ} = -2.9030 + 0.1191LNL + 0.1767LNK + 0.9238LNM \qquad (5)$$

$$t = (\text{-}15.1702) \quad (2.0986) \quad (3.0664) \quad (15.5361)$$

$$p = (0.0000) \quad (0.0521) \quad (0.0074) \quad (0.0000)$$

$$R^2 = 0.998636\ ;\ \overline{R^2} = 0.998380\ ;\ F = 3904.570(p = 0.0000)\ ;$$

$$D.W. = 2.407612$$

The results show that the *R-squared* value is 0.998636, close to 1, and the fitting effect of the regression model is good, that is to say, independent variables, number of airline transportation pilots, number of aircrafts and the amount of air fuel consumption can explain more than 99.86% of the output variation. *Prob (F-statistic)* is close to 0, which indicates that the three independent variables as a whole is statistically significant after taking logarithm. The *p* value of *LNL* and *LNM* can pass t-test at the significance level of 0.05, and *LNK* can pass *t*-test at the significance level of 0.1. $\alpha = 0.119067$, $\beta = 0.176716$, $\gamma = 0.923838$, all meet the conditions of greater than 0 and less than 1.

In order to enhance the credibility of above results, further consideration should be given to the relevant test problems of the classical OLS model after relaxing the assumptions. White test was used to diagnose heteroscedasticity. The white statistic output by Eviews was *Obs*R-squared*=14.54205, and the corresponding *p* value was 0.1043, i.e. the original hypothesis without heteroscedasticity was acceptable at 1% significance level. Durbin Watson method is used for serial correlation test. *D-W* value of Eviews output is 2.407612. According to D.W. distribution table, when sample size is 20, explanatory variable is 3, and significance level is 1%, $d_L = 0.773, d_U = 1.411$,the condition $d_U < D.W. < 4 - d_U$ is satisfied, so it can be considered that there is no first-order autocorrelation. The multicollinearity problem can be preliminarily excluded because the *R-squared* 0.998636 is high and the t statistical value of each explanatory variable is significant. Due to the stationarity of time series data, there may be spurious regression, which will affect the credibility of hypothesis tests such as *t* and *F*. According to the methods of Granger and Newbold, if the *R-squared* value is higher than the Durbin Waston value, there may be a spurious regression. Obviously, this condition is not satisfied in this case, so it can be roughly judged that there is no spurious regression.

The above tests show that the regression model is reliable. Because $\alpha + \beta + \gamma$=1.219621>1, it shows that the returns to scale of the production function are increasing, that is to say, the airline industry as a whole has a certain economies of scale.

Theoretically, if the sample is large enough, the value of $\alpha + \beta + \gamma$ in a fixed period can be calculated to reflect the changes of returns to scale and natural monopoly attribute of the airline industry. Here we try to calculate the results of regression model in all ten consecutive time periods with a span of 20 years (see Table 2). The results show that in addition to the slight rebound in the third period, the value of $\alpha + \beta + \gamma$ in other periods almost shows a unilateral downward trend, and $\alpha + \beta + \gamma$ is greater than 1 in all periods. This means that in the period 1990-2018, China's airline industry as a whole keeps increasing returns to scale, that is to say, economies of scale. Therefore, it is the right choice for China's airline industry to continue to expand its scale in this period, which reduces costs and improves efficiency. On the other hand, the declining value of $\alpha + \beta + \gamma$ indicates the weakening of economies of scale of the airline industry, which to some extent supports the conclusion that the natural monopoly attribute of the airline industry in China is weakening (see Fig. 4).

Back to the regression equation (4), where the three parameters of α, β and γ mean the elasticity of the three independent variables of pilot number, aircraft number and air fuel consumption to the dependent variable *Q*, namely:

$$\alpha = \frac{dQ}{dL}\frac{L}{Q},\ \beta = \frac{dQ}{dK}\frac{K}{Q},\ \gamma = \frac{dQ}{dM}\frac{M}{Q} \qquad (6)$$

In most cases, α, β and γ as calculated are greater than 0, which means that the increased factor input increases the output *Q*, while from 1995-2014, β continues to be negative, which means that the elasticity of the number of aircrafts to the total turnover of transportation is negative, that is to say, there is excessive input of aircrafts. Due to the limitation of sample size, we can not verify the trend more accurately from the empirical analysis. In fact, the sample is still too small, even if the analysis is based on a 20-year cycle. The hypothesis test results of individual variables have encountered some problems. For example, from the period 1994-2013, the *p*-value of the t-test of β has been greater than the significance level of 10%, although the overall *R-squared* value, the *F-static* of the model and the *t*-test results of α and γ are relatively good.

Table 2 Main Results of Regression Model in Ten Consecutive Time Periods

Period	α	β	γ	$\alpha+\beta+\gamma$	R-squared	Prob(F-statistic)
1990-2009	0.119067***	0.176716**	0.923838***	1.219621	0.998636	***
1991-2010	0.148285***	0.144006**	0.916459***	1.20875	0.999007	***
1992-2011	0.139074***	0.15981**	0.914962***	1.213846	0.998977	***
1993-2012	0.135304***	0.118725**	0.949238***	1.203267	0.998942	***
1994-2013	0.143081***	0.068541	0.97385***	1.185472	0.998599	***
1995-2014	0.190106***	-0.050539	1.024947***	1.164514	0.998407	***
1996-2015	0.206278***	-0.096599	1.041849***	1.151528	0.998169	***
1997-2016	0.238974***	-0.133204	1.031951***	1.137721	0.997944	***
1998-2017	0.255113**	-0.169327	1.041177***	1.126963	0.997611	***
1999-2018	0.258298***	-0.047109	0.90654***	1.117729	0.997683	***

Note: * * *, * *, and * indicate statistical significance at the 1%, 5% and 10%.

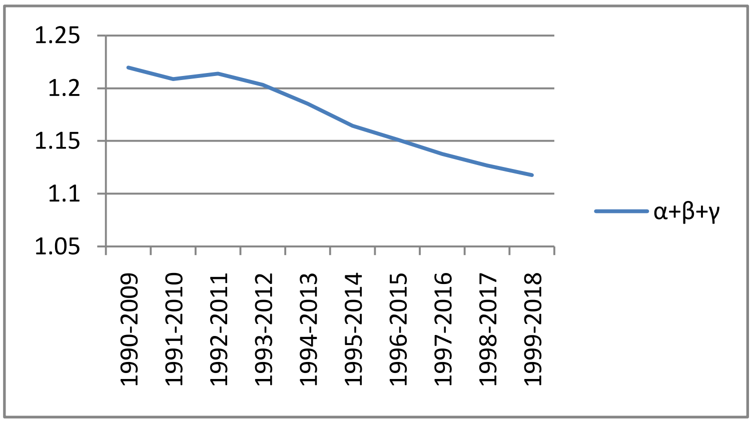


Fig. 4 Trend of Returns to Scale of Airline Industry in China

It should be noted that the inputs of airline industry is not limited to aircrafts, airline transportation pilots and fuel consumption, and these three variables can not fully represent the investment of capital, labor and other factors, but these three factors are indeed the most important inputs in the production function of airlines, so the above conclusion is an approximate description of the real situation.

V. Conclusion

Whether China's airline industry is still a natural monopoly industry? What is the real performance of economies of scale of China's airline industry? These are difficult to get an accurate answer by qualitative analysis. This paper theoretically explains the relationship between economies of scale and natural monopoly, and further explains the mechanism that demand and technology affect the evolution of natural monopoly. Using the improved Cobb-Douglas function, this paper establishes a Log-Linear Regression Model between the air transport turnover, the number of airline pilots, the number of transport aircrafts and the air fuel consumption. It is found that the returns to scale of China's airlines industry continues to decrease. This shows that the economies of scale of Chinese airline industry is decreasing, and then the natural monopoly attribute is weakening.

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