Estimation and Analysis of Technical Efficiency of Aquaculture in China

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01 OPTION

Motivation and Problem Statement

China is a large country in fisheries, especially in aquaculture. Limited by environmental resources and water resources, the improvement of aquaculture efficiency cannot be achieved by continuously investing in human and material resources and continuously expanding the aquaculture area. It is unlikely that a large-scale technological advance or major technological reform can be used to achieve a qualitative leap in a short period of time. Therefore, it is the most effective way to improve the efficiency of aquaculture in China at present. First of all, we should know the current efficiency of aquaculture.

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Research Methods and Data Processing

1.Stochastic Frontier Production Function

$$\ln Y_{it} = \beta_0 + \beta_1 * \ln L_{it} + \beta_2 * \ln K_{it} + \beta_3 * \ln S_{it} + \beta_4 * T + \beta_5 * \ln L_{it} * \ln K_{it} + \beta_6 * \ln L_{it} * \ln S_{it} + \beta_7 * \ln L_{it} * T + \beta_8 * \ln K_{it} * \ln S_{it} + \beta_9 * \ln K_{it} * T + \beta_{10} * \ln S_{it} * T + \beta_{11} * (\ln L_{it})^2 + \beta_{12} * (\ln K_{it})^2 + \beta_{13} * (\ln S_{it})^2 + \beta_{14} * T^2 + V_{it} - U_{it}$$

Y: Aquaculture production (tons)
L: Farm labor input (person);
K: intermediate consumption of the fishery (100 million yuan);
S: Farming area (ha);
i: Provincial code;
T: Time variable, indicating the trend of technology over time

2. The input product output elasticity formula

$$E_L = \frac{\Delta Y}{\Delta L} * \frac{L}{Y} = \beta_1 + \beta_5 * \ln K + \beta_6 * \ln S + \beta_7 * T + 2 * \beta_{11} * \ln L$$

$$E_K = \beta_2 + \beta_5 * \ln L + \beta_8 * \ln S + \beta_9 * T + 2 * \beta_{12} * \ln K$$

$$E_S = \beta_3 + \beta_6 * \ln L + \beta_8 * \ln K + \beta_{10} * T + 2 * \beta_{13} * \ln S$$

E_L: Output flexibility of aquaculture labor force L
E_k: Output elasticity of intermediate consumption K
E_S: Output elasticity of aquaculture area S

3. Technical efficiency loss function

$$m_{it} = \delta_0 + \delta_1 * JG_{it} + \delta_2 * NX_{it} + \delta_3 * RS_{it} + \delta_4 * SP_{it} + \delta_5 * \ln(RGDP_{it}) + \delta_6 * SZ_{it} + \delta_7 * KJ_{it} + \varepsilon_{it}$$

JG: The processing rate of aquatic products;
NX: Net export rate of aquatic products;
RS: Per capita farming area;
SP: Average technical level of technical extension personnel;
RGDP: Per capita GDP;
SZ: Disaster rate of aquaculture;
KJ: Number of fishery aquaculture technical extension agencies

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Research Methods and Data Processing

Data Sources

- The data of aquaculture production, aquaculture personnel, and aquaculture area derived from China Fisheries Yearbook, China Fishery Statistical Yearbook, and China Agricultural Statistics; There is no specific statistical data on the intermediate consumption of aquaculture. Therefore, the proportion of the total fishery production in the aquaculture fishery production is multiplied by the intermediate consumption of the fishery. The relevant data on the middle consumption of the fishery comes from the China Rural Statistical Yearbook.
- The factors affecting technical efficiency include the processing rate of aquatic products, the net export rate of aquatic products, the per capita aquaculture area, the average technical level of technical extension workers, the disaster rate of breeding, and the number of technical extension institutions. The relevant data come from "China Fishery Yearbook", "China Fishery Statistical Yearbook" and "China Agricultural Statistics" over the years, and the per capita regional GDP comes from "China Statistical Yearbook". At the same time, the relevant data eliminate the impact of price changes by using 2007 constant prices.

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Results of Empirical Analysis

Table 1 Parameter Estimation Results of Stochastic Frontier Production Function

Explanatory variables	Parameters to be evaluated	coefficient	Standard deviation	T value
Constant term	β_0	-4.9320**	2.2968	-2.1474
lnL	β_1	1.2693*	0.6962	1.8231
lnK	β_2	-1.9747***	0.6597	-2.9932
lnS	β_3	2.0156 ***	0.3176	6.3463
T	β_4	0.1078	0.1095	0.9840
lnL*lnK	β_5	0.0348	0.0626	0.5565
lnL*lnS	β_6	-0.0899 *	0.0462	-1.9433
lnL*T	β_7	0.0065	0.0091	0.7130
lnK*lnS	β_8	0.2516 ***	0.0375	6.7144
lnK*T	β_9	0.0179	0.0116	1.5460
lnS*T	β_{10}	-0.0280 ***	0.0072	-3.8650
$(lnL)^2$	β_{11}	-0.0017	0.0192	-0.0863
$(lnk)^2$	β_{12}	-0.1203 ***	0.0365	-3.2930
$(lnS)^2$	β_{13}	-0.0742 **	0.0288	-2.5748
T^2	β_{14}	0.0052 **	0.0025	2.0656
σ^2		0.0899***	0.0258	3.4836
γ		0.9746***	0.0196	49.8312
log likelihood function	31.2279***			

Note: *, **, *** are significant at the levels of 10%, 5%, and 1%, respectively

Overall, the logarithm of the likelihood function is significant at a statistical level of 1%, indicating that the model has a good degree of fitness. At the same time, most of the parameter estimates have passed the t-test. The cross-term coefficients β6, β8, and β10 are significant at different statistical levels, indicating that it is appropriate to choose the form of the surpassing logarithmic production function, and the model has a strong explanatory power.

The proportion of technical inefficiency terms γ passed the t-test at a statistical level of 1%, indicating that the error was mainly due to technical inefficiencies U. Therefore, the difference between real output and theoretical output is mostly caused by technical ineffectiveness. It is necessary to further study the influencing factors of technical efficiency.

From the results of specific parameters, the labor force L, intermediate consumption K, and aquaculture area S passed the test at the statistical levels of 10% and 1% respectively. It explains that these three input factors have a significant impact on aquaculture production Y. The coefficient of time T did not pass the test, indicating that there was no obvious technical progress in aquaculture in China during the statistical period.

03 OPTION Results of Empirical Analysis

Analysis of the trend of elasticity of output of various input factors

Table 2 Average Output Elasticity of Input Elements in Various Years

Years	Labor flexibility	Intermediate consumption elasticity	Aquaculture area elasticity	Sum of elasticity
2007	0.3078	0.6424	-0.0135	0.9367
2008	0.2972	0.6813	-0.0358	0.9426
2009	0.3008	0.6829	-0.0334	0.9502
2010	0.3083	0.6838	-0.0413	0.9508
2011	0.3169	0.6771	-0.0462	0.9479
2012	0.3270	0.6581	-0.0313	0.9538
2013	0.3356	0.6541	-0.0336	0.9561
2014	0.3443	0.6528	-0.0392	0.9579
2015	0.3521	0.6591	-0.0538	0.9574
Average	0.3211	0.6657	-0.0365	0.9504

Note: The elasticity of inputs in different years is the arithmetic average of provinces and cities.

The sum of the average output elasticity of aquaculture input elements in China is 0.9504, which is less than 1, indicating that aquaculture in China is in the phase of decreasing returns to scale.

The elasticity of labor output is positive in every year，The labor output elasticity is positive each year, the average output elasticity is 0.3211, and the volatility is small. The labor input has a positive effect on the output increase. Increased labor input will increase the aquaculture production.

The output elasticity of intermediate consumption is positive every year, with little fluctuation, and the average output elasticity is 0.6657. An increase in intermediate consumption input will result in an increase in output, and the positive effect of intermediate consumption on output is greater than the effect of labor input on output.

The output elasticity of input factors in the aquaculture area is negative each year, indicating that the aquaculture area in China has been saturated has been saturated in 2007-2015 years. The increase in aquaculture area will not result in an increase in output, but will result in a decrease in output.

The sum of the elasticity of the three input factors is less than 1, but the overall trend is increasing. This shows that China's aquaculture is in a stage of diminishing returns to scale each year, and the impact of the three input factors on output is continuously increasing.

Analysis of spatial distribution of output elasticity of input factors

Table 3 Average Output Elasticity of Input Factors In Different Regions

Regions	Labor elasticity	Intermediate consumption elasticity	Aquaculture area elasticity	Sum of elasticity
Beijing	0.5769	0.1145	0.2655	0.9569
Tianjin	0.4292	0.3333	0.2552	1.0177
Hebei	0.3023	0.6567	0.0259	0.9849
Shanxi	0.4526	0.5387	0.0109	1.0022
Inner Mongolia	0.2860	0.9469	-0.2432	0.9897
Liaoning	0.2007	0.8096	-0.0349	0.9754
Jilin	0.2274	1.0144	-0.1962	1.0456
Heilongjiang	0.2450	0.8512	-0.1210	0.9752
Shanghai	0.4622	0.3008	0.2200	0.9830
Jiangsu	0.2470	0.5548	0.1732	0.9749
Zhejiang	0.2847	0.6331	0.0288	0.9465
Anhui	0.2338	0.7638	-0.0470	0.9506
Fujian	0.3347	0.3691	0.2634	0.9672
Jiangxi	0.2471	0.7643	-0.0897	0.9217
Shandong	0.2364	0.6203	0.1243	0.9810
Henan	0.2732	0.8407	-0.2101	0.9038
Hubei	0.2369	0.6798	0.0043	0.9210
Hunan	0.2500	0.7494	-0.0785	0.9209
Guangdong	0.2611	0.5650	0.1241	0.9502
Guangxi	0.2989	0.6331	-0.0129	0.9190
Hainan	0.3925	0.5254	0.0121	0.9301
Chongqing	0.3293	0.8465	-0.3437	0.8321
Sichuan	0.3016	0.6834	-0.0941	0.8909
Guizhou	0.3958	0.6476	-0.1561	0.8873
Yunnan	0.3382	0.6811	-0.1058	0.9135
Shanxi	0.3545	0.8048	-0.2442	0.9152
Gansu	0.3972	0.9485	-0.4276	0.9181
Ningxia	0.3878	0.6472	-0.0574	0.9775
Xinjiang	0.3292	0.7821	-0.1027	1.0086
Average	0.3211	0.6657	-0.0365	0.9504

Note: The output elasticity of each province is the arithmetic mean of the elasticity of 2007–2015

Specifically, the output elasticity of the labor force in all regions is positive and has a positive effect on output. The average output elasticity of middle consumption in various regions of China is 0.6657, which has greater impact on output than labor input. In 17 of the 29 statistical samples, the elasticity value of aquaculture area output was negative, indicating that the aquaculture area in most areas of China has been saturated. This may be due to the fact that the input of the breeding labor force and the input of intermediate consumption can not keep up with the increase of the aquaculture area, which reduces the efficiency of the aquaculture and has a negative effect on the output.

03 OPTION Results of Empirical Analysis

Analysis of efficiency loss function

The average technical level of the technical extension staff (SP), the GDP per capita area (RGDP), and the damage rate of the aquaculture did not pass the significance test. The other variables passed the test at different statistical levels, which had a significant impact on the technical efficiency loss.

Table 4 Parameter Estimation Results Of Efficiency Loss Function

Explanatory variables	Parameters to be evaluated	Coefficient	Standard Deviation	T value
Constant term	δ_0	1.9830**	0.8786	2.2569
JG	δ_1	-0.0123 ***	0.0027	-4.5682
NX	δ_2	-0.0021 *	0.0012	-1.7070
RS	δ_3	-0.0338 ***	0.0036	-9.4231
SP	δ_4	-0.2980	0.2876	-1.0361
ln(RGDP)	δ_5	-0.0802	0.0742	-1.0813
SZ	δ_6	0.0005	0.0016	0.3226
KJ	δ_7	-0.0002 *	0.0001	-1.9139

Note: *, **, *** are significant at the levels of 10%, 5%, and 1%, respectively

Analysis of technical efficiency

03 OPTION Results of Empirical Analysis

Table 5 shows the technical efficiency of aquaculture in 29 provinces and cities in China from 2007 to 2015. The average technical efficiency of aquaculture in various regions was 0.6871 over the past years, which has a large room for improvement.

Table 5 The technical efficiency of aquaculture in various regions over the years

year / Region	2007	2008	2009	2010	2011	2012	2013	2014	2015	average
Beijing	0.3845	0.3959	0.4090	0.4155	0.4169	0.4255	0.4361	0.4424	0.3945	0.4134
Tianjin	0.6823	0.6974	0.7167	0.7462	0.7647	0.8018	0.8150	0.8274	0.7968	0.7609
Hebei	0.7328	0.7554	0.7953	0.7226	0.6928	0.7374	0.7962	0.8034	0.8064	0.7603
Shanxi	0.5712	0.5422	0.4704	0.4643	0.5234	0.5880	0.6359	0.7116	0.7221	0.5810
Inner Mongolia	0.9634	0.8403	0.8913	0.8794	0.7164	0.7301	0.7416	0.8270	0.8320	0.8246
Liaoning	0.8880	0.9143	0.8843	0.9486	0.8837	0.9575	0.9626	0.9770	0.9823	0.9332
Jilin	0.9748	0.9137	0.9583	0.9855	0.7702	0.7964	0.8142	0.7997	0.8956	0.8787
Heilongjiang	0.6752	0.4589	0.4328	0.4271	0.4614	0.4121	0.4437	0.4109	0.4022	0.4583
Shanghai	0.3826	0.3907	0.4125	0.4476	0.4741	0.5059	0.5080	0.5096	0.5248	0.4618
Jiangsu	0.4878	0.5013	0.5190	0.5395	0.5017	0.4796	0.4756	0.4774	0.4584	0.4934
Zhejiang	0.7203	0.7015	0.7041	0.7421	0.7318	0.7434	0.7226	0.7402	0.7209	0.7252
Anhui	0.5984	0.6108	0.5954	0.6368	0.6246	0.6176	0.6012	0.6132	0.6208	0.6132
Fujian	0.9436	0.9431	0.9489	0.9527	0.9484	0.9344	0.9350	0.9429	0.9430	0.9436
Jiangxi	0.7009	0.7380	0.7563	0.8363	0.8563	0.8112	0.7890	0.7884	0.7921	0.7854
Shandong	0.9351	0.9325	0.9388	0.9490	0.9494	0.8689	0.8601	0.8588	0.8610	0.9060
Henan	0.5809	0.5839	0.6140	0.6542	0.7831	0.7551	0.8727	0.8775	0.8658	0.7319
Hubei	0.5864	0.5902	0.5982	0.6283	0.6243	0.5874	0.5714	0.5461	0.5241	0.5840
Hunan	0.7061	0.7368	0.7427	0.7388	0.7355	0.7599	0.7607	0.7611	0.7462	0.7431
Guangdong	0.8729	0.8675	0.8925	0.9212	0.9327	0.9336	0.9443	0.9266	0.9199	0.9124
Guangxi	0.9386	0.9453	0.9579	0.9738	0.9114	0.9099	0.9112	0.8836	0.8838	0.9239
Hainan	0.8652	0.8913	0.9076	0.9411	0.9528	0.9558	0.9642	0.9630	0.9012	0.9269
Chongqing	0.4377	0.4562	0.4904	0.6001	0.6363	0.6280	0.6522	0.6849	0.6564	0.5825
Sichuan	0.7195	0.6798	0.5252	0.5557	0.5701	0.5667	0.5760	0.5702	0.5306	0.5882
Guizhou	0.3698	0.3543	0.3886	0.4012	0.2902	0.2730	0.2782	0.3019	0.3143	0.3302
Yunnan	0.5350	0.2775	0.3944	0.4340	0.4731	0.5175	0.5777	0.6512	0.7696	0.5145
Shanxi	0.3705	0.4353	0.6554	0.4150	0.4637	0.4686	0.5076	0.5044	0.4986	0.4799
Gansu	0.5245	0.6010	0.6700	0.7784	0.7229	0.7054	0.7836	0.8418	0.8876	0.7239
Ningxia	0.5246	0.5180	0.5595	0.6213	0.6595	0.6654	0.8256	0.8777	0.9242	0.6862
Xinjiang	0.6954	0.5254	0.5462	0.5991	0.6517	0.7001	0.7348	0.7458	0.7387	0.6597
average	0.6679	0.6482	0.6681	0.6881	0.6801	0.6840	0.7068	0.7195	0.7212	0.6871

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Results of Empirical Analysis

Analysis of technical efficiency

1. Time trend of aquaculture technical efficiency

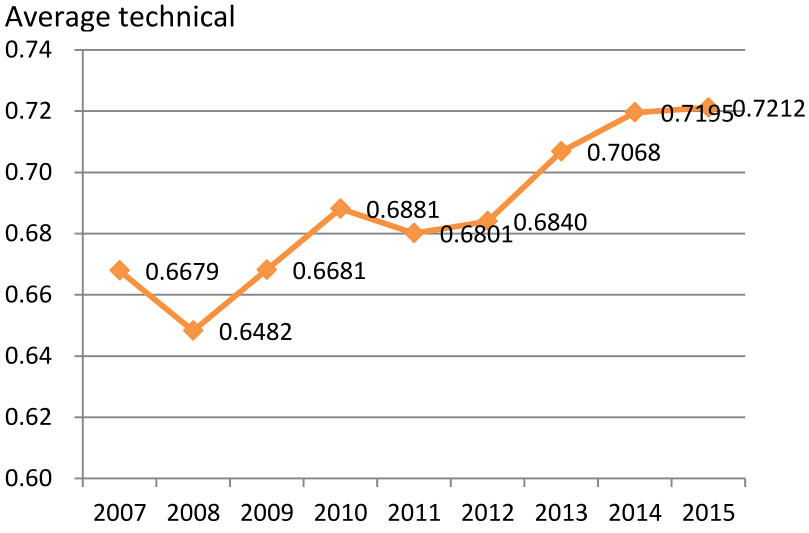


Figure1 Time Trend Chart of Aquaculture Technology Efficiency

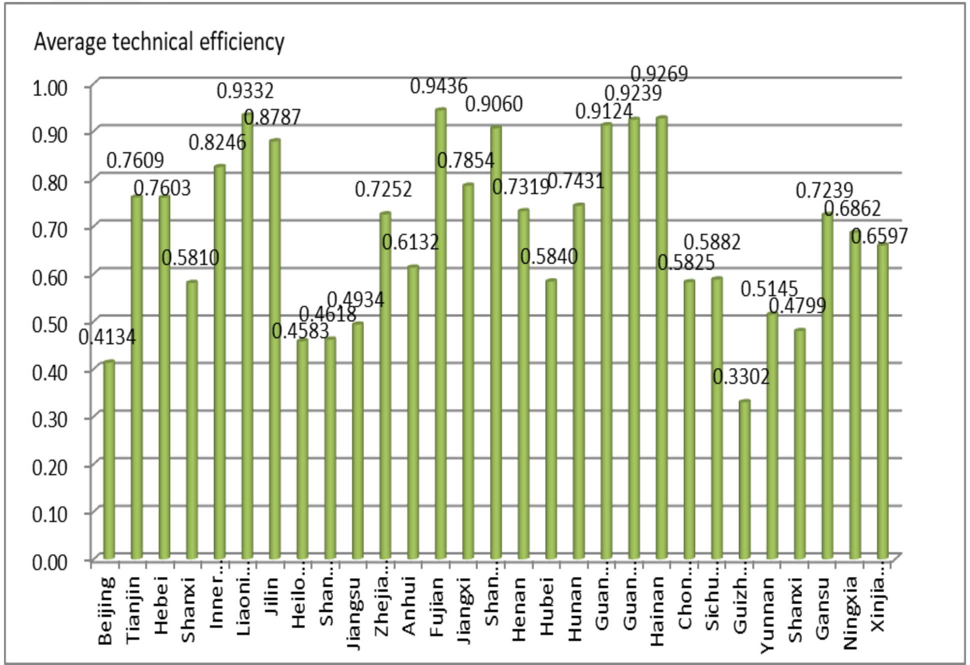
Although the technical efficiency of aquaculture in China has fluctuated from 2007 to 2015, it generally shows an upward In the global economic crisis in 2008, the fishery industry was also affected and was in a recession state, then the efficiency of aquaculture technology dropped significantly. As the country rescues the market, the recession has eased and the technical efficiency has shown an upward trend. The technical efficiency has a slight decline in 2011. From 2012 to 2015, with the improvement of relevant supporting policies, the efficiency of aquaculture technology began to gradually increase steadily.

Results of Empirical Analysis

03
OPTION

Analysis of technical efficiency

2. Analysis of spatial differences of aquaculture technology efficiency



The average technical efficiency of aquaculture varies greatly among regions. The region with the greatest technical efficiency is Fujian Province, where the technical efficiency of aquaculture is as high as 0.9436 and the technical efficiency in Guizhou is the lowest. The efficiency is only 0.3302, and the difference is large. There are six regions with technical efficiency below 50%. There are 15 areas with technical efficiency above 70%, 8 areas with over 80%, and 6 areas with technical efficiency above 90%, namely Liaoning, Fujian, Shandong, Guangdong, Hainan, and Guangxi.

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Conclusions and Suggestions

Conclusions

01

In the past 2007-2015 years, the average technical efficiency of aquaculture in China is 0.6871, and the overall level is relatively high. However, there is still much room for improvement.

02

Aquaculture in China is in a phase of diminishing returns to scale. From a time point of view, the sum of the elasticities of various input factors is less than 1 in each year, but the overall trend shows an upward trend. The elasticity of labor output and the elasticity of intermediate consumption output are positive, and the positive impact of intermediate consumption on output is greater than that of labor input on output. The output elasticity of input factors in the aquaculture area is negative each year. From a spatial point of view, the output elasticity of different input factors in different regions varies greatly. The output elasticity of labor and intermediate consumption in all regions is positive. Of the 29 statistical samples, output elasticity of aquaculture area in 17 areas is negative . It shows that the aquaculture area in most parts of China has become saturated.

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Conclusions and Suggestions

Conclusions

03

Through the analysis of the influencing factors of technical efficiency, we can see that the processing rate of aquatic products has a significant positive effect on aquaculture technology efficiency. The increase in the net export rate of aquatic products and the increase in the number of technical extension institutions contribute to the improvement of the efficiency of aquaculture technology.

04

Although the technical efficiency of aquaculture in China fluctuates in the past 2007-2015 years, it generally presents an upward trend.In 2008, the lowest technical efficiency was 0.6482, and the highest technical efficiency was 0.7212 in 2015. The average technical efficiency of aquaculture varies greatly among regions. The region with the greatest technical efficiency is Fujian Province, where the technical efficiency of aquaculture is as high as 0.9436, and the lowest one is in Guizhou, the efficiency is only 0.3302, the difference between the two is 0.6134.

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Conclusions and Suggestions

Suggestions

Strengthen the promotion of technology and increase the number of technical promotion sites to help aquaculture personnel learn scientific aquaculture techniques and improve the efficiency of existing aquaculture techniques.

Adjust the input structure of factors scientifically, and each region should decide whether to reduce the investment in aquaculture areas based on actual conditions.

Adjust the structure of foreign trade, simplify foreign trade procedures, and encourage the export of aquatic products to achieve the purpose of expanding net exports.

Develop the aquatic product processing industry, expand the sales market for aquatic products, and solve the problem of preservation of aquatic products.

Thanks for your attention

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