

Original Research Articles

The impact of the aquaculture industry agglomeration on output growth in China

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With the rapid development of China's aquaculture industry, the phenomenon of industrial agglomeration is becoming more and more obvious. This study uses the LMDI decomposition analysis method to empirically analyze the impact of aquaculture industry agglomeration on output growth. The study's conclusions include: (1) Aquaculture industry agglomeration plays an essential role in promoting the growth of aquaculture output. From 2006 to 2022, China's aquaculture production increased by 18.8711 million tons, and the agglomeration of the aquaculture industry promoted aquaculture production to increase by 5.162 million tons, with a contribution rate of 27.35 %. (2) The impact of China's aquaculture industry agglomeration on output growth shows different characteristics at different stages. During this period, the promotion effect of the agglomeration effect on output growth and the inhibition effect of the crowding effect on output growth are opposite. (3) Aquaculture industry agglomeration is a significant driving force for the output growth of different aquaculture models. The agglomeration of the aquaculture industry has promoted the growth of aquaculture output in deep-water cage, raft, bottom sowing aquaculture mode in mariculture, and pen, cage, and factory aquaculture mode in freshwater aquaculture. During this period, the agglomeration effect of the industrial agglomeration of the above aquaculture modes on the growth of the aquaculture output of each aquaculture mode is highlighted.

INTRODUCTION

In 2023, China's total output of aquatic products reached 71.16 million tons, of which aquaculture production was 58.1 million tons, accounting for 82 % of the total output of aquatic products. From 2006 to 2023, China's total output of aquatic products increased by 35 %, aquaculture production increased by 62 %, and the proportion of aquaculture production in the total output of aquatic products increased by 14 %. With the rapid development of China's aquaculture industry, the phenomenon of industrial agglomeration is becoming more and more significant. Affected by natural resource endowments, aquaculture is still mainly concentrated in coastal and riverside areas. In 2023, the proportion of aquaculture production in coastal regions of China will reach 67 %. With the continuous improvement of the production technology level of aquaculture, the continuous improvement of fishery infrastructure, and the support of government industries, the aquaculture industry has gradually extended from the traditional aquaculture ar-

reas, such as coastal areas, to various regions of the country. The aquaculture industry in inland areas is also constantly developing,¹ and Xinjiang salmon and Ningxia River crab are also well known. From 2006 to 2023, the growth rates of aquaculture production in Xinjiang and Ningxia were 144 % and 158 %, respectively. At the same time, the regionalization and specialization characteristics of the aquaculture industry have become increasingly prominent, forming a number of aquaculture industry agglomeration areas with distinctive regional characteristics, such as the advantageous aquaculture areas represented by the Yellow Sea and Bohai Sea, the southeast coastal export aquatic products advantageous aquaculture belt and the middle and lower reaches of the Yangtze River advantageous aquaculture area, the middle and lower reaches of the Yangtze River, South China, Southwest China, 'Three North' bulk freshwater fish and famous aquatic products advantageous areas, during the '13th Five-Year Plan' period, a total of 61 national aquatic health aquaculture demonstration counties and 5778 demonstration farms were created.²

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According to Marshall's industrial agglomeration theory, many scholars have conducted in-depth discussions on industrial agglomeration, especially the rise of new economic geography theory, which makes the relationship between industrial agglomeration and economic growth have a substantial connection.³ With the gradual improvement of the theoretical system of industrial agglomeration, more and more scholars have conducted empirical research on the economic effects of industrial agglomeration, and believe that industrial agglomeration will produce economic effects, which may be positive or negative. The positive impact is that the 'agglomeration effect' brought by industrial agglomeration promotes output growth, mainly including resource allocation, spillover, and market effects. The negative impact is that the 'crowding effect' caused by excessive industrial agglomeration inhibits output growth. The crowding effect of industrial agglomeration mainly includes the production factor crowding, market crowding, and ecological environment crowding. Gruber et al. comprehensively combed and summarized the existing theoretical and empirical analysis literature, highlighting the agricultural industry agglomeration's key role in agrarian output growth.⁴ Taking the mango industry in South India as an example, Sudha et al. found that the agglomeration of the farming industry can promote the value of agricultural products and the growth of agrarian output.⁵ Using data from the China Industrial Enterprise Database, Li et al. found that the agglomeration of China's forest products manufacturing industry significantly positively impacts exports, promoting the output growth of the forest products manufacturing industry.⁶ Some studies have found that industrial agglomeration does not show apparent economic effects, and sometimes even has adverse economic effects. Díaz-Bautista used the instrumental variable method to study the industrial agglomeration of 32 states in Mexico, and found no apparent correlation between industrial agglomeration and economic growth.⁷ Bradley et al. and Arin et al. studied small and medium-sized enterprises in Australia and Turkey, respectively. The results show that industrial agglomeration hurts the output growth of small and medium-sized enterprises.^{8,9} Ercole et al. studied Indonesia's manufacturing agglomeration and found that industrial agglomeration.¹⁰

Industrial agglomeration will not only produce agglomeration effect, but also produce crowding effect, which weakens the agglomeration effect brought by industrial agglomeration. So what kind of economic effect will the aquaculture industry agglomeration produce? Although existing research has explored the relationship between industrial agglomeration and economic growth, most studies focus on descriptive analyses of industrial agglomeration, lacking in-depth quantitative analyses of its economic effects. In particular, in the field of aquaculture, there are significant differences in the agglomeration effects at different stages and under different farming modes, which require further investigation. Therefore, this study will employ the LMDI decomposition analysis method to quantitatively analyze the impact of industrial agglomeration on output growth in the aquaculture sector, aiming to (1) examine whether

industrial agglomeration affects output growth in aquaculture; (2) quantify the contribution of industrial agglomeration to output growth in aquaculture if such an effect exists; and (3) analyze the impact of industrial agglomeration on output growth in aquaculture under different stages and farming modes. This is conducive to the relevant departments to give full play to the industrial agglomeration effect and promote the growth of aquaculture output under the premise of maintaining a stable total area of aquaculture, which has important practical significance for promoting the sustainable development of aquaculture.

RESEARCH METHODS AND DATA SOURCES

RESEARCH METHODS

Logarithmic Mean Divisia Index (LMDI) is an analysis method used to decompose changes in energy consumption, carbon emissions or other environmental impact indicators. This method decomposes the total change into several influencing factors in order to identify and quantify the contribution of each factor to the total change. The LMDI decomposition analysis method has the advantages of complete decomposition, no residual, and strong interpretation of the results. At present, LMDI is also widely used in agriculture. Liu et al. selected scale effect, structural effect, technical effect and price effect to study the impact of each effect on the change of total output value of China's planting industry from 1990 to 2012.¹¹ Li et al. selected the four effects of yield effect, scale effect, crop combination effect and spatial distribution effect to study the main contribution factors of China's grain yield change.¹² Ge et al. selected the base effect and scale effect to study the main contribution factors of sugarcane yield increase in the world.¹³ This study draws on Hao,¹⁴ Luo¹⁵ and others' research on the main contribution factors of wheat and rice yield changes, selects agglomeration effect, technical effect and scale effect to study the influencing factors of aquaculture yield changes, and calculates the contribution rate of the three effects.

When studying the impact of aquaculture industry agglomeration on output growth, according to the LMDI model, the decomposition formula of aquaculture output change is :

$$Q_t = \sum_{i=1}^n Q_{it} = \sum_{i=1}^n \frac{Q_{it}}{S_{it}} \times \frac{S_{it}}{S_t} \times S_t \quad (1)$$

Among them, t represents the year, i represents the aquaculture waters; Q_t represents the total output of aquaculture in period t , Q_{it} represents the total output of aquaculture in period t of water area i , S_{it} represents the aquaculture area in period t of water area i , S_t represents the total area of aquaculture in period t . In order to write simply, further make : $a_{it} = \frac{Q_{it}}{S_{it}}$, that is, the aquaculture yield per unit area in the period of i waters t , that is, the technical effect; $b_{it} = \frac{S_{it}}{S_t}$, which represents the proportion of aquaculture area in the total area of aquaculture in the period t of water area i , that is, the agglomeration effect ; $c_t = S_t$, which indicates the scale of aquaculture, that

is, the scale effect. According to the 'China Fisheries Statistics Yearbook', aquaculture waters include: sea, beaches, ponds, lakes, reservoirs, ditches and others.

When studying the impact of aquaculture industry agglomeration on output growth under different aquaculture modes, the representation of each letter in Formula (1) is redefined as follows:

$$Q_{tk} = \sum_{i=1}^n Q_{itk} = \sum_{i=1}^n \frac{Q_{itk}}{S_{itk}} \times \frac{S_{itk}}{S_{tk}} \times S_{tk} \quad (2)$$

where t denotes the year and i denotes the region; Q_{tk} represents the total breeding output of each breeding mode in period t , Q_{itk} represents the total breeding output of each breeding mode in period t of region i , S_{itk} represents the breeding area of each breeding mode in period t of region i , S_{tk} represents the total breeding area of each breeding mode in period t . In order to make the writing simple, further make: $a_{itk} = \frac{Q_{itk}}{S_{itk}}$, indicating the breeding yield of each breeding mode in the t period of the i region, that is, the technical effect; $b_{itk} = \frac{S_{itk}}{S_{tk}}$, which means the proportion of the breeding area of each breeding mode in the t period of the i region to the total breeding area, that is, the agglomeration effect; $c_{tk} = S_{tk}$, indicating the scale of each breeding model, that is, the scale effect. According to the 'China Fishery Statistics Yearbook', the aquaculture models of mariculture include: ponds, Traditional cages, deep-water cages, rafts, Suspended cages, bottom sowing, and factory aquaculture; freshwater aquaculture models include: pen, cages, factory aquaculture.

According to the LMDI model, this study decomposes the change of aquaculture production from base year 0 and target year t into:

$$\Delta Q = Q^t - Q^0 = \Delta Q_a + \Delta Q_b + \Delta Q_c \quad (3)$$

Among them, ΔQ is the change of aquaculture production in 0- t years; Q^t is the aquaculture production in t year; Q^0 is the aquaculture production of base year 0; ΔQ_a is the effect of 0- t year technical effect on the change of aquaculture production; ΔQ_b is the effect of 0- t annual agglomeration effect on the change of aquaculture production; ΔQ_c is the effect of scale effect on aquaculture yield change in 0- t years.

DATA SOURCES

This part takes 2005 as the base year to study the contribution of agglomeration effect, technical effect and scale effect to the change of aquaculture production since the 'Eleventh Five-Year Plan' (2006-2022). The data involved

include aquaculture production and aquaculture area data from 2005 to 2022. The data are derived from the 'China Fisheries Statistical Yearbook' from 2006 to 2023. In view of the availability of aquaculture production and aquaculture area data of different aquaculture models, when studying the impact of aquaculture industry agglomeration on output growth under different aquaculture models, taking 2011 as the base period, this paper studies the contribution of agglomeration effect, technical effect and scale effect to the change of aquaculture production from 2012 to 2022. The data are derived from the 'China Fisheries Statistical Yearbook' from 2012 to 2023.

RESULTS

RESEARCH ON THE IMPACT OF AQUACULTURE INDUSTRY AGGLOMERATION ON OUTPUT GROWTH

According to the cumulative change of the decomposition effect of the national aquaculture production change, from the perspective of the change trend of the contribution value, taking 2005 as the base year, the cumulative change of China's aquaculture production from 2006 to 2022 showed an overall upward trend. The effects of the three effects on the changes of China's aquaculture production show significant differences. The overall trend of the agglomeration effect is similar to the trend of the cumulative change of aquaculture production, showing an upward trend. The technical effect shows a trend of decreasing first and then increasing, while the scale effect shows a trend of increasing first and then decreasing. From the perspective of contribution value, China's aquaculture production increased by 18.8711 million tons from 2006 to 2022. Among them, aquaculture industry agglomeration promoted aquaculture production to increase by 5.162 million tons, with a contribution rate of 27.35%. Aquaculture technology promoted aquaculture production by 17.3011 million tons, with a contribution rate of 91.68%. The decrease in aquaculture area led to a decrease in aquaculture production of 3.592 million tons, with a contribution rate of -19.03% (Table 1). This shows that since the 'Eleventh Five-Year Plan', the growth of aquaculture production in China mainly depends on the improvement of aquaculture technology and the agglomeration of aquaculture industry. Although the contribution of aquaculture industry agglomeration is not as great as the contribution of aquaculture technology progress, it is also an important factor in the growth of aquaculture production. This is mainly because,

According to Ang's¹⁶ LMDI decomposition method, the factorization of formula (3) is obtained:

Technology effect	$\Delta Q_a = \sum_{i=1}^n \frac{Q_i^t - Q_i^0}{\ln Q_i^t - \ln Q_i^0} \times \ln \frac{a_i^t}{a_i^0} \quad (4)$
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Agglomeration effect	$\Delta Q_b = \sum_{i=1}^n \frac{Q_i^t - Q_i^0}{\ln Q_i^t - \ln Q_i^0} \times \ln \frac{b_i^t}{b_i^0} \quad (5)$
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Scale effect	$\Delta Q_c = \sum_{i=1}^n \frac{Q_i^t - Q_i^0}{\ln Q_i^t - \ln Q_i^0} \times \ln \frac{c_i^t}{c_i^0} \quad (6)$
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Table 1. Cumulative changes in the decomposition effect of changes in national aquaculture production (Unit: ten thousand tons).

Year	Total effect	Technology effect	Agglomeration effect	Scale effect
2006	180.51	66.77	4.65	109.09
2007	-128.86	820.15	-48.4	-900.61
2008	4.69	442.48	39.63	-477.42
2009	214.28	245.05	85.99	-116.76
2010	413.43	233	122.32	58.1
2011	612.14	339.24	121.57	151.32
2012	864.08	440.81	143.71	279.55
2013	1105.50	535.45	168.83	401.21
2014	1311.60	712.94	162.73	435.92
2015	1490.95	850.35	160.88	479.71
2016	1688.03	1131.54	145.67	410.82
2017	1420.11	1267.1	292.84	-139.84
2018	1466.60	1304.81	469.44	-307.66
2019	1496.61	1407.44	450.9	-361.75
2020	1608.15	1542.3	477.17	-411.32
2021	1747.59	1669.29	508.52	-430.23
2022	1887.11	1730.11	516.2	-359.2

as mentioned above, during the period 2006-2022, in order to achieve the sustainable development of the aquaculture industry, the government has continuously adjusted and optimized the layout of the aquaculture industry through the implementation of relevant industrial policies. The gradual rationalization of the aquaculture industry layout highlights the agglomeration effect and promotes the growth of aquaculture production.

From the decomposition effect share and contribution rate of national aquaculture production in [Table 2](#), it can be seen that with 2005 as the base year, China's aquaculture production increased by 4.1343 million tons from 2006 to 2010. During this period, the contribution share of agglomeration effect to the growth of aquaculture production was 1.2232 million tons, and the contribution rate was 29.59%. The contribution share of technical effect is 2.33 million tons, and the contribution rate is 56.36%. The contribution of scale effect to the growth of aquaculture production was at least 581,000 tons, with a contribution rate of 14.05% ([Table 2](#)). It can be seen that the growth of aquaculture production in China from 2006 to 2010 is the result of technical effect, agglomeration effect and scale effect. The contribution rate of agglomeration effect is second only to technical effect, which is an important factor to promote the growth of aquaculture production. This is mainly because during the '11th Five-Year Plan' period, the regional layout of dominant aquatic products breeding represented by the 'two zones and one zone' with the dominant aquaculture zones in the Yellow Sea and the Bohai Sea, the southeast coast and the middle and lower reaches of the Yangtze River as the main body was basically formed.¹⁷ At the same time, healthy aquaculture has been comprehensively promoted, more than 1700 standardized healthy aquaculture demonstration sites (areas) have been created,

and intensive aquaculture methods such as deep-water anti-wave cage aquaculture have developed rapidly. The gradual rationalization of the industrial layout of the aquaculture industry has highlighted the agglomeration effect and promoted the growth of aquaculture production.¹⁸

From 2011 to 2015, China's aquaculture production increased by 10.7752 million tons, and the contribution of agglomeration effect to the growth of aquaculture production was only 385,600 tons, with a contribution rate of 3.58% ([Table 2](#)). Although the contribution rate of agglomeration effect to the growth of aquaculture production was not high during this period, and the promotion effect on the growth of aquaculture production was lower than that of the previous stage, it still played a role in promoting it. This is mainly because, during the 'Twelfth Five-Year Plan' period, although the continuous adjustment and optimization of the aquaculture industry layout and aquaculture species structure, to speed up the 'two belts and one area' as the representative of the advantages of aquatic products aquaculture regional layout, and the middle and lower reaches of the Yangtze River, South China, Southwest, 'three north' bulk freshwater fish and famous aquatic products advantage area layout basic formation, and the popularization and application of healthy aquaculture models and standards. However, during this period, the crowding effect has increased the inhibition of aquaculture production growth. From the perspective of ecological environment crowding, the current trend of fishery resources reduction and water environment quality decline is accelerating, and the problem of insufficient water resources has become more serious. These factors seriously threaten the natural resources and environmental basis of fishery industry development. From the perspective of market crowding, there is a phenomenon of structural surplus in the aquatic product mar-

Table 2. Sub-periods of national aquaculture production decomposition effect share and contribution rate.

Year	Total share (ten thousand tons)	Technology effect		Agglomeration effect		Scale effect	
		Share (ten thousand tons)	Contribution rate (%)	Share (ten thousand tons)	Contribution rate (%)	Share (ten thousand tons)	Contribution rate (%)
2006–2010	413.43	233.00	56.36	122.32	29.59	58.10	14.05
2011–2015	1077.52	617.35	57.29	38.56	3.58	421.61	39.13
2016–2022	396.16	879.76	222.07	355.32	89.69	-838.92	-211.76
2006–2022	1887.11	1730.11	91.68	516.20	27.35	-359.20	-19.03

ket. The supply of major bulk varieties has become saturated, while the supply of high-quality products is still insufficient, resulting in an intensified contradiction between supply and demand. In addition, the price of some aquatic products has been at a low level for a long time, and the price of some products has even fluctuated sharply. At the same time, the production cost has been rising, and the relative economic benefits of fisheries have also declined.¹⁹ Therefore, during the 'Twelfth Five-Year Plan' period, the crowding effect of aquaculture industry agglomeration inhibited the growth of aquaculture production, offsetting the promotion effect of partial agglomeration effect on the growth of aquaculture production, so the contribution rate of industrial agglomeration to the growth of aquaculture production was not high at this stage.

From 2016 to 2022, China's aquaculture production increased by 3.9616 million tons, which was close to the cumulative increase of aquaculture production in the first stage. During this period, the growth of China's aquaculture production was the result of the combined effect of technical effect and agglomeration effect. The contribution share of agglomeration effect was 3.5532 million tons, and the contribution rate was 89.69%. The contribution rate of agglomeration effect was second only to technical effect. During this period, the scale effect inhibited the growth of aquaculture production, resulting in a cumulative reduction of 8.3892 million tons of aquaculture production, with a contribution rate of -211.76% (Table 2). It can be seen that the promotion effect of industrial agglomeration on the growth of aquaculture production at this stage is higher than that at the previous stage, and industrial agglomeration is still an important factor to promote the growth of aquaculture production. This is mainly because during the '13th Five-Year Plan' period, China shifted the focus of aquaculture development from focusing on quantity growth to improving quality and efficiency. To ensure that the regional layout and the carrying capacity of resources are coordinated, the product structure can basically meet the needs of consumers' upgrading, and the industrial structure can better adapt to the needs of transformation and upgrading. At the same time, it ensures that the factor allocation is basically consistent with the direction of industrial development,² thus reducing the ecological environment. The crowding effect and market crowding effect have a negative effect on the growth of aquaculture production. Therefore, at this stage, the agglomeration effect increases and is greater than the crowding effect, making industrial agglomeration promote the growth of aquaculture production.

STUDY ON THE IMPACT OF AQUACULTURE INDUSTRY AGGLOMERATION ON OUTPUT GROWTH UNDER DIFFERENT AQUACULTURE MODES

Taking 2011 as the base year, from the perspective of time periods, the agglomeration effect in 2012-2015 promoted the growth of aquaculture production in four aquaculture modes, namely, deep-water cage and raft aquaculture mode in mariculture, pen and cage aquaculture mode in freshwater aquaculture. The contribution share of agglomeration

effect to the growth of aquaculture production was 75300 tons, 677,000 tons, 76,000 tons and 305,800 tons respectively, and the contribution rate was 152.12%, 65.02%, 16.74% and 339.40% respectively (Table 3). This is mainly because during the 'Twelfth Five-Year Plan' period, the relevant government departments have adjusted and optimized the layout of aquaculture models. On the one hand, the long-term high-density traditional cage culture has led to the deterioration of fishery resources and the pollution of offshore ecological environment.²⁰ Therefore, during the 'Twelfth Five-Year Plan' period, offshore aquaculture such as deep-water cages has been actively expanded, and the deep-water cage culture model has been rapidly developed. On the other hand, during this period, the relevant government departments reasonably controlled and scientifically planned cage and pen culture. The raft culture mode is mainly based on the cultivation of shellfish and algae. As mentioned above, shellfish and algae culture plays an important role in alleviating regional water pollution and reducing the impact of regional climate changes, which promotes the rapid development of raft culture mode. Therefore, the industrial layout of deep-water cages, rafts, pen, and cage aquaculture models has been reasonably adjusted and optimized, making the agglomeration effect prominent and promoting the growth of aquaculture production.¹⁸

From 2016 to 2022, the agglomeration effect promoted the growth of aquaculture production in six aquaculture modes, including deep-water cage, raft, bottom sowing aquaculture mode in marine aquaculture, pen, cage and factory aquaculture mode in freshwater aquaculture. The contribution of agglomeration effect to the growth of aquaculture production was 121,100 tons, 173,400 tons, 743,100 tons, 268,000 tons, 204,100 tons, and 48,900 tons, respectively. The contribution rates were 42.03%, 10.62%, 210.21%, 9.64%, 32.23%, and 27.15% (Table 4). Compared with 2012-2015, in 2016-2022, industrial agglomeration has promoted the growth of aquaculture production under more aquaculture modes, and their contribution share of industrial agglomeration to the growth of aquaculture production is basically increasing. This is mainly because, as mentioned above, during the '13th Five-Year Plan' period, in order to control the decline of fishery resources and the pollution of ecological environment, the state scientifically delineated the prohibited aquaculture areas, restricted aquaculture areas and aquaculture areas, and further adjusted and optimized the layout of each aquaculture mode. During this period, cage and pen aquaculture were further reasonably controlled and scientifically planned, which promoted the development of offshore deep-water cage aquaculture, ecological aquaculture, inland environmentally friendly cage aquaculture, and industrialized recirculating aquaculture, and realized the overall planning and coordinated development of aquaculture waters. Therefore, compared with 2012-2022 and 2012-2015, in more breeding modes, industrial agglomeration has played a role in promoting the growth of breeding production and the contribution share of industrial agglomeration is basically increasing.

Table 3. The decomposition effect of aquaculture yield in each aquaculture mode from 2012 to 2015. (Unit: ten thousand tons).

Breeding mode		Total effect	Technology effect	Agglomeration effect	Scale effect
Mariculture	Pond	39.32	18.96	-3.67	24.03
	Traditional cage	11.83	-12.52	-10.99	35.34
	Deep-water cage	4.95	-6.29	7.53	3.71
	Raft	104.12	114.62	67.70	-78.20
	Suspended cage	50.68	10.45	-9.31	49.54
	Bottom sowing	96.60	55.49	-72.39	113.50
	Factory	5.94	-1.04	-2.50	9.48
Freshwater aquaculture	Pen	-4.54	-3.11	0.76	-2.19
	Cage	9.01	11.86	30.58	-33.43
	Factory	2.60	-4.54	-0.40	7.54

Table 4. The decomposition effect of aquaculture yield in each aquaculture mode from 2016 to 2022. (Unit: ten thousand tons)

Breeding mode		Total effect	Technology effect	Agglomeration effect	Scale effect
Mariculture	Pond	57.27	76.54	-7.18	-12.09
	Traditional cage	17.33	50.19	-50.01	17.15
	Deep-water cage	28.81	-15.74	12.11	32.44
	Raft	163.29	31.36	17.34	114.59
	Suspended cage	42.12	26.47	-4.53	20.18
	Bottom sowing	35.35	78.84	74.31	-117.8
	Factory	19.81	9.51	-2.25	12.55
Freshwater aquaculture	Pen	-27.81	7.38	2.68	-37.87
	Cage	-63.33	6.18	20.41	-89.92
	Factory	18.01	0.21	4.89	12.91

From the perspective of the two periods, industrial agglomeration in 2012-2022 has promoted the growth of aquaculture production in deep-water cages, rafts, bottom-seeding aquaculture models in mariculture, pen, cages, and factory aquaculture models in freshwater aquaculture. The contribution shares are 196,400 tons, 850,400 tons, 19,200 tons, 34,400 tons, 509,900 tons, and 44,900 tons, respectively, and the contribution rates are 58.18 %, 31.80 %, 1.46 %, 10.63 %, 93.87 %, and 21.79 %, respectively (Table 5). It can be seen that industrial agglomeration is an important driving force for the growth of aquaculture production in different aquaculture models.

CONCLUSIONS AND DISCUSSION

With the rapid development of China's aquaculture industry, the phenomenon of industrial agglomeration is becoming more and more obvious. This study decomposes the increment of total aquaculture output into the contribution of agglomeration effect, technical effect and scale effect,

and uses LMDI decomposition analysis method to empirically analyze the impact of aquaculture industry agglomeration on output growth. The main research conclusions include: (1) Aquaculture industry agglomeration plays an important role in promoting the growth of aquaculture output. From 2006 to 2022, China's aquaculture production increased by 18.8711 million tons, and aquaculture industry agglomeration promoted aquaculture production to increase by 5.162 million tons, with a contribution rate of 27.35%. (2) The impact of China's aquaculture industry agglomeration on output growth shows different characteristics at different stages. During this period, the promotion effect of agglomeration effect on output growth and the inhibition effect of crowding effect on output growth are opposite. The growth of aquaculture production in China from 2006 to 2010 is the result of the combined effect of technical effect, agglomeration effect and scale effect. The contribution rate of agglomeration effect is second only to that of technical effect and is not much different from that of technical effect. The agglomeration effect also played a role in promoting the growth of aquaculture production in

Table 5. The decomposition effect of aquaculture yield in each aquaculture mode from 2012 to 2022. (Unit: ten thousand tons).

Breeding mode		Total effect	Technology effect	Agglomeration effect	Scale effect
Mariculture	Pond	96.59	95.50	-10.85	11.94
	Traditional cage	29.16	37.67	-61.00	52.49
	Deep-water cage	33.76	-22.03	19.64	36.15
	Raft	267.41	145.98	85.04	36.39
	Suspended cage	92.80	36.92	-13.84	69.72
	Bottom sowing	131.95	134.33	1.92	-4.30
	Factory	25.75	8.47	-4.75	22.03
Freshwater aquaculture	Pen	-32.35	4.27	3.44	-40.06
	Cage	-54.32	18.04	50.99	-123.35
	Factory	20.61	-4.33	4.49	20.45

2011-2015, although its contribution was small. The growth of aquaculture production in China from 2016 to 2022 is mainly the combined effect of technical effect and agglomeration effect, and the scale effect does not play a role in promoting. (3) Aquaculture industry agglomeration is an important driving force for the output growth of different aquaculture models. Aquaculture industry agglomeration has played a role in promoting the growth of aquaculture production in deep-water cages, rafts, bottom sowing aquaculture models in mariculture and enclosures, cages and factory aquaculture models in freshwater aquaculture. During this period, the industrial agglomeration of the above aquaculture models has highlighted the agglomeration effect on the growth of aquaculture output of each aquaculture model. At the same time, based on industrial agglomeration theory and the empirical analysis results of this study, we believe that the impact of industrial agglomeration on output growth in the aquaculture sector is formed by the interaction of agglomeration effects and crowding effects. The agglomeration effect manifests as positive externalities generated by industrial agglomeration, which promote output growth in the aquaculture sector, mainly including resource allocation effects, spillover effects, and market effects. In contrast, the crowding effect manifests as negative externalities arising from industrial agglomeration that inhibit output growth in the aquaculture sector, primarily involving factor crowding, market crowding, and ecological environment crowding. When the aquaculture sector is moderately agglomerated, the agglomeration effect becomes prominent and positively influences output growth; however, when the aquaculture sector is excessively agglomerated, the crowding effect becomes significant and negatively affects output growth.

Based on the main conclusions of the study, in order to formulate a more targeted aquaculture industry policy and promote the sustainable development of aquaculture, this study puts forward the following policy recommendations: in the process of promoting industrial agglomeration, the scale of development should be reasonably controlled, and the aquaculture industry agglomeration area should be sci-

entifically evaluated and planned. (1) From the production factor crowding effect perspective, the government can collaborate with universities and research institutions to establish joint industry-university-research projects, promoting technology transfer and application. By enhancing technological innovation, the utilization rate of production factors can be improved. At the same time, relevant departments need to guide the flow of factors related to the aquaculture industry, such as government policies that direct capital and labor towards efficient farming areas, thereby optimizing resource allocation and reducing the production factor crowding effect resulting from industrial agglomeration. (2) From the market crowding effect perspective, on one hand, the distribution system for aquatic products can be improved. The government can increase investment in cold chain logistics and storage facilities for aquatic products to enhance circulation efficiency. On the other hand, relevant departments can establish an information service platform for aquatic products, accelerating the digitalization of the aquatic market, timely releasing market supply and demand information, and price dynamics, thereby reducing the risk of price fluctuations caused by information asymmetry and mitigating the market crowding effects resulting from industrial agglomeration. (3) From the ecological environment crowding effect perspective, relevant departments should implement specific policies focused on the standardized upgrading of inland aquaculture ponds and the treatment of aquaculture effluent to meet standards, promoting the centralized discharge of aquaculture pond effluent and installing intelligent water quality monitoring and environmental adjustment systems. It is also recommended that the government scientifically plan the scale and density of aquaculture based on regional resource carrying capacity, effectively preventing pollution from the aquaculture industry, reducing excessive use and destruction of local resources by farmers or enterprises, and thereby alleviating the ecological environment crowding effects arising from industrial agglomeration to promote the healthy and sustainable development of the aquaculture industry.

Although this study has achieved certain results in examining the impact of industrial agglomeration on output growth in the aquaculture sector, there are also some limitations that need to be addressed in future research. (1) This study analyzes the impact of industrial agglomeration on output growth from a macro perspective, lacking in-depth exploration of different regions. Future research may conduct further analysis when data becomes available. (2) Due to the availability of data and the limitations of the LMDI method, the study only considers agglomeration effects, technological effects, and scale effects, while neglecting other factors that may influence output growth. Future research could incorporate other research methods for further analysis.

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AUTHORS' CONTRIBUTION

Writing – original draft: Jing Wang (Lead). Writing – review & editing: Jing Wang (Equal), Chen Sun (Equal), Yanfang Wu (Equal), Hongtao Jin (Equal). Data curation: Jing Wang

(Lead). Software: Jing Wang (Lead). Conceptualization: Chen Sun (Equal), Yanfang Wu (Equal), Hongtao Jin (Equal). Methodology: Chen Sun (Equal), Yanfang Wu (Equal), Hongtao Jin (Equal). Supervision: Chen Sun (Equal), Yanfang Wu (Equal), Hongtao Jin (Equal). Funding acquisition: Hongtao Jin (Lead).

COMPETING OF INTEREST – COPE

No competing interests were disclosed.

ETHICAL CONDUCT APPROVAL – IACUC

This study did not involve any experimental research on animals or plants.

INFORMED CONSENT STATEMENT

All authors and institutions have confirmed this manuscript for publication.

DATA AVAILABILITY STATEMENT

All are available upon reasonable request.

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