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ABSTRACT

This paper analyzes the state and conditions of aquaculture in South China Sea both from technological and economic perspectives. We state from the basic marginal cost analysis and construct a two sector model for this issue. Base on the comparison on the cost between aquaculture sector and traditional agricultural sector, we conclude that China has a big potential in aquaculture and the government should impulse this industry by necessary policy instrument.

Keywords: aquaculture; agriculture; marginal cost

1. Introduction

Aquaculture has been existed in China for more than 2500 years and it started by the farming of carps. In the modern aquaculture, China's fisheries industry as well as aquaculture was suffering difficulties before the 1980s and short supply of aquatic products existed in not only rural but urban areas in China. However, after the reform and Opening-up in 1978, the aquaculture had been expanded since the 1980s. With the development of modern aquaculture, it has separated into two sub-sectors, one is freshwater aquaculture and the other one is marine aquaculture. In this paper, it will be focusing on marine aquaculture only. More than 1.33 million hectares of suitable area for marine aquaculture are available in China and there are extremely large potential to be developed in the future. Therefore, the marine aquaculture could provide numerous nutrition and energy for the huge population in China and further relieve the land use pressure. But historically, the nutrition for the population in China is mainly provided by the agriculture on the land.

In this paper, it would firstly focus on the historical and literature review in terms of aquaculture and the reason why specifically concentrating on the marine aquaculture would be given. Then a methodology of dual sectors economy model will be introduced in order to be used to explain the marine aquaculture's comparative advantages in terms of cost theory. Furthermore, a real case of Giant Clams in China including data and analysis will be raised as an example to prove that marine aquaculture truly has low cost advantage. Finally, several generally political proposals would be given.

2. Historical and Literature Review

China has the largest population (more than 1.3 billion) in the world and the aquaculture has been developed in China since 1000 BC and spread to Asia as well as the rest of the world (Nash 2011). In terms of modern aquaculture in China, because of the booming of its population, the land resources are inadequate and therefore the animal protein and crops cannot match the sharply increasing demand. After the Reform and Opening up in 1978, marketization happened in China and pricing system had been operated in China's fishery industry and then management system as well as fishermen's motivation had been activated. After that, aquaculture has been emphasized by the China's government since 1980s and the purpose is to provide not only nutrition but also economic benefits and additionally relieve the pressure of the farming land (Yang et al, 2004). Then after 1980s, China has had become the biggest country with the greatest production in terms of aquaculture in the world (Fang et al, 2001; Qing 1994). Aquaculture commonly has two sub-sectors, one is freshwater aquaculture and the other one is marine aquaculture. According to the China Marine Statistical Yearbook in 2009, the total proportion of marine aquaculture is 1578909 hectares and the total area of freshwater aquaculture is 4971023 hectares, the ratio in terms of marine/freshwater is 1: 3.15, which means that there is a great difference between the marine aquaculture proportion and the freshwater aquaculture proportion. However, the production per hectare of marine aquaculture is 8489 kg/hectare which is much higher than it of freshwater aquaculture (3916 kg/hectare). All these data demonstrates that the marine aquaculture has a tremendous potential to be further developed in China. Therefore, the marine aquaculture will be mainly focused in this paper.

In China, marine aquaculture industry mainly establishes along the coast in shallow seas and bays at depths no more than 15 meters but afterwards expanding up to 50 meters (Yang 2004). According to the data from the State Oceanic Administration (SOA) as well as the China Marine Statistical Yearbook, the production of marine aquaculture in 1985 is 1246500 tons and then increases to 7215100 tons in 1995 and rockets to 28380000 tons in 2005. But comparing with the development of land agriculture, especially after the agricultural taxes were forever eliminated in 2006, the concentration and the development of marine aquaculture is relatively not enough.

Actually, the marine aquaculture was initially focused by the scholars in 1970s. Idyll (1973) lists several problems that should be deeper resolved including the suitable species researches, cultivated species' pathology, legal and institutional research, which are similar to groundwork in the field of marine aquaculture. Shang (1973) takes Taiwan as a specific region to compare its marine aquaculture, ocean fisheries as well as land farming and achieve a conclusion that marine aquaculture has a relatively higher returns. Then in 1975, Huguenin reports that Environmental Systems Laboratory of the Woods Hole Oceanographic Institution was focusing on the facilities and flows of using larger scale of seawater for searching in the marine aquaculture, sea pollution control and biology along the coasts. Within 1980s, marine aquaculture in particular regions as well as the related systems started to be concentrated and it gradually grew to be a mature industry. In other words, it was a decade that many regions in the world realized that marine aquaculture was an industry with a huge potential. For instance, researches of marine aquaculture in Sweden by Ackefors (1982) and Carlberg (1982), concentration on the aquaculture management in Bangladesh is raised by Bashirullah et al (1989) and the nutrition that provided by the seafood cultivation is also emphasized by the United States' scholarly journal SEA TECH in 1981. Folke and Kautsky (1989) even point out that marine aquaculture should be developed together with the improvement of ecosystem. During 1990s, the marine aquaculture had been separated into different segments in terms of different marine species such as Giant Clams, Salmon and Shrimp. However, specifically in China, since 1980s, the decade after the Reform and Opening-up in 1978, numerous scholars also have had multiple researches towards the marine aquaculture. But most of them are just constructing the structural development or publishing the technical innovation in terms of practical cultivation or suggesting stimulation from trade perspective. For example, Lei (2010) suggest that the policy orientation should shift to guide the marine aquaculture to a larger scaled production. Xu and Xu (2008) claim that China's marine aquaculture could be driven by the increasing trade of the marine products.

As can be seen above, most of them are focusing on the technics or the development of general policy suggestions towards marine aquaculture. None of them discusses the general marine aquaculture from an economic point of view to analyze the reason for deeper development of marine aquaculture in China. Therefore, marine aquaculture will be analyzed from the economic point of view, especially in terms of cost theory comparing with agriculture.

3. Methodology

3.1 Dual Economy Model

One-sector model was initially concerned in neo-classical growth model, but most developing countries are facing to multiple sector economic growth situations such as different marginal costs of different sectors or different levels of productivity in different sectors. Jerry (1992) states that the two-sector model was first rose by the French physiocrats. And he further presents that the classical dualism then was focused by Ricardo in 1815 and Marx in 1857 which consists of agricultural and industrial sectors. Then, Lewis (1954) first brought the concept of ‘modern dual economy model’. In modern dual economy theory, two sectors, traditional sector and modern sector are commonly assumed. In terms of traditional sector, it is defined by numerous scholars, but it is typically referred to a productive sector which is predominantly rural and is restricted by some fixed resources such as land and generally has relatively lower productivity (Basu 1997; Lewis 1954; Ranis 1988). In the following work, agriculture is considered as traditional sector and the aquaculture is referred to modern sector.

Wang (2005) focuses on the marginal costs in terms of dual sectors production model in his book. Specifically, traditional sector has a relatively higher marginal cost during its production process but modern sector has a lower marginal cost, especially after the production expansion. Details could be seen in Figure 1.

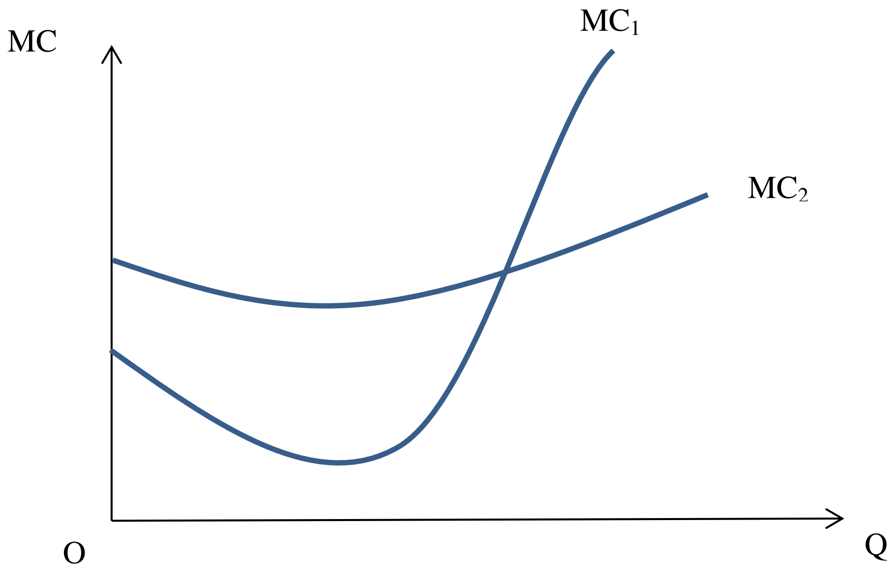

Figure 1. Two sectors' marginal cost

As can be seen in Figure 1, it is assumed that there are two manufacturing shops in a factory. Sector 1 is relatively older and lower productivity but is appropriate for small scale production (MC_1 is its marginal cost and the curve slope will be steeper which means that its marginal cost would be increased when the quantity is increased); sector 2 is relatively newer and higher productivity but is appropriate for large scale production (MC_2 is its marginal cost and the curve slope will be smoother which means that its marginal cost would be decreased when the quantity is increased). According to these characteristics, it is obvious that the MC_1 curve is below MC_2 curve when the output quantity is less and MC_1 curve is above MC_2 curve when the output is larger. Then, the Figure 1 could be reversed along the horizontal axis which is illustrated in Figure 2.

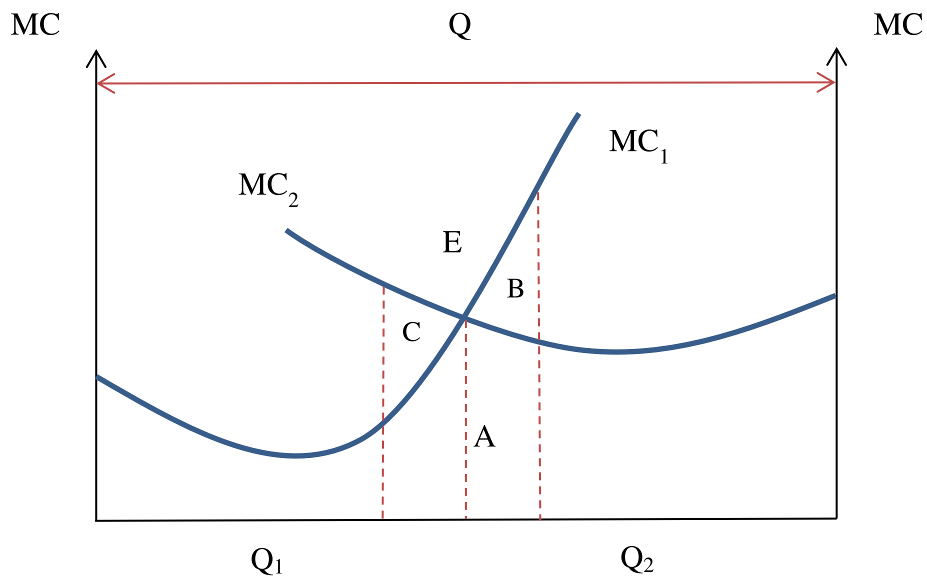

Figure 2. Distribution of output (small scale)

Figure 2 demonstrates that the total output target is Q and when the curves are crossed on equilibrium point (point E), the total variable cost is the lowest illustrated by area A and the distributed quantities for sector 1 and sector 2 are Q_1 and Q_2 respectively. If the output of sector 1 is increased, the variable cost will be increased as well, which is demonstrated by area B. Adversely, if the output of sector 2 is increased, the variable cost will be increased as well, which is illustrated by area C.

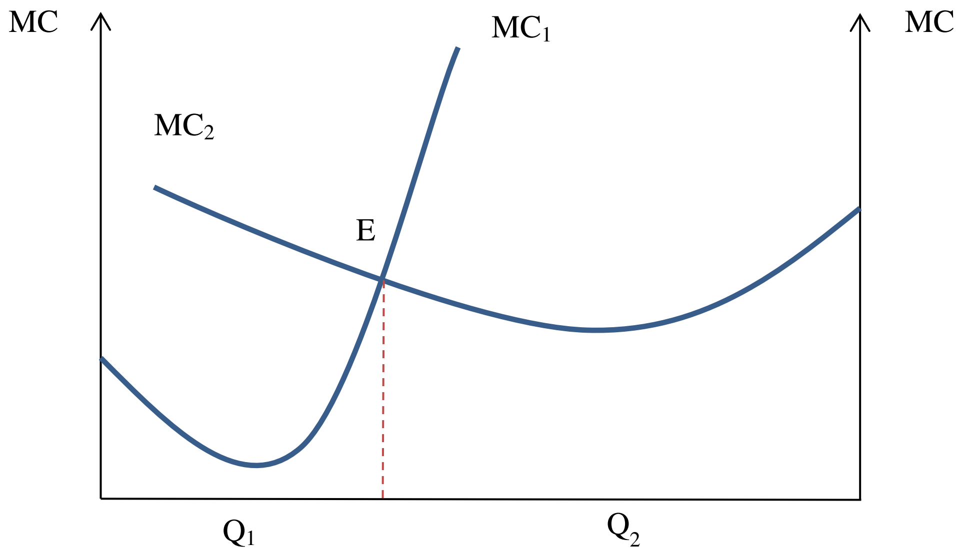

Figure 3. Distribution of output (expanded production)

However, when the factory expands its production, the comparative advantage of sector 2 will be appeared (Figure 3) because of the higher productivity or higher technology. In other words, sector 2 has much more potential than sector 1 when the production is expanded and it is obvious that Q_1 is less than Q_2 under this situation.

According to what have been discussed above, a conclusion can be drawn that when a factory is using two sectors to produce, the optimal situation (lowest cost) is when the marginal cost for each sector is the same ($MC_1 = MC_2$).

3.2 In this case

In this particular case in China, the agricultural sector is considered as sector 1, which is relatively lower productivity and has lower technologies and higher marginal cost; and the marine aquaculture is referred as sector 2 which has lower marginal cost when the economy is under the assumption that he total social output will be increasing ever which is same as 'expanded production in factory' (evidence will be given by a particular example in China in next section). It can be seen in Figure 4.

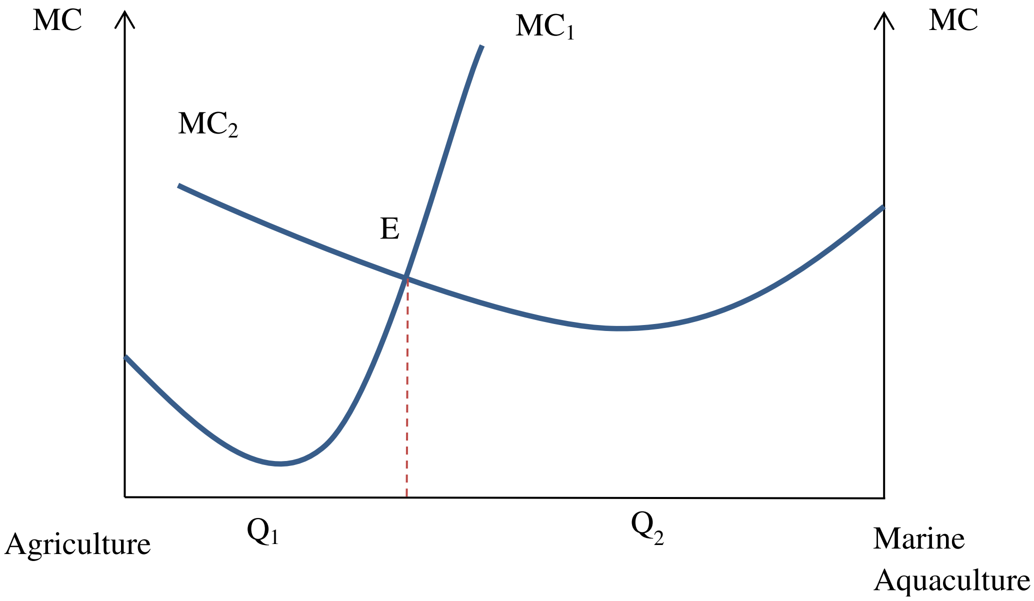

Figure 4. Macro Agriculture and Aquaculture Distribution

4. A real case in China

The cultivation of Giant Clams is considered as a particular example in terms of marine aquaculture to be used in this paper in order to prove that its characteristics are similar to 'sector 2' which means that its marginal cost of cultivation is lower than the 'sector 1' agriculture.

4.1 Background

Tridacninae, the common name of Giant Clams, is one kind of the largest bivalve mollusks in saltwater and there are 6 subspecies which are *Tridacna gigas, Tridacna* *derasa, Tridacna squamosa, Tridacna maxima, Tridacna crocea* and *Hippopus hippopus*. And the biggest one is *Tridacna gigas* which has ever found is 130 centimeters length, 500 kilograms weight and living for more than 60 years (John 1998). Giant Clams were dominant species which lived around coral reef ever, and were widely distributed in the Pacific and the Indian Ocean. But since 1960s, the Giant Clams had been significantly destroyed by human beings and disappeared in many ocean areas. However, it had been becoming a hot marine resource again since 1980s because of its extremely high economic, environmental as well as ecological values. Therefore, aquaculture of Giant Clams was deeply researched by the Pacific and Asian countries.

4.2 Advantages of Giant Clams cultivation

Giant Clams are worth being researched mainly because first it has ecological valuation. Yonge (1975) reveals that the mainly positive characteristic of Giant Clam is the symbiotic relationship between the Giant Clam and the zooxanthellae, which means that the nutrition could be provided by the zooxanthellae. In other words, Giant Clam can directly use the inorganic salt in shallow water which means that it is easy to cultivate and has high ecological values. Secondly, the cultivation of Giant Clam also has high quality of economic values. Specifically, the mollusk meat has wide sale market especially in Japan and Taiwan. Furthermore, the dried scallop which is made by its adductor is extremely famous in Taiwan. Finally, in terms of Carbon Sink Fishery, the cultivation of Giant Clams has its special meanings.

In terms of Carbon Sink Fishery, Giant Clam cultivation has a significant impact on it. A process of absorbing CO_2 in the ocean by cultivating the aquatic lives and transferring carbon out of ocean and then into marine production is called Carbon Sink Fishery. Davies (1984) reports 90 percent to 95 percent of carbon which is concentrated by the zooxanthellae's photosynthesis is transferred from the ocean into the host. In this case, large amount of carbon is transferred into the shell of Giant Clams. According to many researches, different carbon sequestrations of different species could be given in Table 1.

	Production per （ton/hectare *yr）	Inventory per （ton/hectare）	carbon sequestrations （ton/yr）	Ref.
Tridacna gigas	180	400	18	1
Sinonovacula constricta	12	12	1	2
Scallop	11.4	11.4	1	3
Forest		63（m^3）	1.4	4

Table 1. Carbon sequestrations

Table 1 illustrates that Giant Clams have significantly comparative advantage rather than other three items. In addition, the shell could be considered as a permanent Carbon Sink. In other words, carbon which has already been sunk into shells would require millions of years to cycle back to the atmosphere as well as the oceans (Xiao & Liu 2010).

4.3 The lower costs of cultivation of Giant Clams

In terms of cultivation cost, its marginal cost is relatively low. It could be focused on two sides, one is its living conditions and the other one is its rate of growth. Specifically, the level of living requirement is extremely low and the growth rate is absolutely high,

[1] Lucas, JS 1992, 'Density of Clams and Depth Reduce Growth in Grow-out Culture of Tridacna gigas'
[2] Lin, ZH & You, ZJ 2005, 'High-tech model of shellfish cultivation in intertidal zone in ZheJiang province'
[3] Li, CL 2011, 'The development strategies of scallop cultivation in ShanDong province'
[4] Li, NY, Song, WM & Zhang, SD 2009, 'Forest Carbon Sink management and development'

which means that the marginal cost of cultivation is relatively low. Data will be used as evidences as follows.

As can be seen above, its living habits (symbiotic relationship between the Giant Clam and the zooxanthellae) determine that this species is easy to cultivate. Richard (1997) examines that Giant Clams could be remaining the unchanged growth rate although they are within the environment which has relatively low level of nutrients in sea water. In other words, the cost towards facilities or stations could be lower.

In addition, the time it uses to grow up is extremely short. Stephen (1976) points out that the living requirement of Giant Clam is similar to other bivalve mollusks but its maturation age is only 3-5 years. Moreover, 6 subspecies in China's nearby sea areas have high growth rates and many literatures are concentrating on its rate of growth (centimeters) which is listed in Table 2.

Species	Ref.	Area	Years to grow up								
			1	2	3	4	5	6	10	15	20
Tridacna gigas	5	Palau	4.80	16.91	27.47	36.69	44.74	51.77	72.01	85.82	92.82
	6	Phil	4.80	12.73	20.00	26.67	32.78	38.38	56.49	71.84	81.77
	7	AUS		14.16	20.72	26.63	31.95	36.74	56.96		
	weight (kg)			0.54	1.79	3.95	7.02	1.90	43.38		
Tridacna derasa	5	Palau	4.7	11.67	17.56	22.55	26.77	30.35	39.92	45.63	48.10
	7	AUS		9.87	13.66	17.06	20.12	22.86	34.32		
	weight (kg)			0.11	0.36	0.79	1.43	2.25	9.61		
Tridacna squamosa	5	Palau	4.75	7.82	10.62	13.17	15.51	17.64			
	8	AUS	4.75	9.16	12.99	16.32	19.22	21.74			
Tridacna maxima	8	AUS	2.08	5.09	7.78	10.19	12.34	14.27			
Tridacna crocea	9	AUS	2	3.5	5						
	10	JAP	1.88			6.61					

5 Beckvar N 1981, 'Cultivation, spawning and growth of the giant clams Tridacna gigas,Tridacna derasa and Tridacna squamosa in Palau, Caroline Islands'

6 Alcala, AC 1986, 'Distribution and abundance of giant clams (family Tridacnidae) in the south central Philippines'

7 John, L 1988, 'Mortality and Potential Aquaculture Production of Tridacna gigas and T. Derasa'

8 Munro, JL & Heslinga, GA 1983, 'Prospects for the commercial cultivation of giant clams(Bivalvia: Tridacnidae)'

9 Hamner, WM & Jones, MS 1976, 'Distribution, burrowing and growth rates of the clam,Tridacna crocea, on interior reef flats'

Hippopus hippopus	[5]	Palau	5.04	8.37	11.38	14.10	16.57	18.80				
	[8]	AUS	5.04	11.75	17.17	21.55	25.09	27.90				

Table 2. Growth of Giant Clams

It could be demonstrated that a sizable return commonly has been existed since fifth or sixth year, which is a relatively less time cost while cultivating Giant Clams. All these evidences above could prove that the marginal cost of developing aquaculture is extremely low for China. According to data from the World Bank website, the proportion of farming land out of usable land in China has been over 56.2% since 2009. Undoubtedly, the marginal cost will be higher while further developing agriculture with the scarce land sources in China, especially under the fact that it has such a huge population.

4.4 Key Issues Description

Although the aquaculture such as Giant Clam cultivation has such numerous advantages, the current situation is that the aquaculture does not achieve enough attention in China.

Taking Giant Clam cultivation as an example again, according to National Technology System for Conventional Freshwater Fishery Industry website, the total marine aquaculture area is 15790 km^2. Additionally, around 280 km^2 water areas near Scarborough Reef in the South China Sea which has been used for cultivating Giant Clams are only accounts for nearly 2% out of total aquaculture area are suitable for aquaculture and areas such like this are not enough while comparing with agricultural areas on the land (Zhou et al, n.d.). They further argue that areas suitable for cultivation exist in massive areas of the South China Sea, which has similar conditions as Orpheus Island in Australia (successfully establishing the industry of Giant Clams cultivation). Furthermore, based on the Report of China's Territorial Resources in 2008, total agriculture areas are 1217352 km^2, which is extremely greater than it of aquaculture

[10] Murakoshi, M 1986, 'Farming of the boring clam, Tridacna crocea Lamarck'

areas. In other words, all these information prove that there are obvious potentials in terms of aquaculture in China.

Another barrier for developing aquaculture in China is the disputes in the South China Sea. According to the review above, most of the aquaculture and fisheries are operating in the Southeast sea of China. But in the South China Sea, the most suitable area for establishing aquaculture cultivation stations, there are many conflicts between China and its neighbors such as Philippines and Vietnam, which is deeply limiting the development of aquaculture.

5. Conclusion

Based on the discussion above, a conclusion could be drawn that not only the production quantity but the policy orientation is limiting the development of aquaculture in China. There is an unbalanced development between the agriculture and aquaculture in China. One confirmed reality is that the production as well as productivity in China will be continuously increasing in the future. According to the two sector model, under this circumstance, the social variable cost is not the minimum and the extra amount is represented by area I, which is demonstrated in Figure 4.

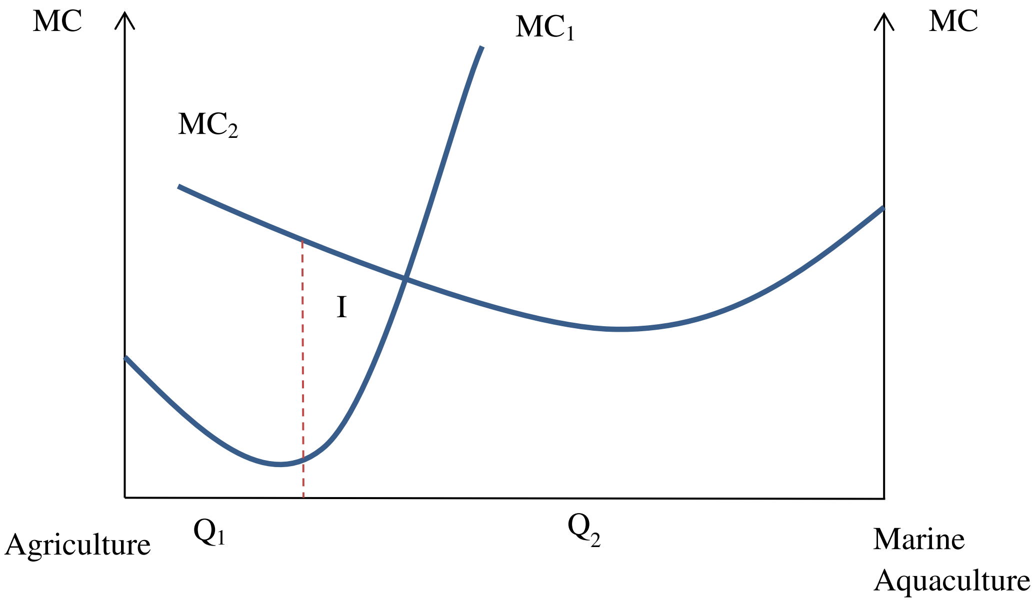

Figure 5. Real Case in China

Therefore, all actions which would be done by the government should focus on moving the dash line (in Figure 5) rightwards in order to be closer to the equilibrium point. In other words, the duties that government should be taken are to create incentives for the aquaculture industry expansion in order to achieve the target of minimizing social variable costs.

6. Generally Political Proposals

First of all, the policies of taxation towards aquaculture should be follows it of agriculture. As the agricultural taxes completely cancelling in 2006, the taxes on aquaculture should be reduced or even cancelled and subsidies should be given to aquaculture industry. Especially in terms of technical innovation, which is focusing on the cultivation cost elimination, subsidies should be increased to promote the industry to the equilibrium. From a perspective of labor force, around 8.1 million fishermen as well as 4.5 million culturists are doing aquaculture in China, but as the average culturists related to aquaculture increasing 6 % from 2000 to 2006, it is decreasing 3 % in China.

If the taxation as well as subsidies policies could be changed, this situation will be changed as well.

Secondly, in terms of the regional conflicts with China's neighbors, a committee of aquaculture and aquaculture could be established in the South China Sea. It could be a pure management and research institution only focusing on the development of aquaculture not on the sovereignty. Although current situation is much complex, under the peaceful negotiation of shelving disputes and carry out joint development, the problem could be partially solved in the future. Thus, it could be supposed that the barrier of aquaculture development would be effectively moved away.

In addition, focusing on the aquaculture industry itself, a better system should be established. The current problem in China is that the commercialization of aquaculture industry is not complete, individual producers with low efficiency accounts for the dominant proportion. Additionally, the investments towards the infrastructures as well as industrialization are not enough therefore the cost of resources and environment is relatively high. So, the government should publish new policies to promote the clinic integration and national rewards should be established in order to encourage aquaculture innovation and increased productivity as well as the pollution controls.

Finally, public policies should lead the aquaculture to the circular economy in the future. Since 1990s, China has been ranked No. 1 in the world in terms of aquatic production, but its trend is 'massive production, massive consumption, massive wastes', which is the common problem in China's industries. The target of government's policies is to change current situation to 'optimal production, moderate consumption, minimum wastes', which is considered as the circular economy. Dai and Bu (2006) presents this concept in China's aquaculture industry which is related to 'reduce, reuse, recycle' principles in order to complete the target of sustainable development in China.

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