

# A Big Data Analysis Research on Improving the Inefficiency and Uneven Distribution of Fishery Industry by using Game Theory

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**Abstract:** International fishery stocks are consumed faster than ever before, and the management of it comes to the center of the stage. However, lots of issues are here in terms of managing international fishing stock. It can be known that there is a lack of potential research and application with big data analysis on international fishery stocks. By conducting this research, and by using big data analysis, the author expects to have a better command of the current situation of international fishing resources and its core problems, and thus providing corresponding solutions to improve or tackle the dilemma. In terms of the detailed big data analysis method, Game theory is utilized. Game theory, including one of its subtopics, Nash equilibrium, is mainly used to analyze the situation of international fishery stocks and provide relevant countermeasures. This research adopts a method by organizing and analyzing data of various populations of international fishery stocks, which focuses on southern ocean region, and then comparing the status of the populations before and after the implementation of international treaties, the change manifests. The research result shows that economy, together with ecology welfare, have been improved to a better level. The research conclusions are as follows, by using big data analysis incorporating Game Theory, cooperation among different countries, should be realized by passing international laws and subscribing international agreements, which facilitate managing international fishery stocks using ecosystem principles.

## 1 INTRODUCTION

There are still many problems in the management of international fishery resources. Illegal and unreported fishing activities, non-cooperation among countries, over-exploitation of resources by fishermen, and uneven distribution of international fishing resources, all of which make it hard to deal with the current management problem of international fishing resources. But the problem is still essential to solve. The motivation of this paper is to prove that further measures should be taken to improve the situation and thus provide potential solutions to change and improve the international fishing resources management situation. By conducting this research, more knowledge is gained to lay a firm foundation for solving the problem above, such as how the world fishery status is, the urgency of strengthening cooperation among countries, especially encouraging more developing countries to join in.

The research methods used in the research process are game theory and its relative concept, as

well as the Nash Equilibrium. By conducting game theory and strengthen the international cooperation, both economic and ecological optimum can be achieved, specifically, by passing legislation and signing international agreements. Although game theory has been applied in lots of fields and been also put emphasis by fishery economists now, it is the late 1970s when internationally shared fish stocks begin to draw the application of game theory. The development path of game theory in international fishery stock, although being long and burdensome, is still an effective strategic interaction in the premise of the application of game theory. In addition at first, economists care not much about the fish resources. They are considered as internationally shared, before the advent of UN Third Conference on the Law of the Sea (Grønbaek et al., 2018). After then, coalition games are then used mainly on trans-boundary stocks and straddling fish stocks.

It means a lot when game theory is applied to the international fishery stock. It can be known from the tragedy of commons where individuals just consider their own best self-interest when using shared

resources, the resources will be depleted quickly if everyone does so. That is also true for the fishery stocks.

## 2 DISCUSSION

### 2.1 What Game Theory Is

Game theory is developed with the purpose of helping decision makers understand the situation better and further interact with each other. Conflict and cooperation are happening constantly and alternately. It is also relevant to questions involving participation, compliance, and enforcement of international agreements. Different models are used in different situations when applying game theory. When there is game with perfect information, Nash equilibrium Mixed Strategy and some other models can be used. When there is imperfect information, Bayesian game is one of choice. However, no matter what kinds of models of game theory is used, rational choices of the participants are the premise of the application of game theory. According to Martin, “rational” does not focus on the nature or the quality of the participants’ preferences, instead, the rationality means the participant can always make consistent decisions when different set of actions are available. Simply put it, game theory provides general mathematical techniques for analysing situations in which two or more individuals make decisions that will influence one another’s welfare. In consequence, game theory offers insights of fundamental importance for scholars in all branches of the social sciences, as well as for practical decision-makers.

When it comes to international issues, the international institutes are always weak, for the reason that they cannot force any country to do something. In addition, the international cooperation often provides incentives for the free riders to take advantages of what has been done by some other countries, which is unfair. However, the game theory helps improve the situation.

To be more specific, free-riding and betrayers in a game can be seen as two main problems when it comes to how to manage and utilize international fishery stock. Game theory, or Nash equilibrium, can be used to illustrate the idea and as a solution to mitigation these two problems for the following two reasons. On the one hand, threat of trade restrictions could play in prevention of free riding. On the another hand, punishments for betrayers are

necessary to sustain the game and make it fair for every participant.

Now dive into how participants should behave in repeated games using game theory. Participants could condition current actions on the history, in other words, if the opponents participant B cooperated in the past, participant A continues to cooperate and participant A defects otherwise, that is so-called time when participant A switch to “punishment regime”. By doing these, the cooperation can be sustained, compared with not punishing the opponent B when they betray participant A in the game, the game can be sustained. It is quite like social norms, when everyone follows the social norm in the past, participants will continue to follow it in the present. If the deviation from the social norm is detected, participants who have followed the norms will then switch to punishment.

Usually, this kind of social norms are self-sustaining and require the interaction with the same players. Besides, it is always difficult to sustain “non-equilibrium” social norm in large anonymous societies. In addition, here comes the importance of punishing the one that betrays. When the prisoner’s dilemma for two or more finite periods are repeated, from backward induction it is known that no matter how many times agents interact, as long as it is finite, cooperation cannot be self-sustained. Two possibilities are here to deal with this, first, change the time horizon to infinite. Second, use the worst as a punishment for a deviation from cooperation.

### 2.2 How Game Theory Was Applied in the History

At first, there is a lack of interest in applying game theory to fish stocks, for fish stocks are considered common resources if they are in international waters. However, the situation of the management of world fisheries has been changed thoroughly since the UN Third Conference on the Law of the Sea (Grønbaek et al., 2018). The Exclusive Economic Zone regime has set up then, the member of which are mainly states that borders on sea. It is of great importance to bring the problem of fishery stock in the field of vision. It is the Exclusive Economic Zone regime that made the consumption of fishery resources an issue that is related to the whole world. Any fishery resource, as long as it relates to two or more than two states, should be managed correspondingly (Monro et al., 2004).

### 2.3 How Game Theory Can Be Applied to Facilitate Cooperation

Now use some simple numbers to show how game theory can be used to determine what the best results are for the participants and the importance of punishing the betrayers. In the following example, games will be played for two times. If this game is played only for one time, (D1, d1) and (D2, d2) are two pure strategy Nash equilibrium. And the first equilibrium dominates the second one. People may wonder whether (C, c) is a sustainable strategy for the first period, cause it would be beneficial for both players. In order to check that, play (C, c) in the first period and if (C, c) was played at  $t = 1$  then (D1, d1) is going to be played at  $t = 2$ . Otherwise, to serve as a punishment when one of participants act for their own best interest and hurts the benefit of another player, the betrayed player plays (D2, d2) at  $t = 2$ . By using one-step deviation, people can get the answer that there is no profitable deviation from C in certain circumstance.

As for what strategy should be applied for infinitely repeated games, Grim trigger strategy should be played. Punishment for not carrying out punishment is also necessary, due to an incentive to sustain a punishment and the need to make the game and promise credible. Thus these incentives are achieved by imposing a punishment for not carrying out punishment. This requirement of punishing the party when it does not carry out the punishment when another party betrays is suitable when it comes to fishery sock.

Table 1: Repeated iteration and cooperation: multiple inefficient equilibria.

	c	d1	d2
C	2,2	-2,3	-3,3
D1	3,-2	1,1	-2,-2
D2	3,-3	-2,-2	-1,-1

### 2.4 Existing Problems of International Fishing Industry

#### 2.4.1 Unregulated Fishing Is in the Way of Successful International Fishery Management

Lack of regulation is one of the major threats to the success of international fishery management. However, some international fishery laws are considered as “soft law”, for they have no-binding treaties of global nature. Besides, the intensity of supervision and the perfection of the supervision

system are very different for different species of fish. As it is decided by FAO (Food and Agriculture Organization), only 16 out of more than 30 Regional Fisheries Management Organization all over the world are qualified as the ones with the ability of setting up both conservation and management measures. In addition, these Regional Fisheries Management Organization have discrete focus. In other words, some fish species, like tuna, are monitored and regulated by many Regional Fisheries Management Organization. However, some other species are left with little, or even no measurement at all (Erickson, 2004).

Over-exploitation is one of the main challenges that is faced by international fishery stock. It is directly associated with the illegal, unreported, and unregulated fishing. However, some other factors also contribute to the over-exploitation of the fish. The fishery is always considered as common property resource, especially when it comes to the one that in the border and territorial waters of coastal states. According to the state of world fisheries and aquaculture and to a report in 2020 by Food and Agriculture Organization of the United Nation, there had been a 14% rise in global capture fisheries production resources from 1990 to 2018 (FAO, 2020). Increasing awareness of the health benefit of the fish and rising incomes world worldwide make consumers more willing to consume fish. As a result, the wild fish is consumed at a speeding rate. Here is a quick look of the global situation of the 600 marine fish stocks monitored by FAO. Until 2011, the percentage of moderately exploited and fully exploited had been 20% and 52%, respectively. What is worse, 17% of fishery stock were over-exploited and 7% of it were depleted totally (FAO, 2011).

The sustainability of international stock fishery should be paid much more attention, due to the fact that the sustainability level of some of the populations of the international fishery stocks which were considered as sustainable have dropped to a large deree. It is shown in the figure 1, that the degree of the sustainability level of some once sustainable fishery stocks poplutions have declined, from 90 % to 65.8 %, and it only took 43 years for these biologically sustainable population to be overexploited, and thus the fraction of the biological sustainability declines. The proportions of the unsustainable international fishery stock and underfished stock were also changed. It manifests that the percentage of underfished stock has declined, to a lowest point in 2017, and the percentage of the unsustainable fishery stock has expanded, continuously.

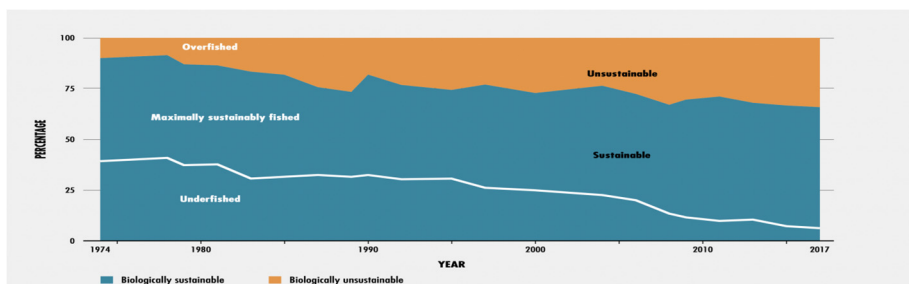


Figure 1: Global Trend in the State of the World’s Marine Fishery Stock, 1974-2017 (FAO, 2020).

Beside over-exploitation, by-catching is another problem that happens on a day-to-day basis, and the problem is encountered by fish not only on a local scale but also worldwide. The scope of influence is far more wide-ranging than people think. Normally, by-catching happens in the circumstance where the caught animals cannot be sold and kept, which include fish, together with rare marine creature like dolphins, seabirds, and whales. However, the unintentional catches are not the only cases that make the marine creature suffer from injuries or die after they are caught and then discarded. By-catching also happens when some marine species are encountering fishing gears or vessels directly, which will cause the mortality and injury of marine animals. It is of great importance to take measures and to tackle the problem of by-catching, due to the reason that by-catching causes the loss of fecundity, and thus threat the efforts of the authorities who aims at rebuilding the fish stock (NOAA, 2021). Not to mention that the damage it causes to the ecosystem and marine creatures.

### 2.5 Collective Efforts of Government and Public Organizations on Passing International Agreement and Law

International fishery stock is hard to control and manipulate, due to the essence of which is straddling and migration. Besides, it is of great importance to conduct cooperation among different countries, to utilize the fishery stock judiciously, so that the resource can be sustained, and each country can gain a better benefit, especially when it comes to the fish stock with characteristics of trans-boundary, straddling and frequently migratory [7]. To avoid over-exploitation and thus the depletion of fishery stock, public management should be considered as an effective way. By passing international fishery laws and subscribe international fishery agreement, the behavior of fisherman can be forecast to some extent.

On the contrary, if there is no regulation in terms of the exploitation of fishery stock, the fishery will be consumed and run out at an accelerated speed, that is consistent with the concept of “common tragedy”, where non-existing, poorly defined or not enforceable property rights lead to over-exploitation of resources. It also describes the situation in which self-interested agents deplete a resource through their collective behaviors. By applying good management, both biological and economical optimal can be achieved. Collective efforts should be done in terms of negotiating cautiously and then subscribing and passing the international agreements and laws regarding code of conduct for participating countries.

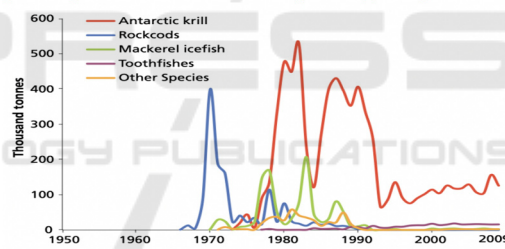


Figure 2: Annual Nominal Catches of Selected Species in Antarctic Atlantic, Antarctic, Indian Ocean and Antarctic Pacific (FAO, 2020).

Great achievement has been done by developed countries, through the way of utilizing game theory, the core of which is to strengthen international cooperation, regulating and restricting code of conduct. And in some parts of the world, the consumption of the international fishery stock has been improved, by popularizing the game theory and punishing the participants who do not behave right. Figure 2 shows some of the effectiveness in terms of relieving overfishing of some international or transboundary fishery populations. By researching and studying the statistics published by FAO and the Commission for the Conservation of Antarctic Marine Living Resources jointly, the effectiveness of implementing game theory and agreeing to and signing international agreement and passing

international is self-evident. It is conspicuous that before 1990s, the number of annual nominal catches of several selected species in southern ocean were huge. It seems that the nineteenth century was a turning point. The catches of selected species shown by the legend have dropped, which lots of factors contribute to. however, it is also consistent with the fact that during the early 1990s, lots of international conferences were held, in which several developed countries and regions talked about the fishery resources status, and consequently passed several international treaties laws, to make sure participating countries behave well. under this circumstances, the depletion amount of fishery stock dropped obviously.

Many public organizations actually contribute a lot to improving the management situation of international fishing resources. They facilitate the international cooperation, advance regulatory programs, and even bring about the international engagement of many countries. NAFO, The Northwest Atlantic Fisheries Organization, or NOAA mentioned above, are all working like catalyst in helping improve the international cooperation in terms of managing fishing resources.

## 2.6 On Monitoring and Regulating Fishermen's Behavior

To limit fishing effort, it is vital to switch the economic incentive of fishermen thoroughly, the initial incentive that each fisherman seeks to pursue a maximum share of the catch actually facilitate the competition among all fisherman and thus undermined the effort of regulation, as it is conducted in an EU-funded project (Asche et al., 2005), and the previous regulation has not changed the fishery stock's essence of common property. When there is a regulation that normalize fisherman's behaviors, they will always choose the option that is best for all participants' interest, the idea of which is also consistent with game theory and Nash Equilibrium.

## 2.7 Game Theory of Redistribution between Developed Countries and Developing Countries

### 2.7.1 What Developed Countries Have Done

Common but differentiated responsibilities are here for both developed countries and developing countries in terms of managing natural resources such as fishery stock. How much wild fish each country should catch, how they should act when they know or they do not know other countries' choice,

and what actions one country should take after another country do not obey the rules settled in an international agreement, all of these questions can be solved by using game theory, or in other words, Nash Equilibrium. Furthermore, it is said that the current fishery stock has been over-exploited, although it is true, however, according to Smith, only small fraction of fishery stock has been affected due to selective fishing, which is also intensive. As a consequence, it is worth a try to shift from the current concentrated fishing species to species that are still not exploited (Zhou et al., 2014).

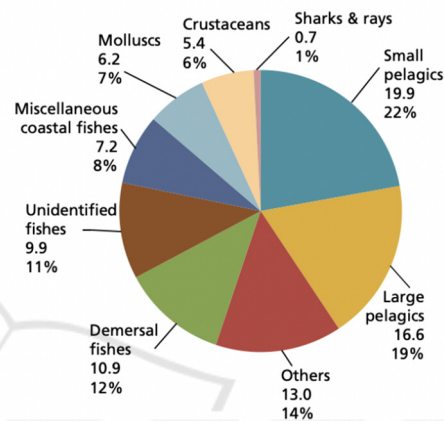


Figure 3: World Marine Catch by Main Species Group in 2009, Million Tonnes and Percentage (FAO, 2011).

However, it is always said than done and great tackles are here for the developing countries to change their behaviors. By nevgating the FAO Review of the state of world marine fishery resources, consumers have still been fishing selective species. It shows clearly that from Figure 3, small pelagics and large pelagics, together with crustaceans, made up more than 50% international fishery stock production and consumption. however, chances are still there if developing countries can set the developed countries as an example in terms of engaging in international cooperation and monitoring each other's behavior such as whether they exploit the international fishery stock appropriately. This effort needs the practical action, coalition, and collaboration from bilateral and multilateral, or both the developing and developed countries.

### 2.7.2 What Developing Countries Expected

As it is reported by FAO, in 2018, there is a huge increase from the average previous three years, which is up to 5.4 percent, and the total global capture fisheries production has become the highest

level in the history. People may then wonder where that consumption comes from. Here is a list of top consumption countries, they are China, Indonesia, Peru, India and the Russian Federation, together with the U.S. and Vietnam, most of which are developing countries, and they consume around 50% total global capture production (FAO, 2020).

For developing countries, the fishery stock can be seen as an important food source highly in protein, which can function as backup resources in guaranteeing global food security (Zhou et al., 2014). On the other hand, for developed countries, the fishery stock in international common seas is more different, they care more about tastes and preferences. The change means a lot for the developed countries. If this shift can be achieved, it is possible gain a higher total fishery production amount, and at the same time reduce damage to ecosystems.

## 2.8 Future Development Areas

However, to solve the problem of over-exploitation of international fishery stock and make it sustainable from generation to generation, cooperation among countries, finding the Nash Equilibrium, punishing the betrayers and thus sustaining the “game” are not enough. The solution to the international fishery stock over-exploitation problem should also be found. In addition to overfishing in global level, the nature of the problem finally centers on the selected fishery species, which means the fisherman always harvest species with specific requirement (Zhou et al., 2014).

## 3 CONCLUSION

To sum up, by applying game theory, some enforcement of international agreements can be done, and the potential cooperation barriers can be identified. Besides, by applying game theory, the behavior of participants can be understood better. It helps facilitate the international cooperation in terms of fishing resources management. Collective but differentiated efforts should be made, from both developing countries and developed countries. As far as fishery resources are concerned, public organizations act as catalysts and promote the promulgation and signing of international laws and agreements to capture and consume fishery resources. The issue of how to manage international fishery stock is more complex than expected, due to the nature of marine creature that marine captures

migrate in various sea areas sometimes. To make the fishery stock more sustainable, it is worth a try that different countries to cooperate and find the equilibrium that both sustain the fishery stock and at the same time consume it to an extent that can meet consumer needs. In addition, according to the game theory, when there is an agreement among different countries in terms of how much fishery stock they plan to consume, it is often important to punish the one that betray the agreement and serve for their own best interest. It is the decision that makes the game sustainable.

As for how the future research should be conducted, it should focus on how developing countries can engage more in the international game. The developing countries rely on the fishing industry to provide numerous job opportunities and considerable incomes, as well as the basic daily nutrient intake, which makes it tricky for developing countries to engage in an international game whose requirements are strict. Some shortcomings can be improved and revised probably. Although the document mentions some existing problems, such as unregulated fishing, which hinders the sustainable development of international fisheries, illegal and unreported fishing activities are not included in the document due to length constraints. These two factors are also important and worthy of investigation.

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