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Collective Fishery Management in TURFs: The Role of Effort Corrdination and Pooling Arrangement

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Collective Fishery Management in TURFs:
The Role of Effort Corrdination and Pooling Arrangement

Abstract

Fishery co-management has recently garnered a considerable amount of interest from fishermen and regulators in both developed and developing countries. The trend is in response to the failure of traditional fishery management, which relied on direct command-and-control regulations, and as an alternative to other individual-rights-based systems, including individual transferable quotas. The key feature of fishery co-management is that fishermen form a group to manage the fishery in a collective manner based on mutually agreed rules. Community-based fishery co-management has been actively promoted both by local governments, particularly in developing countries, and by international aid institutions.

Despite increasing interest and attention, however, fishery co-management is not yet well understood. Economists have been skeptical about the effectiveness and sustainability of such resource management regimes, primarily because they involve collective action by individual fishermen. Other disciplines such as sociology and anthropology, on the other hand, have been studying co-management regimes for some time, mainly from a qualitative point of view. To generalize the factors that are key to successful fishery management, it is necessary to go beyond case studies and quantitatively examine different types of fishery co-management regimes, their "rules of the game," and institutional designs.

This study investigates fishery co-management regimes adopted in coastal fisheries in Japan. Utilizing the nationwide abundance of fishery co-management examples, it searches for key co-management measures and operations beyond the layers of traditional, cultural, and social influences. The study focuses on the rules of the game adopted by Japan's co-managing groups, called Fishery Management Organizations (FMOs). An examination of several cases of successful fishery co-management identified two distinctive measures: effort coordination and pooling arrangements. Anecdotal evidence suggests that a pooling arrangement is a vital supporting measure for effective coordination, suggesting that these two measures may be essential to successful fishery co-management. The challenge is how to align individual fishermen's incentives with those of the group. A conceptual dynamic model developed in this study shows that such alignment is likely to occur when pooling arrangements are employed. The model shows that full pooling achieves perfect alignment, which may explain why full pooling is the dominant choice among FMOs with pooling arrangements.

Hypotheses from the case studies and conceptual model are subsequently tested with real-world data from two sources – Japan's fishery census published by the government and data from a survey developed and conducted by the author. The survey was designed to supplement the fishery census by collecting information on effort coordination and self-imposed regulations. The results from the two empirical analyses indicate that (1) merely establishing co-managing groups, such as FMOs, has limited effect; (2) FMOs with pooling arrangements generate greater revenue, particularly when combined with effort coordination activities; and (3) pooling arrangements and effort coordination coupled with marketing activities resulted in the greatest revenue.

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Chapter 1

Introduction

It is common knowledge that there are certain fishery resources that, in terms of both species and geographical regions, are heavily exploited and require management for their sustainable use. The State of World Fisheries and Aquaculture 2004 published by the United Nations Food and Agriculture Organization (FAO) estimates that 52% of the world's main fish stocks are fully exploited to their maximum sustainable yield levels and 24% are beyond that level – in other words, they are over-exploited (United Nations Food and Agriculture Organization, 2004). The Marine Conservation Society is distributing a "Pocket Good Fish Guide" that informs consumers about which kinds of fish to avoid purchasing in retail shops based on the sustainability of the fish species, fishing methods, and their place of origin.[1] Overexploitation issues exist in a wide range of fisheries, from highly industrialized ones such as deepwater tuna to artisanal fisheries in developing countries.

Over the years, various types of fishery management regimes have been enacted (Figure 1.1). An open access regime is one in which there are no barriers to entry

[1] http://www.fishonline.org/information/MCSPocket_Good_Fish_Guide.pdf

and exit by fishers and there are no regulations regarding fishing operations. Gordon (1954) showed how an open access regime draws too many harvesting inputs that cause both economic inefficiency (i.e., rent dissipation) and potential depletion of biological fish stocks. The traditional method for fixing this problem was so-called "command and control" whereby an authority sets and enforces regulations covering almost every aspect of fishing operation, including gear restrictions, seasonal closures, and harvest caps. The entry and exit of fishers can be free (regulated open access) or it can be restricted by schemes such as licensing (limited entry). The effectiveness of these traditional regulations, however, has been limited; in fact, the consensus among the researchers is that these methods have failed to meet their expectations in many cases.

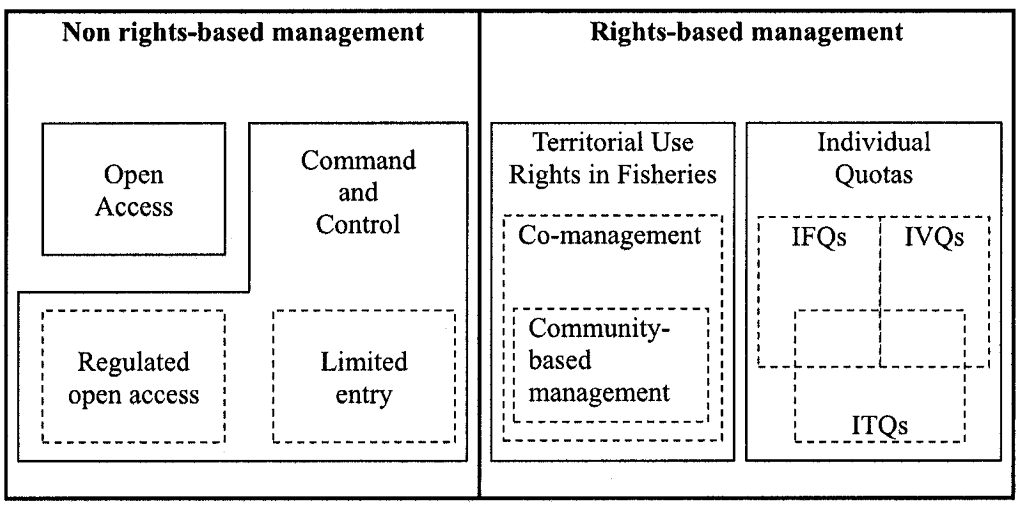

Figure 1.1: Schematic categorization of fishery management regimes. IFQ and IVQ are individual fishing quota and individual vessel quota, respectively.

Gordon's key message was "everybody's property is nobody's property" (Gordon, 1954, p.135), and fishery resources were exactly that. Scott (1955) confirmed this assertion by showing analytically how a hypothetical sole owner would exploit the resource he owns. Without adequately defined property rights for the resource, users have no incentive to properly manage the resource because they cannot fully appropriate the benefits that would result from such management. The notion and the importance of property rights in fishery resource management were thus placed on the main stage.

Establishment of individual transferable quotas (ITQs) as a rights-based fishery management regime was first proposed by Christy (1973) (as cited in Copes, 1986, p.279). The fact that the quotas are transferable gives fishers something akin to property rights over the fish they are entitled to harvest. Since then, ITQ regimes have been implemented in some countries for which fishing is an important industry, including Iceland, Australia, and New Zealand (Arnason, 1993; Newell et al., 2005).

At the same time, there has been resistance to wholesale adoption of ITQs in many countries for reasons that range from spurious to substantive. ITQs have been subjected to a fairly constant din of criticism by skeptics. The often cited Copes (1986) critique offered many reasons why we might expect ITQs to fail in practice, including data fouling, black market off-loading, and high grading. More recent criticism has focused on "fairness." The fairness issue relates to various concerns, including actual distributions of rents generated, exclusion of some bona fide fishermen in initial allocations, and granting of initial wealth to the original participants (e.g., Matulich and Sever, 1999). The latter two issues are particularly acute in the context of developing countries in which fisheries are the dominant, if not only, foundation of the community's livelihood.

An alternative rights-based fishery management regime is territorial use rights in fisheries (TURFs). TURFs are typically granted to the local fishing community or to groups of local fishermen. These groups then assume responsibility for collective management of the fishery, which I refer to as "co-management." Co-management can be done through a partnership or power-sharing arrangement with authorities or the TURF-granted community can opt to manage the resource on its own. In either case, the key features of fishery co-management are that fishermen form a group by which to manage the fishery in a collective manner based on mutually agreed rules and that territorial use rights are granted to such groups. This regime differs from an ITQ because, within the context of rights-based management, it involves centralized and coordinated decision-making.

Co-management as a concept in fisheries has gained much attention in recent years, particularly in developing countries. For example, community-based fishery co-management has been actively promoted by both local governments and international aid institutions. In practice, co-management is implemented in many fisheries around the world and in some cases the regimes have endured for quite a long time (Wilson et al., 2003; Cunningham and Bobstock, 2005).

Despite of all of this interest and attention, fishery co-management is not yet well understood. Economists have been skeptical about the effectiveness and sustainability of such resource management regimes, primarily because they involve collective action by individual fishermen. Skeptics argue, for example, that, even if incumbents cooperate and manage to enhance the economic rents from the fishery, success will attract new entrants to the industry, dissipating that rent. In fact, if incumbents anticipate this event, cooperation may not take place at all. Co-management also can be vulnerable to cheating. Other disciplines such as sociology and anthropology have conducted many case studies of co-management, and some researchers have derived conditions that would enhance the success of co-management, including biological characteristics of the resource and institutional arrangements (e.g., Ostrom, 1990; Baland and Platteau, 1996; Agrawal, 2001). To generalize the key factors of successful fishery co-management, however, it is necessary to go beyond case studies and quantitatively examine different types of fishery co-management regimes, their "rules of the game," and institutional designs. However, there are few quantitative analyses of whether co-management regimes can generate higher returns and what rules of the game would maximize such returns.[2] One of the major obstacles to conducting quantitative analysis is the lack of reliable data since existing studies of resource co-management have been conducted using cases from rural areas of developing countries. Cross-sectional analysis is thus confined to a collection of small samples from various countries, which then causes an identification problem because there are so many variables to control with so little data (Agrawal, 2001).

It is important to advance our understanding of fishery co-management, the rules of the game, and institutional designs that enhance success. For one thing, this may be the only hope for rational management in developing countries in which enforcement and monitoring infrastructures are weak. Co-management strategies are spreading outside of developing countries; for example, there is some momentum behind movements to establish harvester cooperatives to co-manage fisheries, and other resources, in North America based on successes of newly established cooperatives for Pacific Whiting and Bering Sea Pollack fisheries. These new applications of fishery

[2]To the best of my knowledge, one exception is Carpenter and Seki (2005). They compared the productivity of two fishermen groups in the same fishery, one with the pooling arrangement and the other without it. However, their focus was the impact of social preference of each fisherman on fishing productivity and whether the pooling arrangement would facilitate more cooperation through the evolution of social preference, thus not the impact of FMOs, pooling arrangement, or effort coordination per se.

co-management regimes in both developed and developing countries call for a quantitative analysis that delineates the factors that are key to successful co-management.

To understand the nature and performance of fishery co-management, I looked to the Japanese experience with management of its coastal fisheries. The primary reason for this choice was the fact that there are abundant cases of fishery co-management regimes since virtually all of Japan's coastal inshore fisheries are governed by fishermen's groups. These self-governing bodies of local fishermen are called Fishery Cooperative Associations (FCAs). Fishery co-management is carried out by FMOs (Fishery Management Organizations), which can be the FCA itself, a subgroup of FCA members, or an alliance of fishermen from multiple FCAs.

The advantage of studying Japanese cases to understand co-management is that there were 1,608 FMOs in 2003 (Ministry of Agriculture, Forestry and Fisheries,, 2005), most, if not all, established in affiliation with local FCAs. These FMOs vary in terms of the type of fishing gear used, targeted species, membership size, and the management measures they have implemented. And yet, unlike the case of a multi-country analysis, they all operate under one set of national fishery rules and laws and to some extent their cultural and social characteristics also are identical. The existence of this wide variance in key fishery-related variables while other influential and difficult to observe national disturbances remain controlled is a great advantage for quantitative analysis. However, to the best of my knowledge, no study has yet looked at FMOs nationwide and analyzed the relationship between characteristics and economic performance using variations in their operations and management measures – the primary goal of this study.

One last note on why it is worthwhile to study Japanese fishery co-management is in order, as some might argue that the Japanese experience is based on that country's unique historical, cultural, and social characteristics and thus has limited applicability to other regions. Through my interviews with Japanese fishermen, I concluded that they are equally competitive as entrepreneurs and no more cooperative-minded than fishermen elsewhere. Cohesiveness of the community surely would enhance the likelihood of cooperation and compliance, but such social characteristics of small coastal communities can readily be observed outside of Japan. Thus, the notion that Japanese fishermen are more cooperative and that this social and cultural characteristic enabled co-management to flourish is anything but true.

Also, it is true that Japanese fishery co-management and operation of FMOs hinge on two unique institutions. One is the aforementioned FCAs and the other is fishing rights (a Japanese version of TURFs) that are protected by law. The historical evolution of these institutions and their administrative structures is well documented in the literature (e.g., Asada et al., 1983; Ruddle, 1987; Yamamoto, 1995; Makino and Matsuda, 2005). However, there seems to be an overemphasis on the historical background of these institutions that has often led to a conclusion that Japanese success in fishery co-management is due mainly to the tradition of these institutions and thus has little relevance for regions that do not have such a tradition.

I argue that, while the two institutions themselves may be unique, the functions they perform are universal. Fish stocks under open access can be characterized as impure public goods. According to the theory of clubs (Buchanan, 1965), such impure public goods can be converted into club goods if three conditions are met: there are clearly defined geographical and membership boundaries, an affordable exclusion method is available, and members are better off by forming a club. FCAs and fishing rights, with accompanying laws, function to meet the first two of the three conditions. This, in return, implies that any institution that is suitable in a particular region in terms of cultural- and social-norm characteristics is applicable as long as its functions meet the first two conditions. The remaining piece is to ensure that club members are better off by forming a club, which, in our context, is determined by benefits of fishery co-management being perceived by FMO members as sufficient. This is an issue that has little relevance to tradition, and Japanese experience can provide hints for how to meet this last condition.

In the next chapter I present an overview, discuss the significance of Japanese coastal fishery co-management regimes, and delineate some of the key management measures that seem to be associated with co-management success. Chapter 3 develops an economic model of one of the key measures often found in high-performing FMOs – pooling arrangements – and analyzes whether a pooling arrangement is theoretically capable of making co-management successful. Chapters 4 and 5 empirically analyze the effect of two key management measures – pooling arrangements and effort coordination – using two different sets of data. Chapter 4 utilizes panel data generated from the fishery census and focuses on the effect of pooling arrangements and other measures and activities that are combined with it. Chapter 5, on the other hand, is based on data from the survey that I conducted in 2005 of FMOs throughout Japan. Its focus is on both effort coordination and pooling arrangements, and in particular I examine whether the two measures perform better in combination. Finally in Chapter 6 I summarize my findings and discuss future research possibilities for studies of co-management in fisheries and other common pool resources.

Chapter 2

Japanese coastal fishery management and institutions

2.1 Introduction

The objective of this chapter is to present an overview of Japanese coastal fisheries management that focuses on management organizations, and their institutional designs and functions. It is intended to provide comprehensive background information on Japanese fishery co-management for subsequent chapters, especially those that conduct empirical analyses on the performance of Japanese fishery co-management.

As aforementioned, Japanese coastal fisheries management hinges on two unique institutions. One is the Fishery Cooperative Associations (FCAs). The other is fishing rights, which are analogous to territorial user rights for fishing (TURFs) that are protected by law. The historical evolution of these institutions and their administrative structures are well documented in the literature (e.g., Asada et al., 1983; Ruddle, 1987; Yamamoto, 1995; Makino and Matsuda, 2005). However, there seems to be an overemphasis on the uniqueness of the historical background of these institutions. This often has led to a conclusion that Japanese success in fishery co-management is due mainly to their historical tradition (e.g., Hanna, 2003), thereby implying little relevance for regions that do not have such tradition. I argue that, while the two institutions themselves may be unique, the functions they perform are universal, which justifies the need to analyze them carefully.

After a brief historical overview of the evolution of FCAs and TURFs, I present the growth of fishery co-management regimes over the years and across the nation, demonstrating that fishery co-management is more common than an exception in Japan and has been implemented for various targeted species and types of fishing gear. In fact, virtually all Japanese coastal capture fisheries are managed using co-management principles. Then I explain the functions of these two institutions based on the theory of clubs. I present some of the interesting measures that have been implemented by co-management regimes, providing their background, objectives, and general performance.

2.2 An overview of co-management institutions

2.2.1 FCAs and TURFs

Japanese coastal fisheries are governed by FCAs. Members of these FCAs are mostly fishing households and "small" companies, as defined by the number of employees and gross tonnage of vessels owned. The functions of FCAs are similar to any other harvesters' cooperative and include joint purchases of inputs (e.g., gas, ice, and boxes), administration of the ex-vessel marketplace, and provision of insurance and credit to members. In addition, FCAs have one unique function, and that is to manage fishing rights and the area covered by TURFs, which are granted by the government. These two institutions –FCAs and TURFs– form the basis of Japanese fishery co-management.

FCAs are typically associated with coastal communities that historically have depended on fisheries resources, and each FCA encompasses a large number of diverse fisheries. FCA members are generally granted responsibility for managing all of the fishery resources within their jurisdiction. These often include sedentary shellfish resources such as clams and mussels, sea urchins and abalone, and shrimp. They also include moderately mobile groundfish, including various flatfish and rockfish, and more mobile fish such as mackerel and herring. Typical FCAs involve a wide range of gear types that include dredges, gill nets, seines, and small trawls and also include fisheries that are prosecuted by divers.

The history of how FCAs and fishing rights evolved is an interesting topic and has been documented in the literature; here I present a brief summary. Historically, coastal waters have been defined as public areas by legal codes dating back as far as 645 A.D. (Makino and Sakamoto, 2002). Under customary use rules, anyone could come and extract available resources from coastal waters as is the convention in many Western countries today. The idea of "fishing rights" in ancient Japan was thus nonexistent. During the feudal era in 16th century, the rule changed and fishing was permitted only by residents of coastal villages that did not have enough arable land on which to grow rice. Coastal villages were given a certain area of coastal waters for exclusive use, and fishermen guilds were formed in these villages to protect the resource from outside poachers (Asada et al., 1983). When the feudal era ended in the late 19th century, fishermen guilds were transformed into formal organizations that eventually evolved into FCAs. In 1948 the Fishery Cooperative Law was established as the legal foundation of FCAs (Yamamoto, 1995).

When coastal villages with insufficient arable land were allowed to fish back in feudal times, a sense of territorial rights over the coastal waters emerged among the villagers and those rights were eventually recognized by the samurai lords (Asada et al., 1983). In 1901 when Fishery Law was enacted, these ad hoc user rights were given legal status as fishing rights. The rights were subsequently granted to FCAs, and their task was to administer the use of these rights (Yamamoto, 1995).

Fishing rights apply only to coastal fisheries.[1] They consist of three categories: common, large set nets, and demarcated. Demarcated fishing rights are granted for aquaculture. Large set nets are treated separately from small set nets, which fall under common fishing rights because their impacts on fisheries operating in their vicinity are potentially large (Asada et al., 1983). The interest of this study is in common fishing rights, which include all fisheries other than large set nets and aquaculture. Hereafter, I use the term "TURF" to refer to this particular type of common fishing rights.

TURF area boundaries on land typically correspond to municipal boundaries, and they are extended straight outward to the sea. How far they extend varies from one case to another; some have only one kilometer or less while others extend more than five kilometers. The extension distance is a function of targeted species, the type of gear used, and the landscape of the ocean floor.

[1]Near-shore and high-sea fisheries are excluded; these fisheries are typically governed by a license system that is managed by either the central or the prefectural government. Near-shore licenses are granted to FCAs when there are many applicants and then the distribution of licenses is internally decided. Otherwise, the licenses are granted to individual fishermen Ruddle (1987).

As previously mentioned, by law TURFs are granted only to FCAs and not to individual members. FCA members are entitled to fish within the TURF area. FCAs administer the use of TURFs; that is, rules regarding who, how, where, and when to fish are decided internally. For example, the Maizuru FCA of Kyoto regulates octopus fisheries to "individual members" (who) "using pot-traps" (how) and "north of the line connecting points A and B" (where). As will be seen later, the fact that TURFs are not granted directly to the resource's users (FCA members) but to an administrative body has an important implication in necessary conditions for successful co-management.

2.2.2 Fishery Management Organizations

Co-management of coastal fisheries is carried out by fishery management organizations (FMOs). An FMO is a group of fishers who share the same fishing ground and/or operate the same fishery and who are collectively engaged in fishery resource and/or harvest management according to mutually agreed rules (Ministry of Agriculture, Forestry and Fisheries,, 2001). FMOs are autonomous organizations and some of them in Japan have been in operation for decades. These management regimes were codified and implemented as Japan's national fishery policy in the early1980s. The number of FMOs has increased steadily, both before and after implementation of the policy (Table 2.1).

Table 2.1: Changes in the total number of FMOs: 1962–1998

Year	1962	1967	1972	1977	1982	1988	1993	1998
Total	508	670	811	970	1,128	1,339	1,524	1,734
Increment	–	162	141	159	158	211	185	210

Ministry of Agriculture, Forestry and Fisheries, (1991,1996,2001).

How are FMOs and FCAs related? In sum, nearly 95% of FMOs are operated by an FCA or by an affiliate organization. There are several types of operating bodies for FMOs (Table 2.2). For example, if an FCA is small in terms of the number of fisheries, gear types, and targeted species that need to be managed, then such an FCA can add fishery management – the task of an FMO – to its responsibilities. The top row in Table 2.2 corresponds to this case; there were 463 FCAs that also functioned as FMOs. If an FCA is large in scale and involves multiple types of gear targeting various species, fishermen often form a subdivision by the type of gear or targeted species (a small-scale trawler group or an abalone harvesters' association) to serve for the benefit of that group. If, for example, management for abalone becomes necessary, then its harvesters' association will assume that task and consequently becomes an FMO (second row of Table 2.2). An autonomous group within the FCAs refers to, for example, an abalone harvesters' association that did not previously exist but was formed due to its necessity for management. Finally, most FMOs cover only their own TURF area. But since some targeted fish species migrate across TURF boundaries, managing only within a single TURF area is not always appropriate and effective. In such cases, two or more FCAs jointly manage such fisheries (fourth row of Table 2.2).

Table 2.2: Types of operating body of an FMO as of 1998

Operating body	Number of FMOs
FCA	463
Subdivision of FCA	742
Autonomous groups in FCA	333
Alliance of FCAs	106
Other	90
Total	1,734

2.3 The role of FCAs and TURFs

In the preceding section I showed that FMOs are mostly operated by FCAs, subdivisions of FCAs, or other FCA-affiliated organizations. This implies that the functions of an FCA facilitate establishment and operation of an FMO.

An often cited advantage of establishing a fishery co-management regime atop an FCA is the low transaction costs that are associated with co-management, such as consensus building and negotiation, monitoring, enforcement, and conflict resolution (Hanna, 2003). Since an FCA is itself an institution for collective action with a long history, it is not surprising that FCAs have established their own mechanisms for building consensus and handling internal disputes. Also, since many members of FCAs live in the same community in close relationship, there is an accumulation of social capital among the members that facilitates co-management regimes. This in turn explains why many FMOs are formed as affiliates of FCAs. From these facts, many researchers have concluded that successful fishery co-management in Japan rests on the long tradition of FCAs.

I argue that FCAs have other important roles, including transforming impure public goods into a class of club goods. This transformation is essential for successful fishery co-management, as explained in the next section. This particular role of FCAs is purely economic and has little to do with tradition, making this role applicable more widely to regions other than Japan.

2.3.1 Conceptual framework

Fish resources under the pure or regulated open access regime can be viewed as impure public goods. They are nonexcludable by definition of open access and subject to rivalry. Such characteristics of fishery resources create incentives to race for fish, which lead to overexploitation of fish resources, overinvestment (capital stuffing), and dissipation of rents.

If one can make the fish resource excludable, then much of the problem is solved. There are several ways to achieve exclusion; one is to completely privatize the resource by means of fishing quotas. Alternatively, one can establish a TURF defined over a certain area of the sea, grant it to a group of fishermen, and have them manage it collectively. Japanese FMO-based fishery management is the latter type. Some FMOs have been successful in achieving their objectives despite the fact that this type of regime is often thought to be less likely to succeed because it involves cooperation and collective action among individuals.

Based on the theory of clubs (Buchanan, 1965), my conceptual framework begins by viewing an FMO as a club; it is an institution that converts fish resources from impure public goods to a class of club goods (see Figure 2.1). A club good is a transformed impure public good for which benefits can be made exclusive to a limited number of people at a reasonable cost (Sandler, 1992). There are three necessary conditions to successfully transform an open access fish resource into a class of club goods. First, boundaries of the TURF area must be defined in accordance with the ecology of the targeted species. Second, membership must be defined and controlled. Finally, and most importantly, the group must be *privileged*; collective management under the FMO regime necessarily must bring a higher present value of benefits than the status quo. The first two conditions are related to excludability while the third is related to profitability (or an incentive constraint of forming an FMO). They are also interrelated – whether a group is privileged depends on how well the benefits are made exclusive to its members.

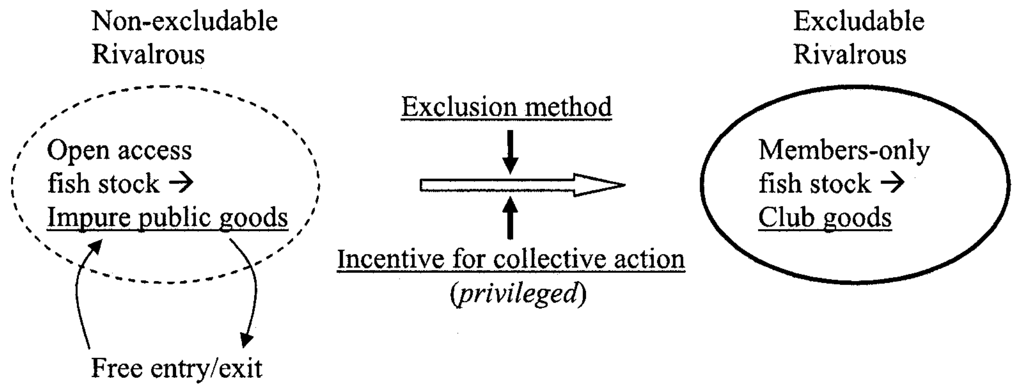

Figure 2.1: Conceptual framework of transforming impure public goods to club goods

2.3.2 Defining boundaries

The geographical boundaries of an FMO are often defined by that of the TURF area. This is no surprise since many FMOs are closely related to FCAs. Establishment of new boundaries and provision of necessary legal support for the purpose of fishery management is clearly costly. Using existing TURF systems not only saves costs but is likely to be easier to implement and operate for co-management.

The problem with using TURF boundaries for fishery co-management is that the boundaries do not necessarily coincide with the migratory patterns of the targeted species. According to the tenth fishery census, many FMOs also manage migratory species such as pollacks, snappers, and yellowtails (Ministry of Agriculture, Forestry and Fisheries,, 2001). One way to solve this transboundary problem is to form an FMO that is a collaboration of multiple FCAs so as to expand the managerial boundaries to cover the whole migration path of the targeted species. As shown in Table 2.2, there were 106 FMOs established under an alliance of two or more FCAs.

The membership boundary of an FMO is delineated by the eligibility conditions of FCAs. In other words, one must be a member of an FCA to join an FMO. As noted earlier, the Fishery Cooperative Law is explicit regarding eligibility conditions, and while there is room left for each FCA to tailor the details of those conditions, the conditions themselves are unambiguous.

2.3.3 Exclusion method: FCA membership control

There are two exclusion methods to be considered – one for the TURF area and the other for FMO (and equivalently FCA) membership. TURF area exclusion is typically accomplished by FCA members keeping an eye out for intruders and poachers. Since TURF areas are typically along the coast and adjacent to communities that constitute an FCA, this is not a difficult task. FCA membership control, on the other hand, is generally more challenging.

In the theory of clubs, an exclusion method refers to setting a toll or user fee such that an optimal membership size is achieved. In the context of FMOs, however, such exclusion methods are not feasible. Because of its cooperative nature, the FMO's premise is that all fishermen involved in the fishery to be managed join the FMO. The focus, therefore, is on preventing an inflow of new members in the future, particularly when management succeeds and the fishery becomes profitable. If the FMO is successful so that profitability improves, it attracts new members that lower the share of benefits to everyone and could undermine the FMO itself. Moreover, if the incumbent fishermen cannot be assured that they can fully appropriate the benefits from their own collective action, they may not form an FMO at all. This is referred to as the "new member problem" in the literature, which argues that an uncontrolled inflow of new members undermines the stability of FMOs and of any form of co-management regime (Pintassilgo and Duarte, 2000).

Membership control by FMOs is effectively done by the FCAs since most FMOs are an affiliate of an FCA. Therefore, the question is how an FCA controls its membership.

The Fishery Cooperative Law defines eligibility conditions for becoming an FCA member with some flexibility allowed in the details so that each FCA can adjust the conditions to its own articles to make them suitable for its needs. Eligibility conditions that are applicable to individuals and set by law are that each member (1) must be a local resident and (2) have a record of engagement in commercial fishing for more than a between 90 and 120 days annually.[2] Based on the law, FCAs tailor the eligibility conditions in their articles. For example, according to the documents I acquired from the Maizuru FCA of Kyoto and the Ohikawamachi FCA of Shizuoka, both set the minimum number of operating days at 90. The length of the fishing season for the targeted species and engagement in off-fishery jobs likely determine this requirement. Regarding company eligibility, the Maizuru FCA sets the maximum tonnage at 1,500 whereas the Ohikawamachi FCA sets it at 3,000.

[2]There are two fundamental principles underlying FCA membership; small-scale and active fishing operations. These principles came about after World War II, when the existing fisheries laws were revised in an effort to withdraw the fishing rights of absentee owners and protect small-scale fishing operations against wealthier ones that owned all of the fishing gear (Asada et al., 1983). Other entities allowed to join FCAs are local fishery producers' cooperatives and fishery companies with less than 300 full-time employees and gross tonnage of registered vessels less than a predetermined level that ranged from 1,500 to 3,000 tons.

At first glance, these eligibility conditions seem to have little to do with new membership control. In addition, the Fishery Cooperative Law does not allow FCAs to refuse applications from eligible prospective entrants without legitimate reasons or to impose more stringent conditions than those applied to current members. The essence of an FCA's membership control, therefore, is to prevent a prospective newcomer from becoming eligible.

The mechanism of membership control is as follows. To become eligible to be an FCA member, one must be engaged in fisheries in that local region for more than 90 days (or more as set by the FCA) in any given year. Recall, however, that nonmembers are not allowed to fish for commercial purposes within the TURF area that the FCA administers.[3] The only legitimate way to accumulate fishing days is to get hired as a crew member by an incumbent fisherman. However, these fishermen can refuse to hire a new member if they feel that there are already enough fishermen working the area. Since hiring decisions are solely up to the fishermen as part of their business decisions, incumbents are able to effectively exclude new members by not allowing them to become eligible.

One might argue that this mechanism can control against new additional members but not against a new member who is replacing an incumbent through a transfer of membership. A quick answer is that transfer of FCA membership is typically prohibited or restricted. The law and corresponding FCA articles state that a nonmember who seeks to obtain a transfer of membership must meet the same eligibility condi-

[3]One might argue that the newcomer can start fishing outside of the fishing rights area. There are two reasons why this is less likely to happen; one is that most fishing practiced outside of the fishing rights area is regulated by a license system and the priority of granting a license is given to currently active fishermen or an FCA member. Another reason is that the start-up cost for off-shore fishing is much higher than for coastal fishing and there are more high-value species in coastal waters than in off-shore waters. Thus, it is unlikely that entering from an off-shore fishery would be profitable.

tions. Even if the transfer is an inheritance to a family successor, approval from the FCA is necessary. The more subtle question is why such restrictive control on membership transfer by an FCA is possible. It is because, unlike legal property rights, FCA membership is simply a status granted by the FCAs. TURFs are legal quasi-property rights but are not granted to individual FCA members and so cannot be transferred, at least not at the will of an individual member.

The important point is that there are two necessary conditions for fishery co-management to be successful, namely the definition of boundaries and implementation of effective exclusion methods, and that these conditions are universal. Meeting these two conditions is not contingent on the tradition or uniqueness of Japanese fisheries, culture, or custom. The ways that these functions are brought into effect are affirmatively affected by such social aspects and, as such, FCAs/FMOs and TURFs are certainly not silver-bullet solutions. But these functions can be delivered by other methods and institutions such as a fishing license system in place of a TURF.

Thus far I have addressed two of the three conditions set forth by the theory of clubs. The last condition, that club members must be better off (privileged), is related to how FMOs manage their fisheries.

2.4 Co-management by FMOs

The management regime employed by FMOs can vary from simple to sophisticated. As a starting point, it must be remembered that simply having an allocation of allowable harvest assigned to a group like an FMO does not necessarily get fishermen's incentives, and thus their behavior corrected One end of the spectrum is thus no different than a conventional limited-entry program in which a limited group is given unallocated rights to a total allowable catch. This configuration would likely invite the race-to-fish incentives that are well documented in the literature. A simple co-management regime would be where operational and output restrictions are self-imposed, leaving other fishing decisions to individual fishermen. At the other end of the spectrum is the corporate or sole-owner model in which operations of the FMO are completely coordinated to maximize total profits. Then there are a range of options in the middle that are characterized by group agreement on broad rules of behavior, leaving an opportunity for individual initiative and decision making by participants.

Upon examination of some successful FMOs in Japan, it became apparent that two interesting features, which I refer to as "effort coordination" and "pooling arrangements," were often present. Effort coordination occurs when individual fishing operations are coordinated with a goal of increasing the efficiency of the overall fishing effort. This includes, but is not limited to, eliminating the race to fish and avoiding congestion at fishing grounds and potential damage and loss of fishing gear. Typical methods employed to achieve these objectives are fishing ground rotations and/or assignments, alternating fishing days, joint search/assessment of fish stocks, and, in some cases, joint ownership of vessels and fishing gear. Through well-conducted effort coordination, FMOs are able to solve spatial and temporal issues regarding the efficient allocation of fishing effort.

A pooling arrangement is an agreement among FMO members by which harvests, revenues, and/or profits are pooled and then distributed back to the members.[4] The

[4]Pooling as considered here does not include insurance purposes, as in risk pooling, since such fishery insurance is already offered by FCAs.

redistribution rule is either uniform (all participating fishing units receive the same amount) or weighted by indicators such as vessel size and number of crew members. The key element of a pooling arrangement is that it breaks the link between the individual fishing effort applied and actual earnings received. This dampens the incentive to compete aggressively, which is favorable in light of the excessive fishing effort that is applied in the absence of co-management. However, a pooling arrangement is a double-edged sword: if the incentive dampening effect goes too far, shirking problems can undermine the FMO's stability.

In the literature, a pooling arrangement is typically characterized as a supporting mechanism for effort coordination (Gaspart and Seki, 2003; Hasegawa, 1985; Baba, 1991). This is because, in essence, effort coordination is a restriction of the individual freedom of fishing operations and the differentials in harvest levels resulting from effort coordination must be addressed and adjusted. A pooling arrangement is a method for handling this distribution problem.[5]

In my aim to describe how effort coordination and pooling arrangements are implemented in actual FMO operations, I present an example from a sakuraebi (*sergia lucens*) fishery that is known as one of the most successful and sophisticated fishery co-management efforts in Japan.

[5]Alternatively, FMOs can handle this distribution issue by rotating fishing opportunities so that assignments rotate over hot spots and cold spots in some regular way. The pollack fishery in western Hokkaido is one such example.

2.4.1 Sakuraebi fishery in Japan: An example of effort coordination and pooling arrangement

An overview of the fishery

Sakuraebi is a small shrimp similar to krill with a jaw-to-tail length of only 4-5 centimeters (approximately 2 inches) when fully grown. Its lifespan is about 15 months and it normally spawns only once in its lifetime. Spawning season is during the summer (late June to late October) and occurs about a year after hatching. The sakuraebi do not crawl on the sea floor like other crustaceans but rather spend their entire lives floating in the water. Once they are fully grown, they spend daylight hours at a depth of 200-300 meters (approximately 900 feet) underwater and scattered. As dusk approaches, they begin to cluster together and move upward to about 60 meters (180 feet) in depth.

The sakuraebi fishery is located in Suruga Bay in Shizuoka prefecture west of Tokyo. Sakuraebi is not exclusive to Suruga Bay; in fact, it exists in other waters, including Tokyo Bay. It is harvested in Suruga Bay only, however, since in other places the shrimp does not clump into high enough densities for fishing to be feasible.[6] The sakuraebi of Suruga Bay are believed to remain in the bay throughout their lifetimes; they are not biologically linked to other populations.

The method used to fish for the shrimp is closely related to its biological characteristics. Fishing is done at night when sakuraebi cluster and ascend to about 60 meters underwater as it is much more efficient to harvest them at that time. The

[6] It is believed that the ocean floor landscape of Suruga Bay – steep slopes reaching more than 2,400 meters (approximately 1.5 miles) below the surface just off the coast – forces the shrimp to cluster in high density as they ascend during the night.

fishing gear is called a paired-boat trawl net and is shown in Figure 2.2. A pair of boats is referred to as a single "unit" and it is often formed by family members who join their boats in a single operation. Ownership of the vessels and nets varies from one unit to another. Typically, the vessels are owned individually, although there are cases of co-ownership. The net is either owned solely by one side of the pair or owned jointly. The structure of ownership is reflected in the distribution of revenues from the harvest. An average crew numbers 12 to 13 individuals (six or seven per vessel). In 2005, there were 60 units (120 vessels) engaged in sakuraebi fishing from two FCAs in the region. The Yui Harbor FCA included 42 units and the Ohikawamachi FCA commanded 18 units.

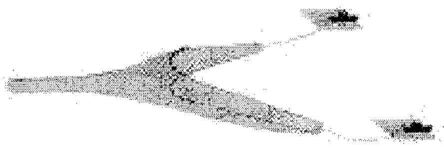

Figure 2.2: Paired-boat trawl net used in sakuraebi fishery

There are two fishing seasons for sakuraebi, one in spring along the coast of the Yui area (inner side of the bay) and another in fall near the coast of Ohikawamachi (near to the mouth of the bay). Shizuoka prefecture restricts the fishing season for sakuraebi to between October 1 and June 10; the three summer months are excluded as they coincide with the shrimp's spawning season. However, fishermen voluntarily limit the harvest to between late October and the end of December (fall season) and from late March until early June (spring season). They voluntarily excluded the three winter months because shrimp stay in deeper waters during these months, making fishing at that time of year less efficient. Actual days spent fishing are even more limited, mostly due to weather and market conditions (explained later). The average annual number of fishing days for 1974 through 2003 was 48 days during the four and a half month season. For this reason, income from the sakuraebi fishery is very high per unit of effort but the total is not enough to support the livelihood of a typical fisherman's family.[7]

Sakuraebi FMO

The sakuraebi FMO is called the Sakuraebi Harvesters' Association. It was established in 1946 by vessel owners and fishermen who were engaged in sakuraebi fishing from two FCAs, Yui Harbor and Ohikawamachi. Its objectives were to serve as a bridge between fishermen and the government and, more importantly, to set starting and ending dates for each season and other rules concerning fishing practices. The primary motivation for setting up the association was that disputes from racing for fish harvests had begun to repeatedly escalate to violence and fishermen (particularly the vessel owners) realized the need for an institution that could resolve and prevent conflict (Omori and Shida, 1995).

A milestone of sakuraebi fishery management came in 1967 when the fishing committee was established in an effort to unify and coordinate fishing operations (Figure 2.3). The committee consists of 21 members representing vessel owners and fishermen (often skippers). Committee members meet every afternoon during the fishing season to decide (1) whether to go fishing; (2) if they will go fishing, the time of departure; (3) vessels' location assignments; (4) the target harvest volume; and (5) the landing volume for each of the three landing ports plus any other operational items as neces-

[7]In 1993, a crew earned on average $336 per fishing day, keeping in mind that typical fishing hours per day is three to four hours in sakuraebi fishery. However, annual earning is only $17,000 due to the small number of fishing days (Omori and Shida, 1995).

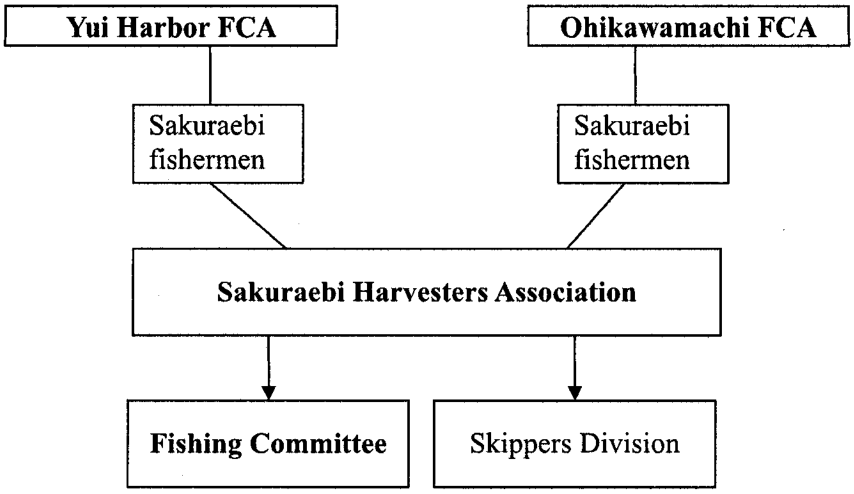

Figure 2.3: Structure of sakuraebi fishery management organizations

sary. Decisions by the committee command all 60 units that currently hold licenses and are absolutely final.[8]

Effort coordination

On the first day of each fishing season (spring and fall), all 60 units are coordinated to conduct a fishing-ground search to locate the hot spots for the season. Based on this information, units are allocated to hot spots by the committee on each fishing day.

The committee also decides how much to harvest on that particular day. This decision is made based on recent ex-vessel prices and information on the processors' inventory levels. In sum, the committee aims to avoid a market glut. For this reason, the committee sometimes calls for a day off when the weather is perfect but the processors' inventories are high.

[8]Individual claims, of course, do still occur. I was told that being a member of the committee – and especially being the committee chair – is a very tiresome task.

Fishing operations are completely synchronized. There are three leader skippers who are responsible for coordinating operations out on the sea. All units maintain radio contact with one of the three leaders, and the leaders communicate on the radio among themselves as well. Each unit reports in when it is ready to cast the net. When all of the units are ready, leaders give a go sign. After 10 minutes or so of trawling, leaders then radio to the units to haul in the nets. Each unit then reports the amount they caught – experienced fishermen can approximate the harvest by number of boxes when they see the volume of shrimp caught in the net. Leaders then calculate the total harvest and, if the target amount has been met, they call off fishing for the day. Otherwise, they ask several units to go for a second haul.

There is another form of effort coordination that is related to the over-capacity problem. On any fishing day, all 60 units leave the ports but only about half of them actually cast and haul their nets. With improved gear and technologies such as the global positioning system (GPS) and underwater scanners, sakuraebi fishermen know that 60 units are simply too many relative to the target harvest volume. The fact that they keep 60 units while only half of them are necessary to harvest the target amount suggests that the fishermen's objective is not just economic efficiency. An equally important objective is to find ways for every member to survive and continue in the business.

However, the question remains-why should all 60 units leave port? Thirty units could take turns leaving port, which would save some expense. Explanations given by sakuraebi fishermen all boiled down to the emotions or mentality of fishermen: they dislike being onshore while others are out fishing. This can be thought of as a limitation of fishery co-management by an organization with a cooperative nature in that it cannot impose stringent principles of economic efficiency.

Another limitation of sakuraebi fishery co-management is that the resource management dimension related to the stocks of fish is somewhat limited. Although leaders of the sakuraebi FMO claim that resource management is an important objective, harvest volume control, for example, does not put much emphasis on the conditions of the fish stocks. As already mentioned, harvest volumes are determined mostly by market conditions. Having said that, it is also the case that Shizuoka Prefecture Fisheries Experiment Station, which is the local public research institute that studies sakuraebi, is currently only capable of giving a forecast of coming season's harvest level but they have no idea whether that is within the "safe" range in terms of sustainability. Therefore, it is not that the committee is completely dismissive of resource management aspects of the fishery, but its ability is limited due in part to a lack of relevant scientific information.

Fishermen are, nonetheless, putting effort into resource management in different ways. The most prominent effort is a reduction of the fall season harvest. Fall season shrimp are mature individuals that have not yet spawned and juveniles that hatched earlier in the spawning season. By decreasing the take of fish during the fall, fishermen hope to secure more mature shrimp for spawning and for juveniles to mature for harvesting in the following spring season. Also, the committee has in the past imposed an "emergency closure" for a week when the catch level was extremely low and they feared that sakuraebi stocks, for reasons unknown, were low as well.

Pooling arrangement

A pooling arrangement is considered to be the key mechanism that keeps effort coordination functioning and has allowed it to endure since 1967. The basic calculation is as follows. First, all revenues are pooled at the FMO level. From this gross revenue, a market commission fee (3%), a port fee (1%), and cooling storage usage costs are deducted. All of these payments go to FCA accounts. Then the remainder is distributed equally to FMO members.[9]

A pooling arrangement was first tried voluntarily on a much smaller scale; five vessel owners from the Yui area started in 1966. Their motivation was mainly cost savings by avoiding the race. Fishermen from other areas followed their lead and formed their own pooling groups. After several trials and failures, three separate pooling arrangements were established in three regions of Suruga Bay and were launched in 1968.

The first three pooling arrangements were not successful, although they lasted until 1976. The primary cause of their failure was the market commission fee. This fee, which is 3% of the landed value, is paid to an FCA that administers and operates the landing port and ex-vessel market in its vicinity. Each of the three pooling groups had a separate landing port. Therefore, though competition among the individual units was removed, competition among the groups remained and intensified. Agreements by the committee were often violated. Although it had some effect on maintaining higher prices by limiting the harvest volume so as not to flood the market, overall performance, particularly with regard to resource management, was poor.

[9] Actual distribution is slightly more complicated, such as differentiating between the vessel owners and crew members. However, the key is that within the same group the payments are distributed equally. Details are illustrated in Uchida (2004a).

In 1977, upon realization of the flaw, the arrangement was modified by the committee and expanded to encompass single and unified pooling arrangements and the market commission fee was included in the pooling calculation.

Note that in the sakuraebi case revenues are pooled but some of the costs are not. If all of the costs, both variable and fixed (capital), are pooled and shared as well, then effectively the organization functions as a single company that owns the resource – committee members are the operations managers and fishermen are employees who receive wages from pooled revenue. Such cost sharing, including joint ownership of a smaller number of and perhaps larger vessels, seems to be a natural next step. At present, however, such movement is nonexistent in this fishery.

2.5 Conclusion

In this chapter I presented the relationship between FCAs, TURFs, and FMOs in the context of fishery co-management in Japan. Although the existence of FCAs in Japanese coastal fisheries is well known and some assert that FCAs enhance the likelihood of fishery co-management regimes to be established and successful, the mechanism of why and how that is so remained unexplained. Using the conceptual framework of the theory of clubs, I illustrated that the significance of FCAs, including their associated laws and rules, for the establishment and effectiveness of FMOs occurs through membership control. As these fundamental concepts are universal, I argued that co-management of Japanese fisheries is far more applicable to other regions' fisheries than has been previously asserted.

With boundary definitions and membership control in place, the task of an FMO is to bring sufficient benefits to its members so that they are better off by operating under the FMO. Simply having an allocation of allowable harvest assigned to an FMO does not necessarily correct the incentives of fishermen so as to mitigate the race for fish, as that scenario is no different than a conventional limited-entry program. Thus, we expect such a configuration to invite the race to fish, leading to poor co-management performance. The management regime employed by FMOs can vary from simple to sophisticated and, upon examination of some successful FMOs, I identified two distinct and essential measures – effort coordination and pooling arrangements. Effort coordination measures are aimed at directly avoiding the race for fish by, allocating fishing efforts across space through assignment or rotation of the fishing grounds. It also includes controlling the landing volume to avoid flooding the market and to maintain prices. Pooling arrangements, on the other hand, are implemented to adjust the harvest differentials caused by effort coordination and also to ease the incentive to race for fish. With effort coordination and a pooling arrangement, an FMO is quasi-corporate in the sense that operations are decided centrally and members are paid in a form similar to a wage. FMOs with effort coordination and a pooling arrangement can operate in a manner that is similar to a sole owner of the resource.

To glimpse how these measures are implemented, I looked at the example of a sakuraebi fishery, one of the most well-known fisher co-management success stories in Japan. With regard to effort coordination, fishermen in the sakuraebi fishery operate under the direction of the fishing committee, which consists of their representatives. The committee decides every aspect of fishing operations, including whether to go fishing on any given day during the season. Once it is decided to go fishing, the committee determines a spatial allocation of vessels by assigning each vessel to a fishing location and a target harvest volume for the operation as a whole. During the operation, casting, trawling, and hauling of the net are perfectly synchronized. Harvest volume is determined based on the market price and the inventory level of processors, and any time that there is concern that the market is being flooded they can elect to not fish even if the weather and other conditions suggest otherwise. Pooling arrangements went through some revisions since the original implementation; the current scheme is set in such a way that individual incentives are aligned with maximizing returns at the group level. As a result, sakuraebi fishermen's earnings per unit of effort are high, making it one of the most lucrative fisheries in Japan.

At this juncture a question naturally occurs – is the experience of the sakuraebi fishery an isolated case or can we make some general statements about the effects of effort coordination and pooling arrangements? The sakuraebi fishery is marked by several distinctive characteristics, such as it is harvested only by these fishermen (i.e., a natural monopoly) and that there are very few substitutes in the market. The processing procedure is labor intensive and thus many operations are small-scale family-owned businesses, enabling fishermen to exert bargaining power by controlling the landing volume. These characteristics are by no means universal. On the other hand, if the incentive to race to fish is the leading culprit for low performance of fisheries, then mitigating or eliminating such an incentive through well-coordinated fishing operation can, in principle, bring higher returns without monopolistic market conditions. These questions are addressed and analyzed analytically and empirically in subsequent chapters.

Chapter 3

A dynamic model of a regulated restricted-access fishery

3.1 Introduction

This chapter develops a theoretical model of optimal resource use under different management regimes. The model assumes there are many but a fixed number of resource users. On one extreme, these users can coordinate their fishing efforts and effectively behave as a sole owner and on the other extreme they can compete with each other and harvest in a noncooperative manner. Then there is a third regime in between, the pooling arrangement, in which a portion of each individual's harvest is pooled with that of other group members and then distributed back to them equally. The primary objective of this chapter is to theoretically analyze the impact of pooling arrangements on optimal paths of fishing effort and harvest volume.

The use of output sharing to promote joint production, which is one form of collective action, has been considered in the literature on labor-managed firm dating back at least to Sen (1966). In the context of fisheries, output sharing was first studied in the context of contractual choices between boat owners, captains, and crew members (e.g., Platteau and Nugent, 1991). The pooling arrangements considered here, in contrast, are contracts among independent business owners/entrepreneurs in fisheries.

Several streams of literature have considered such pooling arrangements as an instrument for common pool resource management. Platteau and Seki (2001) studied a white shrimp fishery in Japan in which a group of fishermen had implemented a pooling arrangement. Based on their observations, Platteau and Seki claim that a pooling arrangement effectively dampens the incentive to race for fish. The incentive to shirk, on the other hand, was mitigated by individual's status-seeking motivation (i.e., being the top fisherman in the group). The perception of pooling arrangements for Platteau and Seki is, however, that it is a supporting mechanism for finely tuned effort coordination among members of a fishing group. A pooling arrangement in their view is not a resource management tool; rather, it is a complementary scheme that supports core management measures.

Gaspart and Seki (2003) modeled the individual fisherman's optimization problem with the pooling arrangement. Their model showed that without pooling the total fishing effort exerted exceeded the socially optimal level but with full pooling there was too little fishing effort. Thus there is a level of pooling that leads to a socially optimal outcome. Their model, however, was static and did not consider fish population dynamics, which are affected by harvesting.

Chakraborty (2004) developed a dynamic model of fishery resource use under the pooling arrangement regime. However, Chakraborty's model viewed the pooling arrangement as an implicit resource-use tax. Collected taxes or pooled proceeds from taxes are distributed equally among consumers, which may or may not be the fishermen. The fundamental idea is analogous to pollution and other environmental tax schemes. He closed the model by assuming an open access regime in the fishery so that profits were zero (the tax is levied on harvest volume). Thus, in this model, any profits that are potentially generated as the harvest level is curtailed towards the social optimum are taken away by means of the resource tax. The model also finds an optimal tax rate such that the total harvest coincides with the socially efficient level.

The model presented here differs from preceding ones. First, it is dynamic as it incorporates changes in the fish population as a result of harvesting. My pooling arrangement model is similar to that of Gaspart and Seki (2003) in that certain portions of individual revenue (or any form of proceeds) are pooled at the group level and then distributed back equally to group members. Since the flow of pooled revenue is confined within the group, it is necessary to allow a nonzero profit to be generated.

The context of this model is one in which fishermen are maximizing their individual or collective profit by choosing a level of fishing effort and a terminal date, the fishing season length, optimally. I assume that the minimum escapement level for the fish population for a fishing season is exogenously determined by either the fishermen as part of their self-governance or by regulators and thus the season closes when that population level is reached.

The model shows that the pooling arrangement affects the optimal trajectory of a noncooperative harvesting regime by lowering the level of fishing effort exerted at any point in time during the fishing season. As the pooling share increases, the level of fishing effort declines, the per-period harvest volume decreases, and the season gets longer.

A rather surprising result is that the outcome of a pooling share of 100% (all individual revenue is shared) coincides perfectly with that of a sole-owner regime regardless of the size of the membership. In light of the shirking incentive associated with pooling arrangements, this result seems to be somewhat of an overstatement, particularly when the membership size is large. On the other hand, with full pooling, the incentive to maximize one's own payoff is closely aligned with maximizing the group's total payoff. Also, there is ample evidence of pooling arrangements in the real world in which the sharing ratio is 100% and equally redistributed, so the outcome of the model is not necessarily implausible. One can at least claim that a pooling arrangement alters the incentive of fishermen as their fishery operation changes from noncooperative harvesting toward a well-coordinated sole-owner-like operation.

3.2 The model

The context in which the models are established is as follows. I consider the decisions of a resource user, or a group of users if in cooperation, in terms of how much fishing effort to invest. In the former case, I assume that each individual optimizes his own effort while assuming that the decisions made by the others are exogenous and fixed. The planning time horizon is a single fishing season, and therefore I assume no recruitment or fish population growth within the time horizon. The fish population level at the beginning of the fishing season is determined by nature, and the terminal population level is predetermined by either the group or the regulator. The season length, however, is treated as endogenous. Lastly, a linear harvest function is assumed.

3.2.1 Model 1: Perfect cooperation

I first consider the case of perfect cooperation among resource users. This is qualitatively equivalent to assuming a single resource user, and the results will serve as a benchmark for subsequent models. The optimal control problem is

$$\max_{E_t} \int_0^T e^{-rt} \left[pqE_tX_t - \frac{1}{2}cE_t^2 \right] dt \tag{3.1}$$

$$\text{subject to } \dot{X}_t = -qE_tX_t$$

$$X(0) = X_0$$

$$X(T) = X_T,$$

where E_t is the aggregated fishing effort level, X_t is the fish population level, q is the catchability coefficient, p is the output price, and $r \in [0, 1]$ is the discount rate. The cost function is assumed as $C(E_t) = (1/2)cE_t^2$, where c is a nonnegative constant.

The current value Hamiltonian of this optimal control problem is

$$\mathbb{H}_t = pqE_tX_t - \frac{1}{2}cE_t^2 - \lambda_t(qE_tX_t),$$

where λ_t is the co-state variable that has the usual economic interpretation as the shadow value of fish left not harvested at time t. The first order conditions are

$$E_t: \; pqX_t - cE_t - \lambda_t qX_t = 0 \tag{3.2}$$

$$X_t : \dot{\lambda}_t - r\lambda_t = -\left(pqE_t - \lambda_t qE_t\right) \tag{3.3}$$

$$\lambda_t : \dot{X}_t = -qE_tX_t. \tag{3.4}$$

It can be shown that following system of ordinary differential equations (ODEs) can be derived by utilizing the above first order conditions

$$\begin{aligned} \dot{E}_t &= r\left(E_t - \frac{pqX_t}{c}\right) \\ \dot{X}_t &= -qE_tX_t. \end{aligned} \tag{3.5}$$

The strategy is to utilize the phase diagrams of this system of ODEs to analyze the solution to the optimal control problem (3.1). The $\dot{E}_t$ nullcline can be derived from (3.5) as

$$\dot{E}_t = 0 \Leftrightarrow E_t = \frac{pq}{c}X_t, \tag{3.6}$$

a linear function with positive slope that goes through the origin. As for the $\dot{X}_t$ nullcline, by setting (3.4) equal to zero one finds that any combination of $(X_t, 0)$ or $(0, E_t)$ will result in $\dot{X}_t = 0$. This implies that both the horizontal and vertical axes are $\dot{X}_t$ nullclines. A fixed point is thus $(X_t^*, E_t^*) = (0, 0)$. This is a direct consequence of an assumption that within-season population growth does not exist.

The last piece of information necessary is the directions of vector fields around the nullclines. First, take a derivative of (3.5) with respect to X_t and E_t

$$\begin{aligned} \frac{\partial \dot{E}_t}{\partial X_t} &= -\frac{rpq}{c} < 0 \\ \frac{\partial \dot{E}_t}{\partial E_t} &= r > 0. \end{aligned}$$

This implies that E_t is increasing in the region above the nullcline and, conversely, E_t is decreasing below the nullcline. Next, take the derivative of (3.4) with respect to X_t and E_t

$$\frac{\partial \dot{X}_t}{\partial X_t} = -qE_t < 0$$
$$\frac{\partial \dot{X}_t}{\partial E_t} = -qX_t < 0.$$

Thus, x_t is decreasing in the first quadrant region. The phase diagram of this ODE system is illustrated in Figure 3.1.

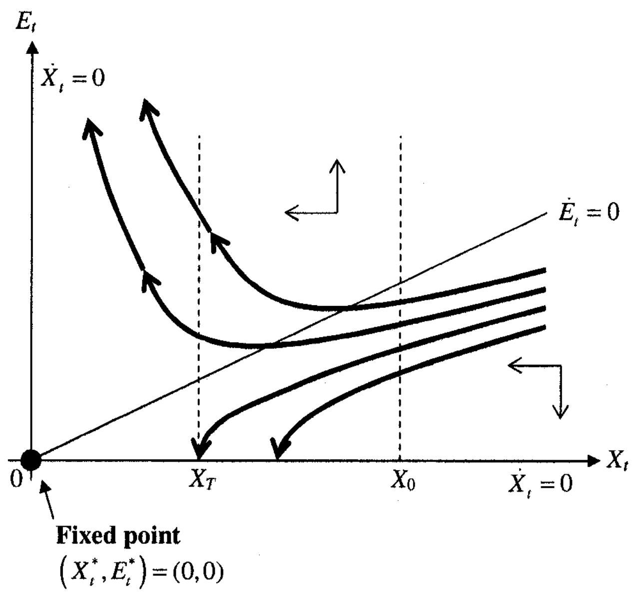

Figure 3.1: Phase diagram of Model 1: perfect cooperation (qualitatively equivalent to $n = 1$)

Lastly, the transversality condition of the optimal control problem (3.1) must be considered. The transversality condition corresponding to the endogenous terminal date T requires the value of Hamiltonian at time T to be equal to zero:

$$\mathbb{H}_T = pqE_TX_T - \frac{1}{2}cE_T^2 - \lambda_T(qE_TX_T) = 0.$$

Also from (3.2) and solving for λ_t,

$$\lambda_T = p - \frac{cE_T}{qX_T}.$$

Substituting this into the preceding Hamiltonian equation yields $E_T = 0$.

The result implies that the trajectories (such as crossing the $\dot{E}_t$ nullcline and curving upwards) as shown in Figure 3.1 cannot be the feasible path for this problem. Therefore, with a perfectly coordinated fishermen's group acting as a single resource user, the aggregate effort level will monotonically decrease during the fishing season in such a way that the regulated minimum fish population level X_T is just reached when the group's decision is to terminate the season; i.e., $E_T = 0$.

3.2.2 Model 2: Non-cooperative harvesting

Here I consider the case in which there are many (n) fishermen and each competes against the others in individualistic manner. Let us denote the individual i's level of fishing effort exerted in time t as ϵ_{it}, and $E_t \equiv \sum_{i=1}^{n} \epsilon_{it}$. Also, define the aggregate fishing effort by other than individual i as $E_{-it} \equiv \sum_{j \neq i}^{n} \epsilon_{jt}$. I also assume that the individual harvest volume is proportional to the share of that fisher's effort among the group (e.g., Cheung, 1970; Schott, 2003; Gaspart and Seki, 2003).

The model for this optimal control problem is

$$\max_{\epsilon_{it}} \int_0^T e^{-rt} \left[\frac{\epsilon_{it}}{\epsilon_{it} + E_{-i,t}} pq(\epsilon_{it} + E_{-i,t})X_t - \frac{1}{2}c\epsilon_{it}^2 \right] dt \tag{3.7}$$

$$\text{subject to } \dot{X}_t = -q(\epsilon_{it} + E_{-i,t})X_t$$

$$X(0) = X_0$$

$$X(T) = X_T.$$

The current value Hamiltonian is

$$\mathbb{H}_t = \frac{\epsilon_{it}}{\epsilon_{it} + E_{-i,t}} pq(\epsilon_{it} + E_{-i,t})X_t - \frac{1}{2}c\epsilon_{it}^2 - \xi_t q(\epsilon_{it} + E_{-i,t})X_t.$$

A quick note on the choice of co-state variable ξ_t used here instead of λ_t as in the previous Model 1 is in order. This is done intentionally. In Model 1, interpretation of the co-state variable was the shadow value of the resource stock that remained for the sole owner, which is the true or socially optimum value. In Model 2, the interpretation is slightly different; it is the shadow value perceived by a single user i who shares the resource with $n - 1$ users. Because of the public goods nature of a common pool resource, this generally will be a lesser value than the value perceived by the sole owner. I note this difference explicitly by using different notation.

The first order condition of optimization problem (3.7) is

$$\epsilon_{it} : pqX_t = c\epsilon_{it} + \xi_t qX_t \tag{3.8}$$

$$X_t : \dot{\xi}_t - r\xi_t = -\left(pq\epsilon_{it} - \xi_t qE_t\right) \tag{3.9}$$

$$\xi_t : \dot{X}_t = -qE_tX_t. \tag{3.10}$$

The first order condition (3.8) shows the consequence of a noncooperative use of common pool resource by many individuals. The left hand side, namely pqX_t, is the marginal product value of effort of individual i ($p\frac{\partial h_{it}}{\partial \epsilon_{it}}$). This is equated to his marginal expenditure of effort ($c\epsilon_{it}$) and the marginal cost of today's harvest based on the *private* shadow value of the resource stock (ξ_t). Since $\xi_t < \lambda_t$, this leads to a higher level of fishing effort level than Model 1.

For a symmetric Nash equilibrium, first replace $\epsilon_{it} = (1/n)E_t$ for all i. By imposing this symmetry to the first order conditions and after some algebraic procedures similar to that of Model 1, we arrive at the system of ODEs for this optimal control problem:

$$\dot{E}_t = rE_t - \frac{n-1}{c}pq^2E_tX_t - \frac{nrpq}{c}X_t$$
$$\dot{X}_t = -qE_tX_t.$$

The $\dot{E}_t$ nullcline is

$$\dot{E}_t = 0 \;\Leftrightarrow\; E_t = \frac{nrpqX_t}{rc-(n-1)pq^2X_t}. \tag{3.11}$$

The slope of the nullcline must be determined in order to draw a phase diagram. It can be shown that

$$\frac{\partial E_t}{\partial X_t} = \frac{nr^2pqc}{(rc-(n-1)pq^2X_t)^2} > 0$$
$$\frac{\partial^2 E_t}{\partial X_t^2} = \frac{2nr^2pqc(n-1)pq^2X_t}{(rc-(n-1)pq^2X_t)^3} > 0,$$

for any $n \geq 2$. Thus, the $\dot{E}_t$ nullcline has a positive and monotonically increasing slope, i.e., it is a convex curve.

As for the $\dot{X}_t$ nullcline, $-qE_tX_t = 0$ implies $(X_t, 0)$ or $(0, E_t)$ as before. From (3.11), $X_t = 0$ implies $E_t = 0$; if $E_t = 0$ then $X_t = 0$ is the only feasible solution. Thus, a fixed point of this ODE system is $(X_t^*, E_t^*) = (0, 0)$.

For the directions of vector fields, take the derivative of $\dot{E}_t$ and $\dot{X}_t$ each with respect to E_t and X_t and check the signs of each result

$$\begin{aligned}
\frac{\partial \dot{E}_t}{\partial X_t} &= -\frac{nrpq + (n-1)pq^2E_t}{c} < 0 \\
\frac{\partial \dot{E}_t}{\partial E_t} &= \frac{rc - (n-1)pq^2X_t}{c} > 0 \\
\frac{\partial \dot{X}_t}{\partial X_t} &= -qE_t < 0 \\
\frac{\partial \dot{X}_t}{\partial E_t} &= -qX_t < 0.
\end{aligned}$$

The sign for $\partial \dot{E}_t/\partial E_t > 0$ is based on the denominator of (3.11) and the fact that $E_t \geq 0$. These results imply that E_t is increasing in the region above/left of the $\dot{E}_t$ nullcline and decreasing on the other side of the nullcline, and that X_t is decreasing in the first quadrant region.

The phase diagram for this model is depicted in Figure 3.2. Note that since the slope of this nullcline near the origin is

$$\lim_{X_t \to 0} \frac{r^2ncpq}{[rc - (n-1)pq^2X_t]^2} = \frac{r^2ncpq}{(rc)^2} = \frac{npq}{c},$$

the nullcline curve lies above the line $E_t = (npq/c)X_t$. This fact becomes useful later in comparing results among the models.

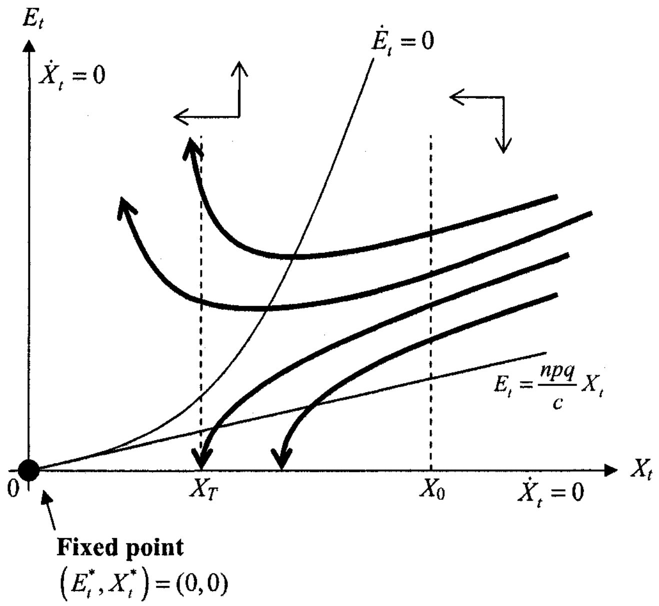

Figure 3.2: Phase diagram of Model 2: non-cooperative users ($n \geq 2$)

The transversality condition of this optimal control problem is

$$\mathbb{H}_T = \frac{\epsilon_{iT}}{E_T} pqE_T X_T - \frac{1}{2} c\epsilon_{iT}^2 - \xi_T qE_T X_T = 0.$$

Also from (3.8)

$$\xi_T = p - \frac{c}{qX_T}\epsilon_{iT}.$$

Substituting this into the preceding transversality condition yields

$$pqX_T\left(1 - \frac{E_T}{\epsilon_{iT}}\right) + c\epsilon_{iT}\left(\frac{E_T}{\epsilon_{iT}} - \frac{1}{2}\right) = 0,$$

and by imposing symmetry one obtains

$$E_T = \frac{2n(n-1)}{c(2n-1)} pqX_T. \tag{3.12}$$

Note that if $n = 1$, which is the case for Model 1, (3.12) returns $E_T = 0$ as expected. On the other hand, as the number of fishermen (n) become very large (but finite), (3.12) can be approximated to

$$E_T|_{\text{large } n<\infty} \doteq \frac{npq}{c}X_T,$$

which is the supporting line of the $\dot{E}_t$ nullcline as depicted in Figure 3.2. Thus, unlike the case in Model 1, noncooperative harvesting by $n \geq 2$ users will reach the terminating population level X_T in a shorter time than they would if they voluntarily stop harvesting (i.e., $E_T = 0$). The terminal fish population level would have been lower than the regulated level of X_T if it was left to be determined endogenously.

3.2.3 Model 3: Non-cooperative and pooling arrangement

The third model considers the case in which each fisherman operates in an individualistic manner; there is no explicit cooperation among fishermen but the pooling arrangement is implemented. In particular, I model a portion σ of individual revenue being pooled with a portion of the revenue of other fishermen in the group. The total pooled revenue is then equally distributed back to each fisherman so that each gets a share equal to $1/n$.

The optimal control problem under this scenario is

$$\max_{\epsilon_{it}} \int_0^T e^{-rt}\left[(1-\sigma)\frac{\epsilon_{it}}{\epsilon_{it}+E_{-i,t}}pq(\epsilon_{it}+E_{-i,t})X_t + \sigma\frac{pq(\epsilon_{it}+E_{-i,t})X_t}{n} - \frac{1}{2}c\epsilon_{it}^2\right]dt \tag{3.13}$$

$$\text{subject to } \dot{X}_t = -q(\epsilon_{it} + E_{-i,t})X_t$$

$$X(0) = X_0$$

$$X(T) = X_T.$$

The current value Hamiltonian is

$$\mathbb{H}_t = (1-\sigma)\frac{\epsilon_{it}}{\epsilon_{it} + E_{-i,t}}pq(\epsilon_{it}+E_{-i,t})X_t+\sigma\frac{pq(\epsilon_{it} + E_{-i,t})X_t}{n}-\frac{1}{2}c\epsilon_{it}^2-\xi_t(q(\epsilon_{it}+E_{-i,t})X_t).$$

The first order conditions are

$$\epsilon_{it} : \left(1 - \frac{n-1}{n}\sigma\right) pqX_t - c\epsilon_{it} - \xi_t qX_t = 0 \quad (3.14)$$

$$X_t : \dot{\xi}_t = (r + qE_t)\xi_t - pq\epsilon_{it} \quad (3.15)$$

$$\xi_t : \dot{X}_t = -qE_tX_t. \quad (3.16)$$

Note that (3.15) is identical to that of (3.9) in Model 2 regardless of the value of the pooled ratio σ. Also (3.14) should coincide with (3.8) in Model 2 when $\sigma = 0$, and one can easily verify that it does.

An interesting result is when $\sigma = 1$, or under "full pooling." In this case, all revenues are pooled so that each member earns exactly the same revenue. Substituting $\sigma = 1$ into (3.14) yields $(1/n)pqX_t = c\epsilon_{it} + \xi_t qX_t$. By imposing symmetry so that $\epsilon_{it} = (1/n)E_t$, one can obtain

$$pqX_t = cE_t + n\xi_t qX_t. \quad (3.17)$$

Since $E_t \equiv \sum_i e_{it}$ is the aggregated level of fishing effort for a group, with the specific functional form assumed here the left hand side of (3.17) is the marginal product value of the aggregated effort. This is equated to the marginal expenditure of aggregated effort plus private marginal cost of reducing the fish population today multiplied by the number of individuals in a group (n). This is equivalent to the first order condition of the sole owner optimization problem.[1] This model does not assume any explicit cooperation among fishermen, and yet with a full pooling arrangement the first order condition regarding the effort level coincides with that of a sole owner.

From (3.15) and (3.17) one can derive the system of ODEs

$$\begin{aligned} \dot{E}_t &= rE_t - (n-(n-1)\sigma)\frac{rpq}{c}X_t - \frac{n-(n-1)\sigma-1}{c}pq^2E_tX_t \\ \dot{X}_t &= -qE_tX_t. \end{aligned} \tag{3.18}$$

The nullcline for $\dot{E}_t$ is

$$\dot{E}_t = 0 \;\Leftrightarrow\; E_t = \frac{(n-(n-1)\sigma)rpqX_t}{rc-(n-(n-1)\sigma-1)pq^2X_t} \tag{3.19}$$

The slope of this nullcline can be shown to be

$$\begin{aligned} \frac{\partial E_t}{\partial X_t} &= \frac{(n-(n-1)\sigma)r^2pqc}{(rc-(n-(n-1)\sigma-1)pq^2X_t)^2} > 0 \\ \frac{\partial^2 E_t}{\partial X_t^2} &= \frac{2(n-(n-1)\sigma)r^2pqc(n-(n-1)\sigma-1)pq^2X_t}{(rc-(n-(n-1)\sigma-1)pq^2X_t)^3} > 0, \end{aligned} \tag{3.20}$$

for any $n \geq 2$. Thus, the equation (3.19) curve is positively sloped and convex. As for the $\dot{X}_t = 0$ nullcline, $-qE_tX_t = 0$ implies $(X_t, 0)$ or $(0, E_t)$ as before. From (3.19),

[1]Note that symmetry assumption implies $n\xi_t = \lambda_t$.

$E_t = 0$ implies $X_t = 0$; if $X_t = 0$ then $E_t = 0$ is the only feasible solution. A fixed point of this ODE system is hence $(X_t^*, E_t^*) = (0,0)$.

The derivatives to determine the directions of vector fields are

$$\begin{aligned}
\frac{\partial \dot{E}_t}{\partial X_t} &= -\frac{(n-(n-1)\sigma)rpq + (n-(n-1)\sigma-1)pq^2E_t}{c} < 0 \\
\frac{\partial \dot{E}_t}{\partial E_t} &= \frac{rc-(n-(n-1)\sigma-1)pq^2X_t}{c} > 0, \\
\frac{\partial \dot{X}_t}{\partial X_t} &= -qE_t < 0 \\
\frac{\partial \dot{X}_t}{\partial E_t} &= -qX_t < 0.
\end{aligned}$$

Thus, as in Model 2, E_t is increasing in the region above/left of the $\dot{E}_t$ nullcline and decreasing on the other side and X_t is decreasing in the first quadrant region. The phase diagram will be qualitatively identical to Figure 3.2 so it is not reproduced here. However, the line that bounds the $\dot{E}_t$ nullcline from below in Model 3 is

$$\lim_{X_t \to 0} \frac{\partial E_t}{\partial X_t} = (n-(n-1)\sigma)\frac{pq}{c},$$

which is less than that of Model 2 but more than the $\dot{E}_t$ nullcline in Model 1.

The transversality condition for Model 3 is

$$\mathbb{H}_T = (1-\sigma)\frac{\epsilon_{iT}}{E_T}pqE_TX_T + \frac{\sigma pqE_TX_T}{n} - \frac{1}{2}c\epsilon_{iT}^2 - \xi_T qE_TX_T = 0.$$

With some algebra one arrives at

$$pqX_T\left[1-\sigma+\frac{\sigma}{n}\frac{E_T}{\epsilon_{iT}} - \left(1-\frac{n-1}{n}\sigma\right)\frac{E_T}{\epsilon_{iT}}\right] = \frac{1}{2}c\epsilon_{iT} - cE_T,$$

and imposing symmetry yields

$$E_T = \frac{2n(n-1)(1-\sigma)}{c(2n-1)} pqX_T. \tag{3.21}$$

This result will be utilized in the next section.

3.3 Analysis of the results

3.3.1 Effort level and season length

I first focus on Model 1 ($n = 1$) and Model 2 ($n \geq 2$ without pooling) and compare their optimal paths utilizing the phase diagram. There are two key differences and the first is the nullclines. In Model 1 the $\dot{E}_t$ nullcline was a linear function $E_t(1) = (pq/c)X_t$, where the numbers in parentheses denote the model number. In Model 2 the nullcline was bounded from below by a line $E_t(2) = (npq/c)X_t$, which clearly lies above $E_t(1)$, and hence so does the Model 2 nullcline.

The second difference is the transversality condition. In Model 1 this condition yielded $E_T = 0$. In Model 2 the result was $E_T \risingdotseq (npq/c)X_T$ if n is very large (Figure 3.3a) and $E_T = (4/3)(pq/c)X_T$, which is slightly higher than the Model 1 nullcline, when $n = 2$ (Figure 3.3b).

Figure 3.3 clearly shows that the aggregated effort level in the Model 2 regime is higher than that in Model 1 throughout the planning horizon when $n \geq 2$. However, the total harvest for the season, which is $X_0 - X_T$, must be the same in both regimes as they are assumed to be exogenous and fixed. Therefore, the season length must be shorter for the noncooperative regime than for the perfect cooperation regime, i.e.,

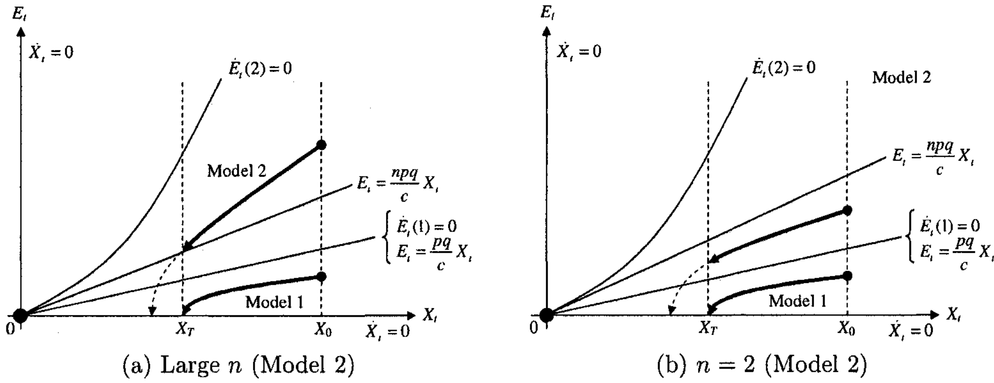

Figure 3.3: Optimal path comparison between the perfect cooperation regime (Model 1) and non-cooperative harvesting regime (Model 2)

$T(2) < T(1)$.

Additionally, at any point on a trajectory, say point A at coordinates $(\widehat{X}, \widehat{E})$, the harvest volume is approximately the area of a rectangle $O\widehat{E}A\widehat{X}$ since I assumed the linear production function. The positioning of optimal paths in Figure 3.3 thus indicates that the noncooperative regime is not only shorter in season length but also harvests more by volume at any given point in time during its season than the perfect-cooperation regime. These implications of the model are consistent with the phenomena typically seen in fisheries under such regimes.

I now turn my attention to Model 3. The focus is on how the results of Model 3 change by varying the level of the pooled ratio σ while holding the number of fishermen at some finite number n. The $\dot{E}_t$ nullcline from Model 3 was

$$E_t = \frac{(n - (n-1)\sigma)rpqX_t}{rc - (n - (n-1)\sigma - 1)pq^2X_t}.$$

It is easy to verify that

$$E_t = \frac{nrpqX_t}{rc - (n-1)pq^2X_t}, \qquad \text{if } \sigma = 0$$

$$E_t = \frac{pq}{c}X_t, \qquad \text{if } \sigma = 1.$$

These expressions are identical to the nullclines of Model 2 ($\sigma = 0$) and Model 1 ($\sigma = 1$). This implies that the nullcline for Model 3 pivots around the origin between the two nullclines spanned by Model 1 and Model 2 (Figure 3.4a).

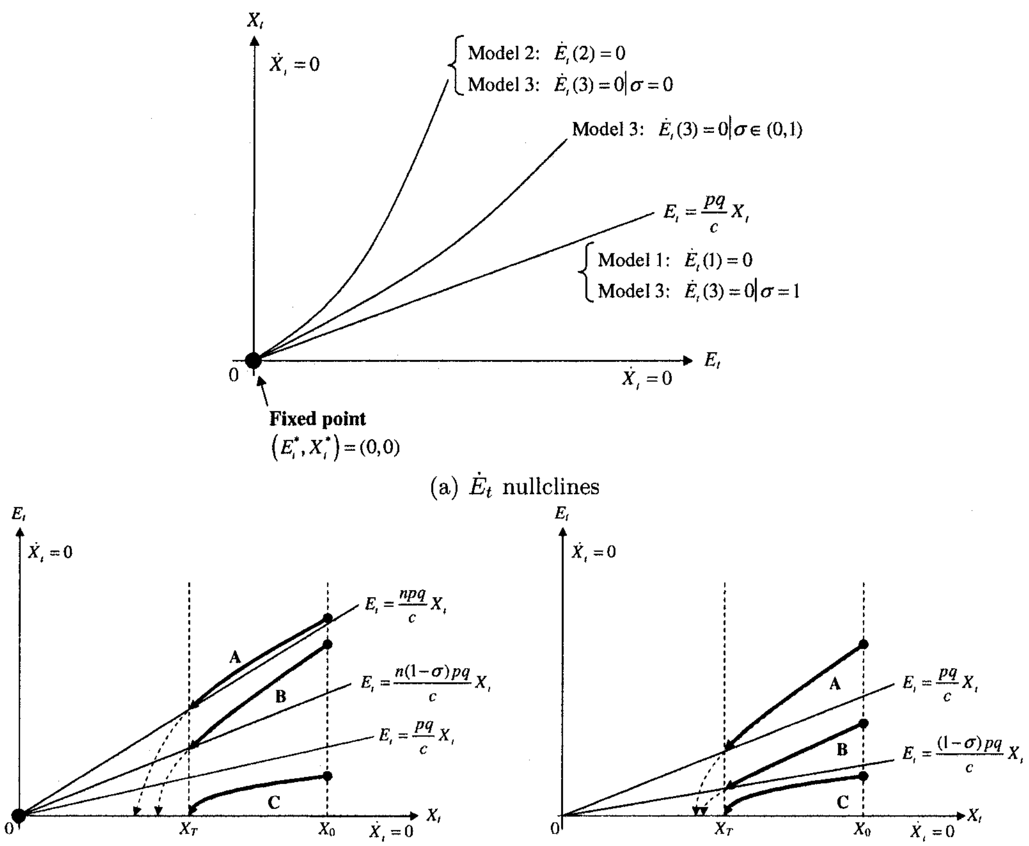

Figure 3.4: Optimal paths of pooling arrangement regime (Model 3) with $0 < \sigma < 1$

Next, I compare the optimal paths. The transversality condition indicated that at the terminal date the aggregate effort level should be

$$E_T = \frac{2n(n-1)(1-\sigma)}{c(2n-1)} pq X_T.$$

First, it can be easily verified that, when $n = 1$, equation (3.21) yields $E_T = 0$, which is an identical result as Model 1 as expected. Note that this result holds regardless of the level of σ. For finite but very large n, the preceding transversality condition can be approximated to

$$E_T|_{\text{large } n<\infty} \fallingdotseq \frac{n(1-\sigma)pq}{c} X_T,$$

for some value of $\sigma \in (0, 1)$. Note that in Model 3 the effort level at the terminal date lies between those of Model 1 and Model 2, i.e., $E_T(1) < E_T(3) < E_T(2)$, since

$$\frac{pq}{c} X_T < \frac{n(1-\sigma)pq}{c} X_T < \frac{nrpq}{c} X_T.$$

If $\sigma = 0$ then $E_T = (npq/c)X_T$, which is identical to Model 2 as expected; and if $\sigma = 1$ then the transversality condition is identical to that of Model 1, $E_T = 0$, even with a large value for n.

I have already established that when $n = 1$ the results of Model 3 coincide with those of Model 1 regardless of the level of σ. The next question naturally is the case when $n = 2$. The transversality condition implies that the effort level at the terminal date will be

$$E_T = \frac{(1-\sigma)pq}{c} X_T.$$

Figure 3.4c illustrates the change of optimal paths as σ varies between 0 and 1. Thus, for a given finite $n \geq 2$ the optimal path of Model 3 shifts down from that of Model 2 towards Model 1 as σ varies from 0 to 1. This is depicted in Figure 3.4b and Figure 3.4c as the movement of curves $\mathbf{A} \rightarrow \mathbf{B} \rightarrow \mathbf{C}$.

The effect of a pooling arrangement, by means of varying σ, can be summarized as follows. The upper bound of the aggregate effort level E_t is the noncooperative harvesting level (Model 2), and they coincide when $\sigma = 0$. The optimal path of Model 3 shifts downward as n decreases and/or σ rises and approaches 1. When $\sigma = 1$, so that all revenues are pooled, the optimal path coincides with that of a sole owner (Model 1) regardless of n. These observations imply that with a pooling arrangement the level of aggregate effort is lower than without any pooling throughout the season, and consequently the season length is longer given that the total change in fish population from X_0 to X_T is fixed.

3.3.2 Open access case

For completeness I present the case of the open access regime using this model and compare the results with those presented in the previous section.

I begin by characterizing the open access equilibrium as zero aggregate profit at any given point in time during the season. Furthermore, since I assume identical fishermen in solving for the symmetric Nash equilibrium, it follows that the profit of each fisherman at any given point in time is also zero:

$$pq\frac{E_t}{n}X_t - \frac{1}{2}c\left(\frac{E_t}{n}\right)^2 = 0.$$

I also assume that each fisherman does not consider the impact of his own fishing activity on the fish population as a whole so that the state equation does not enter his optimization problem. This aspect is what separates the open-access regime considered here from the noncooperative harvesting regime (Model 2).

Utilizing the preceding equation one can derive the following relationship

$$E_t = \frac{2npq}{c} X_t.$$

Thus, the open-access path lies even higher, above the optimal path of Model 2, with a very large and finite n. This confirms our intuition that with an open-access regime the aggregate effort levels are the highest throughout the season and, consequently, the fishing season is the shortest.

3.4 Conclusion

This chapter developed a model in which there are many fishermen using the same common property resource and considered three regimes for resource management. The first regime is perfect cooperation (Model 1). The second regime is noncooperative harvesting in which individualistic competition prevails but each user is conscious of the impact of his own harvest on the total fish population while assuming others' actions as constant (Model 2). The third regime is noncooperative harvesting with a pooling arrangement in which some portion of individual's revenues are pooled and then distributed back to group members equally (Model 3). Model 1 is qualitatively equivalent to the sole owner's resource use problem and the results are socially optimal. For the other models, identical fishermen were assumed and the model was solved for the symmetric Nash equilibrium. The results were compared with those from Model 1.

I made several assumptions about exogenous variables in setting up these models. The focus of this exercise was how harvests and fishing operations evolve within a fishing season depending on differences in management regimes. For this reason, I assumed that the terminal fish population level, X_T, was given. Such is the case where minimum escapement regulations are in place. I also assumed, in an effort to simplify the model, that there was no within-season recruitment or fish population growth.

I compared the model outcomes and the basic results were consistent with intuition. The sole-owner regime will adjust the overall optimal effort path such that at the terminal date the user will stop fishing voluntarily. Fishing effort exerted is at a lower level throughout the season and, consequently, the season length is the longest. In comparison, the noncooperative harvesting regime exerts fishing effort at a much higher level throughout the season. The level gets higher as the number of fishermen, n, increases. Since the total allowable harvest volume is predetermined and exogenous (i.e., $X_0 - X_T$), greater levels of fishing effort imply a shorter fishing season.

The pooling arrangement affects the optimal trajectory of the noncooperative harvesting regime by lowering the level of fishing effort exerted at any point in time during the fishing season. The higher the pooling ratio σ, the lower the effort. The per-period harvest volume is lower and thus the season gets longer.

When $\sigma = 1$ and all individual revenues are pooled and shared equally among the group members, the outcome perfectly coincides with that of the sole-owner regime. In light of the shirking incentive associated with pooling arrangements, this result seems to be somewhat of an overstatement. On the other hand, with full pooling, the incentive to maximize one's own payoff is closely aligned with maximizing the group's total payoff. Technically, the model is set so that the individual harvest is completely dependent on and proportional to the total harvest so the incentive alignment is embedded in the model structure. Also, there is ample evidence of pooling arrangements in the real world for which the sharing ratio is $\sigma = 1$ and redistribution is equal, so the outcome of the model is not completely implausible. One can at least conclude that pooling arrangements affect the incentive of fishermen because noncooperative behavior is altered towards that of a sole owner.

It is conceivable that the changes in season length and per-period harvest volume affect the price level in output markets. The present model assumes a constant ex-vessel price during the season so it cannot capture such an effect; that is left for future model development. However, one can make several conjectures. In general, if the per-period harvest volume is large, the market is more likely to be flooded and to glut. Such a situation will add pressure to lower the market price. The converse is also true; with a reduced harvest volume per period, the market is less likely to be flooded and is likely to maintain a certain price level. If so, another dimension of benefit from a pooling arrangement is this price effect, which would lead to improved terms of trade.

The model suggests the positive effect of a pooling arrangement in a simplified setting. In subsequent chapters I investigate empirically the impact of pooling arrangements and other fishery co-management measurements.

Chapter 4

Fishery co-management in Japan: An assessment

4.1 Introduction

This chapter reports results of an empirical analysis of the Japanese coastal fisheries, many of which are managed by fishery co-management regimes. Its focus is on the impact of FMOs and their practices on the revenues of fishermen, investigating whether fishermen participating in FMOs have higher revenues than those who do not participate. Of particular interest in this paper is the manner in which pooling arrangements and marketing practices adopted by FMOs impact fishermen's income. Pooling arrangements are agreements that harvests, revenues, or profits are pooled and then redistributed back to the members; several theoretical and empirical case studies suggest that such sharing rules could enhance the economic performance of fisheries (e.g., Schott, 2003; Platteau and Seki, 2001; Gaspart and Seki, 2003; Uchida, 2004a). Marketing practices adopted by FMOs include landing the catch alive, quality control (e.g., proper icing), processing (adding value), expanding market channels, and measures taken in ground transportation.

It is important to better understand fishery co-management not only because it is widely implemented but because it could be an alternative solution for many developing countries, where the government is incapable of centralized regulation and where market infrastructures are not developed enough to adopt market-based solutions such as tradable quotas. Perhaps for this reason, many studies on fishery co-management are those in developing countries (Wilson et al., 2003). Fishery co-management in Japan, on the other hand, is not much analyzed despite the fact that Japan has more than 1,700 fishery co-management regimes managing its coastal fisheries (Ministry of Agriculture, Forestry and Fisheries,, 2001).[1] In addition, the statistical data on fishery co-management in Japan are more readily available than in many developing countries. The fact that these regimes are all under the same national laws and policies and share similar social characteristics is a great advantage for empirical analysis. By utilizing the Japanese coastal fishery co-management cases, we can empirically investigate questions such as: does fishery co-management positively impact the economic returns to fishermen? Do results differ depending on the self-management practices adopted by the fishery co-management regime?

The major finding of the empirical work summarized in this chapter is that fishermen participating in FMOs with pooling arrangements have significantly higher revenues. The marketing activities in general had somewhat mixed results, which may be attributed to the effectiveness of marketing. For marketing activities to be

[1]Exceptions include Asada et al. (1983), Ruddle (1987), Yamamoto (1995) and Makino and Matsuda (2005), but none have empirical analysis that quantitatively evaluates the effect of collective fishery management in Japan.

effective they need to be done in a collective manner; indeed marketing activities by FMOs with pooling arrangements had more significant effect on fishery revenue. This supports the argument that the benefits from rationalizing fisheries arising from the output markets (as opposed to cost savings) may be substantial (Homans and Wilen, 2005). Pooling arrangements, which create incentives to support collective action, may be the key for realizing such benefits.

There are several caveats in this analysis, primarily due to data limitations. First, revenue is used as a measure of economic performance rather than profit. This is because the fishery census only reports revenues data; as a consequence we are unable to pick up any cost savings effect of FMOs. Secondly, only the aggregated data at the fishing district level are made available to the public, although the census itself is done at the fishing household level (explained in Section 4.3). This forced the empirical analysis to be conducted with somewhat crude variables such as averages and shares per fishing district, rather than the actual levels per individual. Thirdly, the evaluation of FMOs regarding the resource stock is not analyzed, though it is just as important or more so as a policy driver as economic performance. Lastly, social attributes such as FMO leaders' characteristics are not considered.

4.2 Background

The Japanese government implemented FMO-based co-management of its coastal fisheries as national policy in the early 1980s, although many FMOs have much longer histories. Therefore, it is less the case that the government imposed the co-management regimes on its fisheries; rather it codified the de facto regimes that were already in place. The census began recording data on FMOs in 1988. At that time there were 1,339 FMOs and the number has been increasing steadily; in 1993 there were 1,524 FMOs and in 1998 there were 1,734 FMOs (Ministry of Agriculture, Forestry and Fisheries,, 2001).[2]

FCAs and FMOs are not necessarily the same geographic entity. In TURFs for which there are several FMOs under the auspices of one FCA, the FMOs are essentially sub-organizations of smaller fishermen's groups. In some cases, FMOs within neighboring FCAs have merged and hence, in these cases, the TURF relevant to the FMO may actually be larger than the corresponding FCAs. Among 1,734 FMOs in 1998, nearly 95% of them were operated by an FCA or its subdivisions.[3] For the most part, FMOs devolve management functions to smaller groups of self-organized and specialized fishermen. These smaller groups co-manage or self-regulate in various ways that are generally more intensive than what might have existed under FCA management without the FMOs.

The nature of self-regulation varies among the FMOs. Some FMOs simply self-impose a fishing season to avoid fishing during the spawning period. At the other extreme, some FMOs utilize sophisticated fishing effort coordination schemes with which representatives of member fishermen meet every day during the fishing season to decide the details of that day's fishing operations. The primary objectives differ

[2]The summary of the latest (11th) census, which was conducted in 2003, was published in early 2006. The definition of FMOs has changed in this census; according to this new definition the number of FMOs in 1993 was 1,133, 1,312 in 1998, and 1,608 in 2003. Thus, the general trend is one of increasing FMOs nationwide at present.

[3]It is not surprising, therefore, that many researchers have concluded that successful fishery co-management in Japan rests on the strength of its tradition of FCAs (e.g., (Hanna, 2003)). We believe this is somewhat misleading, as it conveys an impression that such management schemes cannot be implemented in other places that do not have similar traditions. Uchida (2004b) argues the importance of FCAs and fishing rights using the conceptual framework of the theory of clubs, focusing on the *functions* of these institutions that are more generally applicable.

as well; some focus on cost savings through effort reduction while others focus on stringent quality control or the establishment of their own brands in order to increase revenues.

Some FMOs have implemented a system which I refer to as a pooling arrangement. According to the tenth fishery census, 294 or roughly 17% of FMOs have variations of pooling arrangements implemented (Ministry of Agriculture, Forestry and Fisheries,, 2001). Among the FMOs with pooling, roughly half or 144 have uniform distribution of pooled proceeds and 129 (44%) FMOs have weighted distributions. The share of FMOs with pooling arrangements is also increasing over time, rising from 11% in 1988 to 15.6% in 1993, and to 17% in 1998.

The traditional view of pooling arrangements, such as those in the context of labor-managed firms, is that they may give members an incentive to shirk and result in too little collective effort. But most fisheries that exploit common pool resources attract collectively too much effort in the first place. This is why Schott (2003) argues that pooling may be beneficial in a fishery since it curtails excessive fishing effort that otherwise leads to over-exploitation. However, it is ultimately an empirical question how the two opposing incentives might work in practice in a pooling arrangement-system managed fishery, and whether other mechanisms are needed to fine-tune them. The increasing number of FMOs implementing pooling arrangements in the Japanese coastal fisheries seems to suggest that at least Japanese fishermen have found them to be beneficial.

Anecdotal evidence shows that there are FMOs with pooling arrangements that are working reasonably well in Japan. Platteau and Seki (2001) surveyed fishermen in Toyama Bay where there were two FMOs with pooling arrangements under different

FCAs but targeting the same species.[4] Uchida (2004a) studied another FMO with a pooling arrangement in Suruga Bay; in this case fishermen from two FCAs targeting the same species formed one unified FMO. This FMO has adopted a very sophisticated fishing effort coordination scheme, including harvest control to avoid market gluts and collective promotion of their products to consumers as part of marketing activities. In both cases the pooling arrangements are functioning as supporting - perhaps even facilitating - mechanisms for a fine-tuned fishing effort coordination scheme among the member fishermen. These anecdotes and other "snapshot" descriptions of FMOs in the literature make a strong case for more systematic comparisons between and across various cases in order to better understand how these FMOs affect incentives, and how co-management under altered incentives affects fisheries performance.

4.3 Data

Before getting into the details of the data, brief explanations on terminologies used henceforth are in order. **Fishing units** are economic entities engaged in fisheries for commercial purpose. There are six categories of fishing units defined in the fishery census: individuals (typically fishing households), corporations, FCAs, Production Cooperative Associations (PCAs), Joint Operations (two or more individuals jointly operating, JO) and others (government agencies and research institutions). Individual fishing units include only those who own and operate the business; hired fishermen are excluded.

Fishing districts are defined as a community within the boundaries of a local

[4]Platteau and Seki (2001) refers the pooling arrangements as the "pooling system."

municipality that operates fisheries under a common environment, such as sharing the same fishing rights area (TURF) and commonalities in other fishery-related activities. Generally speaking there is one TURF and an FCA that administers it in each fishing district. Due to recent trends of merges of FCAs, however, this is changing rapidly. After mergers, former FCAs often remain as branch offices and retain much of their independence in fishery operations. A fishing district is also a geographical unit for which the data in the fishery census are reported.

The data utilized is from the fishery census compiled by the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF). The first census was conducted in 1949, and the subsequent censuses were done in five-year interval. The census is conducted on fishing units, collecting data on fishing operations, equipment, revenues and other fishing and household characteristics. It also collects data on fishery organizations including FMOs. It is the most comprehensive fishery data collected and made available to the public. However, the published census data are aggregated at the fishing district level, reporting only either the sum or the average values. Due to confidentiality issues, the fishing unit-level data are not available from MAFF. Thus, our unit of observation is at the fishing district level.

A panel data set was formed from the ninth and tenth fishery censuses conducted in 1993 and 1998, respectively. Although the first census was conducted in the late 1940s, data on FMOs have only been collected since 1988. Closer examination revealed that some details of census data have changed over the years, including the data items that were collected. The 1988 census is incompatible with the other two later censuses (1993 and 1998) and the results from the 2003 census are not available yet.

The fact that only aggregated data at the fishing district level are available poses some problems. As aforementioned, there are six types of fishing units. Table 4.1 clearly shows that the levels of average revenue differ substantially between individual units and other types. Furthermore, the distribution of these fishing unit types is not symmetric between FMO-participants and nonparticipants; there are more nonindividual fishing units as nonparticipants. These observations imply that one needs to control for the fishing unit-types in order to examine the impact of FMOs on average revenue. However, since average revenues and other variables are aggregated into a single data point per fishing district, the ability to control for fishing unit-types is imperfect. The remedy is to focus on districts that have only individual fishing units. The justification for this is that the individual fishing units are overwhelmingly dominant among both FMO-participants and nonparticipants (henceforth "FMO units" and "non-FMO units" respectively). Other problems regarding the formats which data are made available and the remedies for each of them are explained in the later sections.

Table 4.1: Fishery revenues and number of fishing units by their unit-types in 1998

	Individuals	Corporations	FCA	PCA[a]	JO[b]	Others[c]
Fishery revenue ($K)	64.8	2,410	1,560	2,220	335.2	570.5
Number of FMO units	58,195	715	56	40	1,169	4
(% of within total)	(96.7%)	(1.2%)	(0.1%)	(0.1%)	(1.9%)	(0.0%)
Number of non-FMO units	84,999	2,348	233	119	2,591	117
(% of within total)	(94.0%)	(2.6%)	(0.3%)	(0.1%)	(2.9%)	(0.1%)

From 10th Fishery Census (Ministry of Agriculture, Forestry and Fisheries,, 2001).

[a] PCA is a processors cooperative association.

[b] JO, or joint operation, is where two or more individual fishing units are operating together as a joint venture.

[c] Others include entities such as fishery research stations.

Lastly, consumer price index data reported from Bank of Japan were combined to capture the general trend of prices over the analysis periods. It contains CPI for each of ten regions of Japan. These will capture the regional-specific trends, which is desirable than using the nationwide average.

4.3.1 Descriptive statistics

The unconditional mean of revenue of FMO units was higher than that of non-FMO units for both 1993 and 1998, but while FMO units' average revenue decreased over this period by approximately $400 non-FMO units' average increased by nearly $2,000. This may be partly due to the increase in vessel tonnage and engine horsepower: non-FMO units on average shifted toward larger vessels with more powerful engines while FMO units remained virtually the same. Another possibility is the decline in fishing days. Although the fishing days declined for both FMO units and non-FMO units, the magnitude is much larger for FMO units (−7.5 days) than non-FMO units (−3.3 days). In fact, the rough estimates of fishing revenue per fishing day show that FMO units experienced an increase by $7.7.

Fishing capacity remained mostly unchanged for FMO units. The number of boats and vessels increased only slightly, and the vessel engine power has decreased. The same pattern can be seen in non-FMO units for number of boats and vessels, but as mentioned above the tonnage and engine power increased by fair margin. Since the number of vessels did not increase as much, this indicates that non-FMO units switched to larger vessels, a typical pattern under the free competition within TURFs. Also an interesting result is the stark difference in the levels of vessel tonnage and engine power between the FMO and non-FMO units. These figures are calculated as per vessel per unit basis, to incorporate the fact that one vessel might be jointly-owned by two or more units. Thus, this result suggests that some FMOs have shifted to joint ownership of vessels, and possibly other fishing gear, to rationalize their inputs.

Table 4.2: Descriptive statistics (mean values) of panel data

	FMOs		Non-FMOs	
Variable	1993	1998	1993	1998
Average fishery revenue (yen)	5,252,090	5,205,887	4,624,336	4,826,802
($1=110yen)	($47,746)	($47,326)	($42,039)	($43,880)
Average number of units per district	60.0	53.5	45.6	38.5
Average number of fishing day per unit	193.1	185.6	177.9	174.6
Rowing boats per unit	0.039	0.024	0.091	0.064
Externally-powered boats per unit	0.773	0.797	0.556	0.576
Vessels per unit	0.628	0.639	0.766	0.798
Tonnage per vessel per unit	0.159	0.159	3.228	3.490
Engine horsepower per vessel per unit	2.522	2.287	41.48	47.31
Share of FMOs with pooling arrangements	0.176	0.208		
Pooling (uniform)	0.056	0.059		
Pooling (weighted)	0.095	0.129		
Share of FMOs with marketing	0.427	0.491		
Onboard activities	0.345	0.425		
Live	0.134	0.171		
Quality control	0.267	0.301		
On-land activities	0.179	0.298		
Processing	0.028	0.063		
Sales	0.131	0.215		
Transportation	0.067	0.090		

Pooling arrangements were implemented by 17.6% and 20.8% of FMOs in 1993 and 1998, respectively, in the sample. When these figures are subdivided by the distributional rule there are more FMOs with weighted distributions than uniform distributions. Under the former distribution rule, weights are based on factors such as landings volume to mitigate the incentive to shirk, the downside of pooling arrangements. The net effect of the two opposing incentives is an empirical question. Other weighting schemes include consideration of vessel tonnage, which is aimed to compensate the cost differential due to vessel investments. This scheme will not distort the (short-run) incentive structure of a fisherman. However, this weighting scheme is not commonly seen due to the fact that vessels in the same fishery have very little variance in size (tonnage and engine horsepower); because of the race-to-fish incentive all vessels are typically at the maximum size allowed by the regulations imposed by central or local government.

Nearly half of FMOs in the sample were engaged in marketing activities, with onboard activities being more popular than on-shore ones. This is intuitive given that these are probably what the fishermen are best in doing. Lower popularity of landing the catch alive ("Live") is probably due to the fact that it involves a significant up-front investment cost for things such as a built-in fish tank on vessels and water temperature controlling devices.

In sum, key FMO-related activities for which the data are available, namely pooling arrangements and marketing activities, were employed by more FMOs in 1998. As these institutional arrangements and activities are costly to set up and maintain, one would expect that there must be some economic returns for such investment.

4.4 Estimation model

4.4.1 Identification strategy

Our primary interest is whether (1) fishery co-management by FMOs brings higher economic returns to member fishermen, and if so, (2) the degree to which such returns differ between FMOs with and without pooling arrangements and marketing activities. The dependent variable of the estimation model is thus the economic return from fisheries, which ideally would be the profits. However, the census does not record information on profits or fishing costs. It only has information on revenue from fisheries, which is used as the measure of economic return from fishery.

Consider first an ideal estimation model. Denote the dependent variable revenue by R_{jt}, where subscripts j and t denote fishing unit and time, respectively. Let FMO_{jt}, $POOL_{jt}$, and MKT_{jt} be indicator variables if a fishing unit j at time t is participating in FMOs, with pooling arrangements, and with marketing activities, respectively. An ideal estimation model can be expressed as

$$R_{jt} = f\left(FMO_{jt}, POOL_{jt}, MKT_{jt}, \mathbf{\Lambda}_{jt}; \boldsymbol{\beta}\right) + \epsilon_{jt}, \tag{4.1}$$

where $\mathbf{\Lambda}_{jt}$ is a vector of other covariates, $\boldsymbol{\beta}$ is a vector of coefficients to be estimated, and ϵ is the error term.

$\mathbf{\Lambda}_{jt}$ consists of factors that could affect the level of fishery revenue per fishing unit R_j. These include fishing capacity measures such as the number of boats owned and their sizes, the number of fishing days in a season, and number of workers hired. Revenue level may be affected by the targeted species as they fetch different prices. Other characteristics that are specific to each fishing district and/or region are also candidates. Lastly, fishermen's group-specific characteristics may also be influence revenue levels.

The challenge of identifying the impacts of key variables is apparent. Among the list of covariates there are unobserved variables, and some of them are likely to be correlated with our key variables and hence will cause an endogeneity problem. For example, certain "ability" attributes of fishermen may lead to higher revenue and a higher likelihood of forming FMOs. Also, some technically observable variables such as targeted species are missing (i.e., not recorded) in the census and hence also may play the same role as unobserved variables.

The panel data analysis methods are utilized for identification. The covariate vector can be separated into two categories, $\mathbf{\Lambda}_{jt} = (\mathbf{X}_{jt}, \mathbf{Z}_j)$, where $\mathbf{X}_{jt}$ and $\mathbf{Z}_j$ are time-variant and time-invariant covariates, respectively. Covariates such as targeted species, gear-types, and characteristics on a region, district, and fishermen's group can be plausibly assumed as time invariant factors, at least for the five-year period considered here. Thus, by employing a class of fixed effects models one can control (eliminate) the effects of these time invariant and mostly unobservable covariates. I chose to take the first difference, so that the covariate vector becomes $\Delta\mathbf{\Lambda}_{jt} = (\mathbf{X}_{j,t} - \mathbf{X}_{j,t-1})$. The decision to choose the first difference model over the within fixed effects model is that the former also controls for potential serial correlation of the error term while the latter does not.[5] The estimate of coefficients, on the other hand, will be identical between the two methods (Cameron and Trivedi, 2005).

Model (4.1) is the ideal model, but the census does not provide enough detailed data to estimate based on (4.1). The main obstacle is that data are aggregated at fishing district level, reporting only the averages and totals. The next section describes how the dependent variable and the covariates are constructed given these data constraints.

4.4.2 Variables

The dependent variable of the estimation model is (log of) average fishery revenue per fishing unit (household) in a fishing district i, $\ln \bar{R}_{it}$. The census provides unconditional average fishery revenue based on all fishing units in a district and the average conditional on FMO units, i.e., for each fishing district i, $N^{-1}\sum_j R_{jt}$ and $N^{-1}\sum_j R_{j\in FMO,t}$. With these data one can compute the average fishery revenue of

[5] Note that this is only true for two-period panel.

non-FMO units. In what follows, I have separated data for each variable into FMO units and non-FMO units within each district, so that the estimation of the ceteris paribus impact of FMOs by means of dummy variable is possible.

The first set of covariates is fishing capital variables ($\mathbf{CAP}_{it}$). Intuitively, the higher the level of capital the higher should be revenues, ceteris paribus. The set of capital variables used includes the average number of boats or vessels owned by a unit, vessel tonnage, and the vessel engine's horsepower. Boats and vessels are divided into three categories: "nonpowered boats" are those with no engines attached; "externally powered boats" are defined as those with external engines attached to otherwise nonpowered boats; and "vessels" are those with integrated engines. Tonnage and engine horsepower are those reported for the vessels category only. Number of boats and vessels are per fishing unit basis, whereas the averages for the tonnage and horsepower are defined as per vessel per unit, to incorporate the fact that one unit might own two or more vessels and one vessel might be jointly-owned by two or more units. These fishing capital variables are separated into the averages of FMO units and non-FMO units. Also note that, since the vessel tonnage and engine power is highly correlated, only the tonnage variable is included in the estimation model.

The second set of covariates is the pooling arrangement ($POOL_{it}$) for FMO units data. The census provides data on the total number of FMOs utilizing pooling arrangements in a fishing district and a breakdown list for uniform, weighted and other forms of distribution rules. The problem is that if, for example, there are three FMOs in a fishing district of which only two have pooling arrangements, then the average revenue of FMO units in this district is a composite of two FMOs with pooling arrangements and one FMO without them. Since there are no methods to decompose the single observation of average revenue, I constructed the share of FMOs with pooling arrangements of each distribution rule (s) in each fishing district, $POOL_{i,s}$ for each period t. Let $S(k,s) = 1$ if an FMO k has pooling arrangement s and $S(k,s) = 0$ otherwise; suppress t for clarity. Then the share $POOL_{i,s}$ is

$$POOL_{i,s} = \frac{\sum_k S(k,s)}{K_i} = \frac{\text{Number of FMOs with pooling arrangement } s}{\text{Total number of FMOs in fishing district } i}.$$

Note that one unit can at most implement one type of pooling arrangement but some FMOs have none. Thus, the shares do not necessarily sum up to one, and the share of FMOs with any pooling arrangement in each t is

$$\widetilde{POOL}_i = \sum_s POOL_{i,s}.$$

The third set of covariates is the marketing activities engaged by FMOs (MKT_{it}). Subcategories of marketing activities as defined in the census are (a) keeping the catch alive ("live"), (b) quality control ("quality"), (c) processing (dressing, etc.), (d) expanding sales channel ("sales") and (e) transportation improvement ("transportation"). Due to high consumption of raw fish (sashimi) in Japan, keeping the catch alive and fresh in a fish tank on a vessel is an important value-adding practice.[6] Quality control includes carefully releasing the catch from a net or a hook, and proper icing while in transport. Processing is another form of adding value to their catch, such as dressing the fish. The fishery census reports the number of FMOs engaged in

[6]Simply keeping the catch alive is not good enough. If the fish become weak during the time kept in a tank then, in terms of the quality of flesh, they might be worse than those being immediately frozen or killed and iced. It takes a great deal of care, such as maintaining the water temperature at optimum, to keep the catch alive *and* well until the vessel reaches the landing port.

any of the above marketing activities. That is, if an FMO is engaged in two or more marketing activities that FMO is recorded in each of them. The marketing variables are calculated as the share of FMOs engaged in a certain marketing practice (m) over the total number of FMOs in that fishing district. Let $M(k,m) = 1$ if an FMO k has engaged in marketing practice m and $M(k,m) = 0$ otherwise. Then the share $MKT_{i,m}$ in each t is

$$MKT_{i,m} = \frac{\sum_k M(k,m)}{K_i} = \frac{\text{Number of FMOs engaged in marketing activities } m}{\text{Total number of FMOs in fishing district } i}.$$

Since one FMO can be engaged in multiple numbers of marketing activities, the shares could sum up to more than one with this calculation method. Also, define the share of FMOs with any marketing activities in each t as

$$\widetilde{MKT}_i = \frac{\sum_k M(k)}{K_i},$$

where $M(k) = 1$ if an FMO k is engaged in at least one marketing practice and $M(k) = 0$ otherwise.

In addition to the above covariates, we have the following variables in our estimation model. The average number of annual fishing days per unit in a district, $DAYS_{it}$, was included. It includes days that a fisherman was engaged in any fishery-related activities, whether out in the sea or on-land. On-land activities include not only the fishing gear maintenance but also various marketing activities. Secondly, we included the number of units as a covariate ($UNITS_{it}$). The general impact of the number of units on fishery revenue per unit is ambiguous. Large number of units in a fishery may, on one hand, intensify the competition that could lead to the downward spiral of large landing volume, market flooding, lowering the price and revenue, and increase harvest to cover the loss. On the other hand, it may facilitate the joint production nature of fishery and increase the per unit revenue. Then there is the FMO-specific impact of the number of units; ceteris paribus, the smaller the membership size, the better the chance of success in co-management (Olson, 1965; Agrawal, 2001). To incorporate this effect, the interaction term of $UNITS$ and the FMO indicator variable were included. Finally, the consumer price index for food items (CPI_{it}), which includes fish products, with base year 2000 was included to control for any overall price changes between 1993 and 1998.

4.4.3 Model specification

The general function $f(\cdot)$ in (4.1) is specified as a linear function. Given that the census only reports averages for fishing district i instead of for each fishing unit j, the model can be written as

$$\begin{aligned}\ln \bar{R}_{it} =& \alpha T + \mathbf{POOL}_{it}^{'}\boldsymbol{\beta}_1 + \mathbf{MKT}_{it}^{'}\boldsymbol{\beta}_2 + \mathbf{CAP}_{it}^{'}\boldsymbol{\beta}_3 + \beta_4 DAYS_{it} + \beta_5 UNITS_{it} \\ &+ \beta_6 (UNITS_{it} \times FMO_{it}) + \beta_7 CPI_{it} + \mathbf{Z}_i^{'}\gamma + \epsilon_{it}, \quad t = 1, 2 \end{aligned} \tag{4.2}$$

where $T = 1, 2$ is the time trend variable and $\mathbf{Z}_i$ is the time invariant fishing district-specific effects.

By applying the first-difference transformation on (4.2) we get

$$\begin{aligned}\Delta \ln \bar{R}_i =& \alpha + \Delta\mathbf{POOL}_i'\boldsymbol{\beta}_1 + \Delta\mathbf{MKT}_i'\boldsymbol{\beta}_2 + \Delta\mathbf{CAP}_i'\boldsymbol{\beta}_3 + \beta_4 \Delta DAYS_i \\ &+ \beta_5 \Delta UNITS_i \beta_6 \Delta(UNITS_i \times FMO_i) + \beta_7 \Delta CPI_i + \Delta\epsilon_{it},\end{aligned}$$

where Δ denotes the first difference between 1998 ($t = 2$) and 1993 ($t = 1$).

The important point is that the preceding first-difference transformation is done for each FMO and non-FMO units data within each fishing district i. For any given fishing district there will be at most two observations: one for FMO units and another for non-FMO units. The key question is thus whether the change in average revenue differs between FMO units and non-FMO units. The estimation model becomes

$$\begin{aligned}\Delta \ln \bar{R}_i =& \alpha + \Delta\mathbf{POOL}_i'\boldsymbol{\beta}_1 + \Delta\mathbf{MKT}_i'\boldsymbol{\beta}_2 + \Delta\mathbf{CAP}_i'\boldsymbol{\beta}_3 + \beta_4 \Delta DAYS_i + \beta_5 \Delta UNITS_i \\ &+ \beta_6 \Delta(UNITS_i \times FMO_i) + \beta_7 \Delta CPI_i + \beta_8 FMO_i + \Delta\epsilon_{it}, \qquad (4.3)\end{aligned}$$

where $FMO_i = 1$ if the observation is that of FMO units in district i and $FMO_i = 0$ otherwise.

An important consequence of the preceding method is that observations in which (non) FMO units disappeared or newly emerged between the two periods are not included in the sample. This may seem an odd decision since such observations are commonly used in the literature, such as in labor economics, to assess the treatment effects. The decision to exclude these observations is the consequence of two factors. Firstly, the number of such observations is very limited. Secondly, the data to actually conduct the treatment effect analysis are not available. For example, consider the case where there were no FMO units in 1993 (so all were non-FMO units) and a subset of those units became FMO units in 1998. Since the census does not provide information at the fishing unit level, one cannot identify which units became FMO units and thus the pre-treatment data for these units are nonexistent. A remedy will be to focus on the districts where all units were non-FMO in 1993 and all of them became FMO units in 1998, and vice versa, but there are less than a handful of such cases.

One last note: in a microeconometric application, it is reasonable to assume that the error term (ϵ_{it}) is independent over i but is potentially serially correlated (over t for given i) and heteroskedastic (Cameron and Trivedi, 2005). The test for heteroskedasticity rejected the null hypothesis (homoskedasticity) at 1% significance level. As already mentioned, serial correlation is eliminated by taking the first difference of the panel data. To control for heteroskedasticity, the White's heteroskedastic robust estimator was employed. Then a heteroskedastic-robust OLS was run on this data to estimate the coefficients of covariates.

4.5 Regression results

The key hypotheses we wish to test are those that examine how FMOs affect the income of fishing units. On the one hand, we anticipate that FMOs must be worth the fixed set up costs or they would not be observed with such frequency (or indeed be growing so rapidly). On the other hand, whether our data is up the task of teasing out the affects of FMOs and how they alter incentives remains to be seen. As discussed above, the only data available from census collections is revenue data and not cost data. Hence we are limited from the outset to mostly testing hypotheses that play out via the market or revenue side of the picture. For example, we might expect that some of the marketing activity covariates measuring specific kinds of market organizations and quality improvements might reveal their impacts statistically. Less certain is how the variable ($POOL_i$) ought to fare as an explanatory variable. As discussed earlier, one hypothesis is that pooling reduces the race to fish by introducing an incentive to "shirk", vis-á-vis open access race-to-fish behavior. But if this simply reduces input costs, it would not reveal an affect in a regression. On the other hand, pooling may actually be adopted to help sustain intertemporal effort smoothing in order to maximize revenues, in which case it would show a statistical effect. Lastly, and for similar reasons, the expected sign for the coefficient of FMO variable (FMO_i) is ambiguous. FMOs per se, would not be expected to have a clear impact on revenues independent of separate effects exhibited via some or all of the marketing measures. To the extent that these variables reflect revenue-enhancing policies, the FMO variable itself would only absorb residual affects

The results of heteroskedastic-robust ordinary least square regression are presented in Table 4.3. Model 1 through Model 4 differs by the specification of $\Delta POOL_i$ and ΔMKT_i; all other covariates are the same. There were 459 observations, of which 126 were FMO units.[7] All models rejected the null hypothesis for overall F test at 1% significance level. Adjusted R^2s were all in the neighborhood of 0.26–0.27.

The FMO dummy variable was estimated to have no statistical significance in explaining the change in average fishery revenue, although the signs were all positive.

[7] The sample size is quite small considering that originally there were 1,738 and 1,615 districts recorded in the 9th and 10th census, respectively. The main cause of this reduction is that the sample was restricted to the districts with only individual fishing units in both censuses. Recall that this was done due to the inability to control for different among the fishing unit-types. Further sample size reduction was caused by the process of data cleaning and the fact that the panel had to be balanced for the first-difference estimation.

Since the panel has only two periods, the estimation results for within fixed effects, first-difference, and pooled OLS models are all identical (Cameron and Trivedi, 2005). This implies that the FMO dummy variable is statistically insignificant with respect to not only the change in revenue but also the revenue level after controlling for other factors.[8] Such results suggest that the FMO coverage in a fishing district has only a marginal impact, if any, on fishery revenues per unit in that district, independent of specific kinds of activities that might be engaged by an FMO.

Contrary to my expectations, the marketing variables showed no statistical significance in all model specifications. Focusing on the estimated signs, onboard activities were positive and on-land activities were negative (Model 2 and Model 4). Considering that fishermen are likely to have more expertise on onboard relative to on-land activities, this is an intuitive result. Models with subcategories of onboard and on-land marketing activities were also estimated but none had statistical significance.

It might be the case that not all marketing activities pursued by FMOs were effective, and that is affecting the above results. There are no specific measurements of marketing effectiveness, but it is a plausible hypothesis that FMOs with pooling arrangements are more effective with marketing. For example, as a result of curtailed fishing effort due to the pooling arrangement, freed effort might then be diverted to marketing efforts. Or, since with the pooling arrangement individual shares will increase as the total revenue increases, FMO units have stronger incentives to make marketing activities more effective.

To test this hypothesis, additional regressions were run based on Model 1 and

[8]The dependent variable for pooled OLS model would be the revenue level, $\bar{R}_{it}$. For pooled OLS model to be compatible with other models, one would need to introduce n dummy variables corresponding for each observation. Cameron and Trivedi (2005) shows that $\hat{\beta}$s with this method will always be identical to that of within fixed effects model.

Table 4.3: Heteroskedastic-robust OLS on first-difference panel data

Variables	Model 1	Model 2	Model 3	Model 4
FMO dummy	0.012	0.018	0.007	0.013
	(0.18)	(0.26)	(0.10)	(0.19)
Number of units	0.004	0.004	0.004	0.004
	(1.63)	(1.62)	(1.64)	(1.63)
Number of units	−0.002	−0.002	−0.002	−0.002
× FMO dummy	(0.79)	(0.81)	(0.86)	(0.87)
Number of rowing	0.170	0.168	0.170	0.169
boats per unit	(1.09)	(1.08)	(1.10)	(1.09)
Number of external-powered	0.177	0.167	0.183	0.173
boats per unit	(1.32)	(1.24)	(1.36)	(1.29)
Number of vessels	0.703	0.696	0.698	0.693
per unit	(3.70)***	(3.64)***	(3.67)***	(3.63)***
Tonnage per vessel	0.056	0.056	0.056	0.056
per unit	(2.34)**	(2.34)**	(2.34)**	(2.34)**
Fishing days per unit	0.006	0.006	0.006	0.006
per season	(5.38)***	(5.57)***	(5.41)***	(5.59)***
Food consumption CPI,	0.009	0.005	0.009	0.005
base year (2000)	(0.27)	(0.14)	(0.27)	(0.15)
Pooling arrangements	0.237	0.230		
(all distribution)	(1.70)*	(1.71)*		
Uniform distribution			0.084	0.094
			(0.75)	(0.85)
Weighted distribution			0.401	0.369
			(1.35)	(1.20)
Marketing	−0.017		−0.015	
(onboard and on-land)	(0.21)		(0.20)	
Onboard		0.145		0.129
		(1.10)		(0.94)
On-land		−0.118		−0.109
		(1.19)		(1.16)
Constant	−0.062	−0.049	−0.061	−0.050
	(0.59)	(0.46)	(0.59)	(0.47)
Observations	459	459	459	459
Adjusted R^2	0.266	0.267	0.266	0.266

Robust t statistics in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

Model 2 with new variables $\Delta POOL_i \times \Delta MKT_i$ (Table 4.4). The overall marketing effect in FMOs with pooling arrangements is now positive with t-value of 1.19 (Model 1'). In Model 2', onboard marketing variable has much higher t-value and on-land marketing variable now has positive estimated sign. Although none were statistically significant at 10% level or higher, these changes suggest that marketing activities are more effective with some kind of collective action mechanism, such as a pooling arrangement.

Table 4.4: Heteroskedastic-robust OLS with marketing and pooling interaction terms

Variables[a]	Model 1'	Model 2'
FMO dummy	0.014	0.022
	(0.21)	(0.32)
Pooling arrangements (all distribution)	0.235	0.196
	(1.77)*	(1.70)*
Marketing (onboard and on-land)	−0.021	
	(0.26)	
Onboard		0.140
		(1.06)
On-land		−0.090
		(1.02)
Marketing×Pooling	0.328	
	(1.19)	
Onboard×Pooling		0.349
		(1.33)
On-land×Pooling		0.199
		(0.69)
Constant	−0.059	−0.048
	(0.57)	(0.45)
Observations	459	459
Adjusted R^2	0.268	0.268

Robust t statistics in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.
[a] Although not shown, other covariates are also included in the regressions.

The estimated coefficients for pooling arrangements were positive and statistically significant at 10% level. Such was not the case when estimated with subdivided variables defined by the distributional rules, but the results suggest that weighted distributional rules have more influence than uniform distributional rules. As aforementioned, weighted distributional rules distort incentives in an opposite direction than pooling arrangements do. It is conceivable that finding the "right" weights that optimally balance incentives to shirk and race to fish is difficult, and could reintroduce an incentive to exert excessive fishing effort, which could lead to lower fishery revenues per unit by over-exploiting. However, while such incentive distortions may occur with weighted distributional rules, the primary motivation to implementing this rule often is more focused on what can be referred to as "fairness restoration." With pooling arrangements, fishermen with higher skills are disproportionately taxed, and thus typically unsatisfied with the new rule. The possibility of these high-liner fishermen leaving or blocking the agreement could seriously undermine the FMO itself. For this reason, some FMOs implement a landing volume-based weighted distributional rule to award, or compensate those with higher catch histories to encourage their buy-in.

The question still remains as to whether the pooling arrangement per se, via altering the incentives of fishermen, is positively influencing the revenue or not. The results might be capturing the effect of effort coordination through pooling arrangements, since pooling arrangements are often implemented as a set with effort coordination (e.g., Gaspart and Seki, 2003). One cannot verify or test this hypothesis with the census data as it does not have information on effort coordination. A direct assessment of effort coordination on economic return of FMOs is investigated in the next chapter.

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4.6 Conclusion

In this chapter I analyzed empirically the effectiveness of fishery co-management in enhancing the economic return, measured by average fishery revenues per unit per year in each district. Using the fishery census data from Japan I found that, at least for the individual fishing units, the mere establishment of FMOs was not associated with significant impacts after controlling for capital levels and other time invariant individual-specific fixed effects.

The analysis shows that FMOs with pooling arrangements had higher fishery revenues, and suggests that it is mainly coming from those with weighted distributional rules. As Platteau and Seki (2001) and Uchida (2004a) observed in their respective cases, pooling arrangements were implemented to support methods of sophisticated fishing effort coordination in order to earn higher price and hence revenues. The results support such view, although the significance levels were rather weak. The question still remains as to whether it is the pooling arrangements per se or the effort coordination that are generating these results; this will be examined in the next chapter. Also, pooling arrangements could be more effective in reducing operational costs than enhancing revenue. As the census do not collect cost data, investigation of such aspects of pooling arrangements is left for future research.

The statistical insignificance of the marketing activities variable on fishery revenue is somewhat surprising, particularly since markets tend to respond quickly. One explanation of such result might be that engaging in marketing is different from being effective in marketing. It might be the case that marketing activities need to be coordinated and pursued in a collective manner for them to become effective. Since pooling arrangements create an incentive for such collective action, I examined whether FMOs with pooling arrangements and engaged in marketing activities had an impact of fishery revenue. Statistically significant results were not obtained; nonetheless the direction of changes in results suggests that our hypothesis is a plausible one.

There are nonetheless several policy implications about successful fishery co-management that can be drawn from this paper. Mere establishment of demarcated areas covered by fishing rights and collective bodies of fishermen, whether they are FCAs or FMOs, seem necessary but not sufficient for successful economic impacts. Among the activities that an FCA/FMO can initiate, marketing practices are high payoff activities for generating returns from fishery co-management, if they are effective. The effectiveness of marketing depends on whether it is done in a collective manner, and for this reason implementing pooling arrangements or any other policies enhancing the chance of collective action should be considered. The fact that marketing has positive impacts on revenue suggests that benefits arising from the output markets can be substantial and important in fishery co-management. Policies aimed at developing market infrastructure, such as the wholesale fish markets, and means of transporting the fish (i.e., linking the markets) may therefore benefit fishery co-management.

Chapter 5

The role of effort coordination and pooling arrangement

5.1 Introduction

The objective of this chapter is to examine the economic performance of FMOs that have adopted effort coordination and/or pooling arrangements. In the previous chapter I looked at the contributions to economic performance, indicated by the average revenue per fishing unit (household) per fishing district of (1) FMOs in general, (2) FMOs with pooling arrangements, and (3) FMOs engaged in marketing practices. The analysis in Chapter 4 utilized the published data from the fishery census in 1993 and 1998. However, for the task of understanding how FMOs use effort and pooling arrangements, the census data had limitations. In particular, while the census data covers marketing activities of FMOs, it does not ask questions about effort coordination activities.

There are several important questions about the actual relationships and interactions between effort coordination and pooling arrangements employed by the FMOs. In the literature, pooling arrangements are thought of as supporting systems that help effort coordination operations function effectively (Gaspart and Seki, 2003; Hasegawa, 1985; Baba, 1991). However, the literature on this topic is drawn from a few select cases and does not provide cross-sectional overview of how these schemes are actually employed and how they perform. Are effort coordination and pooling arrangement generally employed as a pair? Are the cases where only one scheme is employed exceptions (e.g., transitional)? In what ways do effort coordination and pooling arrangements perform better if they are implemented together rather than individually? These questions are still unanswered and they may have important policy implications.

Whether effort coordination and pooling arrangements bring higher economic returns in the first place is an unanswered question that may be important to sustainable fishery co-management. Effort coordination and pooling arrangements can potentially change the way fishermen do fishing by replacing individualistic competition (race to fish) with behavior more similar to a corporate or sole owner style of operation. But making such operational and institutional changes involves long negotiations and, once implemented, a level of monitoring and enforcement effort, which all amount to significant total costs. Since fisheries are no different than any other economic activities, it is vital that implementation of these arrangements bring higher economic return for successful fishery co-management.

Since there were no readily available data sets investigating effort coordination in the detail that was required, a mail survey was developed and implemented in 2005. The survey was pre-tested and then mailed to a sample of FMO managers nationwide in late 2005. This was not the first survey conducted on FMOs or on effort coordination. For example, in 1997 there was a survey conducted under the supervision of the Fishery Agency of the Japanese government. That survey was sent to regional government officers associated with FMOs located within various jurisdictions, who then answered the survey on behalf of FMOs. Our survey differs from the previous ones in two important ways: (1) our survey was sent directly to FMO managers instead of government officials who oversee them, and (2) questions were focused in great detail on effort coordination, pooling arrangements, and other self-imposed regulations and fishing operations in general. The survey was sent out to 433 FMOs nationwide and received 116 usable responses.

The results of this chapter show that members of FMOs with both effort coordination and pooling arrangements had higher "revenue per unit of effort", defined as the revenue per fishing hour, than FMOs with either one or none of these arrangements. For members of FMOs with only effort coordination or pooling arrangements, the estimated impact on revenue per unit of effort were positive, which is consistent with the intuition, but statistically insignificant compared to that of members of FMOs with none of the two arrangements. These results indicate that effort coordination and pooling arrangements are most effective when operated jointly.

5.2 Survey data

One of the first challenges in conducting the mail survey was to identify which FMOs to send the survey. Ideally one would want to send the survey to all FMOs nationwide, but I quickly realized that this was not possible. The main complication is that there is not a single source of contact information for all of Japan's FMOs, primarily due to the fact that FMOs are typically autonomous organizations. An option was to send the survey to all fishery cooperatives (FCAs) for which contact information is available. However, there are many cases where two or more FMOs are formed within a single fishery cooperative and I was advised that a survey sent to generic recipient (i.e., not to specific FMOs) would tend to get less or no attention. For these reasons it became clear that a list of specific contact information of FMOs is needed, which led me to utilize the list of FMOs from the prior survey conducted in 1997 (*vide supra*). As a result, 433 surveys were sent out and 116 usable responses were received.

The "effort coordination" variable was defined as (a) fishing grounds rotation or location assignments, (b) exchanging information on fishing grounds, and/or (c) joint ownership of fishing vessels and gear. Table 5.1 shows the number of FMOs in our sample identified by the combination of effort coordination and pooling arrangements employed. There are significant numbers of FMOs with either effort coordination (Type B) or pooling arrangements (Type C) alone. This suggests that these arrangements are probably not simply transitional or exceptional institutions. Having both effort coordination and pooling arrangements as a pair (Type A) is not necessarily a norm, and the question becomes whether there is a significant benefit of having both. Type D is defined as FMOs without either of the two effort coordination or pooling arrangements.

The primary interest of this chapter is determining how various combinations of effort coordination and pooling institutions affect some economic performance measure. I focus on the revenue per unit of effort, which is defined as the revenue from the managed fisheries per member per fishing hour. The unconditional means of

Table 5.1: Number of FMOs by their type

Type name	Effort coordination	Pooling arrangement	Count
A	x	x	44
B	x		32
C		x	12
D			28
Total			116

revenue per unit of effort ranged from 102.1 thousand yen (about $928) for Type A to 3.7 thousand yen ($34) of Type D FMOs (Table 5.2). These are considerably higher than the revenues per household unit derived from the census data. An important difference is that these are gross revenues before subtracting any expenses for vessels, crew, shore-side facilities, etc. Nevertheless, from these summary statistics alone, there seems to be a good reason to believe that FMOs with effort coordination and pooling arrangements have higher revenue per unit of effort than FMOs without these arrangements. Indeed, simple t-tests among the means indicate that the Type A FMOs' performance measure is statistically different from Type B and D, but not so from Type C. Type B FMOs' revenues per fisherman day was statistically significant only from Type D, while that was not the case between Type C and Type D. This is weakly suggestive of the notion that effort coordination and pooling arrangements are more productive when implemented together. However, we would need to control for other factors affecting the revenue level to be more confident in this claim.

One of the distinctive differences among FMO-types is the number of fishing days per year. Most notably, Type A FMO members spend far less time fishing than Type B or Type D FMO members. Table 5.2 seem to suggest that FMOs with pooling arrangements (Type A and C) tend to fish fewer days than the other two types. This is intuitive, since under the pooling arrangement there is less incentive to go out fishing in bad weather, for example, in comparison with behavior under individualistic competition. Type B FMOs are not individualistically competition, but their numbers of fishing days are the same level as Type D FMOs. A possible explanation for this result is that, for Type B, "fairness adjustments" in response to effort coordination must be made by providing equal chances of fishing at any given fishing ground to a vessel in a season (the pooling arrangement removes the need for this adjustment for Type A and Type C FMOs). Depending on the membership size of an FMO, this equity constraint may translate to maintaining a certain minimum days of fishing per year, and more days make it easier to make that adjustment.

Fishing hours per fishing day are not much different across FMO-types except Type D, which on average exhibits much longer hours per day. This suggests that fishing effort may be more concentrated, presumably around the most profitable times, in Type A and perhaps Type C FMOs.

If Type A FMOs are earning higher revenue per unit of effort, one might expect that, ceteris paribus, (1) membership size of these FMOs are smaller than other types (e.g. Agrawal, 2001), and (2) FMOs would successfully attract younger generation (i.e., successors) to the fishery. Regarding the first point, Type A through Type C FMOs have smaller membership sizes than Type D, but Type A is certainly not the smallest. The average age of FMO members is lower for Type A but not significantly so, and the same is true for average number of years as a fisher. Thus, the two hypotheses above do not seem to be supported by this sample.

Fishing vessels and gear are still largely owned by the individuals rather than the FMO institutions. For Type A FMOs, for instance, it might seem natural to bring inputs such as vessels and gear under joint ownership, just as is done for revenues (i.e., pooling arrangements), in order to fully rationalize the operation and maximize profit. Table 5.2 shows that such a trend, if it exists at all, is still in progress. Interviews with the managers of some of the most progressive FMOs confessed the difficulty of persuading the members to spare their own vessels in the interest of increasing group profit through the joint ownership of fewer (and possibly larger) vessels.

Table 5.2: Descriptive statistics of survey sample data

Variable averages	A	B	C	D
Membership size	49.8	48.1	28.4	73.7
Member age	55.6	59.6	59.7	59.4
Years of experience	31.6	34.2	32.6	30.5
Number of vessels registered	35.4	39.7	26.2	84.7
Number of vessels operating	15.4	19.9	21.9	29.1
Vessel tonnage	9.2	3.7	3.8	6.1
Per member revenue[a]	9,833	5,337	5,388	3,027
Fishing days in a year	66.0	118.9	92.6	120.2
Fishing hours per day	5.3	5.0	4.6	10.6
Revenue per member per fishing hour[a]	102.1	10.4	12.6	3.7
Fishing ground within TURF (No=0, Yes=1)	87.8%	85.2%	80.0%	85.7%
TURF solely owned (No=0, Yes=1)	66.7%	43.5%	62.5%	58.8%
Vessel: individually owned	88.2%	99.3%	97.8%	100.0%
jointly owned	3.8%	0.7%	2.2%	0.0%
owned by an FMO	9.3%	0.0%	0.0%	0.0%
Gear: individually owned	75.0%	96.1%	100.0%	100.0%
jointly owned	7.0%	0.0%	0.0%	0.0%
owned by an FMO	18.0%	3.9%	0.0%	0.0%

[a] Monetary unit is thousand Japanese yen (1 US$ is approximately 110 yen).

5.3 Estimation model

5.3.1 Do FMO-types matter at all?

The primary interest is whether there are any systematic differences between the revenue per unit of effort (*rpue*) and the FMO-types. The objective is to determine how much we can attribute this variation to the difference in management regimes.

As I have mentioned earlier, simply establishing a TURF-based fishery cooperative does not eliminate the incentive to race to fish. New entry will be limited but, if nothing else is done, the race among the incumbents will prevail, leading to a waste of capital, low profitability, and overall depletion of the resource and economic rents. The simple establishment of an FMO will not be much different either, unless other actions are taken by FMO members. With an FMO, the authority of fishery management devolves from the officials to the local fishermen. This decentralization may improve the level of compliance, but since underlying incentives to race for fish are unaffected without additional measures, the impact of such a regime shift on economic outcomes is likely to be limited.

I hypothesized that FMOs with effort coordination and/or pooling arrangements (Type A, B, or C) will have higher performance (revenue per unit of effort) than those without such arrangements implemented (Type D). Successful fishery co-management requires that a restricted group be granted rights to the resource. This is what establishment of the TURF provides. But successful co-management also requires that the restricted group that has been granted rights can successfully overcome internal organization costs and collectively exercise policies that manage the resource sustainably and profitably. Effort coordination is an active management measure that may be used to fulfill this requirement. Pooling arrangements, in contrast, can be thought of as passive measures in the sense that they do not require fishermen to continuously decide on terms of operation. However, pooling arrangements alter the incentive structures in such a way that, if implemented appropriately, individual incentives are aligned with that of a group as a whole. This is because maximizing the total benefit of a group - the whole "pie" - will also maximize one's individual dividend under the pooling arrangement.

Also, FMOs with *both* effort coordination and pooling arrangements (Type A) are expected to exhibit higher revenues per unit of effort than those with only *either* one (Type B or C). Effort coordination deals with the allocation of inputs of harvesting operation, while pooling arrangements deal with the allocation of outputs among the FMO members. Intuitively, coordinating and pooling complement each other and we would expect FMOs with both to be more efficient and effective.

To begin the analysis I first ran the following simple regression to check quantitatively whether the FMO-types matter at all. The model is

$$\ln rpue_i = \alpha + \beta_1 Type\_A_i + \beta_2 Type\_B_i + \beta_3 Type\_C_i + \epsilon_i,$$

where Type_A through Type _C are as defined in Table 5.1 and ϵ_i is the error term. The subscript i denotes an FMO. Note that the Type D FMO variable is excluded from the estimation. The result from heteroskedasticity-robust OLS shows that Type A and Type B FMOs have significantly higher revenue per unit of effort than Type D FMOs (Table 5.3). Thus, it seems suggestive at this junction that FMO-types do have influence over the revenue per unit of effort and the next step is to control for other covariates.

Table 5.3: Regression with only FMO-type variables

Coefficient	Estimate	Absolute t-value
β_1	1.813	4.70***
β_2	0.711	1.97*
β_3	0.781	1.34
α	−1.324	5.17***
F-value	7.39***	
Adjusted R^2	0.165	

Number of observations 72
*** significant at 1%; * significant at 10% level

5.3.2 Other covariates

Other factors that may impact the revenues per unit of effort need to be controlled. These include targeted species-type, product-type (which product markets the harvest is allocated to), and the vessel size. Membership size of FMOs might also be an influencing factor. Literature on commons and collective action often claim that smaller groups have better chances for successful collective action, in terms of sustainability and performance (Agrawal, 2001). Therefore, smaller FMOs might have higher revenue per unit of effort, ceteris paribus. Lastly, there could be a learning effect. The hypothesis is that the longer an FMO endures, the better it is in management performance. This is a plausible hypothesis given anecdotal evidence of actual cases where FMOs often modify and fine-tune their management practices over time (Uchida, 2004b).

Targeted species-types

It is common knowledge that certain harvested species command higher prices than other species in general. In Japan, for example, spiny lobsters and certain species of crabs (e.g., snow crabs) are generally considered as high-end or luxury foods and thus are traded at higher prices. Thus, one would need to control for FMOs' main targeted species.

One needs to be cautious in including the species-type variables into the model. If the case was such that high-value species are caught dominantly by Type A FMOs and low-value species are caught dominantly by Type D FMOs, or vice versa, then including both FMO-type and species-type variables will cause serious multicollinearity problems. To see if this problem exists in our sample, we counted the number of FMOs by targeted species and by FMO-types. There were total of 66 species targeted in our sample, with most of them having only three or fewer FMOs involved. The focus on the "popular" targeted species, and thus I separated species with seven or more FMOs involved. Also, since abalone and turban shell were often harvested as a pair of targeted species, these two were treated as one species entry. Other species with few FMOs targeting were categorized by their mobility characteristics, i.e., migratory fish, local (nonmigratory) fish, and sedentary species. Results are presented in Table 5.4. It shows that there is no systematic correlation between FMO-type and species-type variables, and hence we include the species-type variables into the model.

Product-types

The revenue level can potentially be influenced by the markets types to which harvested fish are allocated. Fish designated to fresh markets generally fetch higher

Table 5.4: Number of FMOs by main targeted species

Species	FMO-type				
	Type A	Type B	Type C	Type D	Total
spiny lobster	8	9	1	1	19
abalone/turban shell	2	5	6	11	24
surf clam	12	2	0	0	14
scallop	7	2	0	1	10
asari clam	2	2	1	2	7
migratory fish[a]	0	2	1	3	6
local fish[b]	6	6	1	1	14
sedentary[c]	7	4	2	9	22

[a] Migratory fish species include squid, mackerel, bonito, and yellowtail.
[b] Local fish species include flat fish, pollack, red snapper, and sandfish.
[c] Sedentary species include sea urchin, sea cucumber, shellfish other than above, and seaweed.

prices than those going to frozen or processed markets. Freshness is of particular importance for Japanese consumers as there is substantial demand for raw consumption of fish. Whether that translates into higher revenue, however, is another question. Nonetheless, implementing rigorous quality control measures so as to allocate their harvest to raw and fresh consumption is a popular practice that FMOs engage in. This is in line with the claim that benefit of rationalized fishery management coming from output markets in terms of increased price is substantial and critical in sustaining the regime (Homans and Wilen, 2005; Herrmann, 1996).

I denote the different markets which harvest is designated to as "product-type." First the product-type was divided into two categories: domestic consumption, including both final and intermediate, and exports.[1] Domestic consumption was further sub-categorized into raw, fresh, processed, and feed. The first two are for final con-

[1] According to the fisheries white paper, during the 2004 fiscal year the domestic fishery production was 1,604 billion yen, of which 148 billion yen or 9.2% was exported (Fisheries Agency, 2005).

sumption, where "raw" is what the supermarkets in the U.S. call "sushi-grade."

It is not uncommon that a single species is allocated to multiple markets. For this reason, the survey asked the respondents to give the share of each product-type, reminding them that the shares should add up to unity (Table 5.5). Overall, the majority of harvests go to either raw or fresh markets, with average of 27.7% going to the raw market and 56.9% to the fresh market. In terms of species-types, most of them have the same pattern of raw and fresh markets dominating the other. Notable exceptions are scallop, local fish and sedentary species, where processes markets are equally or more dominant than the raw market.

Table 5.5: Percentage of designated products for each targeted species-type

	Average share (%)				
Species	Raw	Fresh	Processed	Feed	Export
spiny lobster	40.7	52.7	0	0	6.7
abalone/turban shell	43.9	52.4	3.2	0	0.5
surf clam	23.0	75.5	1.5	0	0
scallop	7.9	59.8	30.5	0	1.9
asari clam	0	100.0	0	0	0
migratory fish	34.0	46.0	20.0	0	0
local fish	34.5	25.0	33.2	2.3	5.0
sedentary species	4.2	73.3	14.2	0	8.3
Total	27.7	56.9	11.7	0.3	3.3

Gear-types

Another factor that might affect the revenue level is the harvest method employed, particularly within a single species-type. Controlling for gear-type is clearly necessary if there are multiple gear-types employed for the same targeted species defined as above, and if that might have an impact on revenue level. Therefore, one first needs to examine the method of harvest by each targeted species-type.

Table 5.6: Number of FMOs by targeted species and gear-type

Species	Gear-type 1	Count	Gear-type 2	Count
spiny lobster	gill net	19		
abalone	diving	17		
surf clam	small bottom trawl	14		
scallop	small bottom trawl	8	aquaculture	1
asari clam	diving	6		
turban shell	diving	3	gill net	3

Table 5.6 shows the top two gear-types used to harvest the popular targeted species.[2] It shows that the issue of multiple gear-types in a single species is quite limited. With an exception of turban shell, all other species are harvested by single gear-type across different FMOs. As for turban shell, since it is often combined with the abalone fishery, diving can be considered as the dominant harvesting method for the two species. From these results, I concluded that including both species-type and gear-types variables would likely to cause multicollinearity problems. Hence, gear-type variables were excluded from the estimation models.

Other variables

There are other variables that can potentially be included in the model. An obvious one is the average tonnage of vessels. This is the average tonnage of vessels owned by FMO members, and it is intended to be a proxy for crew member size. Intuitively, larger crew sizes bring higher revenues for an FMO member, who is typically a vessel owner and skipper, per fishing hour. Since I do not have the crew size variable, the average tonnage of vessels was included based on the assumption that typically larger vessels have more crew members on board.

[2]First I attempted to count the top *three* gear-types, but turned out that there was no third popular gear-type in the sample.

A few more variables are considered primarily in response to the possible issue of endogeneity. Specifically, the main concern is regarding the omitted variables that not only affect the level of per member revenue but also the likelihood of a group choosing a particular FMO type.[3] One such variable is the FMO's membership size. As Ostrom (1990) and others have pointed out, smaller groups have better chance of implementing collective action, and perhaps more sophisticated forms of collective action than larger groups, ceteris paribus. This suggests that group size affects the choice of FMO types; smaller groups tend toward of being Type A.

In addition to membership size, we considered the FMOs' established year index variable. This variable range from 1 to 11, each corresponding to an interval of five years where 1 is the oldest (established on year 1935 and prior) and 11 is the most recent (established year 2001 and after).[4] The question is whether any learning effect is present or not. Also, it is often the case that FMOs modify, and in many cases fine-tune their management schemes and rules over time. One would expect that such modifications take place in aim to increase the return from the fishery, because making such changes incur cost.

[3]There is **no** selection bias issue here; there are observations on revenue for all four types of FMOs and which revenue data belongs to which FMO-type is exactly known. Also, since the sample is confined within FMOs one cannot address the question of what factors determine the establishment of FMOs.

[4]The survey was constructed such that respondents were asked to check the interval that their date of FMO establishment falls into. This particular format was employed based on the experience of past surveys, results from pre-tests with local FMO managers, which all indicated that FMO managers typically do not know the exact year of establishment (particularly so if it is in the distant past) but comfortably knew *around when* it was established. This format choice was one of the strategies to enhance response rate by easing the burden of the respondents.

5.3.3 Model specification

The estimation model with all the variables mentioned in preceding section would be

$$\begin{aligned}\ln rpue_i = \alpha &+ \mathbf{type}_i^{'}\boldsymbol{\beta} && \text{(FMO-types)}\\ &+ \mathbf{species}_i^{'}\boldsymbol{\gamma} && \text{(species-types)}\\ &+ \mathbf{products}_i^{'}\boldsymbol{\delta} && \text{(product-types)}\\ &+ \nu_1(tonnage)_i + \nu_2(membersize)_i + \nu_3(years)_i + \epsilon_i, && (5.1)\end{aligned}$$

where ϵ_i is an error term. Whether all variables should be included, however, needs to be examined.

Table 5.7 shows the regression results of various model specifications based on (5.1).[5] Firstly, the outcomes of our variables of interest, namely FMO-types, are robust across all models. Compared to Type D FMOs' revenue per unit of effort, Type A FMOs' level is consistently estimated to be significantly higher. The statistical significance level is at 1% for all but Model 2.

First, consider the comparison between Model 1 and Model 2. My decision was to take Model 1, that is, to include the species-type variables but not the product-type variables. There are several reasons for this decision. Firstly, the level of adjusted R^2 for Model 1 is higher than that of Model 2. This was also the case when Model 1 was estimated with the same data set as Model 2. Secondly, there is a stark contrast of the results between these two models, namely the significance levels of all variables have dropped by large margin. Not only the significance level of Type A variable was

[5] As aforementioned, there are 116 responses that are the basis of descriptive statistics. However, some of these responses were missing data on one or more of the regression-related variables, which were then consequently excluded from the regression.

Table 5.7: Heteroskedastic-robust OLS estimation results

Variables[a]		Model 1		Model 2		Model 3	
		Dependent variable: log of revenue per unit of effort in 10K Japanese yen					
FMO-type	Type A	1.355	(3.29)***	1.050	(2.23)**	1.183	(3.26)***
	Type B	0.110	(0.29)	−0.255	(0.42)	0.132	(0.36)
	Type C	0.909	(1.47)	0.844	(1.14)	0.528	(0.80)
Species-type	spiny lobster	−0.145	(0.18)	0.099	(0.07)	−0.932	(1.34)
	abalone[b]	−1.267	(2.20)**	−1.234	(1.50)	−1.421	(2.31)**
	surf clam	−1.159	(2.23)**	−1.231	(1.53)	−1.256	(2.34)**
	scallop	0.561	(0.99)	0.056	(0.07)	0.462	(0.81)
	asari clam	−1.570	(1.95)**	−1.649	(1.70)*	−1.904	(2.04)**
	migratory fish	−0.606	(1.06)	−0.841	(1.02)	−0.883	(1.58)
	local fish	0.887	(1.46)	0.861	(0.78)	0.926	(1.31)
Product-type	raw			−0.430	(0.65)		
	processed			0.686	(0.89)		
	feed			−4.322	(1.65)		
	export			−0.503	(0.59)		
FMO member size						−0.001	(0.18)
Vessel tonnage						−0.008	(1.73)*
Years since FMO establishment						−0.029	(0.48)
Constant		−0.547	(0.91)	−0.224	(0.32)	−0.051	(0.09)
Adjusted R^2			0.377		0.310		0.441
Number of observations			72		58		67

Absolute value of t-values in parenthesis. Significance levels are indicated by *** (1%), ** (5%), and * (10%).

[a] Following variables were excluded to avoid perfect multicollinearity: Type D, sedentary species, and fresh product-type.

[b] Abalone *and* turban shell.

lowered but *all* but one species-type variables became statistically insignificant. Yet, the F-statistic of Model 2 was 2.60, which rejects the null hypothesis of F-test at 1% significance level. A significant F-test and nonsignificant t-tests of coefficients are symptomatic of multicollinearity, which suggests that both species-type and product-type variables should not be included in the estimation model. Finally, I regressed the following model, which is analogous to Model 1 except the species-type variables are replaced by the product-type variables

$$\ln rpue_i = \alpha + \mathbf{type}_i^{'}\boldsymbol{\beta} + \mathbf{products}_i^{'}\boldsymbol{\delta} + \epsilon_i.$$

The result was an adjusted $R^2 = 0.194$, which is considerably lower than that of Model 1. Hence, the conclusion was to retain the species-type variables in the estimation model.

Models 3 is a modification of Model 1 by adding vessel tonnage, FMO member size, and years since FMO establishment variables. All combinations of these three covariates were tested but the results were qualitatively identical to those presented in Table 5.7. In particular, the estimated coefficient of the Type A variable is positive and statistically significant, one or more species-type variables were significant, and the vessel tonnage variable is negative and significant. The statistical significance of these additional three covariates is weak, but excluding any of these variables is not appropriate. As previously mentioned, there are theoretical grounds supporting the need to include them. Excluding them is likely to cause omitted variables bias and, especially in the case of membership size and number of years since FMOs establishment, endogeneity issues for the variables of the most interest – the FMO type – can arise. In addition, the higher level of the adjusted R^2 for Model 3 than for Model 1 also justifies inclusion of these covariates.

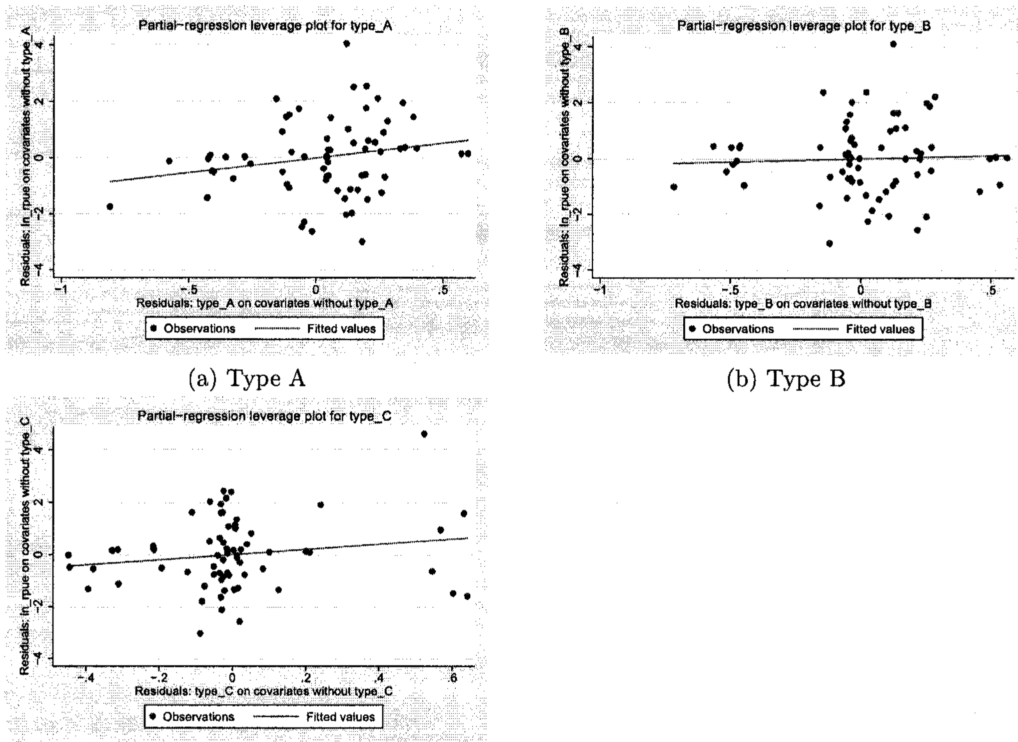
In conclusion, the estimation model will be specified as that of Model 3, to wit

$$\begin{aligned}\ln rpue_i =& \alpha + \mathbf{type}_i^{\prime}\boldsymbol{\beta} + \mathbf{species}_i^{\prime}\gamma \\ &+ \nu_1(tonnage)_i + \nu_2(membersize)_i + \nu_3(years)_i + \epsilon_i.\end{aligned} \tag{5.2}$$

5.3.4 Regression diagnostics

One of the issues with mail survey is that the researcher does not have a full control on how the respondents respond to the questions, as opposed to face-to-face interviews. Every effort to make important aspects of our questions explicit and comprehensible was made with wording and layout of the survey itself. Nonetheless, one needs to pay attention to possible measurement error of the data. As such, much of the time was devoted for cleaning and checking the data for apparent inconsistencies. Beyond that there is little one can do without resorting to ad hoc methods, which is inappropriate. However, one would want to avoid the situation where small numbers of erroneous but undetected data outliers to dominate the model estimates and predictions. For this reason a set of regression diagnostics was conducted to detect influential observations and outliers. The strategy pursued was to look for such observations, and then take closer looks at the data points to determine whether they are legitimately occurring outliers or erroneous data.

Following Belsley et al. (1980), the diagnostics were conducted on two main issues: (1) influential observations on estimated coefficients (the slope of fitted curve), and (2) normality assumption of the error term. For the first diagnostic, since the variables of the primary interest are FMO-types (A, B, and C), whether there are any observations influencing disproportionately the estimated coefficients of these variables was examined.



(a) Type A

(b) Type B

(c) Type C

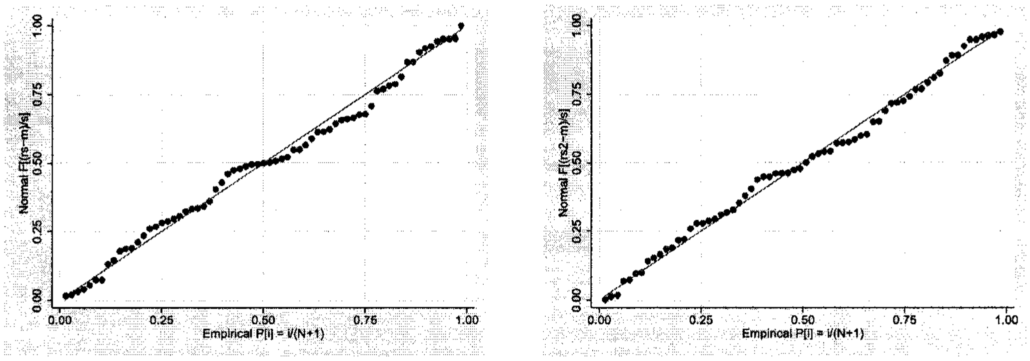
Figure 5.1: Partial regression leverage plots for FMO-type variables (Type A, Type B, Type C)

Partial regression leverage plots, which visually show the influential observations, are presented in Figure 5.1. The slope of fitted line represents the estimated coefficient for the respective variables. In panel 5.1b there are no apparent observations suspected of disproportionately influencing the slope of the fitted line. In panel 5.1a, an observation to the far left is suspected of pulling down the fitted line on that end, thus creating a significant and positive slope. In panel 5.1c, a data point at upper right-hand corner could be pooling up the fitted line on that end, thus creating a significant and positive slope. However, DFBETA statistics, which gives numerical values of an observation's influence on estimated coefficients, indicates that these particular observations were below the threshold level (i.e., the null hypothesis that this observation is not influential was not rejected). In fact, there was no incident where DFBETA statistics were above the threshold, thus none of the 67 observations in Model 4 was statistically influential. The possibility of the existence of multivariate outliers were also tested and rejected.

The results from partial regression leverage plots and other statistics such as DFBETA suggest that there is no influential outlier in the regression sample, but clearly this does not imply that the data is error-free. However, with 67 observations – not terribly large but certainly not small in statistical sense – one can assume that any bias will on average cancel out.

Normality assumptions of the error term in the model, and thus the regression residuals, are critical in making inference of the regression results. A moderate departure from normality can impair estimation efficiency and the meaningfulness of standard hypothesis tests. A commonly used method to detect such departures from normality is the normal probability plot, where observed cumulative probabilities of occurrence of the standardized residuals are plotted against the expected normal cumulative probabilities of occurrence. If the regression residuals are truly distributed normally, then the result will be the 45-degree line. Thus, departure from this line will indicate that normality assumption is violated.

Panel 5.2a is the normal probability plot of Model 3 using its full sample ($n = 67$). Plots are remarkably coincident with the 45-degree line. RSTUDENT statistics,



(a) $n = 67$ (b) $n = 66$

Figure 5.2: Normal probability plot of Model 3 in Table 5.7

based on the studentized regression residuals, indicate that there is one observation that is above the threshold level of normality assumption. Panel 5.2b is the normal probability plot after deleting this observation ($n = 66$). As expected, plots are closer to the 45-degree line indicating an enhanced validity of normality assumption.

Now that the observation that is adversely influencing the normality assumption is identified, the question is whether this data point should be deleted from the regression sample. Deleting observations is certainly a drastic measure and potentially can cause different bias and other issues, and therefore one would want to avoid that decision whenever possible. The key is whether the outcomes regarding the variables of primary interest are sensible to this single observation. For example, if the signs of estimated coefficients alternate or the significance levels fluctuate then there is a problem. It turns out, however, that such was not the case. Qualitative results from regressions with and without this observation were identical. Thus, it was decided to retain this observation because (1) the departure from normality assumption is not severe (Figure 5.2), and (2) adverse consequence of even smaller sample size could be more substantial than the benefit of deleting one observation.

In sum, the conclusion is that Model 3 with its full 67 observations can be used confidently in making inference on estimation results.

5.4 Regression results

5.4.1 FMO types

The coefficient estimate of the Type A FMO variable is 1.18 and it is statistically significant at 1% level. Since only the dependent variable is in a natural log form, the interpretation of coefficients is the percentage change in revenue per unit of effort in response to a unit change in explanatory variables. Thus, it is estimated that a member of Type A FMOs earn approximately 118% more revenue per unit of effort. This is within the plausible range based on the result from the descriptive statistics (Table 5.2).

How does Type A compare with Type B and Type C? The model estimates that Type A FMO members earn significantly, in a statistical sense, higher revenue per unit of effort than Type B FMO member at 1% significance level. Such was not the case, however, between Type A and Type C. In addition, estimated coefficients of Type B and Type C were not significantly different from each other.

These results suggest the following regarding the relationships among effort coordination, pooling arrangement, and revenue per unit of effort: (1) neither effort coordination nor pooling arrangement *alone* has a significant impact on the level of revenue per unit of effort, (2) there is no superiority of effort coordination over pooling arrangements or vice versa, and (3) combining effort coordination and pooling arrangement has super-additive impact on revenue per unit of effort.

I hypothesized that FMOs with either effort coordination or pooling arrangements perform better than those without either of the two schemes. This is partly supported by the fact that estimated coefficients for Type B and Type C were positive, but not fully supported since both were statistically insignificant. The second hypothesis is that FMOs with both perform better than those only with either one was almost fully supported, as only the coefficient for Type A was estimated to be significantly different from Type D. I say "almost" because while the difference between Type A and Type B was significant, it was not so between Type A and Type C.

The result that there is no significant difference in revenues per unit of effort between Type A and Type C FMOs raises an interesting question as to how exactly Type C FMOs operate. If the revenue is pooled but without established central decision-making mechanisms (such as committees), how does each individual fisherman in Type C FMOs operate? For example, do they operate the same way spatially (i.e., in choosing fishing grounds) but simply less intensively? An interview with one of the Type C FMOs' manager provides hints about answers to these questions. This particular FMO harvests surf clams, and the purpose of employing the pooling arrangement was to mitigate the members' incentive to race to fish. On each fishing day, revenue is shared only among the members who participate in fishing; those who stay on shore are excluded. This eliminates the incentive to free-ride by staying on shore. Also, in this fishery there are several fishing grounds that are distant from their port, but nonetheless need to be cultivated. With the pooling arrangement in place, no individuals have the incentives to fish in these grounds since fishing costs are not shared. There are no explicit rules as to how to take turns to harvest these fishing grounds, but there is an implicit rule-of-thumb that if you operate in nearby fishing grounds for three days you would go to more distant grounds for a day. If a member is caught not following this implicit rule, based on peer monitoring, this member will be penalized in the form of reduced share of pooled revenue. In essence, this Type C FMO has implicit effort coordination in place. We have no method to verify if this is the norm for any of the surveyed Type C FMOs. If it is, however, then the distinction between Type A and Type C becomes vague, and this would explain why we do not detect significant differences in revenue levels between these two FMO types.

5.4.2 Other self-imposed regulations

Next I analyzed whether the combination of effort coordination and pooling arrangement is solely responsible for higher revenue per unit of effort. There are many other types of self-imposed regulations and measures that FMOs can employ, and they indeed do so (Table 5.8). I categorized these self-imposed regulations as follows.

Marketing: quality control measures (proper icing, careful release from nets, etc.), development of new value-added products, and branding.

Harvest control: setting TAC and/or individual quota, control daily landing volume to avoid market glut, and fish size and age restrictions.

Operation regulations: restrictions on fishing hours and days, seasonal closure, setting no-fishing zones, and restrictions on fishing method, fishing gear, and number of crew on a vessel.

Vessel regulations: restrictions on number of vessels, tonnage, and engine power.

Note that some of above regulations are also imposed by the local or central government but in the survey we explicitly asked for self-imposed regulations, including those are more stringent than existing government regulations.[6]

Table 5.8: Number of FMOs by self-imposed regulations

Regulations	Type A	Type B	Type C	Type D	Total
Marketing	27	10	4	5	46
Harvest control	25	13	6	8	52
Operation regulations	31	18	6	8	63
Vessel regulations	18	4	2	2	26

Note: Counted within the Model 4 sample of $n = 67$.

I first estimated whether these four categories of self-imposed regulations have any impact of their own on revenue per unit of effort (see Model 3a in Table 5.9). Results show that none has a statistically significant impact. The estimated positive sign for the marketing variable is intuitive since such activities are typically aimed at increasing revenue. The negative sign for the harvest control variable is plausible if the market price did not respond enough to supplement the reduced landing volume.

Note that the Type A FMO variable remained statistically significant even after the addition of self-imposed regulation covariates. Thus, the next question is whether the combinations of Type A FMOs *and* self-imposed regulations have significant impacts on revenue per unit of effort. To do so, interaction terms of Type A and regulation variables were introduced. The model is

$$\ln rpue_i = \alpha + \mathbf{type}_i'\boldsymbol{\beta} + \mathbf{species}_i'\boldsymbol{\gamma} + (Type\_A_i \times \mathbf{regulations}_i)'\,\boldsymbol{\eta} + \epsilon_i, \qquad (5.3)$$

[6]The primary reason for constructing our survey in such a way is that virtually all coastal fisheries in Japan have some sort of government regulations and they typically include operational restrictions and vessel regulations. Therefore, there will not be much variation had the survey simply asked whether the fishery has regulations imposed. Thus, I focused the attention to what actually varies among the coastal fisheries, which is the existence of self-imposed and typically more stringent regulations.

where $\mathbf{regulations}_i^{'}$ is a row vector of self-imposed regulations dummy variables, which equals 1 if implemented by an FMO i.

I first estimated the model with the regulations vector consisting of four regulation categories: marketing, harvest control, operation regulations, and vessel regulations (Model 3b in Table 5.9). Each category has multiple subcategories, and so these dummy variables were constructed such that if one or more of subcategories were employed then the dummy variable equals 1; otherwise it is 0. Results show that marketing employed by Type A FMOs has positive and almost statistically significant – corresponding p-value of 0.101 – impacts on revenue per unit of effort. This suggests that marketing practices could be effective in increasing the revenue if they are conducted under the effort coordination supported by the pooling arrangement, which is consistent with our intuition. On the other hand, I find that harvest controls have negative and significant impacts. Harvest control often involves curtailing the harvest volume, which then leads to reduced total revenue. However, one would also expect that fishing hours would also decrease since now fishermen are not catching as much as they used to, and therefore the change in revenue per unit of effort (i.e., per fishing hour) is ambiguous *a priori*.

In the next estimation model, both marketing and harvest control were divided into their subcategories to investigate which of these subcategories were most influential. Marketing variables includes quality control, new product development, and branding. Harvest control variables include total catch limit (or TAC), individual catch limit (or IQ), supply/landing volume control, and size/age restrictions. Each subcategory was interacted with Type A FMO dummy variable (Model 3c in Table 5.9).

Table 5.9: Heteroskedastic-robust OLS with interaction terms of Type A and other self-imposed regulations based on Model 3 in Table 5.7

Variables[a]		Model 3a		Model 3b		Model 3c	
FMO-type	Type A	1.189	(3.05)***	1.599	(3.77)***	1.082	(1.81)*
	Type B	0.213	(0.51)	0.241	(0.63)	−0.202	(0.47)
	Type C	0.511	(0.76)	0.484	(0.73)	0.439	(0.61)
Marketing		0.330	(0.70)				
Harvest control		−0.262	(0.45)				
Operation regulations		−0.267	(0.54)				
Vessel regulations		0.109	(0.30)				
Interaction terms: generic	Type A× Marketing			0.951	(1.67)		
	Type A× Harvest control			−1.181	(2.36)**		
	Type A× Operation regulations			−0.373	(0.80)	0.448	(0.74)
	Type A× Vessel regulations			0.481	(1.26)	0.066	(0.11)
Interaction terms: marketing	Type A× quality control					−0.786	(1.47)
	Type A× new product development					0.819	(1.11)
	Type A× branding products					−0.670	(1.35)
Interaction terms: harvest control	Type A× TAC					0.615	(1.11)
	Type A× individual quota					1.250	(1.87)*
	Type A× supply control					−0.340	(0.51)
	Type A× size/age control					−0.860	(1.74)*
Constant		0.166	(0.31)	−0.196	(0.35)	−0.398	(0.62)
Observations		67		67		66	
Adjusted R^2		0.407		0.444		0.457	

Robust absolute t-statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

[a] Although not shown, species types, vessel tonnage, FMO member size, and years since FMO was established were included in all regression models presented here. The results were qualitatively identical to those shown in Table 5.7.

There are several interesting results from Model 3c. Firstly, none of the marketing subcategories were significant. A plausible explanation could be that the success of marketing depends heavily on the product-type and market conditions on case-by-case basis, thus no specific marketing activities can be a silver bullet. The result with the aggregated marketing variable in Model 3b, in return, implies that Type A FMOs are engaged in different but most effective marketing activities given their conditions.

Secondly, results on harvest control subcategory variables show that individual catch limits (IQs) has positive, and size and age control has negative impacts on revenue per unit of effort, both statistically significant. Size and age restrictions either reduce the harvest volume or prolonged fishing time trying to compensate for the volume loss.[7] Thus, revenue per unit of fishing effort typically decreases in such cases.

Interestingly, FMOs with IQs in the sample also have size and age controls. The fact that IQ subcategory was estimated to have a positive and significant impact on revenue per unit of effort suggests the strength of IQs. There are two possible scenarios. One is that while with only size and age restrictions, fishermen are driven by the incentive to race and hence spend too much time fishing. To the extent that the revenue per unit of effort decreased, such excessive fishing is eliminated by capping the harvest volume via IQs, which results in higher revenue per unit of effort. However, recall that we are examining the impact of these self-imposed regulations within the context of Type A FMOs, who have both effort coordination and pooling arrangements. Therefore, the incentive to race to fish is likely to be less intense, and

[7]Harvested volume could increase since now each harvested individual is larger even though the harvested number has decreased. Although this is possible in principle, it is an unlikely case because the current condition is often such that stock depletion is accompanied with shrinking size of harvested fish, i.e., large fish are long gone.

so this scenario is probably unlikely. Another scenario is that IQs are functioning as a "benchmark" to detect shirking members. Because of the presence of the pooling arrangement, FMO members are in principle prone to shirking. If a member returns from his fishing trip with a harvest volume way below his quota to an extent that it is beyond a reasonable daily fluctuations, that could be used as an indicator that he might have been shirking out in the sea. IQs can be used to replace physical peer monitoring among the members, which can be useful in fisheries where vessels are operating in a dispersed manner.

On a final note, the Type A FMO's dummy variable's significance level has decreased with an introduction of interaction terms of Type A and self-imposed regulations variables. This result suggests that in practice just coordinating effort and pooling revenues is not enough; members need to engage in revenue-enhancing activities that that make best use of those managerial schemes.

5.5 Conclusion

Using the survey data collected directly from a sample of FMO managers across Japan, I investigated whether FMOs with fishing effort coordination and pooling arrangements perform better than those without these management arrangements. Theoretically, effort coordination will convert the fishing operation from individualistic competition under the limited access environment to more sole owner-like operation. Pooling arrangements alter incentives such that individual incentives are aligned with the group incentive, thereby further enhancing the possibility of sound and sustainable collective fishery management. However, whether and how that translates to greater economic returns, such as increased revenue, is an open question.

I estimate that a member of Type A FMOs (both effort coordination and pooling arrangement) earn approximately 118% more revenue per unit of effort than a member of Type D FMOs (none of the two implemented). Members of Type A FMOs earn significantly higher revenues per unit of effort than Type B FMO (only effort coordination) members. Although this might seem to suggest that pooling arrangements have larger influences on revenue than effort coordination, Type B and Type C (only pooling arrangements) were not significantly different from each other, *and* neither was significantly different from Type D. Thus, our hypothesis that FMOs with either effort coordination or pooling arrangement perform better than those without the two arrangements was not fully supported, although the estimated coefficients had the expected positive signs. Our second hypothesis that FMOs with both perform better than those with only either one was almost fully supported.

As a policy implication, does these results indicate that effort coordination and pooling arrangement are the essential ingredients, particularly so when put together, for successful fishery co-management? My conjecture is that is the case to a certain extent, but there are other conditions that are essential. In particular, effort coordination and pooling arrangements are still frameworks to act within their institutions, and the question remains as to "what actions do we take with coordinated effort supported by pooling arrangements?"

One answer this study suggests is that active marketing practices enhance revenues in collectively managed FMOs. There are several ways to do this depending on the market conditions which the industries/communities face. If the fish they catch is well known by consumers (e.g., salmon) then an effective marketing strategy could be to pursue stringent quality control with the aim of differentiating locally caught fish in the market from those caught elsewhere. On the other hand, if the product itself is not well known in designated markets then promotion marketing can be effective. Taking this one step further, one might be able to create a new market by introducing new products. If these activities are sought in fisheries that are dominated by small-scale fishers, as was the case in most of the Japanese coastal fisheries, then they need to be carried out collectively to be effective. Thus, effort coordination and pooling arrangements become essential and complementary institutional frameworks.

Note that the dependent variable of estimation models was revenue per unit of effort, which was defined as revenue per FMO member per fishing hour. This means that even if the revenue per unit of effort is high, one's total (or annual) revenue level can still be low, or not enough to support a livelihood throughout the entire year. Effort coordination, particularly rotating fishing grounds and days, could mean that your turn to go out fishing comes only once in a while. Pooling arrangements will discourage one to go fishing under uncomfortable conditions, such as in bad weather. All of these result in fewer fishing days. Indeed, according to Table 5.2, the number of fishing days per year was much smaller for Type A, followed by Type C FMOs.

The possibility of fisheries being lucrative but unable to bring enough total revenues to support the livelihood of fishermen means that income from outside the managed fisheries can be critical for successful and sustainable fishery co-management. This point was raised by many FMO managers and local researchers I interviewed. Such outside income sources include fisheries other than the managed ones, farming, and nonprimal industries sector jobs such as construction work.

This is not, of course, necessarily always the case. Like the case of the Pacific halibut fishery, a fishery management policy that reduces the race to fish and redirects more effort to quality control can achieve both a more lucrative fishery and a prolonged fishing season. In such a case, the availability of outside income sources might not be of significant importance. The conclusion of this chapter is thus that effort coordination and pooling arrangements may not be *the* most important, but certainly may be *one of the* important factors for successful fishery co-management.

Chapter 6

Conclusion

Fishery co-management has gained much attention in recent years in response to the failure of traditional fishery management strategies that relied on direct command-and-control regulations. This is particularly true in developing countries where co-management has been actively promoted by local governments and international aid institutions. In these settings in particular, it may be the only hope for rational management of fisheries when the enforcement and monitoring infrastructure is weak. Despite all of this interest and attention, however, fishery co-management still is not well understood. As co-management regimes become more and more common in developing and developed countries, quantitative and systematic analyses that delineate the factors that are key to their success has never been more important.

To understand the nature and performance of fishery co-management, I looked to Japan's experience in managing its coastal fisheries. Utilizing the nationwide abundance of fishery co-management examples there, I examined the measures and operations employed in Japan, extending my analysis beyond layers of traditional, cultural, and social influence that many past researchers have claimed as the keys to co-management's success in Japan.

6.1 Key findings

The first step was to take a closer look at the functions of Fishery Cooperative Associations (FCAs), fishing rights (referred to as TURFs), and Fishery Management Organizations (FMOs). In Chapter 2, I argued that FCAs and TURFs set boundary definitions and control membership and thereby allow FMOs to appropriate the benefits of co-management for their members. The task of an FMO is to bring benefits to its members at a level that makes the members better off by operating under the FMO. Simply allocating the allowable harvest assigned to an FMO does not necessarily generate appropriate incentives; more proactive management measures are needed. Upon examination of some successful fishery co-management cases, I identified two essential measures – effort coordination and pooling arrangements. With these two measures, FMOs operate as quasi-corporate in the sense that operations are determined centrally and members are paid in a form that is similar to a corporate dividend. I presented the example of the sakuraebi fishery co-management regime to illustrate how these two measures function within a fishery that has become one of the most lucrative in Japan.

Based on my review of the literature and field interviews, effort coordination and pooling arrangements seem to be correlated with the success of co-management regimes. The sakuraebi example also confirms this. However, a natural question arises – can we make some general statements about the effect of effort coordination and pooling arrangements? For instance, several of the sakuraebi fishery's characteristics, such as its status as a natural monopolist, are by no means universal. On the other hand, if the race-to-fish incentive is the leading culprit behind the poor performance of traditional fisheries management, mitigating or eliminating such an incentive through well-coordinated fishing operations could, in principle, bring higher returns without the presence of monopolistic market conditions. Furthermore, if the pooling arrangement is a vital supporting measure for effective effort coordination, as several researchers have claimed, then these two measures may actually be key to successful fishery co-management.

In Chapter 3, I analyzed conceptually how individual incentives and aggregated outcomes are affected by implementation of a pooling arrangement. The model I developed showed that pooling arrangements affect the optimal trajectory of a non-cooperative harvesting regime by lowering the level of fishing effort exerted at any point in time during the fishing season. As the pooling ratio increases, the level of effort required decreases, per-period harvest volumes decrease, and season lengths get longer. When the pooling ratio is one (all individual revenues are pooled and shared equally among the group's members), the outcome perfectly coincides with that of a sole-owner regime. In light of the shirking incentive associated with pooling arrangements, this result may be an overstatement generated by the simplified world assumed in the model. There are reasons to believe, however, that this conclusion is not implausible; we can at least conclude that pooling arrangements affect the incentive for fishermen in that their noncooperative behavior is shifted toward that of sole owner.

With anecdotal evidence and the conceptual analysis suggesting that effort coordination and pooling arrangements can enhance the success of fishery co-management, I then turned to an investigation of whether the data support such a claim. In Chapter 4, I utilized published fishery census data and focused on the pooling arrangements and marketing activities employed by FMOs. I was not able to test effort coordination directly as the necessary data were not available from the census. The analysis showed that FMOs with pooling arrangements had greater revenues and that marketing activities were more effective when coupled with a pooling arrangement. This is an intuitive result since effective marketing requires collective action by all members and a pooling arrangement provides each member with an incentive to act collectively.

The question of whether it was the pooling arrangements per se or effort coordination that drove the results was addressed in Chapter 5. Using a survey, I collected data from FMOs throughout Japan with a specific emphasis on effort coordination, pooling arrangements, and the content of other self-imposed regulations. Based on this survey data, I estimated that a member of an FMO that employed both effort coordination and a pooling arrangement earned much greater revenue per unit of effort than a member of an FMO that did not use such measures. Although the empirical estimation results were not clear-cut, they nonetheless suggested that FMOs with either effort coordination or a pooling arrangement do better economically than those without and that the difference is marked when an FMO uses both measures.

With effort coordination and a pooling arrangement in place, what actions can FMO members take to enhance the fishery's economic performance? Consistent with the results outlined in the previous chapter, here again the analysis suggests that active marketing practices enhance revenues for collectively managed FMOs. The actual content of such marketing activities varies from place to place and perhaps from time to time as well, and there is no silver bullet. FMO members must observe the markets they face, the markets that surround them, and the products that are in competition with theirs in order to devise an effective marketing strategy. My empirical results make it clear that marketing activities must be done collectively to be effective for fisheries that are dominated by small-scale operations. With anecdotal evidence suggesting that increased revenues are more persuasive for fishermen than longer-term cost savings, successful marketing is the key to enduring co-management. As a consequence, effort coordination and a pooling arrangement are not only advantageous but a necessity for FMOs. Also, policies aimed at developing market infrastructure (e.g., wholesale fish markets) and means of transporting the fish (as a way to link markets) may become important for successful fishery co-management.

6.2 Implications

What are the policy implications of this study for successful fishery co-management? First, a clear definition of boundaries, both geographically and in terms of membership, must be made. This can be done by coupling TURFs and fishermen's groups (FCAs/FMOs) or by use of licensing measures. The point is to set up institutions that deliver the necessary functions, not the institutions per se. The next step is to implement the pooling arrangement. The pooling ratio and the method of redistribution can be tailored to suit the needs of actual applications. The greater the pooling ratio is (i.e., the closer to one), the easier it is to implement and maintain effort coordination. This study suggests that, among the activities that an FMO that uses both key measures can pursue, marketing is most likely to yield positive and significant returns. If it does, fishermen will be convinced that co-management is beneficial for them and will be willing to maintain the regime. In addition, once fishermen perceive the fishery resource as a sustainable source of wealth, the chances of them being good stewards of the resource improve, simultaneously achieving biological objectives for the resource.

One caution with respect to the policy implications of the study results must be emphasized. Note that the dependent variable used in the analysis in Chapter 5 was revenue per unit of effort, which was defined as revenue per FMO member per fishing hour. This means that an individual fisherman's annual revenue can remain low, perhaps too low to provide a livelihood for an entire year, even if the revenue per unit of effort is high, as was the case for the sakuraebi fishermen (Chapter 2). The possibility of fisheries being lucrative and yet unable to generate enough revenue to support the livelihood of fishermen means that income from outside the managed fisheries can be critical for successful and sustainable fishery co-management. This is not, of course, necessarily the case; but when it is the policies established must be comprehensive in the sense that such outside income options are made available.

One last note: it is conceivable that, as a result of effective fishery co-management, markets will no longer be flooded and season lengths can be extended, raising prices for fisherman in output markets. My conceptual model (Chapter 3) assumed a constant market price during the season so it cannot capture such an effect; nor were the empirical models explicit about such price effects. In general, if the per-period harvest volume is large, then the market is more likely to be flooded and cause a market glut. Since fish products are generally perishable and thus their markets are regional in scope (there are, of course, exceptions, such as markets for frozen products), such situations will add pressure to lower the market price. The converse is also true; with reduced harvests per period, the market is less likely to be flooded and can maintain a certain price level. If that occurs, another dimension of benefit from successful fishery co-management is the potential for this price effect to improve the terms of trade. The impacts of fishery co-management are multidimensional, and this thesis sheds light on but one of those dimensions. Numerous opportunities for future research exist.

6.3 Concluding remarks

This thesis showed that there are fundamental factors that are grounded in economic principles associated with successful fishery co-management. As long as fishermen are rational in the sense that they seek to maximize their incomes (contingent on other things), then these factors can be generalized and applied beyond the case of Japanese coastal fisheries. In light of increasing application of fishery co-management around the world, it is my hope that the results of this study will be of some use in these applications.

Is co-management a panacea for fisheries in which traditional regulations have failed and ITQs are not feasible? Certainly not. Beyond the fact that initiating and maintaining cooperation among fishermen who are otherwise very individualistic is generally difficult, there are some potential pitfalls. The most important point with regard to the objectives of fishery management is that biological management of the resource tends to get a somewhat low priority. As mentioned, tangible and pecuniary benefits tend to convince fishermen to buy into the idea of co-management. Thus, to keep those fishermen happy, an FMO tends to overemphasize market benefits.

This trend is caused in part by a lack of reliable biological information; the role of government and fishery research institutions is thus critical as a source of such information. There is hope that co-management can manage both economic and biological objectives if fishermen are convinced that, in order to sustain good economic returns, the levels of the resource stock must be adequately maintained.

Nevertheless, co-management should continue to be considered in the future as a viable option in fishery management. Its major advantage over other rights-based management schemes such as ITQs is that co-management can accommodate objectives other than maximizing the resource rent. For example, it can sacrifice economic efficiency to a certain extent to keeping the fishing community intact. Whether it is the lack of outside options or simply an emotional quandary, forcing fishermen to go out of business is not a desirable path to take. It is conceivable that a community would seek social utility maximization in which resource rent is maximized only so long as all of its members can remain in business. This is one of the reasons that the concept of co-management is popular in developing countries and among international aid institutions, but fishing communities in developed countries also may be interested.

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