MEASURING THE POTENTIAL TO ADOPT SELF GOVERNANCE

FOR THE MANAGEMENT OF A COMMON POOL RESOURCE

A Dissertation

by

SERGIO COLIN CASTILLO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2011

Major Subject: Agricultural Economics

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Approved by:

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ABSTRACT

Measuring the Potential to Adopt Self Governance

for the Management of a Common Pool Resource. (December 2011)

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Self governance has proved to be a suitable instrument for the management of a common pool resource like fisheries. Under self governance, individuals organize themselves for the use of a resource, to deal with problems derived from the free access: overexploitation and low profit levels. Although there is a large amount of research devoted to investigate the common pool resources and self governance, there are two areas that represent a gap in the current research. One, what are the main variables related to likely self governance adoption? Two, how is the potential for self governance related to the economic efficiency of the resource users?

Unlike most of previous research that involves ex-post analysis, this is an ex-ante assessment of the potential for self governance for management of a common pool resource: a small-scale fishery located in Mexico. This research hypothesizes a positive relationship between fisher's technical efficiency and the likely adoption of self governance for the management of the fishery.

Taking a set of theoretical conditions, this research assesses the fishers' perception on the adoption of self governance. Further, a stochastic frontier analysis is applied to estimate the technical efficiency of each fisher. Finally, a relationship between the potential for self governance with technical efficiency, revenue, and other variables such as education and fisher experience is explored. The results show no significant effect of technical efficiency and revenue on the potential for self governance, as well a weak positive effect of fisher experience on the likelihood for self governance adoption. The findings of this research may be useful to improve the efficiency of the fishing activity and encourage the adoption of self governance in the study site.

The method proposed in this research is based on attitudes of the fishers, and it represents a step toward understanding *apriori* whether self governance would be implementable or not. Thus, as an *ex-ante* assessment, it is hoped to help predicting individual's behavior to deal with the overexploitation and low income levels derived from the use of a common pool resource.

DEDICATION

A Ruth, Acatzin y Max que son mi razón y mi todo. A mis viejos que ya no están pero siguen tan presentes como si estuvieran.

A mis hermanos, colegas y amigos de México por su apoyo y entusiasmo.

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NOMENCLATURE

CPR	Common pool resource
DOCi	Direct Ostrom condition question for *i=1,…,6*
LCR	Lázaro Cárdenas reservoir
LHS	Left hand side
OCi	Ostrom condition for *i=1,…,6*
OCs	Ostrom conditions
$\widehat{OC_i^j}$	Ostrom condition index for *i=1,…,6*
PCA	Principal component analysis
PC1	Principal component 1
$-q_i$	Indirect negative question related to each OCi
q_i^k	Indirect positive questions related to each OCi
RHS	Right hand side
SES	Social ecological system framework
SFA	Stochastic frontier analysis
SGM	Self governance for the management
TE	Technical efficiency

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CHAPTER I

INTRODUCTION

Motivation, objectives and hypothesis

This dissertation addresses the problem of managing a resource where a large number of people have unlimited access, *common-pool resource* (CPR). In our case, the resource is a lake that suffers from over-extraction and a poor profitability level of the commercial fishers. This situation is common in CPRs, and Gordon (1954) characterized it as the fisheries problem. Each fisher or CPR user (from here on these two terms will be synonymous) may know that to avoid the fisheries problem, the harvest must be reduced and a fishery management need to be implementing. But at the same time, each fisher faces a dilemma: if limit his own catch and other fishers do not, the fisheries problem will be worst meaning a loss for everybody, and especially for those who did sacrifice. Gordon (1954) and Demsetz (1967) described this problem and Hardin (1968) reformulated the idea positing that human groups cannot solve this problem because of the selfish behavior; in his view, we are trapped in a *tragedy of the commons*.

Previous research has established the theoretical background to analyze the fisheries problem, reformulating to cover other resources like forest, grazing lands, marine areas, etc. and named as the CPR problem (Ostrom 1990).

This dissertation follows the style of the *International Journal of the Commons*.

Through the years, and especially since Ostrom (1990), new ideas and methods have been developed to study the CPR problem. Although, most of the empirical research has focused on the *ex-post* analysis seeking to explain the ways that groups organize to face the CPR problem.

Based on a theoretical framework proposed by Ostrom (1990), the main objective of this thesis is to analyze the potential for self governance as a way to deal with the CPR problem. Under *self governance,* individuals organize to set and enforce rules for the use of the CPR. We explore the *self governance management* (SGM) for a CPR, a small-scale fishery in Mexico. The research has three particular objectives. (1) Investigate the perception of a fishers' group, on their predisposition toward SGM. (2) Measure the technical efficiency (TE) of the fishers in the same small-scale fishery. (3) Explore the relationship between the fishers' propensity to adopt SGM, as evaluated using Ostrom's conditions, and the fishers' TE in this small-scale fishery.

The main research questions are. How can we assess the likelihood of a successful adoption of self governance? What is the role of users' TE on the self governance adoption? Ideally, it would be good to answer these questions *before* embarking on the encouragement of self governance. Knowing the predisposition of the CPR users may save resources and improve the decision making process.

With this research we identify three contributions to the literature. First, to the best of our knowledge, this is the first *ex-ante* assessment of the likelihood of SGM success. Second, by including a measure of efficiency at user level, the TE, we relate the significance of economic behavior with the potential for the adoption of self governance.

To do this we hypothesize a positive relationship between TE and the predisposition of fishers to adopt SGM. Economic models often assume all economic agents to be homogeneous and fully efficient. We relax this assumption, and study producer efficiency as a factor that explains the user's predisposition towards the adoption of self governance. Finally, this study offers insights about whether or not a change in governance is feasible and desirable.

Overall, this is an *ex-ante* assessment that brings information useful for decision makers to decide, for example, between continuing with the management implemented by the government (*status quo*) or promoting self governance. Further, evaluating the potential for SGM may offer guidance as to how to remedy the low profit levels and overexploitation accrue to the use of the CPR, and help to define strategies for the assistance of the fishing communities.

In addition to this introductory chapter, the data section and a conclusion, this dissertation is presented in three main chapters. In Chapter III we used the Ostrom conditions to evaluate the potential for SGM. In Chapter IV the TE was estimated, finding the most relevant variables that explain the efficiency of the fishers. In Chapter V the relationship between the fishers' the fishers' predisposition toward a system of self governance and their TE and other socioeconomic variables is modeled.

CHAPTER II

SURVEY, DATA, STUDY SITE

Study site

The study site is the Lázaro Cárdenas Reservoir (LCR). The LCR is in the municipality of Inde, Durango, a poor and arid region, located in the upper watershed of the Nazas River, best known as “La Laguna”, a region located at the north-central part of Mexico. LCR has a storage capacity of 3,336 million m^3 of water on 15,000 hectares (INEGI 2005). Three fishing communities are situated on the banks of the reservoir: El Palmito, Las Delicias, and La Victoria. The fishers are not the legal owners of the reservoir, but they enjoy unlimited access. These communities are largely dependent on fishing, supplemented by minimal agriculture-livestock activities and remittances from U.S. emigrants. The biggest community is Las Delicias and the smallest is La Victoria. These two communities have developed agriculture and livestock activities while El Palmito community depends almost entirely on fishing. In El Palmito fishers have higher revenue, spend more time fishing, have more experience, and have higher catch. El Palmito may be the more affected if any change in the fishery management is implemented. Recreational fishing is infrequent, but increasing, although this activity provides little benefits to commercial fishers.[1]

The LCR fishing fleet is composed of small fiberglass boats with outboard motors; although a few fishers do not use motor and row their boats (Tovar et al. 2009).

[1] Development of recreational activities requires the coordination of fishers. By reasons of competing technologies (hand lines vs. nets), recreational and commercial fishing cannot operate simultaneously.

Most of the fishers use gill nets, but a few use angling gear (hook and line). Some fishers share boats to split the operation costs. The fisher group is exclusively formed by men. An average fisher is an individual between 40 and 50 years old, with elementary school education level, living in a family of 4 individuals or more. Most fishers use an old boat and an old engine and work every day of the week.

As it was detected in the survey, most of the fishers agree that fishery is in a critical condition because they have very low profits and catch small individuals. Government rules allow fishers to use a gill net with mesh openings of 4 inches; however the use of smaller mesh sizes is common. The result is the declining harvest and size of the fish (Tovar et al. 2009). From 1983 to 1992, fish production was about 1,000 tons/year (71 kg/ha/yr), with a maximum yield of 1,200 tons/year (FAO 1996). According with the interviews to leaders and fishers, the number of fishers using the LCR varied from 204 in 1992 to 134 in 2007. At the time of the survey, 148 fishers were found registered in the three cooperatives, although it is generally believed that only about 100 are active fishers. Based on informal agreements, each cooperative has an area to fish. The harvested species are *Micropterus salmoides* (lobina or largemouth bass), *Ictalurus punctatus* (bagre or channel catfish), *Cyprinus carpio* (common carp), *Oreochromis aureus* (blue tilapia) and *Pomoxis annularis* (robaleta or white crappie) and *Lepomis macrochirus* (mojarra or bluegill).

In general, weak regulation in the LCR fishery has been observed. The municipal government and CONAPESCA, the federal agency, exhibit a lack of personnel and limited budgetary resources that restrict management efforts. As a result, there is very limited monitoring and enforcement of existing regulations. Agency decisions lack scientific criteria for seasonal closures, fish stocking, and gear restrictions in LCR (Tovar et al. 2009). This situation is not unique to LCR, it is representative of most of the inland fisheries of Mexico. Based on Salas et al. (2007) and Andrew et al. (2007); this case may be also representative of other inland small-scale fisheries of other developing countries. Overall, this description suggests that commercial fishery has overharvested the resource and used it in an inefficient way, a typical case of an open access fisheries as described by Gordon (1954).

Data

The data were gathered from a survey on LCR. The survey was administered in the summer of 2010. From a total of 148 fishers in the 3 communities, 111 completed surveys were obtained. The instrument was pretested using two focus groups, one with students of Universidad Juarez of Durango and the other with fishers of Francisco Zarco, another small lake in the region. Recently graduated biology students were hired as enumerators to conduct most of the surveys. Many of the fishers cannot read, so the enumerators read the questions directly to the fishers. To increase the response rate, each fisher received a compensation of 50 Mexican pesos (about 4 US dollars) and a prize which was from a random drawing at the end of the survey.

The questionnaire was divided in three sections. The first one captures data related to production and the socioeconomic state of the fishery. The second section capturers the data related to self governance. The third section captures the data related to the income of the fisher.

The average fisher is 45 years old, had six years of schooling, lives in a family of five people, and has three dependents. Each fisher uses an average of seven nets, work six days per week and his boat and engine have more than 10 years of use. Fishers use small fiberglass boats of 4.3 meters long on average, with an outboard motor of 20 horse power average. About a half of the fishers share a boat with other fisher. The average number of years working as a fisher is 24. As compared to the neighborhood, less than 50% of the fishers have never worked for the cooperative administration neither participates in the conservation activities of the lake. Table A.1 of Appendix A describes the complete set of production and socioeconomic variables.

In the data used to assess the potential for self governance, the questions were designed to describe the conditions for a likely adoption of self governance. Three sets of questions were formulated. Indirect positive and indirect negative questions designed to test reliability. Direct questions designed to test validity. In this section of the questionnaire, all the questions have answers on a Likert scale of 1 to 5. These data are described in full in the Chapter II.

More than 50% of the fishers depend primarily on the fishing activity. Although, the revenue derived from the fishing activity is very low, 500 to 600 pesos per week (about 50 US dollars). About a third of the fishers obtain remittances from relatives living in the US. Income from non fishing activities is important, especially during the season closed to fishing, as 33% of the fishers do not have any other source of income, 36% complement their income with agriculture and livestock activities and, and only 4% have another business activity.

CHAPTER III

EVALUATING THE POTENTIAL OF SELF GOVERNANCE IN THE FISHERY

Introduction

Common pool resources (CPRs) like fisheries, forest, marine areas, lakes or open grazing lands, are resources available to more than one person. These resources suffer problems associated with the unlimited access like overuse, resulting in degradation and poor economic performance. This is called the *CPR problem*. Hardin's (1958) "Tragedy of the Commons" paper describes this problem stating that users of the CPR will not manage the resource in common nor take into account the consequences of his actions on other users. Contrary to Hardin, however, there has been steadily growing interest and use of the common management approach to deal with the CPR problem. Such common management, best known as *self governance*,[2] involves user groups taking control of the CPR and overcoming the incentive problems that plague CPRs. Under self governance, individuals can achieve benefits derived from common work that improve the economic viability of the CPR (Ostrom 1990; Dietz et al. 2003).

This chapter focuses on *self governance for the management* (SGM) of a fishery as a way to solve the CPR problem. Fishery management is an issue that researchers and policy makers have devoted considerable attention. Instruments for resource regulation have become more sophisticated and extensive over time. Besides policies like individual transferable quotas, fees, taxes, and protected areas; self governance is now

[2] Governance is the exercise of policy definition to assure rules to manage the resource. Thus, in self governance the resource users themselves have the decision-making responsibility on defining such rules.

recognized as a viable tool for fishery management (Grafton et al. 2008, 2006; Hilborn 2007b; Degnbol et al. 2006; Panayotou 1998). These policies are not mutually exclusive, but can be combined depending upon the conditions of the fishery (Tietenberg 2003; Hughey et al. 2000; Yang et al. 2009).

"Successful" cases of self governance have been documented around the world (see Townsend and Sutton 2008; Ostrom 1990), suggesting SGM is a suitable option to manage CPR. Self governance systems are *successful* if the institution allows CPR users to develop solutions by themselves, aligning extraction rates with resource productivity to achieve a common benefit, and overcoming the problems of free riders and opportunistic behavior (Ostrom 2005, 1990).

Empirical evidence is essential to the development of our understanding of self governance and the CPR problem. The study of these cases has been useful to derive the characteristics of successful[3] cases. Nonetheless, the ability to predict a successful adoption of SGM is still limited. To the best of our knowledge, no previous study has attempted to conduct an ex ante assessment of the likelihood of adoption SGM. Carrying out such an evaluation is the principle objective of this chapter.

Adopting self governance can be difficult. Excluding individuals from the use of the CPR can be complicated and costly; incentives for free riders and opportunistic behavior will always exist. If not all the CPR users are successful in adopting self governance; what characteristics do we need to check *ex-ante* to know the potential for

---

[3] A successful SGM can exclude external users, adapt management rules to local conditions, allow most users to participate in the decision-making process, is recognized by other authorities and have an effective monitoring, graduated sanctions, and cheap-easy mechanisms of conflict resolution (Ostrom, 1990).

SGM? The approach taken here is to evaluate the prospects for SGM before it has been implemented by looking at the predispositions of the CPR users (i.e. the fishers). This study fills a gap in the literature, offering insights about how to predict whether a change in governance of the CPR is feasible and desirable. Such *ex-ante* assessments would provide valuable information for policy makers to define strategies to use to assist the fishing communities.

Built on the institutional analysis proposed by Ostrom (1990), we assess the perception of the fishers in a small-scale fishery as to whether SGM can be implemented to manage the resource on which their livelihoods depend. Distinct from most of the previous empirical analysis in the area, which are *ex-post* in nature (study cases after SGM has been installed), this is an *ex-ante* assessment to explore the potential for SGM. We propose an approach for carrying out this assessment and implement it at LCR, an overharvested small-scale fishery of Mexico.

Knowing *ex-ante* the likelihood for self governance may save resources and direct the effort to an efficient management of the CPR. Governments or private entities spend a lot of effort and scarce resources to regulate environmental issues, and in many cases the implementation of policies is not effective. For example, while public sector in OECD countries spent 0.7% of GDP from 1990 to 2004 for pollution abatement and control, the governmental offices have struggled to regulate the commons (Townsend 1995; Ostrom 2003). Indeed, fisheries have a long history of overexploitation, marine biodiversity loss is increasingly impairing the ocean's capacity to provide food, preserve water quality and recover from perturbations (Worm et al. 2009, 2006).

The chapter is divided as follows. First, it presents a literature review of the self governance and CPR problem. Second, a modeling approach is proposed. Next, the survey and data aggregation is described and a discussion about validity and reliability comprises most of the subsection. The results and discussion are accompanied with remarks of descriptive statistics. Finally a set of conclusions is presented.

Literature review

This section gives a broad overview of literature on self governance as a way to solve the CPR problem, focusing in the question of what conditions favor the adoption of SGM in fisheries.

Fisheries problem and the effective governance

Papers have documented that fisheries activity is facing global challenges (Hilborn 2007a; Worm et al. 2006, 2009; Grafton et al. 2006; Salas et al. 2007; Andrew et al. 2007). As was discussed by Grafton et al. (2006), several factors may lead to a decline in fisheries including inappropriate incentives, high demand for limited resources, poverty, inadequate knowledge, ineffective governance, interaction among fishers sectors, and other aspects of the environment. Here we focus on two problems, the existence of inappropriate incentives and ineffective governance.

With regard to the existence of inappropriate incentives, we mean that policies are sometimes poorly designed or inefficiently adopted. Market options like protected areas, fees, taxes, and individual transferable quotas need to be adjusted to the site conditions (Panayotou 1998; Tietenberg 2003; Degnbol et al. 2006). These policies may, however, require specialized studies. Cases have been identified where species-based management by governmental agencies has failed to stop the fisheries decline (Grafton et al. 2006, 2008; Hilborn 2007b; Ostrom 1990, 2005). And there is a consensus on the need of effective governance for the fisheries management. By *governance*, we refer to the exercise of rules and norms (understandings) to influence the behavior of resource users (Stiftung 2009; Sissenwine and Mace 2003; World Bank 1991).

Overall, neither the market approach nor state institutions alone have been universally successful in achieving sustainable long term productive use of fisheries (Degnbol et al. 2006; Grafton et al. 2006). Institutions are rarely entirely private market based or public government based; they are a mixture of private and public institutions that vary from case to case (Ostrom 1990, 2005).

A claim from previous findings and used in this research is that improvements in fisheries should align the fishers' incentives with social targets and ecosystem health (Hilborn 2007a; Degnbol et al. 2006; Grafton et al. 2006, 2008). The key point is that institutions often fail in this regard because they ignore endogenous institutions and recommend either coercion or privatization of resources to achieve policy targets (Sarker and Itoh 2003). While community-based management has been argued as the best way to rebuild and recover the small-scale fisheries (Worm et al. 2009). In SGM, fishers themselves have the decision-making responsibility. The advantage is that when successful, SGM reduces management costs and increases the certainty and legitimacy of the users' decisions (Ostrom 1990).

How to achieve common management of a CPR?

Various related models have sought to explain the CPR problem and describe how difficult it can be for individuals to reach collective benefits. We describe three models used extensively in previous research. The first model, the “tragedy of the commons” by Hardin (1968), is probably the most famous argument against common management. Hardin posits that individual’s interests goes in opposite direction of the group or community interests. When this happens, individual’s interest will work against SGM and overexploitation will be unavoidable. Gordon (1954) and other scholars stated similar arguments describing how a diverse set of resources can be overexploited (Llyod 1977; Dales 1968; Clark 1976, 1980; Dasgupta and Heal 1979; Norman 1984; Thompson 1977; Wilson 1985). For Gordon, the CPR is “anybody’s property,” to a source of wealth that is free for all but valued by no one. As consequence, the proper time to use it is now, before others use it. This argument has been used for years by economists to explain the overuse of the fisheries and the low profits of the fishers.

The second model to represent the challenge on the management of the CPR is the Prisoner’s Dilemma game. This can be thought of as a general formalization of Hardin and Gordon models to explain the CPR problem as a non cooperative where all players have complete information of the outputs, but the agreements among players are not binding while communication is forbidden or impossible (Dawes 1975; Ostrom 1990).[4] In a two player’s game, the dominant strategy is to defect, rather than cooperate, i.e. take care of one’s self. But if both players choose to defect, the resulting equilibrium

---

[4] You can find a good description of this game in Mas-Colell, Winston, and Green (1995).

leads to lower payoffs for both. In short, a rational individual strategy may lead to collectively irrational outcomes (Ostrom 1990; Campbell 1985).

The third model that explains the dynamic process by which individuals pursue a collective outcome is the called the *logic of collective action* (Olson 1965). This model considers group and individual welfare gains. Individuals may support the actions towards a common interest if they will be better off. This logical premise of having self interested and rational behavior of individuals to achieve their objectives would be sufficient to generate a collective action, though Olson wrote against such logic. He argued that rational self interested individuals will not act to achieve the common interest unless there is coercion or the number of individuals is very small.[5] This model challenged the optimism of theorists who favor the idea that individuals with common interest will pursue a possible benefit for their group (Ostrom 1990).

Overall, these three models capture the essence of the CPR problem: how free riders and opportunistic behavior presents large challenges for the management of natural resources that are classified as open access (Ostrom 2005; 1990). They are the basis for the empirical analysis carried out by Ostrom and scholars of the institutional change school.

Self governance: Importance, principles and complications

The literature about how common management can overcome the challenges of CPR management is most closely associated with the work of Ostrom (1990). She describes the principles of self governance and related complications that can arise. She

[5] Another issue was opened by defining the size of the groups and what is “very small.”

stated eight design-principles that characterize the configuration of rules devised and used by "robust," or long-enduring and stable, CPR institutions:

(1) Clearly defined boundaries that allow the exclusion of external users;

(2) Rules for the CPR use adapted to local conditions;

(3) Collective arrangements that let most users take part in the decision-making process;

(4) Effective monitoring under responsibility of the local users;

(5) A scale of graduated sanctions for users who violate community rules;

(6) Cheap and easy mechanisms of conflict resolution;

(7) Community self-determination that is recognized by higher-level authorities; and

(8) In larger CPRs, an organization in the form of multiple layers of nested enterprises, with small local CPRs at the base level.

These design principles have been used to carry out ex post analysis of how robust (long-enduring and stable) are the local institutions managing the CPR (Gautam and Shivakoti 2005).

A related framework for ex post analysis of CPR management systems has been put forth by scholars of institutional change school who have integrated Ostrom's eight design-principles in the Social Ecological Systems (SES) framework (Anderies et al. 2004; Ostrom 2007; Basurto 2008). The SES framework considers the interaction of governance, resource, and users systems to assess the "robustness," or how well the decision making process is supported. Berkes and Seixas (2005) used the SES framework to assess the resilience of the human and nature systems. A SES can be defined as a bio-geo-physical unit and its associated social actors and institutions. SESs are complex, adaptive and delimited by functional boundaries surrounding particular ecosystems and their problem context (Anderies et al. 2004). In a SES, it is necessary to describe the structure and dynamics of the relations between the system's elements, requiring a trans-disciplinary research to fit an adequate problem orientation and integrative results (Hirsch-Hadorn et al. 2008). The dynamics of the ecological and social systems whenever have been hard to address (Anderies et al. 2004).

Beyond the framework noted above, scholars have identified other specific factors that may influence the management of the CPR. Hackett, Schlager, and Walker (1994) have shown how a heterogeneous endowment creates a distributional conflict over access to CPR that may cause an SGM system to fail. Basurto (2005, 2008) discussed how community characteristics may help to mediate the conflict between collective action for the access and use of a fishery in Mexico. The size of the CPR is another characteristic that matters – as the size of the CPR decreases; the easier it may be to manage the CPR (Ostrom 1990, 2009; Berkes 2006). Another factor influencing the SGM adoption is the transaction costs. Townsend (2010) describes how high transaction costs have been an obstacle to self governance in the New Zealand fisheries.

As can be seen, there is an extensive and varied research on CPR management. However, there has been limited the work to empirically evaluate whether the conditions for the adoption of SGM are present in advance of attempts to put such a system in place. Fortunately, the theoretical underpinnings of such analysis do exist.

Predicting the likely adoption of SGM: The Ostrom conditions

Ostrom proposed six conditions (Figure 3.1) that she believed determine the *likelihood* of users to adopt changes in the use of the CPR in favor of SGM. For identification purposes, from here to the end of this dissertation, we call these the Ostrom Conditions (OCs).

> …the *likelihood* of users to adopt rule changes for the CPR use will be feasible if…
>
> (1) *'Most users' conclude they will be harmed if they don't adopt alternative rules*
> (2) *'Most users' conclude they will be affected similarly by the alternative rules*
> (3) *'Most users' highly value continuing the activity*
> (4) *Users share norms of reciprocity and trust*
> (5) *Users face low cost of information, transformation and enforcement*
> (6) *Users group is small and stable*
>
> (Ostrom 1990, 211)

Figure 3.1: Six Ostrom conditions to predict the likely adoption of rules on a common pool resource.

An assessment of the six OCs must account for the influence of the external political regime. The political regime may influence how and when the individuals use the CPR (Ostrom 1990). When the pressure of political regime is essentially nonexistent, Ostrom (1990) calls the situation a "zero condition." The zero condition may exist if the CPR is in a remote location and/or users face indifference from the political regime, such that the regime has a minimum effect on internal choices. When the de facto conditions are such that the zero condition holds, the analysis is simplified since it avoids external distortions on the assessment of the OCs. According with the description presented in Chapter I, this research assumes that zero condition holds in the study site.

It is important to distinguish these six OCs from the eight design principles mentioned earlier. The main difference is that design principles are *ex-post* and are used to frame a systematic evaluation of cases in place. The six OCs offer a framework for *ex-ante* analysis since they reflect the potential of CPR users to adopt changes in the rules for management of the resource.

Predicting a likely adoption of SGM: Other approaches

Before explaining how we will use the OCs to carry out our analysis, we will mention that two alternative frameworks for carrying out an ex ante assessment of the potential for SGM have been proposed. In the first one, Ostrom (1999, 2009) proposed the use of cost benefit analysis (CBA) to assess how easy it is for CPR users to adopt SGM. The second approach has been derived from the SES framework.

The principle behind the CBA approach is that CPR users are expected to favor SGM if the expected benefits are greater than the cost. Unfortunately, if the specific rules to be implemented are not clearly defined, CBA may not be a good approach. CBA would be inaccurate if the CPR users place more weight on the costs, which are probably quite tangible, than the probable benefits, which are more speculative (Ostrom 1999). Moreover, the data to measure the benefits is hard to obtain.

In the second approach, two papers that have proposed the use of SES framework to analyze how easily SGM can be adopted. Dietz, Ostrom, and Stern (2003) suggest five characteristics for an easy achievement of common governance (Figure 3.2, 2nd column). Ostrom (2009) proposed ten second-level variables (Figure 3.2, 3rd column) to identify their positive or negative effect on the likelihood of users to engage in SGM.

There are similarities and discrepancies between the criteria used in previous research (2nd and 3rd columns in Figure 3.2) and the one used in this research (1st column in Figure 3.2). On the similarities, the relevance of reciprocity and trust in these three approaches is clear, though less explicit in the third column as social capital and collective-choice rules. The second similar point is that all frameworks refer to the low cost of monitoring and enforcement, characteristics reemphasized in the second column and not clearly identified in Ostrom (2009). Third, all three refer to the size and stability of the users group; more stable and small user groups are more likely to adopt SGM.

Ostrom (1990)	*Dietz, Ostrom, and Stern (2003)*	Ostrom (2009)
(1) 'most users' conclude that they will be harmed if they do not adopt new rules (2) 'most users' conclude that they will be affected in a similar way by the new rules (3) 'most users' highly value continuing the activity (4) users share generalized norms of reciprocity and trust (5) users face low monitoring and enforcement cost (6) users are a small and stable group	(1) low monitoring cost; (2) changes in resource technology, population, and socio economic conditions take place at moderate rates (3) users have direct and frequent communications and trust each other (4) outsiders can be excluded at low cost (5) users themselves can monitor and enforce their collective agreements	(1) size of resource system (2) productivity of system (3) predictability of system dynamics (4) resource unit mobility (5) number of users (6) leadership (7) norms/social capital (8) knowledge of the SES (9) importance of resource to the users (10) collective-choice rules

Figure 3.2: Proposed characteristics to analyze the potential adoption of self governance.

The main difference between the three frameworks in Figure 3.2 is that Ostrom (1990) conditions focus on users' opinions to predict a change in the use of the CPR, whereas Dietz et al. (2003) and Ostrom (2009) focus on the relationships among systems (users, resource and institutions). Additionally, it looks that Dietz, Ostrom, and Stern (2003) proposed characteristics do not includes the predictability of the system dynamics (probable output and rules effects) neither on the value of the activity-resource to the users. Ostrom (2009) as well, excludes the monitoring and enforcement costs but includes other characteristics such as leadership and knowledge of the system. Overall, 2nd and 3rd columns of Figure 3.2 analyze the interaction between systems rather than focusing on the users' predisposition to adopt SGM. While all three approaches offer insights, we adopted the OC approach because it can be carried out based on the opinion of the fishers gathered through surveys; therefore it is less likely to be based on the subjective interpretation of an analyst carrying out the assessment.

Finally, we should note that recently experimental economics methods have been used to explore trust and cooperation issues among the CPR users (Cardenas and Carpenter 2008). Experimental economics has potential for gathering insights on some dimensions of the barriers confronting SGM. Such analyses need to be well suited in a comprehensive model, including all six OCs, to predict the likely adoption of SGM.

Wrapping up, the research on CPR problems has been extensive. There is empirical evidence on what conditions favor SGM and a better understanding of the characteristics and complications confronting successful cases. Through the years, new ideas and methods have been developed on these matters, though most of the empirical research has focused on the *ex-post* analysis rather than the *ex-ante* potential for self governance. In the next section, we develop the approach used to evaluate *ex-ante* the potential for SGM in the fishery.

Modeling approach

The model used in this chapter is based on the six conditions identified by Ostrom (1990) presented in Figure 3.1. Ostrom's basic proposition is that the probability of a community successfully adopting SGM is a function of the six conditions over all the fishers' communities. Each of the OCs, however, is actually a function of the perspectives of the fishers that make up the community. Thus, the i^{th} condition (OC_i) is considered an aggregation of the form.

$$OC_i = g_i(OC_i^1, OC_i^2, .., OC_i^n) \tag{2.1}$$

where OC_i^j is the i^{th} OC for the j^{th} fisher, j=1,…, n. The challenge for *ex-ante* evaluation is that neither OC_i nor OC_i^j can be directly observed. Consequently, the first question that must be answered is how to assess the preferences for a likely adoption of the self governance? Since neither OC_i nor OC_i^j can be observed, a series of questions were developed that were assumed to be correlated with OC_i^j. These questions were then asked in a survey. The answers to the questions were used to create an index, $\hat{OC}_i^j$, that is a function of the responses to the questions,

$$\hat{OC}_i^j = h_i(q_{ij}^1, q_{ij}^2, .., q_{ij}^m) \tag{2.2}$$

where q_{ij}^k represents the j^{th} fisher's response to the k^{th} question, k=1,…, m, for the i^{th} OC. This process is repeated with different set of questions for each condition.

To arrive at a good set of questions, each OC_i was expressed in slightly different language that could be used in the survey. This language adjustment is important for two reasons. First, we need to adjust each condition to the language of the fishery. Second, since in our case study, the education level of the fishers is low, and we need a “working concept” to guide development of questions in words easily to understand by the fishers. Overall, the adjustment helped us identify the elements of each OC_i. The process is explained below in the section named “the questionnaire.”

Finally, the answers gathered from the questions were aggregated in the resulting index $\hat{OC}_i^j$. This index is a measure of the true but unobserved OC_i^j . The process to obtain the index is presented below in the section named “data aggregation.”

Data

As discussed in Chapter II, the data were gathered from a survey on the Lázaro Cárdenas Reservoir (LCR). Here, we focus on the questions that are specifically made to assess the predisposition of the fishers to adopt SGM. From a total of 148 fishers in three communities, 111 usable surveys were obtained. Three sets of questions were formulated, all designed to have a Likert answer: (1) Indirect positive questions (Q_i^k), designed to be positively correlated with the corresponding OC_i; (2) indirect negative questions ($-Q_i$), designed to be negatively correlated with one specific question of Q_i^k ; and (3) direct questions (DOC_i^j) designed to be positively correlated with OC_i. Each indirect negative question ($-Q_i$), is basically a repetition of one question of the set Q_i^k but the answers is adapted so the Likert scale is reversed.

The questionnaire

Formulating the survey, each condition OC_i was slightly modified to obtain an “operationalizable concept.” This adjustment useful let us to identify elements of each OC_i and arrive at questions in a language easy to understand by the fishers. Every condition has a discussion explaining the changes.

Each question answer was set up as a Likert scale of 1 to 5. For most of the questions, 1 = *strongly disagree* and 5 = *strongly agree*. In the middle, the option 3 = *don’t know* or *no change* was carefully assessed in the survey and the following strategy was used to encourage the respondents to give non-neutral responses. First, the “don’t know” option was not presented to the fisher. Second, only two options were presented (e.g. agree or disagree). Third, once the fisher has chosen his option (e.g. agree), he was asked for another two options (i.e. agree vs strongly agree). Alternatively, if the fisher did not choose any option in the second step, did not agree with the options, or directly said that he did not know, the surveyor marked the option 3. This process was designed to overcome the *neutral responses bias*, a frequent problem in Likert answers (Mogey 1999; Trochim 2006). This effect is also referred to as the central tendency bias, a problem that arises when the survey respondents avoid extreme response categories.

When using Likert scales we also was careful to avoid the *acquiescence bias* or the problem when the respondents are basically agree with every statement and tend to appear as a "normal" person. This problem was avoided by designing questions with a balanced equal number of positive and negative statements (Carifio and Perla 2007).

The last problem to avoid is the *social desirability bias*. This bias arises when individual mark his answers in a socially acceptable fashion or with a favorable or light opinion. To avoid this bias, we address several questions for every $OC_{i,}$ the indirect positive questions Q_i^k . By repeating questions around the same topic, it is possible to capture a probable contradiction or divergence to a light answer (Carifio and Perla 2007). This is the reason why is not recommended to use only one question like the direct questions DOC_i^j.

Finally, some questions although have different response categories (e.g. *Very good = 1, … , Very bad = 5* or *Increase = 1, … , Decrease = 5*). Nonetheless, they share the same scale in that higher numbers indicate greater agreement or inclination towards the SGM adoption. Thus, it will make feasible the aggregation of the Likert answers.

Now reviewing the questions for the OCs; the $OC_{1,}$ *"Most users" conclude they will be harmed if they do not adopt alternative rules* explores the attitudes of the CPR users (i.e. fishers) about the consequences of doing nothing to end the current management scheme governing the CPR (i.e. their perceived future). Ostrom (1999) argues that those whose beliefs are consistent with OC_1 heavily weigh negative events in their decision making processes.

We split the condition into three parts. First, in the context of the LCR, perceived "harm" can be equated with a *loss* in harvests. Second, we propose the use of *maintain* instead of "do not adopt;" and third, the use of *current* instead of "alternative rules." This adjustment leads to the operationalizable version of OC_1 and helps us to develop questions that are easy to understand by the fishers and uncomplicated to aggregate.

The questions used to measure OC_1 are presented in Table 3.1. For example, question 1 asks about current rules instead of "alternative rules." As well, the perceived harm is translated as an increase/decrease in the catch. The use of "next year" seeks to avoid ambiguity on the temporal assessment. Notice that question 1 explores the effect of doing nothing to modify the status quo. The last row presents the question adapted to have a negative answer. This question was designed to contradict the indirect positive question 2. The asterisk (*) in question 1 indicates that the scale was reversed (i.e. 2 was converted to 4 and 1 to 5) to have an equivalent direction on the responses. It will make possible the aggregation of indirect positive questions 1 and 2.

Table 3.1: Indirect and direct questions related to Ostrom condition one (OC_1).

Original OC_1	"Most users" conclude they will be harmed if they do not adopt alternative rules		
Working statement OC_1	*"Most fishers" conclude they will lose harvest if they maintain the current rules*		
Direct question DOC_1	1.	Fishing will decrease if strict fishing rules are not adopted?	1.Strongly disagree 2.Disagree, 3.Don't know 4.Agree, 5.Strongly agree
Indirect positive Q_1^k	1.	If the *current rules* remain for the next year, my catch will (*)	1.Increase, 2.May be increase 3.Don't know, 4.May be decrease 5.Decrease
	2.	How much do you agree or disagree with each statement? Do you favor the adoption of strict management rules (e.g. stop fishing bass)	1.Strongly disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree
Indirect negative $-Q_1$	3.	How much do you agree or disagree with? The *current fishing rules* are very strict	1.Strongly disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree

The OC_2, *"Most users" conclude they will be affected similarly by the alternative rules.* This condition, also explores the expectations of the fishers of LCR. To make OC_2 operational, we modify two parts of the condition. First, we restate "similar affect" as management rules will not affect one person more than another (e.g. by losing harvest). Second, because alternative rules of self governance are not yet specified, we avoid the use of "alternative rules." Instead we use the phrase *a set of rules.*

The adjusted OC_2 and the related questions are presented in Table 3.2. Again, similar to OC_1, the asterisk (*) in question 4.4 indicates that the scale was sorted to have equivalent direction responses and then make it possible to aggregate with the rest of the answers. Finally, in the last row the indirect negative question was designed to contradict the indirect positive question 4.1.

Table 3.2: Indirect and direct questions related to Ostrom condition two (OC_2).

Original OC_2	"Most users" conclude they will be affected similarly by the alternative rules	
Working statement OC_2	*"Most fishers" agree with rules that affect all fishers similarly*	
Direct question DOC_2	2. How much do you agree with a fishing rule that equally affect all fishers?	1.Strong disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree
Indirect positive Q_2^k	4. How much do you agree/disagree with each statement? 4.1. Most cooperative agreements equally affect all fishers 4.2. A good set of rules imply hard work of all fishers 4.3. A good set of rules imply sacrifice from all fishers 4.4. The cooperation among all fishers is not important (*)	1.Strong disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree
Indirect negative $-Q_2$	5. How much do you agree/disagree with? 5.1. Most of the cooperative agreements are made for only few fishers	1.Strong disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree

The OC_3, *"Most users" highly value continuing the activity*. This condition uses the fisher's perception to evaluate the importance of the activity in the eyes of the fisher. To modify OC_3 we analyze two parts of the condition. First, "value" can be complemented with *the benefits derived from* the fishery. Second, we extend the proposition by adding *hence they want continue doing it*, to capture the value of continuing to fish. Accordingly, the working concept of OC_3 and its related questions are presented in Table 3.3. Again, the negative question 8.1 was designed to contradict the indirect positive question six.

Table 3.3: Indirect and direct questions related to Ostrom condition three (OC_3).

Original OC_3	"Most users" highly value continuing the activity	
Working statement OC_3	*"Most fishers" highly value the benefits derived from the fishing activity, hence they want to continue*	
Direct question DOC_3	3. If someone in your family decides to be a fisher, the value for you will be…	1.Very low, 2.Low, 3.Don't know 4.High, 5.Very high
Indirect positive Q_3^k	6. All things considered, how satisfied are you working as a fisher?	1.Not at all satisfied 2.No satisfied, 3.Don't know, 4.Satisfied, 5.Very satisfied
	7. How much do you agree/disagree with each statement? 7.1. I want my sons and grandsons to be fishers 7.2. I teach my son (or I will teach if I have one) how to fish 7.3. I am very proud of being a fisher	1.Strongly disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree
Indirect negative $-Q_3$	8. How much do you agree/disagree with? 8.1. I would like to stop fishing if I find a job with the same salary	1.Strongly disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree

The OC_4, *Users share norms of reciprocity and trust.* This condition assesses the two critical concepts of the condition: reciprocity and trust as they are perceived by the fishers. To modify OC_4 we examine the two parts. First, “reciprocity” was considered to be synonymous with cooperative behavior, so “reciprocity” is replaced by cooperative behavior among the fishers. The resulting OC_4 working statement and the direct and indirect questions are presented in Table 3.4. In this table, the indirect negative question 10 was designed to contradict the indirect positive question 9.1.

Table 3.4: Indirect and direct questions related to Ostrom condition four (OC_4).

Original OC_4	Users share norms of reciprocity and trust	
Working statement OC_4	*Fishers share norms of cooperation and trust*	
Direct question DOC_4	4. The trust among the fishers is…	1.There is no trust at all 2.Not good, 3.Don’t know 4.Good, 5.Very good
Indirect positive Q_4^k	9. How much do you agree/disagree with each statement? 9.1. Very often, you do favors for other fishers 9.2. Most fishers share experiences & knowledge with you 9.3. You trust your community neighbors and fishers 9.4. You trust the fishers of other communities	1.Strongly disagree 2.Disagree, 3.Don’t know, 4.Agree, 5.Strongly agree
Indirect negative $-Q_4$	10. How much do you agree/disagree with? 10.1. Doing a favor among fishers is something very rare to see	1.Strongly disagree 2.Disagree, 3.Don’t know, 4.Agree, 5.Strongly agree

The OC_5, *Users face low cost of information, transformation and enforcement.* This condition analyzes the fisher’s opinion with regard to the cost of monitoring and enforcement, a crucial characteristic to reach self governance. To modify OC_5 we study two parts of the condition. First, for “transformation” we indicate a way to use the information to monitor and enforce the fishing rules. Second, we add *to get* information and delete “of.” Thus, OC_5 becomes “users” faces low cost to get information for the monitoring and enforcement. The questions to evaluate OC_5 are presented in Table 3.5. Here, the indirect negative question 12 was designed to contradict the question 11.2.

Table 3.5: Indirect and direct questions related to Ostrom condition five (OC_5).

Original OC_5	Users face low cost of information, transformation and enforcement	
Working statement OC_5	*Fishers face low cost getting information to monitor and enforce the rules*	
Direct question .DOC_5	5. Monitoring if fishers follow the fishing rules is?	1.Very expensive 2.Expensive, 3.Don't know 4.Cheap, 5.Very Cheap
Indirect positive Q_5^k	11. How much do you agree/disagree with each statement? 11.1. If you violate a rule, you have fear of being punished 11.2. You can easily see how other fishers harvest 11.3. In a cooperative agreement (e.g. no fishing bass). It's easy to see if fishers obey the agreement 11.4. It is easy to detect if outsider fishers are fishing	1.Strongly disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree
Indirect negative $-Q_5$	12. How much do you agree/disagree with the statement? 12.1. If a fisher harvests a lot, the other fishers hardly know it?	1.Strongly disagree 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree

The OC_6, *Users group is small and stable* looks at the fisher's judgment with regard to the number of users group along the time. The OC_6 does not require any modification but the challenge is to assess the stability of the group size. The problem is that it is hard to assess stability without a specific time frame. We take a period of five years to assess OC_6. By adding the time frame, this condition will be: "Users" group has been small and stable during the last 5 years. Table 3.6 presents the questions; we only use one indirect question to assess OC_6. Before the survey it was expected that this condition could be assessed with records of the cooperative members. Unfortunately, there is not a reliable record on the number of fishers during the last five years in the reservoir. Hence we had no choice but to ask for the fishers' perceptions. The $-Q_6$ question was designed to contradict the indirect positive question 13.1.

Table 3.6: Indirect and direct questions related to Ostrom condition six (OC_6).

Original OC_6	Users group is small and stable	
Working statement OC_6	*Fishers group in LCR have been small and stable in the last 5 years*	
Direct question DOC_6	6. On last 5 years, the number of fishers has…	1.Increased a lot 2.Increased 3.No change 4.Decreased 5.Decreased a lot
Indirect positive Q_6^k	13. How much do you agree/disagree with the statement? 13.1. 5 years ago, the reservoir had more fishers than it has today	1.Strongly disagree, 2.Disagree, 3.Don't know, 4 Agree, 5.Strongly agree
Indirect negative $-Q_6$	14. How much do you agree/disagree with the statement? 14.1. The lake never had so many fishers as it has today	1.Strongly disagree, 2.Disagree, 3.Don't know, 4.Agree, 5.Strongly agree

Data aggregation

This section explains how responses to indirect positive questions of Tables 3.1 to 3.6 were aggregated to derive the indices $\hat{OC}_i^j$. The first step in aggregation was to ensure that the answers had the same scale and that they have the same response direction, i.e. a scale from 1 to 5 with the level of agreement with SGM growing for higher numbers. As it was explained before, the answers to the questions indicated with *'s in OC_1 and OC_2 were rescaled so that all responses have the same direction. Further, reliability and validity concepts were used in order to achieve scientifically acceptable results.

- *Validity and reliability*

Internal validity and reliability of the data are important because they are together at the core of what is accepted as scientific evidence. *Reliability* has to do with the quality of measurement. A measure is reliable if it would give us the same result over and over again. *Internal validity* refers to the validity of inferences (Russell 2006), and it holds if a causal relation between two variables -*If X, then Y*- is properly demonstrated (Jimenez-Buedo and Miller 2009). It is more related to the cause-effect of the variables. Validity is analogous to accuracy while reliability is analogous to precision. If a measure is not reliable, it cannot be valid. Reliability however, is a necessary but not sufficient condition for validity (Jimenez-Buedo and Miller 2009; Russell 2006).

In this research, reliability was useful to eliminate inconsistent answers and get a reduced set of 74 observations. Validity was useful to derive a consistent $\hat{OC}_i^j$ index.

- Reliability

Reliability is the consistency of either a set of measurements or of a measuring instrument (Jimenez-Buedo and Miller 2009; Russell 2006). Classical theory defines reliability as the ratio of the *true score* variation and the *observed score* variation, but *g*iven the difficulties to calculate the true score, different methods have been proposed to test reliability (Cortina 1993). Here we use the following to test for a j^{th} respondent's reliability. If the answer ($-q_{ij}$) to the question $-Q_i$ (indirect negative), is positively correlated with his answer (q_{ij}^k) corresponding to the question Q_i^k (the k^{th} indirect positive), then reliability fails.

The correlation between $-q_{ij}$ and q_{ij}^{k} for each condition i^{th}, used to check reliability is presented in Table 3.4. Looking the second row (the raw data, n=111), most of the correlation values are negative, yet some are close to zero and correlation in condition six is actually positive, indicating the need for a close check of reliability.

To improve reliability, we eliminate observations by dropping fishers who gave inconsistent answers. For example, for OC_3 each respondent was asked: How satisfied are you working as a fisher? And then also asked whether he agreed with the statement: I would like to stop fishing if I find a job with the same salary. Reliability would be satisfied if the respondent gave an answer of 4 to the first question and 2 to the second. If both question have 2 (or 4), we count this as inconsistent answer.

Checking every fisher on all OC_i, each fisher had a maximum of six chances to give a contradictory answer, indicating unreliability. On average each fisher was inconsistent in 1.95 OCs. Only a few fishers did not contradict themselves at all while others contradicted themselves five times.

Rounding the average to two, the criteria to eliminate the non reliable observations was: *If the fisher has more than two contradictory answers, the observation is dropped from the analysis*.[6] With this criterion we eliminate 37 individuals and get a more reliable data base of 74 observations. The second row (where n=74) of Table 3.7, presents the correlations for the revised smaller data set. Using OC_3 as an example, the correlation grows from -0.11 to -0.30 and condition OC_6 switch signs from 0.06 to -0.12.

[6] In a sort of sensitivity analysis, another option was to use 3 inconsistent answers. That is, if a fisher contradicts in more than three OCs, the number of observation dropped is 12 reducing the data to 99 observations.

Table 3.7: Correlation on answers to indirect positive ($\boldsymbol{q_i^k}$) and indirect negative ($-\boldsymbol{q_i}$) questions, before (n =111) and after (n =74), reliability improvement.

	$-q_1$	$-q_2$	$-q_3$	$-q_4$	$-q_5$	$-q_6$
(n = 111): $q^k{}_i$	-0.03	-0.18	-0.11	-0.10	-0.01	0.06
(n = 74): $q^k{}_i$	-0.20	-0.51	-0.30	-0.21	-0.21	-0.12

- Validity

Having revised our data to improve reliability, the next task is to establish a valid index $\hat{OC}_i^j$. Validity in our case would hold *if* $\hat{OC}_i^j$ *implies* OC_i^j for all *i, j*. Recall, we seek to aggregate indirect positive questions for each OC to form a set of indices $\hat{OC}_i^j$. Since the Q_i^k questions were designed to be positively correlated with OC_i, the index $\hat{OC}_i^j$ created using the corresponding answers q_{ij}^k is expected to be correlated with OC_i. Further, a direct question DOC_i^j was also designed to be positively correlated with OC_i. Since $\hat{OC}_i^j$ and DOC_i^j are both designed to be positively correlated with OC_i, if $\hat{OC}_i^j$ and DOC_i^j are negatively correlated, internal validity does not hold.

Consider OC_4 an example. Summing each fisher's answers q_{4j}^k we could form an index for condition four. We propose as a measure of the index's validity the extent of its positive correlation with the answer to the direct question DOC_4^j. If a positive correlation exists, such index for condition four appears to be a good estimator of OC_4.

Using the data set (n=74), a positive correlation was found[7] between DOC_i^j and the index formed by adding the fisher's answers q_{ij}^k . Although the resulting positive signs, we detect two problems using this aggregation index. First, the interpretation was difficult because we lose the original scale 1 to 5 (i.e. what is the meaning of passing from value 14 to value15?). Second, by adding very similar questions some degree of collinearity was expected.

To solve this aggregation problem, answers q_{ij}^k were weighted with the first component of a principal component analysis (PCA). PCA[8] is a statistical technique used for data reduction and to learn about the structure of the data (Jolliffe 2002). PCA transforms a possibly correlated set of variables into a new set of values of uncorrelated variables. This new set of values is called the principal components. Applying PCA we can reduce the size of the data since the number of components is less than the number of variables. But also, since the transformation captures the variance in a new coordinate system, it makes the most of the available information to analyze the structure of the data. The first coordinate or first principal component (PC1) captures the greatest variance, accounting for as much of the variability in the data as possible. The second greatest variance is located in the second coordinate, constrained to be uncorrelated (orthogonal) with the first one. The same applies in the third coordinate, and so on, up to the last component, which has the smallest variance (Jolliffe 2002; Johnson and Wichern 2002; Theil 1971).

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[7] A similar positive correlation was also found using the full data set (n=111).
[8] The PCA output estimations and a brief explanation of the PCA procedure is presented in Appendix B.

Using the first component (PC1), on every Ostrom condition and summing for the k questions we obtain the index $\hat{OC}_i^j$, as indicated in equations (3.3) and (3.4).

$$\hat{OC}_i^j = \sum_{k=1}^{m} \delta_i^k * q_{ij}^k \tag{3.3}$$

And $$\delta_i^k = \frac{PC1_i^k}{\sum_{k=1}^{m} PC1_i^k}\ . \tag{3.4}$$

where δ_i^k is the weighting vector so that $\sum_{k=1}^{m} \delta_i^k = 1$. It is a standardized linear combination for every OC_i index.

The resulting aggregation improved the OCs indexes. The correlation between $\hat{OC}_i^j$ and DOC_i^j practically remains the same comparing a simple average and the aggregation after using PC1 (see third and fourth rows in Table 3.8).

Table 3.8: Correlation on answers to direct Ostrom condition (DOC_i) questions and Ostrom condition index $\widehat{OC}_i^j$, before (simple sum) and after (with PC1), validity improvement.

	DOC_1	DOC_2	DOC_3	DOC_4	DOC_5	DOC_6
(n=111) $\hat{OC}_i^j$ simple sum	0.27	0.08	0.27	0.11	0.06	0.38
(n=74) $\hat{OC}_i^j$ simple sum	0.309	0.068	0.441	0.260	0.146	0.461
(n=74) $\hat{OC}_i^j$ with PC1	0.309	0.076	0.435	0.215	0.145	0.461

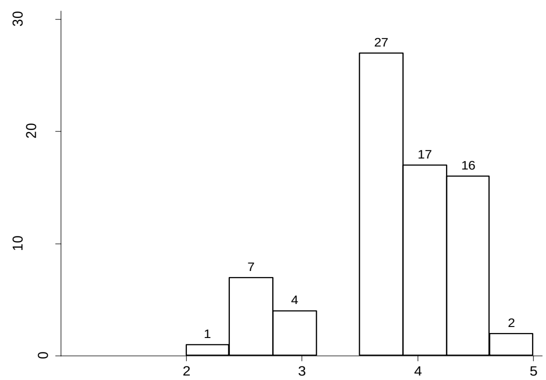
There are several advantages by weighing with the PCA weights δ_i^k. First and the most important is that, it allows us grouping a set of probably correlated answers derived from every Ostrom condition. This weighting makes feasible grouping highly similar questions. Second, it allows us to retain an index with a scale 1 to 5, consistent with our

Likert scale questions. Third, in the range of 1 to 5, the indices can take on continuous values. This change permits, with some caution, the use of the mean and standard deviation to analyze our measures of the OCs. Recall, the recommended measure to analyze of the Likert scales is the median (Stevens 1946; Mogey 1999). Overall, these changes make easy the interpretation of the Likert values and serve as an intermediate step in a more complex data analysis (Härdle and Simar 2007; Johnson and Wichern 2002).

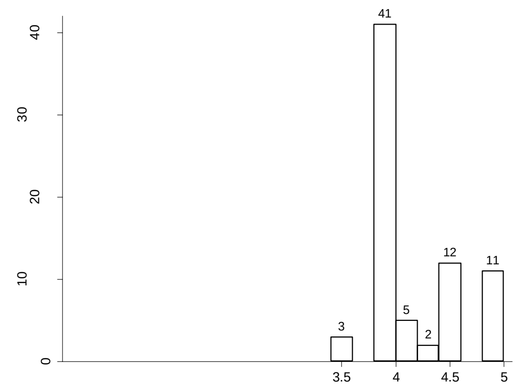
Finally, as a result of this aggregation we got our final data set containing 74 measures of the LCR fishers' predisposition toward SGM, counted over the six OCs. Table B.3 of the Appendix B presents the frequencies of the set of answers that form the six OC_i indexes.

Results

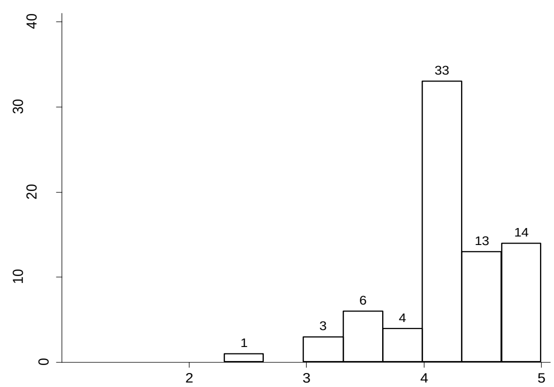
The histograms presented in Figure 3.3 are estimated from the six indexes $\hat{OC}_i^j$. With exception of OC_6, all of the histograms lie almost entirely between 3 and 5. Recall, "don't know" is the half way between 2 and 4 only and it is treated as a neutral response. Overall, from Figure 3.3 we observe a high predisposition towards SGM.



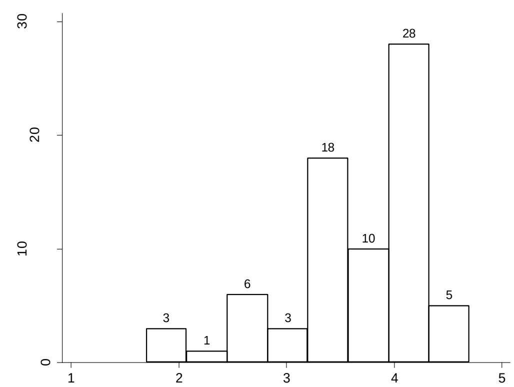
OC_1 *"Most fishers" conclude they will lose harvest if they maintain current rules*



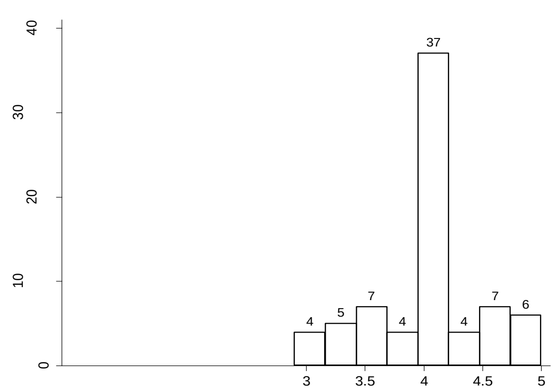
OC_2 *"Most fishers" agree with rules that affect all fishers similarly*



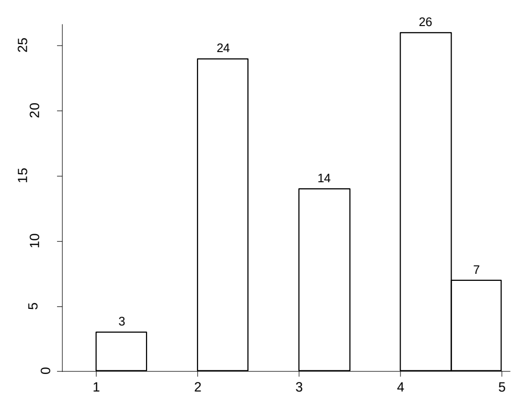
OC_3 *"Most fishers" highly value the benefits derived from the fishing and they want to continuo*



OC_4 *Fishers share norms of cooperation and trust*



OC_5 *Fishers face low cost getting info to monitor and enforce the rules*



OC_6 *Fishers group in LCR have been small and stable*

Figure 3.3: Frequencies of the six Ostrom condition (OC_i) indexes.

Note: 1: Strongly disagree, 2: Disagree, 3:Don't know, 4: Agree, 5: Strongly agree.

The descriptive statistics from the six conditions is presented in Table 3.9. In this table, the mean, the mode and the median confirm the high likelihood to adopt the SGM. The SGM in the table is the average of all the index values over all the fishers in LCR.

Table 3.9: Descriptive statistics of Ostrom condition indexes (OCi) and average.

	Mean	Std Dev.	Mode	Median	Min	Max
OC_1 index	3.73	0.65	3.50	3.50	2.00	5.00
OC_2 index	4.22	0.37	4.00	4.00	3.40	5.00
OC_3 index	4.20	0.51	4.00	4.26	2.26	5.00
OC_4 index	3.57	0.65	4.00	3.65	1.66	4.72
OC_5 index	4.01	0.47	4.00	4.00	2.90	5.00
OC_6 index	3.12	1.10	4.00	3.00	1.00	5.00
OC_i (average)	3.81	0.28	3.82	3.78	3.25	4.69

The analysis of each condition is derived from the Figure 3.3 and the Table 3.9.

The $OC_{1,}$ "*most fishers" conclude they will lose harvest if they maintain the current rules*; falls mainly between 3.5 and 4.5 but it is skewed to the left. Overall, the distribution indicates that "most of the fishers" agree that the status quo is not serving their best interests and will result in falling harvests. Thus, commercial fishers in LCR tend to favor the adoption of stricter fishing management rules.

The condition $OC_{2,}$ "*most fishers" agree with rules that affect all fishers similarly;* evaluates the agreement on a set of rules in general, not a specific set of rules that define the SGM. Avoiding the use of specific rules was intentional because such rules did not exist at the study site at the time that the survey was conducted. However, it is possible to gather information from responses to condition two. Values for OC_2 fall between 3.5 and 5, but mainly around 4. Overall, most of the fishers in LCR agree with cooperative agreements that equally affect all the fishers. Such rules imply a desire for equal treatment and our data may suggest that fishers would accept sacrifice and hard work if the rules are accompanied by cooperation.

In $OC_{3,}$ "*most fishers" highly value the benefits derived from the fishing activity, hence they want to continue;* the value perceived for the fishers could reflect something more than just profit. Therefore, the formulated questions opened the possibility of a general conception of the benefits. It includes a general frame of values derived from the activity. The responses were clear to the questions set; most of the respondents are satisfied and proud of being a fisher and most of them want their next generation to be a fisher. In Figure 3.3 the responses are concentrated between 4 and 5. The relative likelihood that fishers value the benefits derived from the activity is certainly high.

In condition $OC_{4,}$ *fishers share norms of cooperation and trust;* notice the word "fishers." It doesn't mean a general agreement, but the existence of cooperation and trust in the community. The distribution of OC_4 falls mainly between 3.5 and 4.5 (Figure 3.3), although there are 13 observations with indices around 2 and 3. From the data, we find that for the most part the fishers agree that there is an environment of trust, but the data suggest that this may be an area of some concern. If, for an SGM system to succeed trust among the fishers must be very strong and universal across the resource users, then the responses to this OC would suggest some room for concern.

For OC_5, *fishers face low cost getting information to monitor and enforce the rules;* the distribution centered at 4. Exactly half of the sample falls at 4. This implies that fishers tend to agree that monitoring and enforcing the rules would not be costly;

although there is a wide dispersion between 3 and 5. One complication in this regard is that currently the monitoring and enforcement cost is close to zero. Thus, they may not have a good idea how the cost is.

Interestingly, the fishers overwhelmingly say that they have a way to punish violators of cooperative agreements. They agree that it is easy to detect violators and see how much other fishers catch, thus they argue that implementing a monitoring system would be easy. Indeed, the fishers have fear of being punished and in El Palmito and Las Delicias some fishers had received a social condemnation or disapproval because they fished during the closed season. The penalty was exclusion from the fishing cooperative. Such nonmonetary punishment seems to work. However, from the interviews with leaders in these communities and the president of each fishing cooperatives, such penalties have rarely been used and are decided on a case by case basis.

Finally OC_6, *fishers group in LCR have been small and stable during the last 5 years;* indicates that the fishers group in the study site is small, but not stable. One single question was used to measure this condition and the results were clear on the size, but not on stability. The distribution is a bimodal, with roughly the same number of observations falling at “agree” as at “disagree.” Further, the records of registered fishers in every cooperative are not complete and the leaders recognize the limits to account for all current fishers. The complication may be due that the fishers easily rotate from one activity to another, especially in Las Delicias and La Victoria where the livestock and agricultural activities offer the opportunity of alternative income. In these communities the people can be a fisher, but also they can grow corn or emigrate from the region. Most of the young people emigrate to study in the nearby cities or go to work in USA, but several of such emigrants may return and work as fishers.

Under these considerations, maybe the best assessment about stability of LCR fishery is that fishers don't know. Nearly half of the respondents indicated that they do not know if the fishers group has been stable. This is consistent with the dispersion of OC_4; if a fisher does not even know whether the number of fishers has been stable over time, it seems less likely that he would tend to trust the other fishers as a group.

A general measure for each community is presented in Table 3.10 to compare the potential for SGM on every community. Las Delicias has the largest index, but the differences among the three communities is small and all they have an average mean and median around 3.8, a high value that favors the likelihood for SGM adoption.

Table 3.10: Mean and median of Ostrom condition indexes on fishing communities.

	Las Delicias		**El Palmito**		**La Victoria**	
	Mean	Median	Mean	Median	Mean	Median
OC_1 index	3.7	3.5	3.9	4.0	3.4	3.5
OC_2 index	4.2	4.0	4.3	4.0	4.2	4.0
OC_3 index	4.3	4.3	4.1	4.1	4.2	4.3
OC_4 index	3.7	3.7	3.4	3.5	3.5	4.0
OC_5 index	4.0	4.0	4.0	4.0	4.1	4.0
OC_6 index	3.3	4.0	2.7	2.0	3.5	4.0
OC_i (average)	3.9	3.8	3.7	3.7	3.8	3.8

Overall assessment

Pulling together the six conditions, we have a general assessment of the potential for self governance in LCR. Averaging the means yields a global mean of 3.81[9] on the scale of 1 to 5; it means that fishers tend to favor SGM. A composite view of the six

[9] The mode was 3.82 and the median 3.78

conditions is offered in Figure 3.4, where a polygon close to the border line indicates a high inclination of the fishers toward the adoption of SGM.

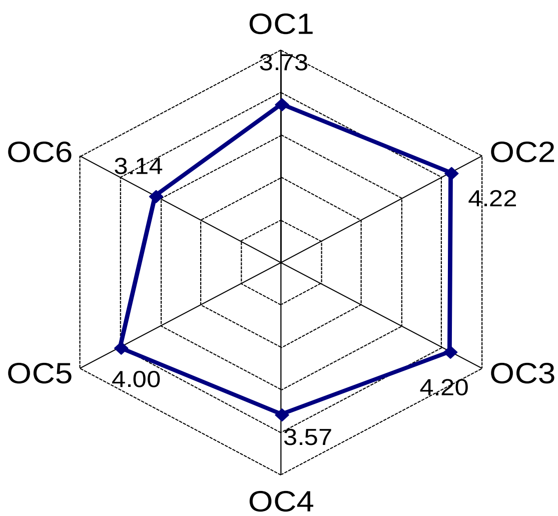


Figure 3.4: A joint representation of the six Ostrom conditions indexes.

The frequency and distribution of the average OCs shows substantial agreement for a likely adoption of self governance but also some areas of concern. The Figure 3.5 presents a histogram of the fishers' averages of the six conditions where the distribution is grouped around 3.75, indicating a high potential for SGM.

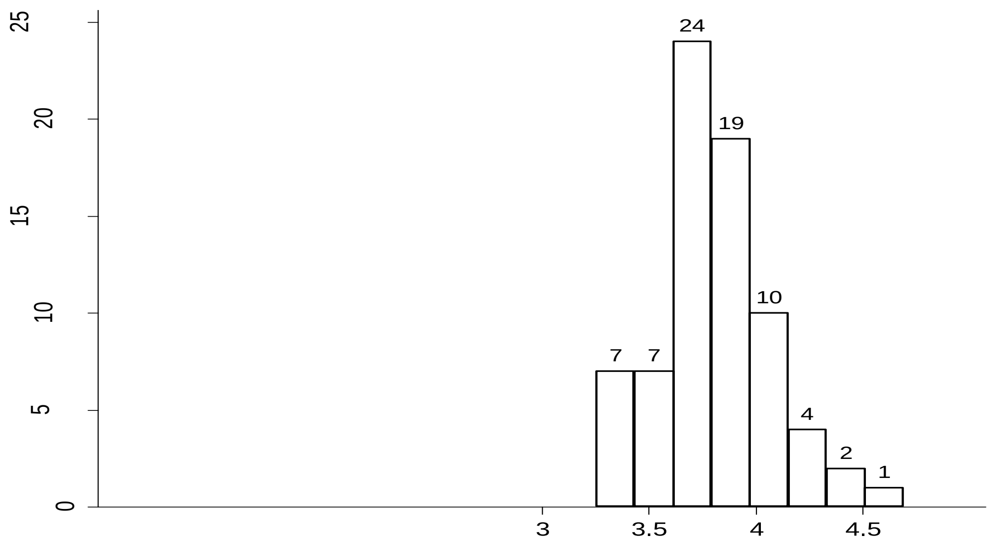


Figure 3.5: Frequencies of Ostrom condition (OCs) average index.

The final assessment is given by the relationship between the potential for SGM and the fisher's revenue (Figure 3.6). At glance, the correlation is -0.11, negative but not statistically significant.[10] While the fishers' revenue increases, the likelihood of adopt self governance virtually stay constant, hence there is no relationship. As we will discuss more carefully in Chapter V, our data results suggest a relationship where the potential for SGM is not related with Hardin's (1958) prediction that individual interest and community interests tend to be inversely related.

[10] The t-value for the correlation is 0.91. It is not significant at 95% level. Making the same correlation test between SGM and the median value, the result was essentially the same. The correlation was -0.13 and the t-value was 1.15, not significant at 95% of confidence level.

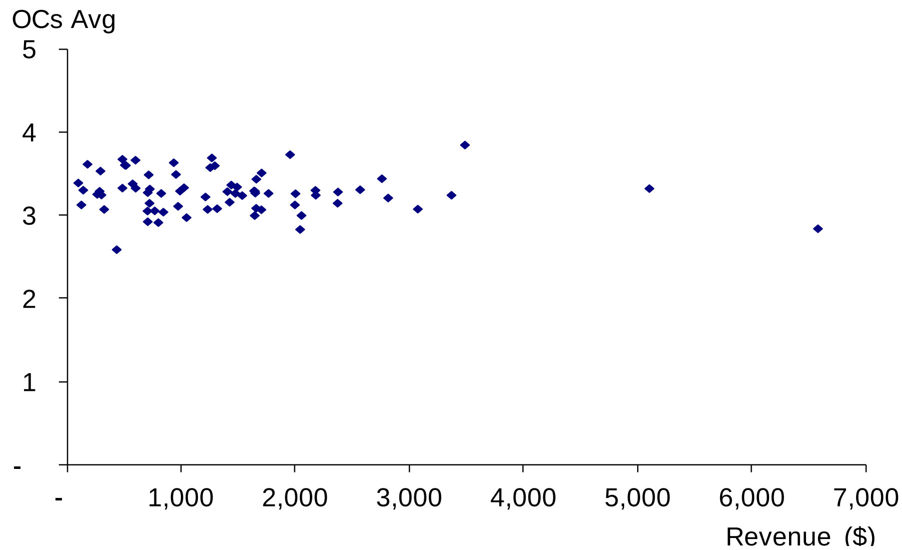


Figure 3.6: Relationship between potential for self governance (OCs Avg) and fisher's revenue at Lázaro Cárdenas reservoir (LCR).

Discussion

On the assessment of the potential for self governance, three major issues arise. First, while this assessment indicates a potential for SGM, it does not indicate a policy action or what to do in LCR. This is an assessment on how much the fisher's perspective might lead to a favorable environment for SGM, but it does not indicate they will adopt self governance.

Certainly, policies may fail because the prospects are not good or because the policies are imposed without considering the interests of the stakeholders. In our perspective, it is preferred to have an approach to assess *ex-ante* whether the policy can work, rather simply guessing or a forcing the policy. This would save energy, time and money, valuable inputs in the policy making process. The advantage of the assessment presented in this research is that it is founded on the scientifically developed base of

Elinor Ostrom's work, widely accepted and used, relevant enough to win the Nobel Prize in Economic Sciences 2009. The six characteristics proposed by Ostrom condense the observed behavior of the CPR users' in a large set of experiences around the globe.

Second, the method used in this assessment offers a way to evaluate *ex-ante* the potential for SGM. Particularly, Ostrom (1990) highlighted the first five conditions as the most appropriate to predict a likely adoption of SGM. Current literature remarks the relevance of cooperation and trust but also emphasizes the low cost of monitoring for successful self governance (Ostrom 2009; Basurto et al. 2008).

Clearly, the most significant constraint in this research is the lack of a true validity measure. We do not observe ex post whether SGM was successful. Therefore, we do not have strong evidence that the answers to six OCs favor SGM or not. Although Ostrom and others scholars have studied and expanded in years of analysis the idea of predicting outcomes for the management of CPR, we are unaware of any attempt to make an *ex-ante* assessment using the six conditions proposed in 1990. Hence, there has not been an opportunity to compare a measure of a community's predisposition toward SGM and then compare that to the outcome over time, which is what would be needed to establish the true validity of such an ex ante measure. In this sense, *ex-ante* assessments like this would be valuable if any time in the future, the SGM is realized. If this is the case, we will be able to assess the validity of the theoretical conditions used in this research.

As we mention earlier, the contemporary research about predictions of the CPR management can be divided into two main lines. A first line analyze the systems:

resource-users-governance as whole (Dietz et al. 2003; Ostrom 2009); and a second line use experiments (Cardenas and Carpenter 2008) but, most of the time focusing on a single condition (e.g. cooperation and trust). Further, the previous empirical analysis has consistently been *ex-post*. Maybe the reason of no previous *ex-ante* analysis has been pointed by Ostrom (2005) when she stressed that predicting outcomes when new and unfamiliar collective- or constitutional choice-rules are selected is very challenging.

This lack of a clear test of validity, however, also represents a great opportunity for future research. Exploring the individual's behavior for a likely adoption of self governance brings a broad perspective for future research and at the same time, it may be useful for the policy making. Knowing ex-ante the individual predisposition toward SGM would make efforts to develop such systems more effective, avoiding a lengthy, difficult and costly process. In the end, although challenging, any work devoted to understanding and predicting the behavior of individuals is indeed at the heart of economic analysis. Social scientists implicitly look for models or theories to predict from empirical data (Bessler and Wang 2010). This research fits within this idea.

There are several other caveats that we should note. First, as it is expected in *ex-ante* analysis, at the moment of the survey we didn't have the rules to have a clear idea how the SGM will be in LCR. This situation increases the level of uncertainty and may affect the responses of the fishers to the survey.

Another point is that we had a weak measure of condition six. It was assessed by only one question. As we note, it would have been better to check the statistics of fishers over time; however such records did not exist. Only anecdotal evidence was available in official publications and no cooperative records could be obtained. The opinion of cooperative leaders about this point is also relative. They know the size of the group in their communities but they are not clear about the other communities.

Finally, before trying to apply these results, policy makers need to be careful and consider at least three points. First, distinct from policy recommendations that focus on actions to be taken by regulators, here we focus on the users of the CPR. Second, when defining the rules for self governance, the fishers themselves will have to take the lead to propose changes in the management of the fishery. Third, in several cases elsewhere, the users have received help from the government officials by giving technical inputs and/or speeding and control the early stages of the process (Townsend 2008). In other cases, fishers and government share the management. In either case, the key of the successful management has been related with a high level of involvement of the users of the CPR.

Overall and despite these caveats, we do believe that this study highlights opportunities to explore new research. We believe that this is the first research that assesses the potential for self governance, a first step that highlights the necessity of new *ex-ante* assessments to derive better conclusions for the management of the CPR.

Final remarks

This research provides a way to evaluate *ex-ante* the potential for SGM. Using six conditions proposed by Ostrom (1990), we carry out what we believe is the first attempt to assess the potential for SGM.

The results show a predisposition of the fishers for SGM in the study site. The average agreement among all fishers is around 77%, a high level along all of the six

OCs. The highest agreement was for rules affecting all fishers similarly. The lowest agreement was in the size stability of the fishers' group. This agreement level was also consistent with the additional interviews and opinions of leaders and stakeholders and with the agreement among the three fishing communities.

On the policy making front, these results need a careful consideration. The high agreement level does not mean a policy action or a recommendation to adopt the self governance in LCR. This is only an evaluation of how much the fisher's favor SGM, but it does not necessarily indicate they would successfully adopt it.

Based on the attitudes of CPR users, our evaluation is a step to understand apriori whether SGM would be implementable. Replicating this assessment would bring opportunities to predict the behavior of individuals towards self governance in other CPRs, a desirable situation to get better conclusions and support for the policy making process about the potential for SGM.

This *ex-ante* assessment would be valuable if any time in the future, the SGM is realized. If this is the case, we will be able to assess the validity of the theoretical conditions used in this research.

CHAPTER IV

MEASURING TECHNICAL EFFICIENCY IN A SMALL-SCALE FISHERY

Introduction

In this chapter, we carry out a technical efficiency assessment for a small-scale fishery in Mexico. *Technical efficiency* (TE) is measured as the deviation of the firm (i.e. fisher) production from the best practice production frontier (Kumbhakar and Lovell 2000). Under TE, fishing production is assumed to be stochastic because the fishing is sensitive to random factors like weather and other environmental influences (Squires et al. 2003). Analysis of TE of small-scale fisheries is relevant for several reasons. There is little information on the small-scale fisheries real contribution to livelihoods and economies in developing countries (FAO 2009). The information on small-scale artisanal and recreational fisheries is scarcer and harder to track with 12 million fishers compared with 0.5 million in industrialized countries (Worm et al. 2009). Indeed, while this type of fishery is common in countries like Mexico, there are a limited number of analyses assessing their efficiency. These small-scale fisheries have the potential to generate significant profits and be more resilient to shocks and crises; two important elements to poverty alleviation and food security. But at the same time, small-scale fisheries may overexploit stocks, harming the environment and generating only a marginal profit level (Gordon 1954; Anderson 1986).

Aiming to identify and assess the variables that constrain TE, this research seeks to provide information that would help in the development of guidance as how to remedy production inefficiencies and provide information to define the strategies to use on the assistance of the fishing communities. Improving TE enhances harvest and can contribute to better use and distribution of scarce resources. It may even help to deal “partially” with the open access problem, but clearly, the decision maker need to be careful because increasing the catch may lead to a probable overexploitation of the resource, making the open access problem more severe. Thus, TE output is a partial solution subject to the existence of a fishery management institution that procures the sustainable use of the fishery. As the fishers become more efficient they provide more food and increase their competitiveness representing a way to improve their profit and alleviate the poverty. While improving TE is only a part of the puzzle, a comprehensive analysis is required to improve the management of the fisheries.

As mention in Chapter II, the analysis use data from the Lázaro Cárdenas reservoir. The fishery in LCR is mainly conducted by small-scale commercial fishers, organized in fishing cooperatives from three communities. These fishers face weak governmental regulation. As a result, the lake has been overharvested and used in an inefficient way (Tovar et al. 2009). The cooperatives, with minor exceptions, commercialize the catch; but they do not cooperate in fisheries management introducing a classic common property situation. The fishers in the LCR are very poor and appear to be more interested in revenue (catch) than in the long-term productivity.

It is desirable to have proficient fishers but, what factors constrain efficiency? Aiming to contribute in the knowledge of small-scale fisheries, this study seeks to estimate the drivers of TE in LCR. The hypothesis is that fisher skills are the main contributors to technical efficiency.

The remainder of this chapter is organized as follows. First, it presents the theoretical background related to TE and gives a brief description of the data and the estimation of TE. Our results section confirms that variables related to fisher skills contribute to fisher TE. A discussion section follows on the ideas of efficiency and the relevance of the TE estimation. Finally, conclusion and extensions are included.

Literature review

Measuring technical efficiency

Traditional economic analysis has linked efficiency with improvements in producer skills; while *productivity* (output per unit of input) has been associated with technological innovations (Fare et al. 1985). Yet, the concept of productivity has evolved. Current assessments of agricultural productivity, for example, include efficiency and technical change as the two principal components (Fuglie and Schimmelpfennig 2010).

Entrepreneurial skill is maybe a major reason why production among firms varies (Kirkley et al. 1998). But productivity may have a distinct interpretation in the fishery and should be studied differently due the open-access nature of fisheries (Jeon et al. 2006). Considering the need for accurate policy recommendations, it is important to separate these two concepts: producer skills and productivity (Fare et al. 1985). This separation makes easy the study of contributing factors to efficiency.

Variables related to managerial skills may explain TE, but there are few studies assessing this relationship in small-scale fisheries and the results are not convincing.

Fisher skills are likely to grow with education and fisher experience, variables that allow testing the “good captain” hypothesis (Kirkley et al. 1998). Though, there is a little empirical evidence about this relationship in small-scale fisheries.

Most of the previous studies of TE are based in large-scale fisheries and developed countries. For example, Pascoe et al. (2001, 2002, 2003) analyzed the Dutch beam trawl fleet, fishing in the English Channel and fleet segments in the North Sea. Fousekis and Klonaris (2003) studied the trammel netters in Greece. Del Hoyo et al. (2004) estimated the TE in the purse-seine fishery of the Gulf of Cadiz, Spain. Alvarez and Schmidt (2006) examined the hake fishery in Northern Spain. Coglan and Pascoe (2007) worked with a set of UK trawlers operating in the English Channel. Madau (2009) explored the TE of small-scale fisheries in the Northwest Sardinian fleet in Italy; and Oliveira et al. (2010) inspected the commercial dredge fleet operating along the south coast of Portugal. Some studies in Java (Jeon et al. 2006), Iran (Esmaeili 2006), Nigeria (Akanni 2008, 2010) and Tanzania (Lokina 2009) reveal some relationships of TE in developing countries.

Overall, empirical evidence indicates some factors related to TE. Vessel age or fleet condition reduces efficiency (Pascoe et al. 2001; Pascoe and Cogan 2002; Del Hoyo 2004). Factors positively related with an increasing efficiency, besides education and fisher experience, are vessel size, (Pascoe et al. 2001; Del Hoyo et al. 2004; Esmaeili 2006; Maravelias 2008), technology advances such as GPS (Esmaeili 2006), and seasonality (Jeon et al. 2006). Indeed, there would be the case that luck is more important than TE to explaining catches, as it was argued by Alvarez and Schmidt

(2006). Factors like fishing area restrictions, gear and catch restrictions have been found to have a positive, negative, or no significant effect.

Some studies have found correlation between TE and variables like education and fisher experience. Esmaeili (2006) suggest a positive relationship between these variables and TE in Iranian fishery, a mixed large-scale fishery. Coglan and Pascoe (2007), working with UK trawlers operating in the English Channel, showed that productivity improvements resulting from increased education and training could exceed those from improvements in technological adoption. Akanni (2008, 2010) analyzing a mixed-scale and artisanal fishery in Nigeria revealed that TE can be improved through a better education and timely provision of credit. Grafton et al. (2000) find a positive effect of labor on efficiency of small vessels in British Columbia halibut fishery, but the model did not disaggregate the skills component of labor. Squires et al. (2003) measured the effect of vessel-skipper characteristics on the fishing fleet of Malaysia, desegregating education and fisher experience. Though the estimated parameters, comparing two fishing communities, the resulting signs and significance of were not consistent. For example, the fishing experience in the west coast region had a positive but not significant effect on the fisher's TE, while it was negative and significant on the east coast region. The variable named education showed the same irregularity pattern.

Overall, while there has been substantial research on TE in fisheries, there remain important areas for further investigation. Specially, there is need for a better picture of efficiency in small-scale semi-artisanal fisheries operating in developing countries. This chapter helps to fill that gap in the literature. Improving knowledge would help to accurate the fisheries policy.

Stochastic Frontier Analysis: The efficiency analysis

The computational method to estimate the efficiency of each fisher is Stochastic Frontier Analysis (SFA). Following the functional form of Battise and Coelli (1995) production frontier, this approach groups the efficiency effects in two equations, production function and efficiency equation. SFA estimates the production function in a stochastic form, allowing for random events that shift the position of fishers in relation to a deterministic frontier (Aigner et al. 1977; Meeusen and Van der Broeck 1977). Thus, in addition to input factors, the TE model approach permits a comparison of individual differences and allows for a flexible specification, including variables like fishing experience and education to assess the fisher skills.

The basic SFA model is

$$y_{it} = f(\mathbf{x}_{it}, \mathbf{z}_i) + v_{it} \pm u_{it} \tag{4.1.a}$$

where the function $f(.)$ denotes the theoretical production function determing y_{it}, the observed output of the i^{th} individual, i=1,2,3 …N, in period t, $\mathbf{x}_{it}$ is the observed vector of inputs and $\mathbf{z}_i$ represents the suspected predictors of efficiency. The error term is divided in two parts: v_{it}, which captures the stochastic part of the fisher’s production that can be either positive or negative, and u_{it} represents the degree of technical inefficiency, which is constrained to be positive if a cost relationship is estimated or negative if a production relationship is considered.

The SFA model was originally proposed by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van der Broeck (1977). By adding a distributional assumption, it is possible to obtain an empirically tractable approach. The key assumption is over the "composed error," ε_{it}, which is the sum of a symmetric, normally distributed random term ($v_{it} \sim N[0, \sigma_v^2]$) and the absolute of a normally distributed variable ($|u_{it}|$ where $u_{it} \sim N[0, \sigma_u^2]$). The model is usually specified in natural logs, so inefficiency u_{it}, is a percentage deviation of the output, y_{it} from the firm's own frontier performance.

The first step is to estimate the vector of technology parameters β from the deterministic part of the equation (4.1.b). This equation is a linear specification of the equation (4.1.a) that reflects the maximum amount of output that can be produced using a given set of input amounts. This step also produces estimates of σ_u and σ_v, the distributional parameters of the error terms in the model

$$y_{it} = \boldsymbol{\beta}'\mathbf{x}_{it} + \boldsymbol{\mu}'\mathbf{z}_i + v_{it} \pm u_{it} \quad (4.1.b)$$

With β estimates in hand, the second step is to estimate the composed error,

$$\hat{\varepsilon}_{it} = v_{it} - u_{it} = y_{it} - \hat{\boldsymbol{\beta}}'\mathbf{x}_{it} \quad (4.2)$$

Coelli (1996) showed that a 2-step approach, estimating equation (4.1.b) first and later equation (4.2), is inconsistent with the assumptions regarding inefficiency effects. If we need to estimate u_{it}, not ε_{it}, a method to disentangle the firm specific heterogeneity effects is needed; and a joint estimation procedure may provide efficient estimates. In this idea, Battise and Coelli (1995) proposed the efficiency effects frontier procedure in which the inefficiency effect (u_{it}) is expressed as an explicit function of a vector of firm-specific variables and random error. In this approach the allocative efficiency is imposed, the first order condition is removed and panel data is allowed (Coelli 1996). This model assumes u_{it} to be independently distributed truncation at zero of N[m_{it}, σ_u^2] distribution; where:

$$m_{it} = z_{it}\delta, \tag{4.3}$$

where z_{it} is the vector of efficiency predictors and δ is the vector of parameter to estimate. With cross section data whit t =1, this model is reduced to a truncated normal specification. The main advantage of Battise and Coelli (1995) procedure is that allows for single stage estimation and produce efficient estimators by reducing the standard error.

An equivalent expression can be formed in equation (4.4) by taking the exponent of equation (4.1.b) with t =1.

$$y_i = f(x_i, \beta)e^{v_i}TE_i \tag{4.4}$$

where TE_i is the technical efficiency term e^{u_i}. The dependent variable y and the production function variables $f(\cdot)$ are transformed to log values. This is a general expression that allows to show how isolating TE we can estimate inefficiencies by forming a non nonlinear specification (4.5),

$$TE_i = y_i / f(x_i,\beta)e^{vi} \leq 1 \tag{4.5}$$

In (4.5), as v_i is non observable, it can be replaced by $\hat{\varepsilon}_i$, the composed error. This substitution takes E[u_{it} |ε_{it}] assuming that inputs x_i are not correlated with v_i. As a result, x_i and the expected values determine the production frontier (Kumbhakar and Lovell, 2000). Deviations from the deterministic output will occur because of random events and because of TE (u_i). While only $\widehat{\varepsilon_i}$ is observable, u_i is predicted by placing a restriction on the distributions of v_i and u_i.[11]

The greater the value of u_i, the greater the estimated inefficiency for the i^{th} fisher. In other words, if a boat is on the deterministic frontier, this means it is technically efficient with $u_i = 0$ and $\widehat{\varepsilon_i} = v_i$. If there are TE effects, $u_i > 0$ and the distribution of $\widehat{\varepsilon_i}$ will have a negative skew (mean < mode and a long tail to the left) and no longer be symmetric (Kumbhakar and Lovell, 2000).

Finally, rewriting from equation (4.3), the TE equation will be

$$u_i^{TE} = g(z_i, \alpha) + e_i, \tag{4.6}$$

where z_i is a vector of efficiency variables of the fisher i, the term α is a vector of parameters to estimate and e_i is an error term to be included depending on the estimation procedure (Kumbhakar and Lovell, 2000). Translog and the Cobb-Douglas specifications are widely used to estimate this relationship, but it should be tested to decide which one provides a better representation of the data.

Data

A detailed description of the survey data is presented in Chapter II of this dissertation. Form the data gathered in the fisher's survey at LCR, here we use 89 observations obtained after dropping one outlier[12] and 21 others because of missing values. The variables used in the estimation of the TE are described in Table 4.1.

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[11] Recall, u_i is reduced to a truncated normal and v_i and u_i are assumed to be independently and identically distributed.

[12] A test for influential observations was carried out. CooksD and R Studentized<2 showed the existence of only one leverage point (Kennedy, 2003)

Table 4.1: Summary statistics of variables used in technical efficiency estimation.

Variable	**Variable description**	**Units**	**Avg**	**StdDev**	**Min**	**Max**
y	Catch	Kg	97.6	142.8	5	920
r	Revenue	$000 (pesos)	1.48	1.36	93	8010
l	Labor per boat	Hrs/ week	27.9	12.9	3.5	63
gas	Gasoline	$ (pesos)	294.4	262.2	0	1,400
row	Rowing	(dummy)	0.17	0.37	0	1
n	Nets in the lake	Number	6.7	3.7	0	15
a	Angling	(dummy)	0.14	0.35	0	1
fex	Fisher experience	Years	23.9	15.0	1	60
class	Taken a training class	(dummy)	0.03	0.18	0	1
shr	Share the boat	(dummy)	0.54	0.50	0	1
incf	Fishing main income	(dummy)	0.73	0.45	0	1
tb	Age of the boat	Years	14.9	9.3	0.5	50
tm	Age of the motor	Years	11.4	9.2	0.3	35
bl	Boat length	Meters	4.26	0.75	2.74	6
ph	Family size	Number	4.4	2.3	1	15
edu	Education	Years	6.0	2.5	0	12

Describing the variables given in Table 4.1, labor (*l*) reflects hours worked per week and shows an average daily journey into the lake of 4 to 5 hours. Fishers used an average of 6.7 nets (*n*) to fish in the week previous to the interview. The variables capturing age of the motor (*tm*) and age of the boat (*tb*) capture the technology limitations because of age of the capital. Years of fishing experience (*fex*), education (*edu*) and if the fishers have ever taken a class to learn how to fish (*class*) are variables that may affect the fisher skills. The average fisher experience is high, 24 years, and the average of 6 years of education reveals a typical elementary school level. Catch (*y*), is the sum of all harvested species during the previous week of the interview. It is very low averaging only 97.6 kilograms per week. Accordingly, revenue (*r*) is also low. The average expenditure on gasoline (*gas*) in that week was high. Clearly, most of the fishers use an old motor, several of them row (*row*), share their boat (*shr*), or use angling (*a*).

Beyond the characteristics of a semi-artisanal fishery, sharing the boat, angling or rowing would be part of a strategy to minimize the fishing costs.

Stochastic frontier analysis model

The empirical model to estimate TE follows Squires et al. (2003) and Grafton et al. (2000), using the production frontier approach proposed by Battese and Coelli (1995). In fisheries, production is generally assumed to be a function of stock size (which is not available in our data), fishing time, and the level of physical inputs employed (Pascoe et al. 2003). Labor (number of hours used to fish) in our model can be a measure for fishing time. The production function model, after imposing constant returns to scale is presented in equation (4.7). Following Grafton et al. (2000), we use a Cobb Douglass functional form,

$$\ln y_i = \ln \beta_0 + \beta_1 \ln l_i + \beta_2 \ln ec_i + \beta_3 \ln fc_i + v_i - u_i^{TE} \qquad (4.7)$$

where y_i is the output (kg of fish harvested, all species) of the last week. Labor (l_i) is the number of hours worked per fisher in the last week. The effort capacity (ec_i) is a measure of the fishing effort and factor capacity (fc_i) measures the inputs used in the fishing activity. Both ec_i and fc_i are formed as linear combinations of other variables to account for very different technologies. Effort capacity captures the energy used to move the vessel based on the fisher's expenditure on gasoline in the last week and a dummy variable if the fisher uses a row boat. Factor capacity is a proxy of capital stock, a variable used in the model of Squires et al. (2003); it is a function of the number of nets used by the fisher in the last week and a dummy identifying if the fisher angles. We explain the creation of the weights for ec_i and fc_i in the next paragraph. All the variables in equation 4.7 are transformed to natural logs.

Certainly, we may use a model like (4.7) by including the expenditures on gas, number of nets, and the two dummies angling and row. However, because we are estimating the model in logs, this would require dropping all observations with zero gas or zero nets, reducing the sample by about 40%, eliminating most of the observations where the fisher's angle or row thus it would lead to a biased estimation.

Our model approach allows for the possibility that any fisher can use motor and row and use the net and angling, plausible possibilities detected in the survey.

Two variables, ec_i and fc_i were constructed based on a non linear model (4.8). This non linear model estimates the equivalence of the dummy "if the fisher rows" in terms of gasoline expenditure; and the equivalence of the dummy "if the fisher angles" in terms of number of nets.

$$nl[\ln y_i = \tau_0 + \psi \ln(gas_i + \phi_1 row_i) + \gamma \ln l_i + \alpha \ln(n_i + \phi_2 a_i) + \varepsilon_i] \qquad (4.8)$$

where "ln" indicates a transformation of the variables to natural logs. Again, y_i is the output (kg of fish harvested, all species) of the last week. The gasoline expenditure (gas_i) in the last week and a dummy to identify if the fisher rows (row_i), will form the effort capacity. As well, factor capacity (fc_i) will be formed by the number of nets (n_i) used by the fisher in the last week and a dummy to identify if the fisher angles (a_i). Labor and output (l, y) enter like they appear in (4.7); plus the variables are transformed into natural logs. The estimation result for (4.8) is presented in Table 4.2.

Table 4.2: Nonlinear regression to estimate effort capacity and factor capacity.

Variables		Coefficient	P-value > |t|	
Constant	τ_0	0.6387133 (0.9235062)	0.491	
Effort capacity (in gasoline expenditure)	ψ	0.1783858 (0.1381035)	0.200	
Row (equivalency to gasoline expenditure)	ϕ_1	89.08926 (142.6562)	0.534	
Labor	γ	0.4950406 (0.1697781)	0.005	***
Factor capacity (in number of nets)	α	0.5097845 (0.2034385)	0.014	**
Angling (equivalency to number of nets)	ϕ_2	1.090787 (1.002418)	0.280	

Notes: Standard errors are reported in parentheses. Asterisk (*), double asterisk (**) and triple asterisk (***) denote coefficients significant at 10%, 5% and 1% respectively. Convergence reached after 12 iterations. R-squared=0.3664, Adj R-squared=0.3283 Root MSE = 0.744656.

The estimated coefficient values of ϕ_1= 89.089 and ϕ_2 = 1.090 roughly mean that rowing has an equivalence of 89 pesos of gasoline and angling is equivalent to 1 net. As indicated in (4.8), multiplying ϕ_1 by *row* and adding to *gas* we form the effort capacity and multiplying ϕ_2 to angling and adding to number of nets used per fisher we form the factor capacity.

The technical efficiency presented in (4.6), is now proposed in equation (4.9), to estimate the contribution of various factors to a fisher's inefficiency:

$$\begin{aligned} u_i^{TE} &= \delta_0 + \delta_1 edu_i + \delta_2\, fex_i + \delta_3 tb_i + \delta_4 class_i + \delta_5 tm_i + \delta_6\, ph_i \\ &+ \delta_7 shr_i + \delta_8 incf \ + \delta_9 bl \end{aligned} \tag{4.9}$$

where u_i^{TE} is the level of technical inefficiency for every fisher; *edu* is the education level, or number of years in school; *fex* is the number of years of fishing experience. The variable *tb* is the time (years) that the fisher has using the boat. *Class* indicates if the fisher' have taken a class to improve his fishing techniques. The variable time (years) using the motor (*tm*) together with *tb* reflects the state of the fishing capital. The number of persons in home (*ph*) is an assessment of the family size of the fisher. The variable *bl* indicates the size of the boat in meters. The last two variables are dummies to identify if the fisher shares the boat (*shr*), and if fishing is the primary source of income (*incf*).

Equation (4.9) has some differences with the Squires et al. (2003) model. The purpose is to test if fisher skills are the main driver for TE and Squire's purpose was to identify the main drivers of efficiency. Thus, *edu*, *fex* and *class* are the main variables to test. In the rest of the variables, *tm* and *tb* are included to assess the influence of the mechanical condition of the fleet. Previous investigations examining large-scale fisheries, where the vessels size variation is notorious, have found variable *bl* to be significant influencing TE. The *ph* and *incf* are relevant to analyze social conditions of the fishers. Having a large family to feed and if fishery is the main source of income, may affect TE. We add *shr* to test if sharing the boat could reduce the TE. While sharing, the number of fishing hours may increase, reducing the cost and TE would increase. Finally, the model does not include variables like remaining economic life of the boat and engine that are included in Squires et al (2003). Such variables are excluded because they were deemed unreliable in the data set and are probably not appropriate in semi-artisanal fisheries such as the LCR.[13]

[13] Indeed, looking the average age of the boat (~15 years) and motor (~11.5 years), it is highly probable that most of the equipment used in LCR is beyond his economic life.

Results

To proceed, we estimate the empirical model and test it for influential values, multicollinearity, and homoscedasticity. All the outputs are presented in Appendix C. Under the standard procedures (Green 2003; Kennedy 2003), we did not detect degrading collinearity.[14] Evaluating homoscedasticity with the non-constant variance score test, we reject the no constant dispersion of residuals. In a global test of production function, using a significance level of 0.05, we observe that skewness, kurtosis and heteroscedasticity are acceptable assumptions for the model. The estimations output is presented in Table C.1 in Appendix C.

In the empirical model, equations 4.7 and 4.9 were jointly regressed using a maximum likelihood procedure. This joint estimation allows getting efficient estimates. Recall, the first equation (4.7) is a production function with output (y_i) on the left hand side and labor, effort capacity and factor capacity in the right hand side. The second equation (4.9) assesses the technical efficiency. Table 4.3 presents the estimated coefficients for these two equations. The estimates were obtained using the program Frontier 4.1 written by Coelli and Henningsen (2011) using the statistical package “R.”

[14] The rule of thumb of Belsley, Kuh and Welsch proposed in 1980, estimates the variance inflation factor (VIF), condition index (CI) and variance proportions (Green, 2003). This rule examines the "conditioning" of the matrix of independent variables. If a "large" CI (>30), is associated a variable having a "large" variance decomposition (>0.5), these variables may be presenting a degrading collinearity problem (Kennedy, 2003).

Table 4.3: Maximum likelihood estimates of technical efficiency empirical model.

		Estimates	Std. Error	Signif.
Production function				
Intercept		0.839	0.656	
ln labor	*l*	0.517	0.159	**
ln effort capacity	*ec*	0.203	0.099	*
ln factor capacity	*fc*	0.417	0.123	***
Efficiency variables				
Intercept		3.346	0.924	***
Education	*edu*	-0.251	0.056	***
Fishing experience	*fex*	-0.052	0.013	***
Training class (D)	*class*	-2.867	1.064	**
Age of the motor	*tm*	0.060	0.015	***
Age of the boat	*tb*	-0.024	0.016	
Boat length	*bl*	-0.061	0.146	
Family size	*ph*	-0.106	0.055	.
Sharing the boat (D)	*shr*	0.110	0.188	
Income from fishing (D)	*incf*	-0.424	0.211	*
Sigma Sq		0.383	0.057	***
Gamma		0.000	0.000	***
log likelihood value		-83.58		

Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1
ln means natural logarithm and (D) means dummy

Three tests were performed[15]. The first test was on the functional form of the production function. The null hypothesis is that Cobb-Douglas is the appropriate functional form. As seen from the output (**i**) of Table C.2 of Appendix C, the likelihood ratio (LR) tests lead to fail to reject H_o. The empirical model favors a Cobb Douglas over a Translog specification. The second test was to see whether the TE effects need to be included in the model. The null hypothesis is that TE effects are zero. By using a generalized LR tests (output **ii** of Table C.2 in Appendix C), the null hypothesis was rejected with 1% of significance, thus u_i^{TE} should be included in the model. If no significant inefficiency effects then we do not need a stochastic frontier model, but

[15] The tests are presented in the Appendix C

rather an augmented production function using an OLS procedure. The estimates of sigma square and gamma are significant; it means that the model accounts for noise (deviations between the observed and the "fitted" values). A gamma zero or close to zero means that inefficiencies are included in the model. Finally, the model was also tested to see the distribution of the data in the model. The H_o is that truncated normal is the appropriate distribution. From the output (**iii**) of Table C.2 of Appendix C, the LR tests let us to fail to reject Ho, thus the model better support the truncated normal over the half normal distribution.

To clarify the terminology used. The model estimates inefficiencies, a positive sign in the efficiency variables regression indicates an increase in the corresponding variable leads to an increase in inefficiency (i.e. a decrease in efficiency), and a negative sign indicates a decrease in inefficiency (or an efficiency improvement). Because the dependent variable in this equation (4.9) comes from the residual part, the marginal effect of the estimates does not have a clear or a meaningful interpretation. Hence, in the estimates of efficiency we only care about the sign and significance level.

In the production function variables, labor, effort capacity and factor capacity are significant and positive, as expected. A 10% increase in the use of labor will result in an increase of 5.2% of catch. As well, a 10% increase in using effort capacity (gas expenditure and/or rowing the boat) will result in an increase of 2% of catch. A 10% increase in the use of fishing capital (number of nets and/or angling) will result in an increase of 4.1% of catch.

For our research hypothesis, variables such as education, fishing experience, and training (or class taken to improve fishing) have a negative sign. In other words, these variables have a positive effect on efficiency. More education, more years of experience and more training makes efficiency increase. In the rest of the variables, time using the motor has a negative effect on efficiency; and family size and fisher income have a significant a positive effect to increase efficiency.

On the assessment of individual TE, the estimated average was 83.1%. The vector of estimates of technical efficiency was bootstrapped to get the standard error (0.02315) and a 95% confidence interval (0.786, 0.877).

Discussion

By estimating TE we assess variations of the error term. Much of the deviations from the mean can be attributed to idiosyncratic variation that is captured in the error term. Here, we model the factors may influence TE following the Battise and Coelli (1995) production frontier. This approach forms two equations (production function and efficiency equation), allowing for: (a) random events that shift the position of fishers in relation to a deterministic frontier, (b) a comparison of individual differences and, (c) an specification that allow us to include variables like fishing experience and education to assess the fisher skills.

Note this assessment is restricted due to the small data set. The estimated average of 83.1% efficiency level is a high when compared to previous studies. Pascoe and Coglan (2002) estimate a technical efficiency in an average of 65%, while Akanni (2008, 2010) found TE in a in a range of 64.5% to 79.7%. Certainly, there are some differences to account from case to case. Pascoe and Coglan (2002) studied large-scale fishing vessels in the English Channel; while Akanni (2008, 2010) analyzed a mixed-scale and artisanal fishery in Nigeria.

Most of the observations lie in the 0.9-1.0 range (Figure 4.1). The graph shows that a lot of fishers have an index of efficiency around the frontier. Indeed, 55% of the fishers have an estimated efficiency greater of 95%.

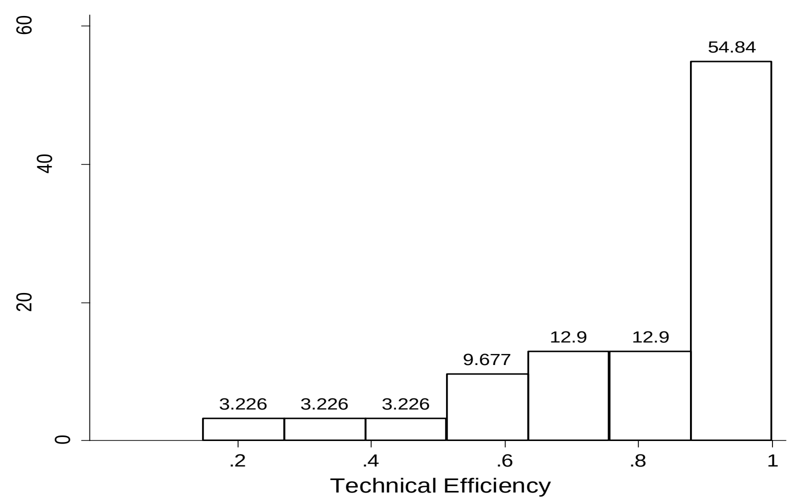

Figure 4.1: Histogram of observed fisher's technical efficiencies.

This result might have two different interpretations. On one hand, it may be due the restriction of the small data set. Possibly the data are insufficient to assess the TE given the small data set and with the relatively homogeneous fleet. In cross section data, we cannot distinguish between a bad (good) week and a bad (good) fisher. In an unlucky week, one fisher ends up with a very low efficiency measure. Using the harvest of only one week may not allow for the natural variation that fishers experience. The consequent recommendation is to use a data set formed with several weeks. On the other hand, it could be the case that a lot of these fishers really use their skills wisely and are on the efficiency frontier; or it could also be that all of the fishers are “equally” inefficient.

The estimates of factors that explain the TE in LCR (Table 4.3), are comparable with Squires et al. (2003), Esmaeili (2006) and Akanni (2008, 2010). Recall, our research hypothesis is that fisher skills (education, fisher experience, and training) have a positive influence on technical efficiency. We find that fisher experience and education were significant, the same result that Esmaeili found in Iran. As well, Akanni (2008, 2010) found a positive relationship between education and TE in Nigeria. Squires’ results were mixed: fishing experience was significant but education was significant in only one regional assessment. Overall, our results indicate that fishing experience and years of school have a positive effect on the fisher’s efficiency. Fishers have an average experience of 24 years, being the most significant variable at 0.001 level. The qualitative variable *class* was also significant, although a very small portion or the fishers (3%) in LCR have received training.

A brief comment is needed for the variables, age of the motor, *tm*, family size, *ph*, and the variable income from fishing, *incf*. These three variables were found to have a statistically significant correlation with TE and the results are in line with previous findings. Fishing technology is relevant in the TE and a positive sign indicates a relationship where old technology (i.e. motor, boat), decrease the efficiency (Pascoe et al. 2001; Pascoe and Cogan 2002; Del Hoyo 2004). Squires et al. (2003) used the variable remaining economic life of engine, instead of time using the motor, and reported inconsistencies in the sign and significance. The "family size" increases the fisher efficiency (Squires et al. 2003). The positive effect may be because a large family may provide more flexibility to how long and when to fish, and allow family members to work more cooperatively and exert greater effort when fishing. Alternatively, a big family may urge the fisher to be more efficient to bring more food or money to home. Last, if the fisher income is mainly derived from the fishing activity, it may increase the efficiency of the fisher in the model. If a fisher mainly works fishing, it seems reasonable that the fisher will be more efficient; having more experience and incentive to get the most out of his fishing. Having a low productivity could lead to a low income. The variable size of the boat, relevant in previous studies (Pascoe et al. 2001; Del Hoyo et al. 2004; Esmaeili 2006; Maravelias 2008), was not significant.

In terms of the policy relevance of this estimation, we may argue it on the relationships of TE and revenue (Figure 4.2). There is a positive correlation (0.54) between efficiency and revenue which is statistically significant.[16] Hence, the enhancement of efficiency obviously matters for the improvement of the fisher's revenue, a relevant argument for the decision makers. Although this result looks obvious[17], some lessons can be discussed. First, our outcome shows the relevance to explore the allocative efficiency. Allocative efficiency takes into account revenue, not just the output units, to account for the opportunity cost if the inputs. Second, the direct relationship between income and efficiency does not necessarily lead to a better policy

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16 The t-value was 4.99 at a 95% of significance level. The t-critical value is 1.99.

17 It since revenue is equals price times quantity, and higher efficiency means higher quantity, efficiency and revenue will be correlated.

making since the fisheries is an open access resource. It means that the policy maker needs to have a more comprehensive policy analysis considering the ecological conditions of the resource and the institutional rules on the use of the fishery.

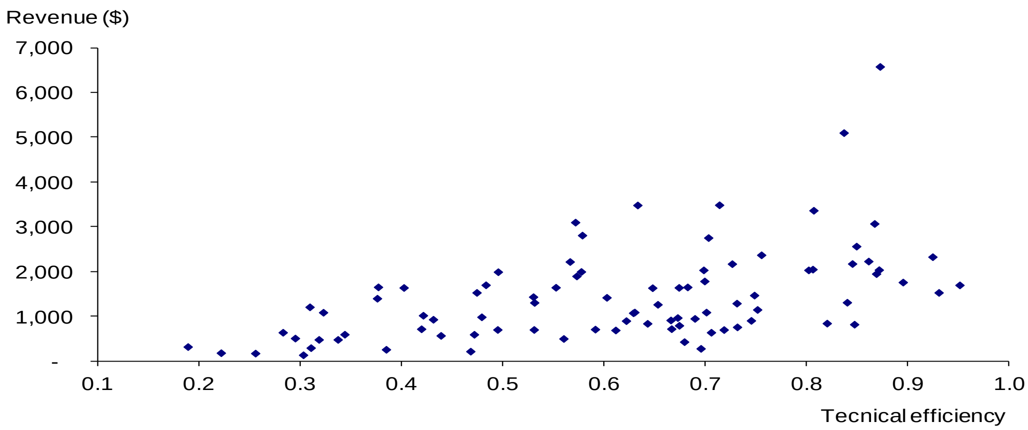

Figure 4.2: Technical efficiency estimates and revenue for the fishers.

Final remarks

This chapter presents the results from an estimation of technical efficiency in a small-scale and semi-artisanal fishery in Mexico. Consistent with our research hypothesis, fisher skills are the most relevant factor that favors efficiency. Other variables are consistent with previous findings.

The results presented are policy relevant. Knowing the factors that constrain or favor TE gives guidance for policy makers to consider how efficiency might be improved which, if the stock does not decline, would lead to an increase in the fishers' revenue and hopefully useful in reducing poverty. However, this information should be carefully used for the management of the fisheries. Recall, the fishery is a resource classified as open access. Improvements in TE without restrictions on entry may lead to a faster collapse of fisher income. Improving the net income of the fishers and avoiding the overexploitation of resource stock has been always on the agenda of policy makers, and they both need to be tackled. Unfortunately, it is not an easy task. For example, restrictions in the open access to control the overexploitation without a correct economic assessment (i.e. in the efficiency), could leave inefficient fishers in devastating poverty and reach the worst scenario in the fisheries problem of Gordon (1954).

Measures implemented on the technology side partially solve the open access problem (Grafton 2006; Ostrom 1990). Improving the fishing capital (nets, motors or boats) is one policy option derived from this research, but it may be more effective to implement a program to, for example, improve the education level of the fishers. This research shows one element of the puzzle by emphasizing key variables that improve the efficiency and the fishers' revenue, but a comprehensive analysis is required to improve the management of the fisheries.

Previous research has emphasized the relevance of technology and fisher's skills to improve the management of the fishery (Salas 2007; Hilborn 2007a; Grafton et al. 2006; Anderson 1986). This research not only corroborates previous research done for large fisheries, but contributes in the knowledge of TE in small-scale fisheries. As Squires et al. (2003), Esmaeili (2006), and Akanni (2008, 2010), our assessment have a relatively high TE. This finding is interesting to corroborate in future research to see if most small-scale fisheries have a similarly high TE.

CHAPTER V

THE RELATIONSHIP OF TECHNICAL EFFICIENCY AND THE POTENTIAL FOR SELF GOVERNANCE IN THE FISHERY

Introduction

This chapter explores the linkage between technical efficiency (TE) and self governance for the management of *common pool resource* (CPR).[18] As it has been documented, due to free access, CPRs are subjected to overuse resulting in degradation and poor economic performance, the *CPR problem* (Ostrom 1990). However, CPR problem may reside not only in the unlimited access, but to an ineffective management of the CPR (Townsend 1995; Grafton 2006). The typical case is when governmental management requires expensive regulatory effort, whereas the agencies often have very limited budgets. As a result, the governmental management may work against effective management of the fishery, failing to preserve the resource stocks and failing to sustain the economic activity, further in some cases, inducing a conflicting relationship between fishers and regulatory offices (Townsend 1995; Hilborn 2007a; Grafton et al. 2008).

Self governance has been recognized as a good option to manage the CPR. In *self governance*, the decision-making responsibility is in the hands of resource users who pursue common objectives, increasing the certainty and legitimatization of their decisions (Ostrom 1990; Dietz et al. 2003). Townsend and Sutton (2008) and Ostrom (1990), analyzing a lot of cases around the world, uncovered the characteristic and

[18] The definitions of common pool resource or CPR, governance, self governance and successful self governance can be checked in Chapter I.

principles of successful regimes. They have shown that under self governance the resource degradation and economic viability of the CPR is more likely to improve than under regulation by a central governmental authority.[19] The challenge is to design a "management system" that is effective, equitable and efficient (Hanna 1995); effective to achieve the objectives, equitable to be fair for all the users and efficient to reach the objectives at the minimum cost.

Certainly, using *self governance for the management* (SGM) of the CPR, users can reach an efficient management system, it means; they can achieve the management targets (rules) at minimum cost. Yet, is not clear how efficient management like the one derived from SGM is related with the efficiency of the resource users.

We consider two types of efficiency at user level. The first is the *resource efficiency*. This refers to the rents generated by the fishery taking into account the system's dynamics. In theory, resource efficiency is achieved by the "private property equilibrium" which has the incentives in place so that the resource is used in a way that is biologically sustainable and maximizes the economic returns from the resource (Hartwick and Olewiler 1998; Gordon 1954). The second type of efficiency is *technical efficiency* (TE), derived from the maximization of at firm level and described in Chapter III.

Most models that focus on resource efficiency assume that all firms to be homogenous in technology, skills, and by extension in efficiency. Our focus on TE

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[19] Ostrom (1990) emphatically shows how this empirical result is different to Hardin (1958) who stated that users of the CPR will not manage the resource in common because the selfish and egoistic behavior of humans. Harding believed that individuals do not take into account consequences of their actions on other users, neither in resource conservation; thus all the common resources inevitable be overexploited.

relaxes this assumption of homogeneity. Differences in TE across fishers may be explained by stochastic conditions (e.g., rain, temperature, etc.) or personal abilities of the fishermen. This research uses TE to capture differences between users.

This chapter takes inputs from previous two chapters and addresses three concepts: Fisher TE, self governance, and management of the system. We consider SGM as a reasonable option to deal with the CPR problem and we use it as a referent of an effective, equitable and efficient management system in the sense of Hanna (1995).

The specific research question of this chapter is: what is the relationship between the support that CPR users might give to the adoption of SGM and the economic performance of those individuals? Is efficiency at user level propelling the adoption of an efficient management system like SGM? Early assessments of TE had brought useful information for the management of the fishery (see literature review of Chapter IV). Further, Grafton et al. (2006, 2007) stressed that fisheries management will not be complete without discussing two elements: the efficiency at the firm level and the type of governance. Specifically, we explore the relationship between conditions proposed by Ostrom (OCs) that indicate greater likelihood for the adoption of self governance (estimated in Chapter III) and the TE of the CPR users (estimated in Chapter IV).

If the resource users are not predisposed toward SGM, then efforts to develop such a system are likely to be lengthy, difficult, and costly and, in the end, the SGM regime may be unsuccessful. Ideally, decision makers would like to know the likelihood that the process will be successful *before* embarking on a difficult process of helping users to adopt SGM. The hypothesis to be tested is that there is a positive relationship between fishers' TE and their predisposition for SGM. That is, we are testing if the efficiency at the user level tends to favor the adoption of SGM. To my knowledge, this relationship has not been assessed.

As explained in Chapter II, our data come from a survey on the Lázaro Cárdenas Reservoir (LCR**),** a small-scale fishery representative of the inland fisheries of Mexico. The fishery exists in an environment of weak regulation and a limited enforcement (Tovar et al. 2009). As a result, the lake has been overexploited and the commercial fishery is not profitable, clear signs of the CPR problem.

Our finding is that fishers TE was not found to be statistically significant in explaining the predisposition toward SGM. When we look instead at some of the variables used to model TE in Chapter IV, several have shown a significant correlation with the OCs including fisher experience, family size and the dummy that accounts if the fisher income depends only from fishing. Overall, this assessment contributes to the knowledge of variables related the potential for SGM, a useful input to define strategies that deal with the CPR problem.

Literature review

There is an extensive and varied research on the CPR management. Current literature seems to center on the identification of conditions related to a successful management of the CPR, while the work devoted to evaluate the drivers for the adoption of SGM has been limited. Nonetheless, the theoretical underpinning of such analysis does exist. This section focuses the review in some definitions of efficiency, in a number of characteristics for the management of the CPR; and in the relationship between fisher's efficiency and the management of the fishery. Ultimately, this section reports evidences on how efficiency of CPR users influences the potential for SGM.

We differentiate three types of efficiencies. The first is the efficiency derived from the management of the resource, here named as *management efficiency*. This type of efficiency is more related with the cost of controlling the fishing activity (primarily transaction costs). In this management efficiency, the target is to reach the management objectives at the lowest cost.

The second efficiency is the *resource efficiency.* It is related to the sustainable rents derived from the fishing harvest, as it was explained by Gordon (1954). Assuming full assignation of property rights and a sole owner, Gordon's model relates the biological nature of the fishing growth with the rent resulting from the fishery. Resource efficiency is satisfied if sustainable rents that can be generated from the fishery are maximized (Hartwick and Olewiler 1998). However, as shown by Gordon, when there is no barrier to entry by other fishers, effort will tend to expand, reducing the rents that the resource can generate. Under certain conditions the rents are eliminated entirely. Hence, in an open access fishery, resource efficiency is not achieved. For years, the Gordon model has been the standard model used by resource economist to understand the fisheries problem.

The third efficiency is derived as a consequence of the purely maximization process of the firm. Here we call *technical efficiency* or TE. It is more concerned with producing at the lowest point on the short run average cost (Fare 1985). Under TE, a

CPR user can be considered as a firm that maximizes his output with the available resources. A better description of this type of efficiency is presented in Chapter III.

The last two types of efficiency are not necessarily the same. Resource efficiency assumes all firms to be homogenous, using the same technology, the same skills; hence all are expected to reach the same efficiency level. Technical efficiency relaxes the homogenous efficiency assumption, but does not consider the efficient use of the resource. TE only focus on the production function as a general frame, and the efficiencies (or inefficiencies) in the production process are explained for stochastic conditions like rain, temperature, and skills of the producers.

In this research we assume that by adopting SGM the users can reach an efficient management of a CPR. Adopting SGM may bring effectiveness, equitability and efficiency in the sense of Hanna (1995).

Fisheries *management* is a system of appropriate rules, implemented with a monitoring and enforcement to achieve an outcome. The fisheries management should strive to be effective, equitable and efficient; characteristics that are difficult to reach all together. According to Hanna (1995), effectiveness is difficult to achieve because of the contradiction between short term individual interests and long term sustainability objectives. Equity is difficult because the diversity of interest and values involved. Finally, resource management efficiency is difficult because of the cost and benefits associated with the use of the CPR. Improvements in TE are desirable provided if there is a management structure that prevents biological and economic overexploitation of the activity (Grafton 2006).

The three concepts that are at the core of this research are presented in Figure 5.1. Changes in individual TE will be correlated with changes in fisheries management and with changes governance. For example, when a new rule restricts the gear to be used by the fishers, this restriction affects their harvest and thus affects their efficiency. In the relationship between self governance and fisheries management (line 1), Ostrom and scholars of institutional change school have been working on this issue for a long time as it was presented in Chapter III. The research between TE and fisheries management (line 2), is not in the same proportion than line 1, especially for small-scale fisheries as it was presented in Chapter IV. The relationship between technical efficiency and self governance (dotted line 3) presents a gap in the research.

Figure 5.1: Relationship of efficiency, governance and fisheries management.

The idea that a fisher's TE may explain the propensity to adopt SGM is motivated by previous findings. On one hand, early assessments of fisher TE (presented in Chapter IV), had brought useful information to improve fisheries management. On the other hand, Grafton et al. (2006, 2007) stressed that fisheries management will not be complete without a discussion of efficiency at the firm level and the type of governance.

This chapter fills a gap in the literature exploring theis relationship between TE, self governance and fisheries management.

As discussed in Chapter III, Ostrom (1990) proposed six conditions that she believed can predict the *likelihood* of users to adopt changes in the use of the CPR (Figure 5.2). In condition five, she argues that a low cost of monitoring and enforcement will favor the adoption of SGM. Beyond that, these six conditions do not have an identifiable link with efficiency at firm or individual level.

> …the *likelihood* of users to adopt rule changes for the CPR use will be feasible if…
> (1) *'Most users' conclude they will be harmed if they don't adopt alternative rules*
> (2) *'Most users' conclude they will be affected similarly by the alternative rules*
> (3) *'Most users' highly value continuing the activity*
> (4) *Users share norms of reciprocity and trust*
> (5) *Users face low cost of information, transformation and enforcement*
> (6) *Users group is small and stable*
> (Ostrom,1990, page 211)

Figure 5.2: Ostrom conditions for the likely adoption of rules on the common pool resource.

Ostrom and colleagues proposed to use the Social Ecological Systems (SES) framework[20] to analyze how easily self governance can be adopted. The SES framework has been applied to explain how the rules to self govern the CPR succeed and survive over time. Building on the SES framework, Dietz, Ostrom, and Stern (2003) and Ostrom (2009), advised that SGM performance also depends on social performance outcomes including efficiency, equity and accountability. However, they refer to the efficiency of

[20] SES was defined in Chapter III as a framework to study the CPR interaction of governance system, users, resource system and resource units, to assess how the decision making process is supported to self govern the CPR (Anderies et al. 2004; Ostrom 2009; Basurto 2008).

the management system rather than the technical efficiency of the users. Their vision of efficiency is more an output, a desirable characteristic for the system management, rather than an input to describe the management of the CPR.

An interesting query is why user's efficiency is not framed in models to analyze the potential for self governance? There is not a clear answer and here we just speculate some reasons. First, it may be the case that self governance is conceived as an institution that deals more with equity issues (and less with effectiveness and efficiency); if this is the case, the derived institution might be a matter of social justice rather than of efficiency (Paavola 2006). Second, in a more comprehensive overview, Ostrom (2008) believes that conventional economic models may not been able to predict the consequences of actions[21] that CPR users have to take based on a model of maximization of short-term individual returns.[22] Is it the case that the user's economic efficiency may not be able to explain the consequences of joint management of the CPR?

Alternatively, in another venue other types of governance had been associated with other assessments of TE. We found interesting analysis in governance at corporate-firm-level. There has been found repeatedly a positive link between TE of the firm and governance of the firm (Garcia-Sanchez 2009; Bozec and Dia 2007; Zelenyuk and Zheka 2006). While TE of the firm increases, the governance of the firm also improves. Here the idea of TE is the same as we explained before, now the individual is the firm.

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[21] CPR users must to: (a) expend time and energy to develop rules of SGM; (b) follow such (costly) rules; (c) monitor each other; and (d) figure them out how effectively sanction the rules breakers.

[22] This a reason why Ostrom decided to use the property rights system as a theoretical base to examine why some individuals self govern the use of resource over long periods of time while others collapsed.

The difference is that governance of the firm depends mainly from the actions of shareholders and board of directors.

Another branch of analysis is the governance at macroeconomic or country level. Others have found a positive relationship between TE and governance at country level (Meon and Weill 2005; Lio and Hu 2009). As governance of a country improves, gains in technical efficiency have been found, but the definition of efficiency is a bit different. It is the difference between the observed and the optimal production at national level. It can also be assessed with the stochastic frontier analysis, the same theoretical framework that we used in Chapter IV. In this level of analysis, the macroeconomic governance is close to the idea of organizational democracy (Hanna 1995). The macro governance has been assessed as a global index formed by different indicators like rule of law, lack of political violence, quality of regulatory framework, efficiency of bureaucracy, control of corruption and accountability of political leaders (Meon and Weill 2005).

Wrapping up, the empirical evidence that relates self governance and economic efficiency has been more oriented to explore the CPR management efficiency (cost and benefits). The relationship between individual efficiency and SGM represents a gap in the CPR literature. Making explicit how TE is related with the potential for self governance may give a light in economics side towards the adoption of SGM.

Data

As discussed in detail in Chapter II, the data were gathered from the survey on the Lázaro Cárdenas Reservoir (LCR). From the 111 surveys completed, we start with the data adjusted by validity and reliability, 74 observations. We eliminate observations with missing values and the final data base was reduced to 62 observations. Table 5.1 describes the variables used in the estimation.

Table 5.1: Statistics of variables used for the models estimation.

Variable	Variable description	Units	Avg	StdDev	Min	Max
OC_1	Ostrom condition 1	index	3.7	0.7	2.0	5.0
OC_2	Ostrom condition 2	index	4.2	0.4	3.4	5.0
OC_3	Ostrom condition 3	index	4.2	0.5	2.3	5.0
OC_4	Ostrom condition 4	index	3.6	0.6	1.7	4.7
OC_5	Ostrom condition 5	index	4.0	0.5	2.9	5.0
OC_6	Ostrom condition 6	index	3.1	1.1	1.0	5.0
SGM	Self governance for management	index	3.8	0.6	2.2	5.0
r	Revenue	dollars	117.4	91.7	11.0	526.2
TE	Technical efficiency	index	0.83	0.22	0.15	0.99
age	Age of the fisher	years	44.6	2.5	0	12
edu	Education	years	6.0	2.5	0	12
exp	Fisher experience	years	23.9	15.0	1	60
coop	Worked for cooperative?	(dummy)	0.45	0.5	0	1
catv	Worked in conservation activities?	(dummy)	0.45	0.5	0	1
shr	Share the boat?	(dummy)	0.54	0.50	0	1
incf	Fishing main income?	(dummy)	0.73	0.45	0	1
fsize	Family size	number	4.37	2.3	1	15

In Table 5.1, the catch is the sum of all harvested species per fisher. The six OC_i indexes are taken from Chapter III and the index for *SGM* is just the average of the six OC_i. The average fisher experience is 24 years, though the variance is very high. About the half of the fishers share a boat, more than 50% depends mainly from the fishing activity. This revenue was estimated using the weighted price per kg of all species harvested by the fisher. The income from non related fishing activity is highly relevant during the seasonal closure. One third of the fishers obtain remittances from relatives living in USA, but 33% of the fishers do not have any other source of income. With regard to other economic activities, only 36% complement their income with agriculture and livestock and only 4% has a different business activity.

Modeling approach

The main variables used in the model are the six conditions (OCs*)* proposed by Ostrom (1990) and assessed in Chapter III; and in the fisher's TE estimated in Chapter IV. The OCs assesses the individual predisposition to adopt SGM in a group of CPR users. The potential for SGM will be a function of OC_i^j for the i^{th} OC, i=1,…, *6;* and the j^{th} fisher, $j=1,\ldots,m$. In this chapter we use $\hat{OC}_i^j$ the index estimated in Chapter III, as a proxy for every condition OC_i. The proposed relationship between $\hat{OC}_i^j$ and TE, together with other variables is represented in equation (5.1):

$$\hat{OC}_i^j = f\,(\,r_j,\, TE_j,\, age_j,\, coop_j,\, catv_j,\, C_{nj}\,) + \varepsilon_j^{i1} \tag{5.1}$$

where the $\hat{OC}_i^j$ index response is assumed to be a function of fisher's revenue (*r*), technical efficiency (*TE*), the age of the fisher (*age*) to assess the effect of experience in general and four dummies. Two variables are used as a proxy of cooperation: the fisher has worked for the fishing cooperative (*coop*) and if the fisher has participated in conservation activities of the lake (*catv*). The last two dummies are used to identify the fishing communities: Las Delicias ($C_{n=1}$) and El Palmito ($C_{n=2}$).

In a modified model, *age* and *TE* were replaced with variables that were used in Chapter IV to assess technical efficiency. Education (*edu*) and fisher experience (*exp*) account for the fisher skills. The variable family size (*ph*) or number of people living in home was included to assess a probable social effect of the fisher family. The dummy (*incf*) indicates if fishery is the main source of income and the dummy (*shr*) indicates if while fishing the fisher shares the boat. These variables are presented in equation (5.2):

$$\hat{OC}_i^j = f\,(\, r_j, edu_j, exp_j, ph_j, incf_j, shr_j, coop_j, catv_j, C_{nj}\,) + \varepsilon_j^{i2} \qquad (5.2)$$

The two models will offer different insights. Equation (5.1) assesses a direct relationship of TE with the potential for SGM. Equation (5.2) explains the potential for SGM but now using the variables that explain TE. Both equations seek to account for the fisher's efficiency, model one is a direct assessment and the second one is an indirect estimation.

Depending on the resulting sign on the coefficients of RHS variables of (5.1) and (5.2), we discuss two contradictory theoretical predictions. A negative sign would support the Hardin (1968) hypothesis, indicating that self interest of the more efficient fishers goes against the likelihood to adoption self governance, they are opposed to the common interest of the fishing group. Here is the reflection of Hardin (1968):

> Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination toward all men rush, each pursuing his own best interest is a society that believes in the freedom of the commons. (page 1244)

An alternative theoretical hypothesis would be supported if the coefficient is positive, and more efficient fishers tend to support SGM. A positive correlation would indicate that self interests of the more efficient fishers do not necessarily work against their propensity to adopt SGM. If they believe in the common work, they would exert a leadership for the likely adoption of SGM. In this regards, Ostrom (2009) mentions that

> "When some users of any type of resource system have entrepreneurial skills and are respected as local leaders as a result of prior organization for other purposes, self governance is more likely" (page 421).

Our research hypothesis goes in line with this idea; we expected to find a positive sign on *TE* and in the variables *edu* and *exp*.

Finally, the coefficients may not be significant, a result that may not necessarily need to be rare. Ostrom (2008) believed that predicting outcomes in a CPR is extremely difficult. Variables like homogeneity, leadership, market integration, etc., are important but predict in a model the effect on the likelihood for self governance is too complex.[23] "The problem of predicting outcomes is specially challenging when new and unfamiliar collective or constitutional-choice rules are selected" (Ostrom 2005, Page 65).

Additionally there are two groups of variables interesting observe. The first one is related with the fisher's income like revenue and the variable *incf*. The second are the variables *coop, catv* and *shr*; those indicate a level of cooperation and willingness to share and work for the community. All these variables are expected to have a positive sign. Here we have basically the same argument indicated above for TE. In SGM the individuals need to avoid their self interest and share and work in common interest. A negative sign therefore would go in line with Hardin (1968), and personal interest will oppose to a likely adoption of SGM. If the coefficients are not significant, the expected benefits from SGM are not able to predict the potential for SGM or they have an effect hard to observe in an ex-ante evaluation as we infer from Ostrom (2008, 2005) thoughts.

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[23] Ostrom (2005) stressed the relevance of predict the economic efficiency. However, she was thinking economic efficiency as an outcome in the management efficiency.

Results

Several steps were performed before to carrying out the final estimation. To test the functional form, every equation was regressed in a Box-Cox[24] transformation model to fit the best response of the data. We find that not all the equations support a log transformation model; they did not converge. For this reason, we present two outputs, one for the semi log functional form and another for the linear functional form.

To fit the model, we test different combinations of socioeconomic variables and check the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). The lowest BIC was consistently reached by the semi-log model approach.

For each model equation, (5.1) and (5.2), we present two specifications: a semi-log and a linear model. The results are presented in Tables 5.3 and 5.4. In Table 5.3 we present the regression in which SGM is used as the dependent variable, capturing each fisher's general propensity toward SGM by averaging across the OCs. Table 5.4 presents the results from the seemingly unrelated regression where the six OCs are used as dependent variables in a system of equations estimation. On the functional form, we transform in natural logs the dependent variables SGM and OCs, and the revenue and TE in the RHS to from the semi-log specification. Following Kennedy (2003), we transform only the variables for which percentage changes make sense.[25]

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[24] Box-cox assumes there is a value of θ which transforming to normality, gives homogeneous variance, and simple model structure. The task is to find "sensible" values of θ by maximum likelihood. The $\theta=1$ means no transformation or that linear model is supported by the data. The $\theta=0$ indicates that log transformation is supported. The $\theta=-1$ indicates that reciprocal transformation is supported.

[25] Kennedy (2003) on pages 402 and 412 argues to transform the data by using the economic sense. "…*data for which percentage changes make more sense in the context of the problem you are investigating should be logged. Typically wages, income, price index and population figures should be logged, but age, years of education and rates of change such as interest rates should not be logged.*"

A general result, where the dependent variable is the average of the six OCs presented in Table 5.2. With exception of the dummy that indicates dependence of the income on the fishing activity, the coefficients are not significant. If the fisher's income depends from fishing, the likelihood to adopt SGM decreases by 0.16 units on the scale of the Likert item. Although small, this value rejects our hypothesis and supports the idea that personal interests will decrease the likely adoption of SGM.

Table 5.2: Seemingly unrelated estimates for the Ostrom conditions average.

		Equation (5.1)				**Equation (5.2)**			
	Variables	**Semi-Log**		**Linear**		**Semi-Log**		**Linear**	
r	Revenue	-0.008		0.000		-0.007		0.000	
TE	Technical efficiency	0.004		-0.066					
age	Age fisher	0.000		-0.001					
edu	Education					0.002		0.006	
exp	Fisher experience					0.000		0.001	
ph	Family size					0.001		0.003	
incf	Income f/fishing					-0.040		-0.166	*
shr	Sharing boat					-0.001		-0.004	
coop	Work cooperative	0.028		0.112		0.019		0.065	
catv	Conserv. activity	-0.003		-0.016		0.002		0.004	
C_1	Las Delicias	0.000		0.003		0.017		0.084	
C_2	El Palmito	-0.045		-0.176		-0.017		-0.050	
	Constant	1.407	***	3.941	***	1.383	***	3.831	***
	R^2	0.075		0.287		0.075		0.286	
	chi^2	0.103		0.101		0.128		0.131	

Notes : Signifiance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Comparing the specification forms, there was no major difference between semi-log and linear specification outputs in regards of the signs and statistical significances of the coefficients. Both specifications did not fit well to explain the OCs (equations 5.1 and 5.2). The semi-log functional form have smaller AIC and BIC criteria (Appendix D).

The results for every $\hat{OC}_i$ are presented in Tables 5.3 and 5.4. In Table 5.3, the variable TE related to our research hypothesis, was not significant in any of the outputs of the Equation (5.1). The standard errors of output Tables 5.3 and 5.4 are presented in Table D.1 of Appendix D.

Table 5.3: Seemingly unrelated estimates for the six Ostrom conditions model: Equation (5.1).

	OC_1 index		**OC_2 index**		**OC_3 index**	
	Semi-Log	**Linear**	**Semi-Log**	**Linear**	**Semi-Log**	**Linear**
Revenue	-0.004	0.000	-0.014	0.000	0.009	0.000
TE	-0.042	-0.418	0.024	0.088	0.012	0.081
Age fisher	0.000	-0.001	0.000	0.001	0.002	0.005
Work coop	0.048	0.168	0.000	0.013	0.005	0.018
Cons. activ.	-0.001	0.037	-0.002	-0.030	-0.011	-0.014
Las Delicias	0.074	0.211	-0.012	-0.049	0.021	0.081
El Palmito	0.120 *	0.408 *	0.013	0.039	-0.031	-0.135
Constant	1.243 ***	3.794 ***	1.534 ***	4.147 ***	1.310 ***	3.933 ***
R^2	0.08	0.10	0.04	0.02	0.05	0.06
chi^2	5.68	6.61	2.52	1.51	3.55	3.80

	OC_4 index		**OC_5 index**		**OC_6 index**	
	Semi-Log	**Linear**	**Semi-Log**	**Linear**	**Semi-Log**	**Linear**
Revenue	-0.004	0.000	0.006	0.000	-0.027	0.000
TE	-0.059	-0.259	0.008	0.067	0.030	-0.003
Age fisher	0.004 **	0.012 **	0.001	0.003	-0.009 ***	-0.025 ***
Work coop	0.015	0.042	0.001	0.018	0.160	0.408
Cons. activ.	0.024	0.078	-0.048	-0.162	0.019	-0.031
Las Delicias	0.061	0.157	-0.003	-0.032	-0.151	-0.358
El Palmito	-0.054	-0.136	-0.020	-0.089	-0.434 ***	-1.122 ***
Constant	1.067 ***	3.322 ***	1.331 ***	3.904 ***	1.797 ***	4.604 ***
R^2	0.16	0.16	0.04	0.04	0.24	0.23
chi^2	11.43	12.15	2.90	2.52	20.11	18.83

Signifiance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ; TE means technical efficiency
Condition OC_1 : "Most fishers" conclude they will lose harvest if they maintain the current rules
Condition OC_2 : "Most fishers" agree with a set of rules that affect to all users similarly
Condition OC_3 : "Most fishers" highly value the benefits from the fishery and they want to continue doing it
Condition OC_4 : Fishers share norms of cooperation and trust
Condition OC_5 : Fishers faces low cost to monitoring and enforce
Condition OC_6 : Fishers group has been small and stable during the last 5 years

In Table 5.4, the output based on model individual Equation (5.2), fisher experience was significant in three conditions of and revenue was significant only for condition two. Several variables that one might expect to be important in affecting a fisher's disposition toward SGM were not significant at all including education, and the dummies *coop* and *catv* that were included to account a willingness for community work. Unobserved variables may help to explain the LHS variables. Indeed, the R^2 was very small in all the outputs.[26]

Table 5.4: Seemingly unrelated estimates for the six Ostrom Conditions model: Equation (5.2).

	OC_1 index		**OC_2 index**		**OC_3 index**	
	Semi-Log	**Linear**	**Semi-Log**	**Linear**	**Semi-Log**	**Linear**
Revenue	0.001	0.000	-0.032 **	0.000	-0.016	0.000
Education	0.011	0.044	-0.006	-0.021	-0.012	-0.047
Fishr experien	0.000	0.001	0.003 ***	0.011 **	0.002	0.009
Age fisher	0.000	0.002	-0.002 **	-0.009 *	-0.001	-0.005
Age motor	0.004	0.011	0.000	0.001	-0.001	-0.003
Family size	-0.004	-0.008	0.008	0.031	0.010	0.041
Income fish	0.037	0.107	-0.012	-0.080	-0.002	-0.069
Sharing boat	-0.004	-0.010	-0.011	-0.051	0.014	0.033
Work coop	0.029	0.073	-0.016	-0.072	-0.004	-0.020
Conserv. activ	-0.002	0.036	0.006	-0.011	0.004	0.016
Las Delicias	0.084	0.291	-0.013	0.011	0.011	0.107
El Palmito	0.111	0.415	0.019	0.094	-0.030	-0.096
Constant	1.079 ***	2.907 ***	1.732 ***	4.514 ***	1.586 ***	4.444 ***
R^2	0.12	0.12	0.19	0.14	0.10	0.12
chi^2	9.07	8.64	15.96	10.59	7.47	8.70

	OC_4 index		**OC_5 index**		**OC_6 index**	
	Semi-Log	**Linear**	**Semi-Log**	**Linear**	**Semi-Log**	**Linear**
Revenue	0.013	0.000	-0.016	0.000	0.010	0.000
Education	0.014	0.045	-0.007	-0.032	-0.010	-0.013
Fishr experien	-0.002	-0.005	0.005 ***	0.017 ***	-0.008 *	-0.015
Age fisher	0.007 ***	0.019 **	-0.003 **	-0.012 **	-0.005	-0.017
Age motor	-0.001	-0.005	-0.001	-0.003	-0.002	-0.008
Family size	-0.013	-0.033	-0.003	-0.012	-0.005	-0.009
Income fish.	-0.035	-0.080	0.013	0.009	-0.303 ***	-0.888 ***
Sharing boat	0.084 *	0.274 *	-0.041	-0.165	-0.010	-0.065
Work coop	0.025	0.066	-0.021	-0.062	0.197 **	0.444
Conserv. activ	0.041	0.147	-0.035	-0.138	0.004	-0.018
Las Delicias	0.095	0.232	-0.030	-0.092	-0.075	-0.131
El Palmito	-0.017	-0.032	-0.045	-0.159	-0.253 *	-0.579
Constant	0.813 ***	2.548 ***	1.667 ***	4.746 ***	1.735 ***	5.065 ***
R^2	0.25	0.25	0.22	0.20	0.34	0.33
chi^2	21.49	21.65	18.93	17.01	33.48	32.05

Signifiance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ; TE means technical efficiency

Discussion

Overall, our results do not find a statistically significant relationship between the OCs and key explanatory variables including TE and fisher education. Fisher experience

[26] For the equations (5.1) and (5.2) we make a sensitivity analysis by running different specifications with revenue, technical efficiency and age squared or in a polynomial form. The results did not change while none of the variables become significant or had a change in sign.

was significant for conditions two, five and six. Although the effect is very small as the coefficient is close to zero, the statistical significance does suggest that fishers with more experience tend to favor SGM. This results support the hypothesis, that fishers with entrepreneurial skills and who are recognized as leaders, may favor the adoption of SGM. Although we are cautious in condition six where we observe a negative effect, it is because of the bimodal distribution of this condition, and the fact that it is obtained from only one question.

The most relevant socioeconomic variable was the age of the fisher. As the age of a fisher increases, his agreement with norms of cooperation and trust also tends to increase. Nonetheless, this coefficient is very close to zero, so that holding all else equal, a fisher who is 57 years old, older than 75% of the fishers in the survey, would on average have a Likert value that is 0.025 points larger than a fisher who is 32 years old, younger than 75% of the fishes in the sample, which is a difference less than tenth of standard deviation in the SGM value

Summing up there are several general lessons learned from the regressions. First, the proposed models do not explain very much of the variation in the OCs. The semi-log specification seems to work better, but does not provide support for either a positive or negative hypotheses. Among the variables that explain TE, only fisher experience is significant for conditions two, five and six. The fisher income related variables in conditions two and six do not support our hypothesis of a positive relationship between income and OCs.

Additional evidence

In this section we present additional evidence as to what variables might tend to favor SGM success. As an alternative to OCs, we can consider a measure of leadership. Ostrom (2009) and Baland and Platteau (1996) discuss leadership as a probable factor that affects the emergency of a new institution. Besides personal criteria, the president of the cooperative and the older fishers are individuals in the community that command respect by the LCR fishers as it is presented in Figure 5.3. Interestingly from the survey, neither the president nor the old fishers are perceived as the more productive fishers. To the question, *Does the one you follow, catch more than you?* Only 31% answered yes; and 54% declared that the leader does not catch more that the fisher surveyed.

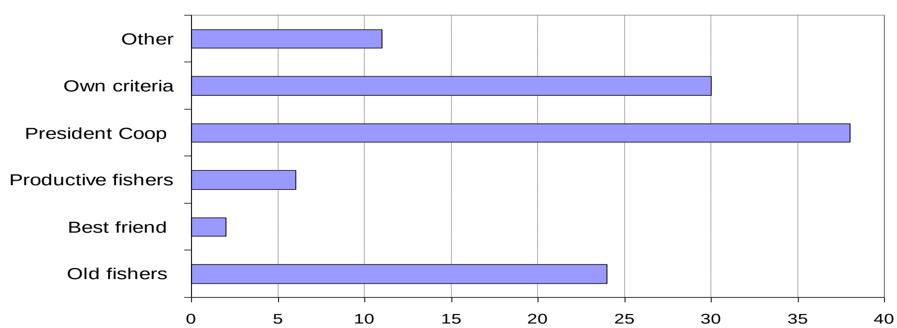

Figure 5.3: Answer frequency of the question:
Who do you follow at the time you vote the agreements in the cooperative?

Finally, in a bivariate representation of the relationship between TE and the potential for SGM (Figure 5.4), we average the six OCs to form a global Likert scale of the potential for SGM. The correlation between our SGM index and our measure of TE was -0.19, it shows a negative relationship, although as seen in the regression results

(Table 5.4) it is not statistically significant.[27] This result presents weak evidence in support of any relationship between SGM and TE. This finding goes more in line of the belief of Ostrom (2008) when she mentioned that independent variables or indicators (e.g. TE in this case), would not help to predict the outcomes derived from a complex interaction between ecological, social, and economic systems.

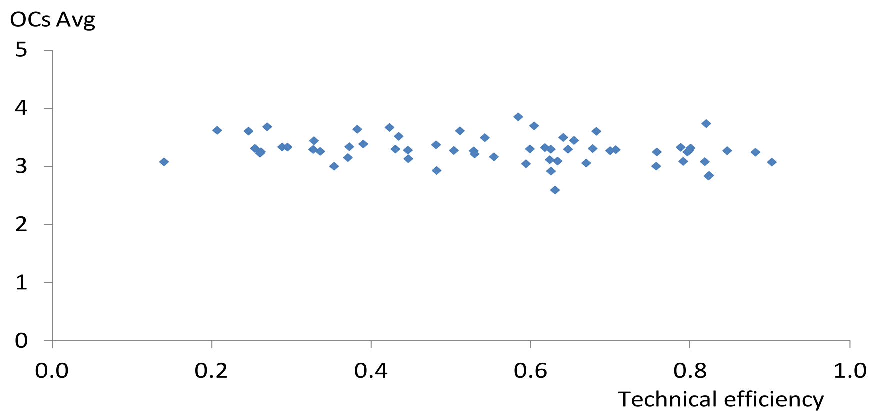

Figure 5.4: Relationship between the potential for self governance (OCs Avg) and fishers' technical efficiency.

Overall, because of the limited scope of the research and the challenge in an *ex-ante* analysis, this research assesses only the predisposition of the fishers toward SGM, not their willingness to pay for its adoption. Our OC measures are intended to provide an indicator of the probability that self governance could be successfully adopted, not how much a person is willing to sacrifice in order to reach the SGM.

[27] The t-value was 1.65. At 95% of confidence level the critical value is 1.99.

Final remarks

This chapter uses the *ex-ante* assessment of the likelihood of the adoption of self governance and our measure of TE from Chapters III and IV of this dissertation to explore the relationship between TE and the potential for SGM.

Overall, our assessment rejects that technical efficiency is related either positively or negatively with a predisposition to adopt SGM. Although there is a negative relationship between these two variables, it is not statistically significant. Therefore, if there is not any effect at all, a fisher's TE may not favor or disfavor the fisher's tendency to support the SGM.

There is a significant and positive relationship between the potential for SGM, fisher experience, and age of the fisher. This supports the idea that entrepreneurial skills and leadership may favor the likely adoption of SGM. On the other hand, the relationship between fisher income and conditions two and six do not support the hypothesis of a positive relationship between income and OCs. If this holds generally, it could suggest that those with the greatest personal interest (as indicated by their income) will oppose the adoption of SGM.

These findings do offer suggestions for policy making. If policy makers want to encourage the adoption of SGM in LCR, it would be a good idea to start the process with the more experienced and older fishers and with leaders of the fishing community. El Palmito community may be a good place to start the process because it has the higher measure of predisposition toward SGM.

CHAPTER VI

CONCLUSIONS

Summary

This dissertation addresses the problem of managing a *common-pool resource* (CPR), a small-scale fishery in Mexico that suffers from what we call the *CPR problem*; an over-extraction of fish and a poor level of profitability of the commercial fishery (Gordon 1954). The fishers face the problem of how to manage the fishery and improve the wellbeing of their fishing community.

Adoption of *self governance for the management* (SGM) of this fishery may be a reasonable option to deal with the CPR problem. For this study, we apply the theoretical framework proposed by Ostrom (1990) to assess the fishers' predisposition towards the adoption of SGM, and relate this potential with a measure of the fishers' economic performance. Three main steps were performed. First, an *ex-ante* assessment of six conditions (OCs) related to the likely adoption of SGM. Second, we measure the fishers' technical efficiency (TE). Third, we explore the relationship between OCs and TE.

We hypothesized a positive relationship between individual TE and the predisposition of fishers to adopt SGM. Economic models often assume all economic agents to be homogeneous and fully efficient. This assumption is relaxed and we study the fishers' TE as a factor that explains the user's predisposition towards the adoption of self governance.

We found a high predisposition toward the adoption of SGM (3.81), as well as, high level of individual technical efficiency (0.831). Nonetheless, we did not find a statistically significant relationship between TE and the potential for SGM. We did, however, find a positive and a significant relationship between fisher experience and the potential for SGM. Thus, years of experience working as a fisher would be relevant to explain the likelihood for the adoption of SGM in the study site.

Overall, this research makes two contributions: (a), this is the first known *a-priori* evaluation of the potential for SGM; (b), this assesses how technical efficiency of CPR users is related with their individual potential for self governance.

Conclusions

This research measure a set of proposed conditions (the Ostrom conditions), to assess the potential for SGM. Replicating this assessment may bring a better evaluation about these conditions and hopefully yield better understanding to support the policy making process with regard to SGM. Replications may also help with the most significant constraint of this research, the lack of a true validity measure. We do not observe *ex-post* whether SGM was successful. Thus, *ex-ante* assessments like this would be valuable if SGM is attempted and, if so, whether it is successful in the future.

Certainly, because of the limited scope of the research and the challenge in an ex ante analysis, this research assesses only the statistical significance over the potential for SGM, not the willingness of the users to sacrifice for its adoption. The high agreement level does not mean a policy action or a recommendation to adopt the self governance in the Lázaro Cárdenas Reservoir. Carefully, this is only an evaluation of how much the fisher’s favor SGM, but it does not necessarily indicate they have to adopt it.

The results on the factors that constrain or favor TE may give some guidance for the policy making. For example, policy makers may not want improvements in TE without a better management of the fishery (i.e. imposing restrictions in access), because it could leave inefficient fishers in devastating poverty and reach the worst scenario presented in the fisheries problem of Gordon's model. Measures implemented on the technology side partially solve the open access problem (Grafton 2006, Ostrom 1990). This advice has been on the table for a long time and this research looks for the applicability in this small-scale semi-artisanal fishery.

Overall, fishers' TE does not have a significant relationship with the conditions proposed to assess the potential for SGM. But according with our findings, if policy makers want to encourage the adoption of rules towards the self governance in the study site, it would be a good idea to start the process with the more experienced and older fishers and with community leaders.

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APPENDIX A

Table A.1: Descriptive statistics of fishing activity in Lázaro Cárdenas Reservoir (LCR): n = 89.

Variable description	Unit	Avg	Var	Std Dev	Min	Max	Delicias	Palmito	Victoria
Community	# fishers						39	35	15
Age	Years	44.6	259.7	16.1	16	90	42.6	45.8	47.1
Family size	Number	4.4	5.5	2.3	1	15	4.3	4.4	4.5
People < 15 years old	Number	1.1	1.9	1.4	-	6	1.0	0.9	1.7
Years of school	Years	6.0	6.3	2.5	-	12	6.0	5.6	6.7
Fisher experience	Years	23.9	223.8	15.0	1	60	20.7	27.4	24.4
Labor	Hrs/week	26.7	194.2	13.9	-	63	20.3	36.1	22.0
Catch Jan (p/week)	Kg	153.1	46,371	215.3	-	1,150	151.3	170.0	119.7
Revenue Jan (p/week)	$000	2.9	12,436	3.5	-	19	2.7	3.0	3.2
Catch last week	Kg	92.3	19,759	140.6	-	920	61.1	137.9	69.7
Revenue last week	$000	1.4	1,855	1.4	-	8	1.1	1.9	1.0
Nets used last week	# nets	6.6	13.6	3.7	-	15	6.5	7.4	4.9
Days fishing	# days	5.7	3.0	1.7	-	7	5.4	6.0	6.1
Gas cost	($ week)	275.8	69,542	263.7	-	1,400	242.3	324.7	251.6
Boat length	Mt	4.3	0.6	0.8	3	6	4.2	4.4	4.2
Engine power	HP	20.0	50.0	7.1	5	48	20.0	21.9	14.1
Age of the boat	Years	14.9	87.0	9.3	1	50	14.0	16.3	14.2
Age of motor	Years	11.4	84.1	9.2	0	35	11.0	11.0	13.7
Fixed cost	$ (,000)	16.0	180,517	13.4	-	64	13.4	19.9	14.0
Nets cost	$ (,000)	1.2	573	0.8	-	3	1.2	1.5	0.8
Maintenance cost	$ (,000)	0.9	1,933	1.4	-	7	0.8	1.3	0.5
Number of dependents	# people	3.1	3.4	1.8	-	9	3.0	3.2	2.9
Income from fishing	$000	0.5-0.6	0.8-1	0.2-0.3	<0.2	>1.5	0.3-0.4	0.6-0.7	0.4-0.5
Total income last week	$000	1-2	<1	<1	<1	6-7	<1	1-2	1-2

APPENDIX B

Principal component analysis (PCA).

Based on Wolfgang and Simar 2007, and Johnson and Wichern 2002.

PCA is a technique that allows us to derive one or more summary measures, the principal components (PCs) from the data. Each PC is a weighted average that maximizes the explained proportion of the variance in the original data set. Each PC is uncorrelated (orthogonal) with the others PCs, in a linear transformation of the data by rotating the vectors to get a matrix where its transpose is equal to its inverse. PCA consist of four steps.

First step, take X_i matrix of *n* observations (*j* rows or fishers, where $j=1,\ldots,74$) occurring in *m* variables (*k* columns or questions, where $k=1,\ldots,m$), for any given Ostrom condition *i*. We subtract the column mean μ_j from each observation in X_i to form a new data set $A_{i\,(nxm)}$.

The second step is to get the (m x m) variance-covariance matrix of A_i. This new matrix is called V_i.

The third step is to get the eigenvalues (λ_i) and eigenvectors (δ_i^k) of V_i. This step is also known as the singular value decomposition of V_i.

The fourth step is to sort λ_i and δ_i^k. The eigenvector with the highest eigenvalue will be the first principal component (or PC1). Ranking all the possible eigenvalues, from the highest to the lowest we get the featured vector $F_{i(px1)}^k$ (where $k=1,\ldots,m;$ and *p* is the number of possible eigenvalues), the vector of principal components (δ_i^k) for every variable (or indirect question q_{ij}^k).

Table B.1: Principal component analysis: Rotation: (unrotated = principal).

	Component	Eigenvalue	Difference	Proportion	Rho
OC_1	Comp1	1.15061	0.301229	0.5753	0.5753
OC_2	Comp1	2.04227	1.10856	0.5106	0.5106
OC_3	Comp1	2.06664	1.16616	0.5167	0.5167
OC_4	Comp1	1.38995	0.472981	0.4633	0.4633
OC_5	Comp1	1.43415	0.253071	0.3585	0.3585

Table B.2: Principal components (eigenvectors).

	Variable	Component 1	Unexplained
OC_1	qoc1_2	0.7071	0.4247
	qoc1_4	0.7071	0.4247
OC_2	qoc2_2	0.4077	0.6605
	qoc2_3	0.5873	0.2955
	qoc2_4	0.5913	0.2859
	qoc2_5	0.3730	0.7158
OC_3	qoc3_1	0.5274	0.4251
	qoc3_2	0.5195	0.4423
	qoc3_3	0.4265	0.6241
	qoc3_4	0.5197	0.4418
OC_4	qoc4_1	0.4765	0.6844
	qoc4_2	0.6619	0.3911
	qoc4_3	0.5787	0.5345
OC_5	qoc5_1	0.4381	0.7248
	qoc5_2	0.5089	0.6287
	qoc5_3	0.5508	0.5648
	qoc5_4	0.4957	0.6476

NOTE: For OC_6 there is only one variable, thus PCA I not allowed

Table B.3: Indirect questions and frequencies to form the six Ostrom condition (OCi) index.

	Likert Scale	1	2	3	4	5
OC_{1w}. "Most users" conclude they will lose harvest if they maintain the current rules						
If the *current fishing rules* remains for the next year, my catch will (*)	[1] Increase [2] Maybe increase [3] Don't know [4] Maybe decrease [5] Decrease	1	6	37	20	10
How much do you agree/disagree with this statement? Do you favor the adoption of strict fishery *management rules?* (e.g. stop fishing bass)	[1] Strongly disagree [2] Disagree [3] Don't know [4] Agree [5] Strongly agree	1	6	1	48	18
OC_{2w} "Most users" agree with a set of rules that affect all user s similarly						
How much do you agree/disagree w/each statement? …most coop agreements equally affect all fishers?	[1] Strongly disagree [2] Disagree [3] Don't know [4] Agree [5] Strongly agree	0	2	0	58	14
…a good set of rules imply hard work of all the fishers		0	1	0	57	16
…a good set of rules imply sacrifice of all the fishers		0	0	0	53	21
…the cooperation among fishers in not important (*)		1	1	0	49	21
OC_{3w} "Most users" highly value the benefits derived from the activity, hence they want to continue						
How much do you agree/disagree w/each statement? …I am very proud of being a fisher	[1] Strongly disagree [2] Disagree [3] Don't know [4] Agree [5] Strongly agree	0	3	1	26	44
…I want my son and my grandson to be a fisher		2	8	8	48	8
…I teach my son (or will teach if I have one) how to fish		1	1	4	53	15
…Above all things considered, how satisfied are you working as a fisher?	[1] Nothing Satisfied [2] No Satisfied [3] Don't know [4] Satisfied [5] Very Satisfied	0	1	2	37	34
OC_{4w} Users share norms of cooperation and trust						
How much do you agree/disagree w/each statement? …very often, you do favors to other fishers	[1] Strongly disagree [2] Disagree [3] Don't know [4] Agree [5] Strongly agree	0	6	0	55	12
…most fishers share experiences and knowledge to you		3	7	0	51	13
…you trust your community neighbors and fishers		1	7	1	45	20
…you trust the fishers of other communities		15	20	0	36	1
OC_{5w} Users face low cost getting information to monitor and enforce the rules						
How much do you agree/disagree w/each statement? …if you violate a rule, you have fear of being punished	[1] Strongly disagree [2] Disagree [3] Don't know [4] Agree [5] Strongly agree	0	5	1	53	15
…you can easily see how other fisher's harvest		0	1	0	57	16
…in a cooperative agreement (e.g. stop fishing bass), it is easy to see if fishers obey such agreement		2	9	1	47	15
…it is easy to detect if outsider fishers are fishing		2	6	0	52	13
OC_{6w} "Fishers" group in LCR have been small and stable during the last 5 years						
How much do you agree/disagree with this statement? …5 years ago, the reservoir had more fishers than it has today	[1] Strongly disagree [2] Disagree [3] Don't know [4] Agree [5] Strongly agree	3	24	14	26	7

(*) means that the questions scale was sorted (i.e. 2 was converted to 4 and 1 = 5) to have equivalent scale

APPENDIX C

Table C.1: Testing the linear model assumptions for the production function, Equation (4.7).

i.- Collinearity: Variance inflation factors: vif(fit)

Labor	Effort capacity	Factor capacity
1.141	1.114	1.227
FALSE	FALSE	FALSE

Note: Criteria will be sqrt(vif(fit)) > 2

ii.- Global test of model assumptions: summary, on 85 degrees of freedom

	Estimates	P-value > |t|	
Intercept	0.535 (0.728)	0.465	
Labor	0.501 (0.163)	0.003	**
Effort capacity	0.179 (0.115)	0.123	
Factor capacity	0.548 (0.139)	0.000	***

Note: Standard errors are reported in parentheses. Asterisk (*), double asterisk (**) and triple asterisk (***) denote coefficients significant at 10%, 5% and 1% respectively. Residuals: Median = 0.03029, Residual standard error: 0.7363. Multiple R-squared: 0.3657, Adjusted R-squared: 0.3433. F-statistic: 16.33 on 3 and 85 DF, p-value: 1.814e-08

iii. Assessment of the linear model assumptions using the global test on 4 df

	Value	p-value		Decision
Global Stat	1.644879	0.8007	Assumptions	acceptable
Skewness	0.096928	0.7555	Assumptions	acceptable
Kurtosis	0.000432	0.9834	Assumptions	acceptable
Heteroscedasticity	0.162792	0.6866	Assumptions	acceptable

Level of Significance = 0.05

Table C.2: Testing Technical Efficiency Frontier approach.

Tastings of the model, Equations (4.7) and (4.9).

i. Functional form

Testing TE affects on a Translog model to a corresponding Cobb Douglas model and comparing the two models by a Likelihood ratio test

	Df	LogLik	Df	Chisq	Pr(>Chisq)
Model 1: Cobb Douglas	16	-83.579			
Model 2: Translog	22	-80.700	6	5.7584	0.4508

Ho: $\beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$, i.e. functional form favors a Cobb Douglas over a translog in the empirical model

ii. Inefficiency

Comparing each of the models to a corresponding model without inefficiency by a Likelihood ratio test

	Df	LogLik	Df	Chisq	Pr(>Chisq)
Model 1: OLS (no inefficiency)	5	-96.940			
Model 2: Efficiency effects frontier (EEF)	16	-83.579	11	26.721	0.003095 **

Ho: $\sigma_u^2=0$, $\gamma = 0$, i.e. the systematic and random TE effects are zero, hence, neither the constant nor the inefficiency effects are at all necessary in the model.
Note: Standard errors are reported in parentheses. Asterisk (*), double asterisk (**) and triple asterisk (***) denote coefficients significant at 10%, 5% and 1% respectively.

iii. Distribution

Comparing a restricted model with truncated normal distribution Vs Unrestricted model with half-normal z distribution by a Likelihood ratio test

	Df	LogLik	Df	Chisq	Pr(>Chisq)
Model 1: truncated normal	7	-95.801			
Model 2: half-normal	6	-95.817	-1	0.0311	0.86

APPENDIX D

Table D.1: Standard error of the estimates for the six Ostrom Conditions (OCs) model.

Seemingly unrelated regression, iterated — STANDART ERRORS — 62 Observations, 7 parameters

	OC1		OC2		OC3		OC4		OC5		OC6		Ocs Avg	
	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear
Revenue	0.036	0.000	0.015	0.000	0.024	0.000	0.038	0.000	0.023	0.000	0.067	0.000	0.013	0.000
Technical Effciency	0.072	0.415	0.030	0.228	0.048	0.311	0.076	0.395	0.045	0.300	0.132	0.627	0.044	1.020
Age fisher	0.002	0.006	0.001	0.003	0.001	0.004	0.002	0.005	0.001	0.004	0.003	0.009	0.001	0.014
Work coop	0.057	0.194	0.024	0.107	0.038	0.145	0.061	0.185	0.036	0.141	0.106	0.294	0.021	0.478
Cons. Activity	0.054	0.181	0.023	0.099	0.036	0.135	0.058	0.172	0.034	0.131	0.101	0.273	0.020	0.444
Las Delicias	0.069	0.234	0.029	0.128	0.046	0.175	0.073	0.223	0.043	0.169	0.128	0.353	0.025	0.575
El Palmito	0.070	0.244	0.030	0.134	0.047	0.183	0.075	0.232	0.044	0.177	0.130	0.369	0.026	0.600
Constant	0.281	0.456	0.119	0.250	0.188	0.341	0.298	0.434	0.176	0.330	0.520	0.689	0.097	1.121
RMSE	0.191	0.654	0.081	0.359	0.128	0.490	0.203	0.623	0.120	0.473	0.355	0.988	0.070	1.608
R2	0.084	0.096	0.039	0.024	0.054	0.058	0.156	0.164	0.045	0.039	0.245	0.233	0.105	0.101
chi2	5.68	6.61	2.52	1.51	3.55	3.80	11.43	12.15	2.90	2.52	20.11	18.83	7.240	7.000
P	0.578	0.471	0.925	0.982	0.830	0.803	0.121	0.096	0.894	0.926	0.005	0.009	0.404	0.429
AIC	-254.4	681.0												
BIC	-152.3	783.1												

Seemingly unrelated regression, iterated — STANDART ERRORS — 66 Observations, 12 parameters

	OC1		OC2		OC3		OC4		OC5		OC6		Ocs Avg	
	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear	Semi-Log	Linear
Revenue	0.032	0.000	0.013	0.000	0.022	0.000	0.032	0.000	0.018	0.000	0.057	0.000	0.012	0.000
Education	0.013	0.045	0.006	0.025	0.009	0.035	0.013	0.041	0.008	0.030	0.024	0.066	0.005	0.112
Fisher experience	0.003	0.009	0.001	0.005	0.002	0.007	0.003	0.008	0.001	0.006	0.005	0.013	0.001	0.021
Age motor	0.003	0.009	0.001	0.005	0.002	0.007	0.003	0.008	0.002	0.006	0.005	0.013	0.001	0.022
Family size	0.011	0.038	0.005	0.021	0.008	0.030	0.011	0.035	0.006	0.026	0.020	0.056	0.004	0.094
Income f/fishing	0.064	0.219	0.027	0.122	0.045	0.169	0.065	0.200	0.037	0.147	0.114	0.318	0.024	0.540
Sharing boat	0.049	0.170	0.021	0.094	0.034	0.131	0.050	0.155	0.029	0.114	0.088	0.246	0.018	0.418
Work coop	0.055	0.190	0.024	0.106	0.039	0.147	0.056	0.174	0.032	0.128	0.099	0.277	0.020	0.470
Cons. Activity	0.050	0.170	0.021	0.095	0.035	0.131	0.051	0.155	0.029	0.114	0.089	0.247	0.018	0.420
Las Delicias	0.073	0.244	0.031	0.136	0.051	0.189	0.075	0.223	0.043	0.164	0.131	0.354	0.027	0.602
El Palmito	0.077	0.266	0.033	0.148	0.054	0.206	0.078	0.243	0.045	0.179	0.138	0.387	0.028	0.657
Constant	0.304	0.651	0.130	0.363	0.214	0.503	0.311	0.594	0.178	0.437	0.546	0.946	0.113	1.607
RMSE	0.184	0.635	0.078	0.354	0.129	0.491	0.188	0.579	0.107	0.427	0.330	0.923	0.068	1.568
R2	0.121	0.116	0.195	0.138	0.102	0.117	0.246	0.247	0.223	0.205	0.337	0.327	0.144	0.147
chi2	9.07	8.64	15.96	10.59	7.47	8.70	21.49	21.65	18.93	17.01	33.48	32.05	11.13	11.36
P	0.697	0.733	0.193	0.565	0.825	0.728	0.044	0.042	0.090	0.149	0.001	0.001	0.518	0.499
AIC	-265.1	735.3												
BIC	94.3	906.1												

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