# Property Rights for Fishing Cooperatives: How (and How Well) Do They Work?

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Devolving property rights to local institutions has emerged as a compelling management strategy for natural resource management in developing countries. The use of property rights among fishing cooperatives operating in Mexico's Gulf of California provides a compelling setting for theoretical and empirical analysis. A dynamic theoretical model demonstrates how fishing cooperatives' management choices are shaped by the presence of property rights, the mobility of resources, and predictable environmental fluctuations. More aggressive management comes in the form of the cooperative leadership paying lower prices to cooperative members for their catch, as lower prices disincentivize fishing effort. The model's implications are empirically tested using three years of daily logbook data on prices and catches for three cooperatives from the Gulf of California. One cooperative enjoys property rights while the other two do not. There is empirical evidence in support of the model: compared to the other cooperatives, the cooperative with strong property rights pays members a lower price, pays especially lower prices for less mobile species, and decreases prices when environmental fluctuations cause population growth rates to fall. The results from this case study demonstrate the viability of cooperative management of resources but also point toward

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quantitatively important limitations created by the mismatch between the scale of a property right and the scale of a resource. JEL codes: O13, Q20, Q22, Q50, Q56, Q57

There is widespread concern for the health of global fisheries: a recent study estimated that 28–33% of fisheries are over-exploited and 7–13% are collapsed (Branch et al. 2011).[1] Since Gordon (1954) and Scott (1956), the static and dynamic externalities that lead to over-extraction have been well understood. However, policy makers and researchers have struggled with how best to ensure that these externalities are properly internalized, particularly in low-income countries. In this paper, we use a blend of theory and empirics to better understand whether, when, and how assigning property rights to fishing cooperatives can resolve the externality problem.[2]

Assigning cooperatives the exclusive right to fish a spatially delineated area—a specific case of a Territorial Use Right Fishery (TURF) (see Wilen et al. 2012)—is an attractive concept. It potentially improves upon much more common solutions to the externality problem, such as catch shares, tradable quotas, and marine reserves (Hilborn et al. 2005; Deacon 2012). While these more common systems have been associated with improved ecological and economic outcomes (Hilborn et al. 2005; Costello et al. 2008; Lester et al. 2009), they require intensive monitoring and enforcement that may be relatively costly. In contrast, cooperatives may be able to leverage social ties to monitor and enforce spatial boundaries at relatively low cost. Moreover, cooperatives can allocate fishing effort across space and time in a manner that avoids both closing a fishery and the race for especially profitable fishing areas or times that is inherent with transferable quotas. A cooperative's ability to coordinate its members' actions could also reduce races to fish within a TURF that is assigned to a less cohesive group of fishers (Costello and Kaffine 2010). Finally, a cooperative could facilitate greater provision of public goods that reduce members' private fishing costs, such as information on the best fishing locations or shared equipment.

Despite these advantages, there are still two major challenges to the effective use of property rights by fishing cooperatives, and empirical evidence on these challenges is scarce. First, the scale of the property right may not match the scale of the resource, thereby giving a cooperative much less incentive and ability to manage its exclusive rights (Ostrom 1990; White and Costello 2011).[3]

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[1] "Over-exploited" refers to stocks less than half of maximum sustainable yield (MSY), while "collapsed" is defined as stocks less than one-fifth of MSY.

[2] Following Deacon (2012), we define fishing cooperatives as "an association of harvesters that collectively holds rights to control some or all of its members' fishing activities." Cooperatives are quite common; for example, Deacon (2012) points to at least 400 cooperatives in Bangladesh and over 12,000 in India.

[3] A similar problem arises if a local user group does not have control over a species that is ecologically connected to the resource it controls. For instance, fishermen outside the group may fish species that are preyed on by species controlled by the group.

The “scale of the resource” refers to the degree of geographic mobility of the organisms targeted by fishers. Second, and less often discussed in the literature, cooperative management may not adapt effectively in the face of environmental variability. For instance, cooperatives may need to ensure members some minimum level of well-being in order to retain members; this may hinder a cooperative’s ability to dramatically cut fishing effort when environmental conditions negatively impact fish populations.

In this paper, we develop a dynamic model of cooperative decision-making and use rich data from Mexico’s Gulf of California fisheries to examine how fishing cooperatives exercise property rights, with a focus on three issues: 1) Whether cooperatives with property rights manage a resource differently from those without; 2) How such differences depend on the scale of the resource; and 3) How such differences respond to predictable environmental fluctuations associated with ENSO (El Niño/Southern Oscillation) events. Mexico is a natural setting for the analysis. The country’s marine ecosystems are rich in biodiversity, which provides an opportunity to examine how fishing cooperatives shift behavior when fishing on species that vary in key traits, such as mobility. Moreover, ENSO events have important impacts on fisheries, with the direction and magnitude of these impacts differing among species.

We begin our analysis with a dynamic model of cooperative decision-making. Cooperative leadership can engage in more aggressive management by lowering the price that is paid to cooperative members for a specific species and, therefore, disincentivizing fishing of that species. The model yields three testable implications for how cooperative price and resulting catch change in response to external factors. Specifically, compared to other cooperatives, a cooperative with stronger property rights manages effort more aggressively, decreases the relative aggressiveness of management if a species is highly mobile, and restricts effort more when environmental forcing (e.g., ENSO events) limit the population growth rate of a species. Throughout, by “strong property rights” we mean the ability to exclude noncooperative fishers from the cooperative’s established fishing grounds.

We test these implications using daily logbook data from three cooperatives in the Gulf of California region, in northwest Mexico. One cooperative, operating on the Pacific coast, retains an exclusive concession for some species and is able to exclude outside fishermen for all other species (Cota-Nieto 2010; McCay et al. 2014). The other two cooperatives are located close to La Paz, the state capital of Baja California Sur (B.C.S.), and compete with other cooperatives and noncooperative fishermen for fish (Basurto et al. 2013; Sievanen 2014). Analysis using the fishing team-level logbook data reveals that cooperative members respond to cooperatives’ chosen prices as posited by the model. Exploiting the fact that one cooperative has stronger property rights than the other two, we use the cooperative-level price and catch data to demonstrate empirical support for the model’s three implications. The difference in price and catch between the cooperative with strong property rights and the other two cooperatives is large, and the cooperative with property rights disincentivizes effort more aggressively than the other two when growth rates are likely to be small. But the magnitudes of the estimates also indicate that the difference in management aggressiveness across the cooperatives shrinks in economically meaningful ways when resource scale is large and growth rates are high.

Given the small number of cooperatives in the analysis, one should be cautious in extrapolating these findings to other settings. Instead, we view our results as improving the general understanding of when and how cooperative-based property rights can be effective. Our work complements the rich literature on community-based resource management institutions. Ostrom (1990) reviews case studies of institutions and derives a set of principles that differentiate those that are successful. We examine the role of some key principles from the Ostrom framework, such as clearly defined boundaries and effective rule enforcement. However, rather than making binary assessments of "success," we empirically quantify the influence of property rights on economic outcomes. Gutiérrez et al. (2011) consider case studies of fishing cooperatives in particular and find predictors of success, including the existence of quotas, enforcement institutions, long-term planning, and resource mobility. Recent economics literature examines the decision-making of villages or other local user groups regarding other resources (e.g., Edmonds [2002] and Foster and Rosenzweig [2003] on forests). In contrast to these studies, we examine the short-term dynamics of resource management, illuminating the mechanisms that institutions may use to achieve management goals. We do so in the context of fisheries, which are characterized by important spatial externalities and environmental fluctuations not relevant to some other natural resources.

The theoretical literature on optimal fisheries management strategies considers these challenges. For instance, Costello and Kaffine (2010) and White and Costello (2011) examine the implications of spatial externalities in area-based property rights, driven by movement of species across large ranges. Reed (1975), Parma and Deriso (1990), Costello et al. (2001), and Carson et al. (2009) look at how management may respond to temporary or permanent environmental changes. Our paper examines similar issues but introduces an important complication arising from cooperative leaders' need to ensure returns high enough to retain members. More importantly, our focus is on empirically testing our theoretical model and presenting quantitative evidence on cooperative decision-making.

Three important, recent papers examine fishing cooperatives empirically. Deacon et al. (2008) and Deacon et al. (2013) develop a model incorporating concerns specific to cooperatives and then empirically test this model. They examine the intraseasonal allocation of fishing effort across space, time, and fishers in a salmon fishery with one cooperative and independent fishers. Our work provides less detail on the location of fishing effort and instead focuses on the allocation of effort across time in the face of species-specific differences in mobility and large-scale environmental oscillations that cycle over several years.

Ovando et al. (2013) use a survey of 67 cooperatives from around the world to examine what management tools cooperatives use and how this is shaped by differing economic, political, and ecological contexts. We focus on a particular management instrument—the choice of what price to pay cooperative members—and we complement our empirical analysis with a detailed theoretical model that delivers clear predictions for how this instrument should respond to a variety of circumstances.

The paper proceeds as follows. Section 1 describes the setting of Mexico's fisheries in more detail. Section 2 describes the data used in the empirical analysis. Section 3 develops the theoretical model and derives three testable implications. Section 4 uses the model to develop empirical tests of these implications and presents empirical results from these tests. Section 5 concludes.

## I. MEXICO'S GULF OF CALIFORNIA FISHERIES

Bordering five Mexican states, the Gulf of California is one of the most biologically productive areas of the world's oceans.[4] While the region's remarkable biodiversity has considerable conservation value, it also is of substantial social and economic importance. The states surrounding the Gulf contribute 71% of Mexico's total fisheries volume and 57% of total value (OECD 2006). As in many parts of the world, the Gulf's fleet is characterized by small-scale subsistence or commercial fishing on small two or three-person boats. Small-scale fisheries are a major source of employment and income, as well as a safety net in times of economic or environmental uncertainty (Pauly 1997; Allison and Ellis 2001; Basurto and Coleman 2010). However, a number of commercially valuable species have declined in recent years due to several factors, including improved technology, population and income growth, and increased export opportunities (Sala et al. 2004; Sáenz-Arroyo et al. 2005; Dong et al. 2004).

Several ecological factors make the Gulf of California an appropriate focus for our study. The species targeted by small-scale fishers have diverse life histories, ranging from those with fairly high site fidelity (e.g., lobster [Acosta 1999]) to those that move extensively as larvae (e.g., shrimp [Calderon-Aguilera et al. 2003]) or adults (e.g., tuna [Schaefer et al. 2007]). This variation allows for an analysis of how cooperatives deal differently with species that vary in their mobility.

Moreover, the region's terrestrial and marine ecosystems respond dramatically to ENSO (El Niño/Southern Oscillation) events, which occur every several years (Polis et al. 2002; Velarde et al. 2004). During El Niño years, ocean waters warm, upwelling slows, and rainfall increases, with important implications for fisheries species (Velarde et al. 2004; Aburto-Oropeza et al. 2007). While ocean productivity varies temporally—both with ENSO and other sources of climatic

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[4] In addition to the Gulf proper, here we also consider the Pacific Coast of B.C.S. as part of the "Gulf region," in keeping with previous work as in COBI/TNC (2006).

variability—and spatially throughout the Gulf region, we find remarkable coherence in the variability of mean concentration of chlorophyll *a*, a common proxy for marine primary productivity (Mann and Lazier 2005) in the vicinity of the three cooperatives for which we have logbook data (Leslie et al. 2015). ENSO's significant role enables us to explicitly test the influence of periodic environmental shocks on cooperatives' decision-making. ENSO may affect species through three channels: recruitment and growth of juveniles, growth of adults, and movement of adults. Here we focus on the recruitment channel.

Fishing cooperatives have had a long history in the Gulf of California—and Mexico more broadly—and continue to be a major factor in the fishing industry today. Under the 1947 Fisheries Law, cooperatives had exclusive concessions to the eight most commercially valuable species and often had rights to bays, estuaries, or lagoons adjacent to their lands (DeWalt 2001; Young 2001). In addition to cooperatives, the fisheries law created two other classes of fishermen: *permisionarios*, who are private individuals or corporate entities with permits to catch—and sell to the open market—species for which cooperatives do not hold concessions; and *pescadores libres*, who have rights to fish within cooperatives' concessions for subsistence only, but are also allowed to fish for *permisionarios* (Young 2001).

To encourage private investment in fisheries, the 1992 Fisheries Law took exclusive rights for the eight species away from the cooperatives and made it possible for *permisionarios* to fish and sell them (SEPESCA 1992; Ibarra 1996; Villa 1996; Ibarra et al. 1998; Ibarra et al. 2000; Young 2001). Consequently, in the present-day system, independent fishers (i.e., *permisionarios*) are able to fish most species and sell their catch as long as they are able to acquire permits to do so. The acquisition of these permits involves important costs, including the administrative burden of applying for a permit, interactions with government officials, travel to (often distant) administrative offices, and the financial cost of the permit itself.

Despite this change, fishing cooperatives continue to play an important role in these fisheries. Our review of the literature, field visits, and conversations with researchers at *Centro para la Biodiversidad Marina y la Conservacion* (CBMC) have revealed that cooperative membership entails a series of restrictions on behavior, a specific form of compensation, and a potentially attractive set of benefits.

In terms of restrictions on behavior, cooperative members are more constrained than those fishers who are not cooperative members. They are nominally bound to the rules of the cooperative, which determine how, when, and where to fish (see Reddy et al. 2013). A one-time membership payment and an agreement to sell only to the cooperative are also typical (J. J. Cota Nieto, pers. com., 2014). While enforcement of these restrictions varies among cooperatives, social ties may aid in enforcement. Cooperative membership requirements vary, both contemporaneously and historically, but typically, cooperative members live in the community and are often sons of prior members (e.g., Petterson 1980).

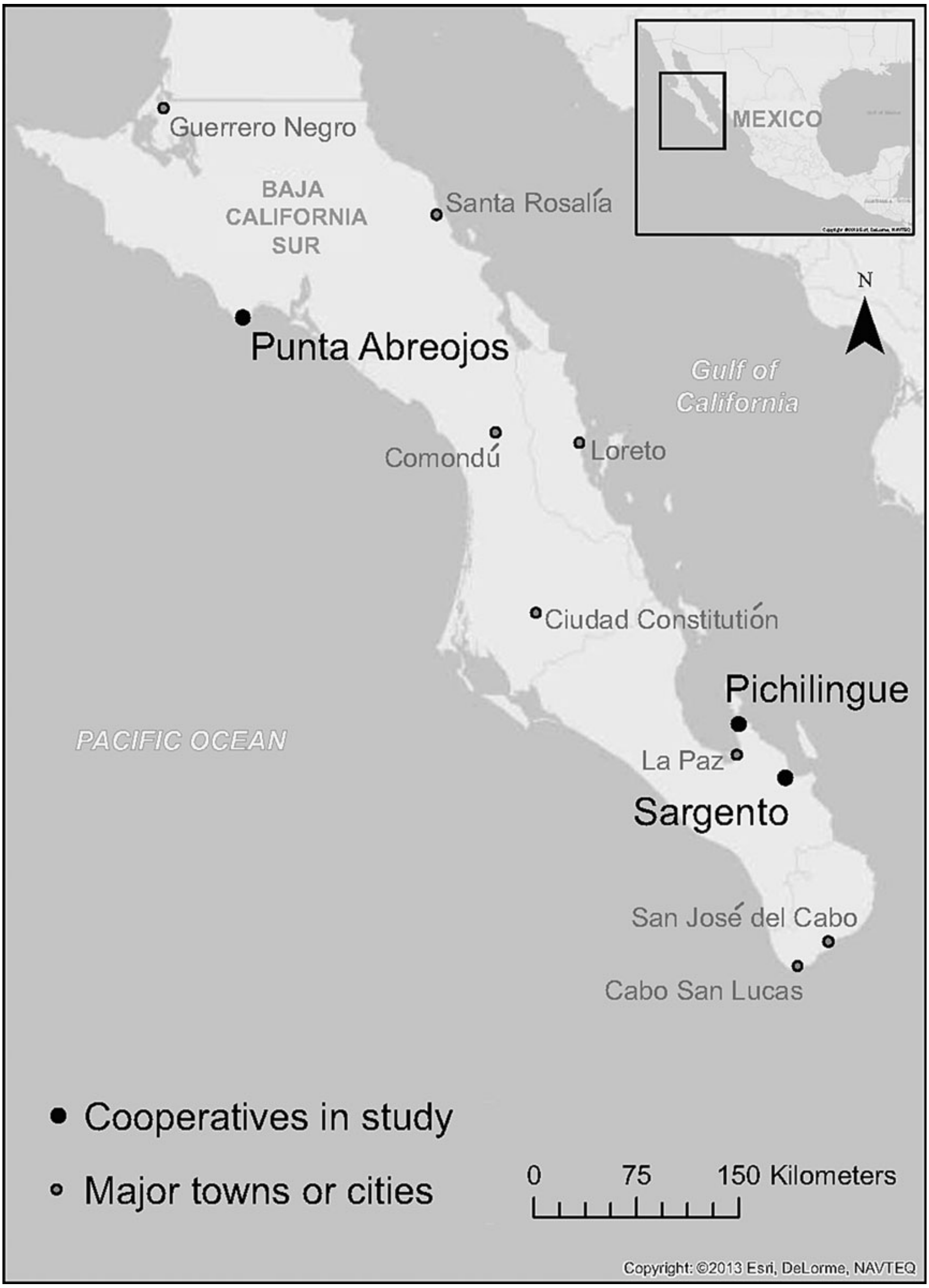
Cooperative membership also entails a specific form of compensation. Cooperative leaders will negotiate with a buyer to supply a certain amount of product. They then set a price and quantity for that species and pay those fishers who return with product that price, which is some fraction of the market price (Reddy et al. 2013; J. J. Cota-Nieto, pers. com., 2014). Importantly, prices are used in combination with direct restrictions or quotas. Cooperative leaders have a sense of what price is required to fill a quota and can lower the price to avoid incentivizing fishing past a quota (G. Hinojosa-Arango, pers. com., 2014). In this sense, the price paid to cooperative members by the cooperative leaders is one form of controlling the effort of cooperative members. Cooperative leaders can use prices as a management tool, in addition to more direct restrictions, to help ensure a certain amount of fishing effort and, ultimately, catch.

Given that the price paid to cooperative members is below the market price, the cooperative accrues revenue that can be used to generate various benefits of cooperative membership. This revenue is used to pay administrative costs that aid the cooperative as a whole, which include the salaries of cooperative officials, travel and legal expenses, and taxes (McGuire 1983). Benefits to members from these administrative efforts include access to fishing permits, gear, state subsidies, and shared resources for processing, marketing, and reporting catch (Petterson 1980; Basurto et al. 2013; McCay et al. 2014; Sievanen 2014). Access to permits is one of the primary reasons for joining a cooperative, according to La Paz area fishers (e.g., Sievanen 2014), and thus, those fishers who do not have the financial or social capital to acquire permits as individuals (as the *permisionarios* do) are more likely to join cooperatives. Revenue may be paid out in annual bonuses, which may be based on fishermen's total annual catch, equal for all members, or determined by some other rule (McGuire 1983). Finally, in some cooperatives, members also enjoy income security through sources such as retirement benefits or credit (McCay et al. 2014; G. Hinojosa-Arango, pers. com., Feb. 2012).

In the theoretical model below, we model these benefits received by cooperative members in two ways: (i) a lump sum payment reflecting discounts on equipment (including boats and motors), credit, or annual bonuses from the cooperative leadership; (ii) a factor reducing the costs of fishing reflecting access to fishing permits and state subsidies for fuel, as well as the absence of costs associated with searching for buyers. To the extent that the size of an annual bonus is dependent on annual catch, the bonus is not appropriately classified as a lump sum payment, as it affects incentives for effort. We do not have information on how often such catch-dependent bonuses occur, but it is important to note from the above discussion that other forms of compensation also make up the lump sum payment.

While the features above are generally shared by many cooperatives in the Gulf of California area, there are key differences among the three cooperatives for which we have daily logbook data and conduct empirical analysis. Figure 1 shows the location of these cooperatives. Pichilingue is located on the outskirts of La Paz, the largest city in the state and a major market in the region, and

FIGURE 1. Map of Cooperatives' Locations



*Source*: Authors' map produced using ArcGIS.

Sargento is a short drive away from La Paz. Punta Abreojos, a member of the federation of cooperatives in Northwest Baja California known as FEDECOOP, is on the Pacific side of the peninsula, adjacent to other cooperatives from

FEDECOOP. For the purposes of the empirical work below, we utilize the fact that Abreojos effectively has more secure property rights than Pichilingue and Sargento and can therefore manage its own members and restrict access for nonmembers more easily.

This arises for five reasons. First, Abreojos fishes in a relatively isolated area, while Pichilingue and Sargento fish in areas that have many cooperatives and fishers (McCay et al. 2014). There is a larger pool of potential fishers for Pichilingue and Sargento to compete with. Second, Punta Abreojos and the other cooperatives in FEDECOOP successfully retained exclusive fishing rights to lobster, abalone, snails, and a few other species even after 1992 (McCay et al. 2014; Cota-Nieto 2010; J. J. Cota-Nieto, pers. com., May 2012). The ten cooperatives in FEDECOOP each have separate, clearly defined polygons in which no other cooperative of FEDECOOP and no non-FEDECOOP fisher can fish these species, unless it is for subsistence purposes. Third, even though these polygons were originally designed for the species with exclusive concessions, in practice they provide clear boundaries for other species as well (Cota-Nieto 2010). Cooperatives with adjacent polygons may fish for species without exclusive concessions in the neighbor's polygon, but this typically involves negotiated agreements between the leaders of the two cooperatives involved (J. J. Cota-Nieto, pers. com., May 2015). Fourth, FEDECOOP has created a system in which fishers in each of the member cooperatives are expected to spend a fraction of their time in monitoring and vigilance efforts to enforce spatial restrictions (McCay et al. 2014). Fifth, FEDECOOP members can be removed from their cooperatives if they fail to sell exclusively to their cooperative or fail to comply with other rules (McCay et al. 2014). The lost benefits from eviction could be much more substantial for Abreojos than for the La Paz cooperatives because of the consistently high value of FEDECOOP fisheries (ensured by productive waters, local monitoring, FEDECOOP's employment of fisheries scientists, and FEDECOOP's engagement with the state) (McCay et al. 2014). While exclusive sale to the cooperative may be a nominal requirement for La Paz area cooperative fishers, the cooperative leadership in La Paz do not have the same degree of control of their members to ensure that sales of product outside the cooperative do not occur (J. J. Cota Nieto, pers. com., May 2014). To be sure, illegal fishing still occurs in the areas fished by the FEDECOOP cooperatives, but for these five reasons the scale of illegal fishing is likely to be less on the Pacific side of the Gulf. We therefore view Abreojos as an "exclusive" cooperative and Pichilingue and Sargento as "nonexclusive" cooperatives for the purposes of testing our hypotheses below.

Finally, it is important to understand whether any given fisher or cooperative can influence the market price of fish through their catch decisions. There are a large number of fishers in the area. As of 2010, based on data compiled by the National Commission of Aquaculture and Fishing (CONAPESCA), the number of fishers in La Paz alone was estimated at 974 people (748 cooperative members plus 226 unregistered fishers) (Leslie et al. 2015). According to data collected from La Paz fish markets by researchers from CBMC and the Scripps Institution of Oceanography, the three cooperatives we studied (Punta Abreojos, Pichilingue, and Sargento) were estimated to each provide approximately 12%, 5%, and 8%, respectively, of the fisheries product sold in the La Paz market (Sanchez, Nieto, Osorio, Erisman, Moreno-Baez, and Aburto-Oropeza 2015). Abreojos is more focused on the export market, however. These numbers come from an effort to enumerate the major players in La Paz markets and may be an over-estimate as smaller sellers are not easy to find. The size of the market shares suggest that these cooperatives will have some market power, but we believe the shares are small enough that this is not a first-order concern.

## II. Data and Descriptive Statistics

The empirical analysis uses daily logbook data from the three fishing cooperatives noted above, Pichilingue, Sargento, and Abreojos. Daily data on catches from fishing teams in each cooperative were recorded from January 1, 2007, to December 31, 2009. Catch records include a team identifier (for Abreojos and Pichilingue only), the common name of the species caught, the weight of the catch (kilograms), and price per kilogram offered by the cooperative (pesos). The composition of the species fished by the cooperatives partially reflects the biogeography of the Pacific vs. the Gulf coast of B.C.S.; however, there is still substantial overlap, thereby allowing a comparison of the behavior of the different types of cooperatives for a given species.

The logbook data have information on the prices cooperatives paid to their fishermen but, unfortunately, do not have information on the price the cooperative sold the catch at in the market. Using the *Sistema Nacional de Informacion e Integracion de Mercados* (SNIIM), available from the Mexican government, we have collected data on daily market prices in La Paz for as many species and dates as possible.[5] Using the dates in the cooperative logbooks, these market prices are matched to the cooperative purchases. In cases where a market price is not available for a particular date, the average price for the corresponding week or month is substituted instead (depending on availability).

To examine whether market prices in La Paz are driven by external forces that are exogenous to supply factors in the vicinity of La Paz, we use the SNIIM to obtain market prices from La Nueva Viga, a large national fish market in Mexico City connecting sources to distributors. The La Nueva Viga data contain information on marine fish, crustaceans, freshwater fish, and mollusks/others. B.C.S. is listed as a source only for the fourth category. This, coupled with the fact that other sources of La Nueva Viga catch have only a partial overlap of species with La Paz, limits the number of species that can be matched to the logbook data. In cases where a market price is not available for a particular date in the logbook, the average price for the corresponding week or month is again used. All cooperative and market prices are converted into 2010 Mexican pesos using a Consumer Price Index obtained from the OECD.

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[5] Available at http://www.economia-sniim.gob.mx/i_default.asp.

We aim to understand how cooperative pricing responds to natural variation that alters population growth rates. The Oceanic Niño Index (ONI) is a three-month running mean of an underlying measure of ENSO cycles, which alter ocean temperature. Data on ONI are publicly available from the National Weather Service Climate Prediction Center.[6] These data are matched to every cooperative purchase in the logbook data. The second half of 2007 and first half of 2008 were marked by a "cold episode" (more negative values), while the second half of 2009 saw the onset of a "warm episode" (more positive values).

Warmer ocean temperatures have three potential effects on organisms. First, they negatively affect juvenile recruitment of some species and positively affect recruitment of others. These population growth rate effects ultimately impact catch with a lag that generally ranges from one to seven years. Second, warmer temperatures can either positively or negatively affect adult population abundance by causing individuals to migrate. Third, adult size may be affected through changes in individual growth. The model focuses on population growth rates and does not incorporate the other two effects for the sake of tractability. Therefore, the empirical tests also focus on the first effect.

Finally, we conducted a thorough review of the ecological literature to construct a detailed classification of species on two dimensions. First, we classify species as "large scale" (i.e., large scale of movement, or highly mobile) or "small-scale" (i.e., small scale of movement, or less mobile). This classification is based primarily on knowledge of the movement of adult organisms, rather than on knowledge of larval dispersal. Second, we create a variable equal to 1 if higher ONI has a positive effect on recruitment (and hence population growth rates) and equal to $-1$ if higher ONI has a negative effect on recruitment. If the effect on recruitment is unknown to us or if there is no effect on recruitment, we set the variable to 0.

Table 1 provides summary statistics on the final merged data set.[7] The first panel shows summary statistics for the three cooperatives together, the second panel shows statistics for Pichilingue and Sargento only, and the third panel shows statistics for Abreojos only.

While the logbook data is at the individual fishing transaction level, the data are aggregated in our tests of the model's implications to the species-year-month-week level by averaging prices and totaling catch. This is because our own field visits suggested that cooperatives do not usually alter prices on a day-to-day basis.[8] Therefore, in all three tables of descriptive statistics, an observation is at the aggregated level.

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[6] Available at http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml.

[7] Observations where the market price is less than the cooperative price are dropped due to concerns about measurement of market prices. This affects only 762 transactions out of approximately 42,000 individual fishing transactions for which we have cooperative price data.

[8] Based on daily transaction data, we do sometimes observe multiple prices paid for a given species on a particular day. It is difficult to know whether this is measurement error or variation in price due to differences in time of day (e.g., a higher price for a more inconvenient time).

Table 1. Summary Statistics

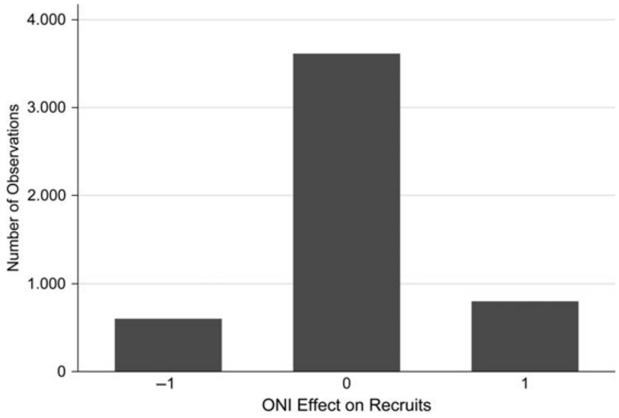
| All cooperatives | | | | | |
|---|---|---|---|---|---|
| Variable | N | Mean | Std. dev. | Min. | Max. |
| Log catch | 5015 | 4.436 | 2.062 | −1.609 | 11.258 |
| Log coop price | 4310 | 2.848 | 1.002 | 0.729 | 6.034 |
| Log mkt price | 3325 | 3.365 | 0.832 | 0.729 | 6.061 |
| Large scale (0/1) | 5014 | 0.373 | 0.484 | 0.000 | 1.000 |
| ONI | 5015 | −0.181 | 0.776 | −1.400 | 1.800 |
| Recruit effect (−1/0/1) | 5014 | 0.039 | 0.527 | −1.000 | 1.000 |
| ONI X recruit effect | 5014 | −0.018 | 0.426 | −1.800 | 1.800 |
| Pichilingue and Sargento | | | | | |
| Variable | N | Mean | Std. dev. | Min. | Max. |
| Log catch | 3091 | 4.170 | 1.646 | 0.000 | 8.790 |
| Log coop price | 3005 | 3.228 | 0.708 | 1.640 | 6.034 |
| Log mkt price | 2145 | 3.476 | 0.714 | 0.950 | 6.054 |
| Large scale (0/1) | 3090 | 0.312 | 0.463 | 0.000 | 1.000 |
| ONI | 3091 | −0.197 | 0.754 | −1.400 | 1.800 |
| Recruit effect (−1/0/1) | 3090 | 0.067 | 0.608 | −1.000 | 1.000 |
| ONI X recruit effect | 3090 | −0.023 | 0.475 | −1.800 | 1.800 |
| Abreojos | | | | | |
| Variable | N | Mean | Std. Dev. | Min. | Max. |
| Log catch | 1924 | 4.864 | 2.537 | −1.609 | 11.258 |
| Log coop price | 1305 | 1.975 | 1.032 | 0.729 | 5.907 |
| Log mkt price | 1180 | 3.163 | 0.982 | 0.729 | 6.061 |
| Large scale (0/1) | 1924 | 0.470 | 0.499 | 0.000 | 1.000 |
| ONI | 1924 | −0.155 | 0.811 | −1.400 | 1.800 |
| Recruit effect (−1/0/1) | 1924 | −0.005 | 0.355 | −1.000 | 1.000 |
| ONI X recruit effect | 1924 | −0.010 | 0.331 | −1.800 | 1.800 |

There is a significant amount of variation in total catch, market prices, and cooperative prices (table 1). Comparing the second and third panels of table 1, the log of cooperative price and log of total catch show a marked difference between the exclusive and nonexclusive cooperatives, despite the fact that average market prices are similar. The log of cooperative price and the log of catch also have a higher coefficient of variation for the exclusive cooperative.

The final rows of each panel show the range of variation for the “Recruit Effect” variable and the “ONI X Recruit Effect” interaction. The majority of observations have a value of 0 for the “Recruit Effect” variable, but approximately 800 observations exhibit a positive recruitment effect, and more than 500 observations exhibit a negative effect (figure 2). This variation permits a test of the model’s third implication regarding population growth rates.

To understand the relationship between market prices in La Paz and market prices external to that fishing area, we use the daily transaction data to estimate a regression of La Paz prices on La Nueva Viga prices, separately for each species for which there are data from both sources. Of the 55,841 daily transactions across Abreojos, Sargento, and Pichilingue, the species that match across the

FIGURE 2. Frequency Distribution of ONI Effect on Recruits



*Source:* Authors' analysis based on cooperative database described in the main text.

logbooks and La Nueva Viga account for only 4,208 transactions. Moreover, some of these transactions have no information on La Paz market prices. In table 2, we run OLS regressions of the log La Paz price on the log La Nueva Viga price by species common name.

The results paint a mixed picture. For five of the nine common names, there is a positive and statistically significant relationship between La Nueva Viga prices and La Paz prices. For these, the R-squared ranges from 0.016 to 0.877, depending on the species. Two of the nine common names have coefficients that are not statistically distinguishable from zero. The remaining two common names have negative and statistically significant relationships. Moreover, these relationships are not simply an artifact of La Nueva Viga sourcing particular species from La Paz. Of the four species that are sometimes sourced from B.C.S. in the data (*almeja*, *calamar*, *ostion*, and *pulpo*), three have a positive coefficient while one has a negative and significant coefficient. Of the species not sourced from B.C.S., two have a positive coefficient, with *cazon* having especially high representation in the logbook data. While this exercise is starkly limited by data challenges, it suggests that the prices for some species are not just locally determined in La Paz.

## III. THEORETICAL MODEL

We first provide an overview of the model and then lay out the details in separate subsections below. We consider a single-species fishery with one cooperative and a continuum of fishers who are characterized by heterogeneous fishing costs. Each time period in the model is divided into two stages. In the first stage, the cooperative chooses a per unit price $P_c$ to pay cooperative members for their catch. The cooperative buys catch from its members at a price $P_c$ and sells that catch on the market at a higher price $P_m$. The retained earnings are used to pay

TABLE 2. Relationship Between La Paz and La Nueva Viga (LNV) Prices

| | Common name of species (in Spanish) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Almeja | Calamar | Camaron | Cazon | Jurel | Lisa | Mojarra | Ostion | Pulpo |
| LNV log price | 0.313** | 0.606*** | −0.146 | 0.102*** | −0.231*** | 0.145*** | 0.124 | −0.207*** | 0.123*** |
| | (0.133) | (0.026) | (0.133) | (0.020) | (0.012) | (0.027) | (0.085) | (0.025) | (0.040) |
| Constant | −0.182 | 0.484*** | 5.769*** | 2.777*** | 3.691*** | 1.971*** | 1.851*** | 5.939*** | 3.637*** |
| | (0.449) | (0.069) | (0.655) | (0.073) | (0.035) | (0.076) | (0.292) | (0.113) | (0.172) |
| Obs | 42 | 80 | 35 | 1528 | 1903 | 110 | 152 | 113 | 103 |
| R2 | 0.121 | 0.877 | 0.035 | 0.016 | 0.170 | 0.207 | 0.014 | 0.373 | 0.085 |

*Note:* All specifications use OLS with the log of the price in La Paz as the dependent variable.

for operating costs, pay cooperative leadership, and provide lump-sum transfers back to cooperative members. In the second stage, individual fishers decide whether or not to be in the cooperative, as well as how much fishing effort to exert. Cooperative members can only sell to the cooperative; if they want to sell to the open market, they must leave the cooperative. This gives the cooperative a limited amount of monopsony power.[9]

The fundamental tradeoff facing the cooperative is that it can increase future stocks by decreasing $P_c$ in the current period (and thereby disincentivizing current effort); but this will lower current earnings and—in the case of a cooperative without exclusive fishing rights—induce some fishers to leave the cooperative and fish independently.

We make four crucial, additional assumptions in the model. First, individual fishers are atomistic: just as individual consumers and producers take market prices as given in the standard competitive model, each individual fisher takes aggregate fishing effort across all fishers and fishery stock as given. Pursuing a model in which individual fishers engage in strategic considerations would be an interesting extension, but we use the simpler approach because of the large number of individual fishers in these fisheries. In addition, the simplification allows for a focus on the basic tradeoff facing the cooperative.

Second, we find an equilibrium in which the highest cost fishers sort into the cooperative. Importantly, low costs in the model represent not just fishing skill, but also how easy it is for fishers to acquire permits for catch, transport catch to market, and purchase fuel and other equipment. Fishers who join the cooperative can lower their costs because the cooperative can acquire permits, transport all catch to market and find buyers, share gear, and coordinate harvesting activities (Ovando et al. 2013). The cost formulation below has the property that high cost fishers obtain a greater benefit from these cooperative activities.

Third, fishers can costlessly move in and out of the cooperative. This assumption, in combination with the assumption of atomistic fishers and no labor-leisure tradeoff for fishers, will ensure that fishers choose whether or not to be in the cooperative in any period $t$ based on a simple comparison of profits in the cooperative versus outside the cooperative in period $t$ alone.[10] This substantially simplifies the dynamic problem. Our work in the study areas suggests that it is not in fact costless to move back and forth between cooperative and independent fishing, but we believe the mathematical simplification makes this assumption worthwhile and keeps the focus on our issue of primary concern: how the

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[9] In practice, cooperative members could also fish outside the cooperative, against the cooperative's wishes. This is likely limited in the three cooperatives used in our analysis, but could definitely be a concern for other cooperatives. Our only goal is to illustrate the influence of fishers' decisions to fish independently versus fish with the cooperative on the cooperative's decisions, and we introduce this feature in the simplest way possible.

[10] The model also implicitly assumes that fishers cannot save. This assumption will affect the model only if there is a labor-leisure tradeoff. Without a value for leisure, fishers with savings vehicles would still choose cooperative membership and hours to maximize profits in every period separately.

cooperative trades off between current returns and conservation and how this is affected by the economic and environmental setting.

Fourth, we assume that market prices do not depend on the cooperative's decisions. As noted above, the cooperatives in our data are important players in the La Paz market, but none of their market shares are above 12%. There is also evidence above that some of the prices in the La Paz market are driven in important ways by external forces, though those results vary markedly by species and speak to only a fraction of the species caught by our three cooperatives.

The following subsections lay out the details of the model and then develop three testable implications.

### *The Evolution of Stock*

There are both static and dynamic externalities associated with a fisher exerting more effort in a particular time period. The "static" externality comes from the fact that when a fisher increases effort today, he decreases the ease with which other fishers can harvest from today's stock. The "dynamic" externality comes from the fact that when fishers exert effort today, they reduce the available stock in future periods. We formulate a simple model that captures both externalities.

As in Deacon et al. (2013), we assume that each unit of fishing effort extracts a fixed proportion $\theta$ of the remaining stock. This does not depend on whether a fisher is fishing individually or in a cooperative. If $X_t$ is the initial stock at the beginning of the period, the stock after aggregate effort $H_t$ has been applied across all fishers is $(1-\theta)^{H_t}X_t$, and the overall quantity extracted is $Q_t = (1-(1-\theta)^{H_t})X_t$. Fishers extract simultaneously, and fisher $i$ receives catch $q_{it}$ in proportion to his effort $h_{it}$: $q_{it} = \frac{h_{it}}{H_t}Q_t$. Both an individual's catch and the marginal return to an individual's fishing effort is decreasing in the effort of all other fishers.[11]

Next, we specify how current stocks and harvests translate into future stocks. Two common choices are the Ricker model and the Beverton-Holt model. In both formulations, harvest and stock growth are sequential: The initial stock in a period is harvested, and the remaining population leads to the new stock. Researchers typically use the Beverton-Holt model in settings where recruitment is relatively insensitive to population size because of density-dependent mortality (Clark 1990, 207–9). Since we would like harvest to have important effects on stocks, we instead use the Ricker model (Clark 1990, 199, 202):

[11] The derivative of fisher *i*'s catch with respect to all others' effort is $\frac{\partial q_i}{\partial H_{-i}} = \frac{h_i}{H}\left(\frac{\partial Q}{\partial H_{-i}} - \frac{Q}{H}\right)$. The term in parentheses is negative, as can be shown by using a second-order Taylor series expansion of $(1-\theta)^H$ about $H=0$. To sign the cross-partial, take the derivative of $\frac{\partial q_i}{\partial H_{-i}}$ with respect to $h_i$. Re-arranging terms shows that the cross-partial is $\frac{h}{H}\frac{\partial^2 Q}{\partial h_i \partial H_{-i}} + \frac{H_{-i} - h_i}{H^2}\left(\frac{\partial Q}{\partial H_{-i}} - \frac{Q}{H}\right)$, which is clearly negative if $H_{-i} \geq h_i$.

$X_t = (X_{t-1} - Q_{t-1})e^{r_t\left(1-\frac{X_{t-1}-Q_{t-1}}{K}\right)}$, where $r_t$ denotes an intrinsic rate of growth and $K$ is the carrying capacity.[12] Substituting in the expression for aggregate catch yields the following equation for the evolution of stock as a function of effort:

$$X_t = (1-\theta)^{H_{t-1}} X_{t-1} e^{r_t\left(1-\frac{(1-\theta)^{H_{t-1}} X_{t-1}}{K}\right)} \tag{1}$$

We do not use the most common fishery model, the Gordon-Shaefer model.[13] We are interested in the dynamic trajectory of prices and harvest toward steady state, and finding an analytical expression for the optimal trajectory is generally not possible when we complicate the cooperative's problem by introducing a joining decision. This forces us to use a numerical solution procedure, so it is natural to use a discrete time stock-recruitment model. Fortunately, Eberhardt (1977) shows that the Ricker growth model is mathematically related to the standard continuous time logistic growth model under certain additional assumptions. Moreover, our way of expressing the static externality is related to the discrete time analog of the Gordon-Shaefer harvest function.[14]

### *Individual Fisher and Cooperative Optimization Problems*

We assume that in any period $t_0$, fisher $i$ chooses $\forall t = t_0, ..., T$, whether to be in the cooperative sector ($D_{it} = 1$) or not ($D_{it} = 0$) and what hours to work in the cooperative sector ($h_{itC}$) or the independent sector ($h_{itI}$). In doing so, she takes current and future cooperative and market prices as given. She solves the problem:

$$\max_{h_{itI}, h_{itC}, D_{it}} \sum_{t=0}^{T} \delta^t \left[ P_{mt} \frac{h_{itI}}{H_t}\left(1-(1-\theta)^{H_t}\right)X_t - \frac{1}{\alpha_i} h_{itI}^2 \right](1-D_{it})$$
$$+ \delta^t \left[ P_{ct} \frac{h_{itC}}{H_t}\left(1-(1-\theta)^{H_t}\right)X_t - \frac{1}{\alpha_i+\beta} h_{itC}^2 + S_t \right] D_{it}$$

where $\delta$ is the discount rate, $P_{mt}$ is the market price, $P_{ct}$ is the cooperative price, $H_t$ is total effort, and $S_t$ is a lump-sum payment from the cooperative based on the revenue it accrues from the difference in the market price and the cooperative

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[12] Under some choices of $r_t$ and $K$, this function can lead to limit-cycle oscillations without steady convergence to any stable equilibrium when there is no harvesting. Our choices of parameters in the numerical simulations ensure this does not occur (Clark 1990, 202).

[13] The Gordon-Shaefer model is a continuous time model in which the growth in stock follows the differential equation $\frac{dX}{dt} = rX(1-\frac{X}{K}) - \alpha HX$, where $H$ is harvesting effort, $K$ is carrying capacity, $r$ is the intrinsic growth rate, and $\alpha$ is a parameter governing the return to effort.

[14] Assuming that harvest and stock growth are sequential and focusing on a constant harvest $H$ for the period $t-1$ to $t$, solve the differential equation $\frac{dX}{dt} = -\alpha HX$ for $X(t)$. The solution implies $X(t) = e^{-\alpha H}X(t-1)$. This is equivalent to our $(1-\theta)^H X(t-1)$ for some $\theta \in (0,1)$.

price. Cooperative fishers are atomistic and therefore take $H_t$ as given, in addition to prices. This will imply that they take $S_t$ as given. (We state how $S_t$ is related to prices, stocks, and aggregate effort below in the cooperative's problem.) Heterogeneity across fishers comes through $\alpha_i$, which denotes the inverse of the cost of effort for fisher $i$. If the fisher remains independent, the cost function is $c_{itI} = \frac{1}{\alpha_i} h_{itI}^2$. If, instead, fisher $i$ joins the cooperative, the cost function is $c_{itc} = \left(\frac{1}{\alpha_i + \beta}\right) h_{itC}^2$, with $\beta > 0$. $\beta$ represents the reduction in costs derived from fishing inside the cooperative.

The cooperative maximizes the present discounted value of current and future harvests from period 0 to period T, minus the present value of members' costs from period 0 to period T:

$$\max_{P_{ct}} \sum_{t=0}^{T} \delta^t \cdot \left( P_{mt} Q_{ct}(P_{ct}) - \int_{i \in coop} \frac{1}{(\alpha_i + \beta)} \left[h_{itC}^*(P_{ct})\right]^2 g(\alpha_i)\, \mathrm{d}\alpha_i \right)$$

where $\delta$ is the discount rate, $Q_{ct}(P_{ct})$ is the aggregate catch by cooperative members as a function of the cooperative price, $h_{itC}^*(P_{ct})$ is the optimal effort choice of each member as a function of the cooperative price, and $g(\alpha_i)$ is the probability density function of $\alpha_i$. We assume that $\alpha_i$ has an exponential distribution: $g(\alpha_i) = e^{-\alpha_i}$. The term $i \in coop$ indicates that the integral is taken over those who choose to be members. When solving the model below, we will show that fishers with $\alpha_i$ below a threshold $\alpha_t^*$ will select into the cooperative, and this threshold is a function of $P_{ct}$.

Total quantity caught by the cooperative is:

$$Q_{ct} = \frac{H_{ct}}{H_t} \left(1 - (1 - \theta)^{H_t}\right) X_t \tag{2}$$

where $H_{ct}$ is the total effort expended in the cooperative. The lump-sum transfer $S_t$ is then:

$$S_t = \frac{P_{mt} Q_{ct} - P_{ct} Q_{ct}}{\int_{i \in coop} g(\alpha_i) d\alpha_i} f(\beta) \tag{3}$$

where the first term is total accrued revenue divided by the mass of fishers selecting into the cooperative, while $f(\beta)$ represents the share of revenues per member remaining after expending money to produce $\beta$—this includes expenditures for transporting goods to market, acquiring permits, lobbying the government for fuel subsidies, etc.

### *Equilibrium*

To find a subgame perfect Nash equilibrium of the model, first note that individual fishers' strictly dominant strategy in any subgame is to select $(D_t, h_{itC}, h_{itI})$ in every period to maximize profits in that period. The fisher profits corresponding to the optimal effort choices in independent and cooperative fishing, respectively, are:

$$\Pi_{iIt} = \frac{P_{mt}^2 \alpha_i}{4H_t^2}(1-(1-\theta)^{H_t})^2 X_t^2 \tag{4}$$

$$\Pi_{iCt} = \frac{P_{ct}^2(\alpha_i+\beta)}{4H_t^2}(1-(1-\theta)^{H_t})^2 X_t^2 + S_t \tag{5}$$

Fisher $i$ will choose to be in the cooperative in period $t$ ($D_t = 1$) if and only if $\Pi_{iCt} \geq \Pi_{iIt}$, and then exerts profit-maximizing effort given that choice.

Fishers' strategies imply expressions for aggregate effort (in the cooperative, in the independent sector, and overall) and for lump-sum transfers, as a function of the cooperative price. Aggregate effort in the cooperative is:

$$H_{ct} = \frac{P_{ct}}{2H_t}(1-(1-\theta)^{H_t})X_t \cdot \int_{i \in coop} g(\alpha_i)(\alpha_i+\beta)\,\mathrm{d}\alpha_i. \tag{6}$$

Correspondingly, aggregate effort in the independent sector is given by,

$$H_{It} = \frac{P_m}{2H_t}(1-(1-\theta)^{H_t})X_t \cdot \int_{i \notin coop} g(\alpha_i)\alpha_i\,\mathrm{d}\alpha. \tag{7}$$

Writing the identity $H_t = H_{ct} + H_{It}$ gives us an implicit formula for $H_t$ in any given time period $t$:

$$H_t = \frac{(1-(1-\theta)^{H_t})}{2H_t}\left[P_{ct}X_t \int_{i \in coop} g(\alpha_i)(\alpha_i+\beta)d\alpha_i + P_{mt}X_t \int_{i \notin coop} g(\alpha_i)\alpha_i d\alpha_i\right]. \tag{8}$$

This equation has a unique solution $H_t$.[15]

Using equations 2, 3, and 6, we see that the lump-sum transfer is:

$$S_t = f(\beta)(P_{mt}-P_{ct})\frac{P_{ct}}{2H_t^2}(1-(1-\theta)^{H_t})^2 X_t^2 \frac{\cdot \int_{i \in coop} g(\alpha_i)(\alpha_i+\beta)\,\mathrm{d}\alpha_i.}{\cdot \int_{i \in coop} g(\alpha_i)\,\mathrm{d}\alpha_i.}. \tag{9}$$

We look for an equilibrium in which all fishers $i$ with $\alpha_i < \alpha^*$ select into the cooperative. This is a natural solution to expect for two reasons: Cooperative

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[15] First multiply both sides by $H_t$ so that the resulting modified equation takes the form $H_t^2 = [1-(1-\theta)^{H_t}]A$, where A is a function of other terms in the model. Note that $H_t^2$ is continuous, has a derivative of zero at $H_t = 0$, and the derivative is strictly increasing with $H_t$. In contrast, the derivative of $1-(1-\theta)^{H_t}$ is continuous, strictly greater than zero at $H_t = 0$ as long as $\theta > 0$, and this derivative is strictly decreasing with $H_t$. It follows that the modified equation has a unique positive solution. While 0 is a solution of the modified equation, it is not a solution of the original equation. Therefore, the original equation has a unique solution.

members face a "tax" on catch since $P_{ct} < P_{mt}$, and members receive the benefit of $\beta$. The tax most negatively impacts the high-$\alpha$ fishers, while $\beta$ disproportionately benefits the low-$\alpha$ fishers. Both effects make cooperative membership most enticing for the low-$\alpha$ fishers.

Substituting equation 9 into 4, using the exponential pdf for $g(\alpha_i)$ and simplifying, the cooperative knows that all fishers $i$ for whom the following is true will join the cooperative:

$$P_{ct}^2\beta+2f(\beta)(P_{mt}-P_{ct})P_{ct}(1+\beta)\geq\alpha\left(P_{mt}^2-P_{ct}^2+2f(\beta)(P_{mt}-P_{ct})P_{ct}\frac{1}{e^{\alpha}-1}\right). \tag{10}$$

It is possible to show that the set of $\alpha$ for which this inequality is satisfied indeed takes the form $\alpha\in[0,\alpha^*]$.[16]

In equilibrium, the cooperative selects $P_{ct}$ for every period taking individual fishers' strategies as given. Given this form of selection into the cooperative and the fishers' optimal effort choices, the cooperative's problem in any subgame beginning at period $t_0$ becomes:

$$\max_{P_{ct_0},\ldots,P_{cT}}\sum_{t=t_0}^{T}\delta^{t-t_0}\cdot(2P_{mt}P_{ct}-P_{ct}^2)\left(\frac{(1-(1-\theta)^{H_t})X_t^2}{4H_t^2}\right)\left(\int_0^{\alpha^*}(\alpha_i+\beta)\,g(\alpha_i)\,\mathrm{d}\alpha_i\right), \tag{11}$$

subject to the constraints:

$$X_t=(1-\theta)^{H_{t-1}}X_{t-1}e^{r_t\left(1-\frac{(1-\theta)^{H_{t-1}}X_{t-1}}{K}\right)} \tag{12}$$

$$H_t=\frac{(1-(1-\theta)^{H_t})X_t}{2H_t}\left[P_{ct}\int_0^{\alpha^*}g(\alpha_i)(\alpha_i+\beta)d\alpha_i+P_{mt}\int_{\alpha^*}^{+\infty}g(\alpha_i)\alpha_i d\alpha_i\right] \tag{13}$$

$$P_{ct}^2\beta+2f(\beta)(P_{mt}-P_{ct})P_{ct}(1+\beta)=\alpha^*\left(P_{mt}^2-P_{ct}^2+2f(\beta)(P_{mt}-P_{ct})P_{ct}\frac{1}{e^{\alpha^*}-1}\right). \tag{14}$$

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[16] To do so, note first that the left hand side is not dependent on $\alpha$. The limit of the right hand side as $\alpha$ approaches zero is, after an application of L'hopitals Rule, $2f(\beta)(P_{mt}-P_{ct})P_{ct}$, which is less than the left hand side. The limit of the right hand side as $\alpha$ approaches $+\infty$ is $+\infty$. Moreover, the derivative of the right-hand side is always positive. The derivative is $P_m^2-P_c^2+2f(\beta)(P_m-P_c)P_c\dfrac{e^{\alpha}-1-e^{\alpha}\alpha}{(e^{\alpha}-1)^2}$. A sufficient condition for this to be positive is that $e^{2\alpha}-e^{\alpha}>e^{\alpha}\alpha$, or simply $e^{\alpha}>\alpha+1$. But the latter expression follows immediately from a Taylor series expansion of $e^{\alpha}$ about 0. It follows that there is only one crossing of the right-hand side and left-hand side, at a point $\alpha^*$, and all fishers with $\alpha_i\leq\alpha^*$ select into the cooperative.

To solve this dynamic programming problem for the cooperative's price trajectory and develop basic implications of the model, we discretize the stock level and apply a numerical backward induction algorithm. That is, we begin with the last period $T$ and find the optimal choice of $P_{cT}$ and optimal value of the objective function for period T at each possible stock level $X_T$. We then move to period $T-1$ and find the optimal choice of $P_{cT-1}$ and optimal value of the objective function from period $T-1$ onwards at each possible stock level $X_{T-1}$, given the continuation values from the previous step. We then move to the previous period and so on. In each step, we solve for $H_t$ and $\alpha_t^*$ using the functions just above. This structure means that the computation time is linear in the number of periods and the number of stock buckets. The computation uses 70 periods and discretizes the stock into 1000 values between 0 and 1. Only the simulated outcomes for periods 10–60 appear in the figures below, as the behavior at the beginning of the cooperative's problem is influenced markedly by the initial stock, and the behavior near time $T$ is influenced by the desire to draw down stock rapidly.

We use the following parameters in all simulation results presented here: $X_0 = .5$, $K{=}1$, $r(t) = .3 + .3^* \sin(\frac{t}{2})$, $\delta = .95$, $\theta = .1$, $P_m = 70$, $g(\alpha) = e^{-\alpha}$, $\beta = 1.5$, $f(\beta) = 0.5$. We normalize stock to a carrying capacity of 1 because no other parameters are denominated in the same units, and so we expect that its absolute size does not affect behavior. On the other hand, $\alpha$ and $P_m$ all factor into the revenues and costs faced by fishers, and so their relationships are important. The distribution of $\alpha$ was chosen to allow some nuance in the proportion of the fishers who select into the cooperative, while $P_m$ was set to ensure that the level of harvest would be positive. We choose $\delta$ to represent a cooperative that gives significant weight to future harvests. To investigate the recruitment effects of the ENSO cycle—a cyclic fluctuation that completes one full cycle over the course of multiple years—on the cooperative price trajectory, we let $r_t$ be a sine function of the time variable.

### *Testable Implications*

The simulated choices of log cooperative prices over time appear in figure 3. Figure 4 is structured analogously and shows the resulting log cooperative catch over time.[17] In all panels of the figures, the left axis provides the population growth rate $r$. Below, we explain each panel of the figure, the mechanics of the simulations underlying the panel, and the resulting testable implication.

### *Implication 1: Price Levels*

We begin by comparing between the two types of models suggested above: a cooperative with endogenous membership coexisting with independent fishers ("nonexclusive" cooperative) and a cooperative operating with no independent

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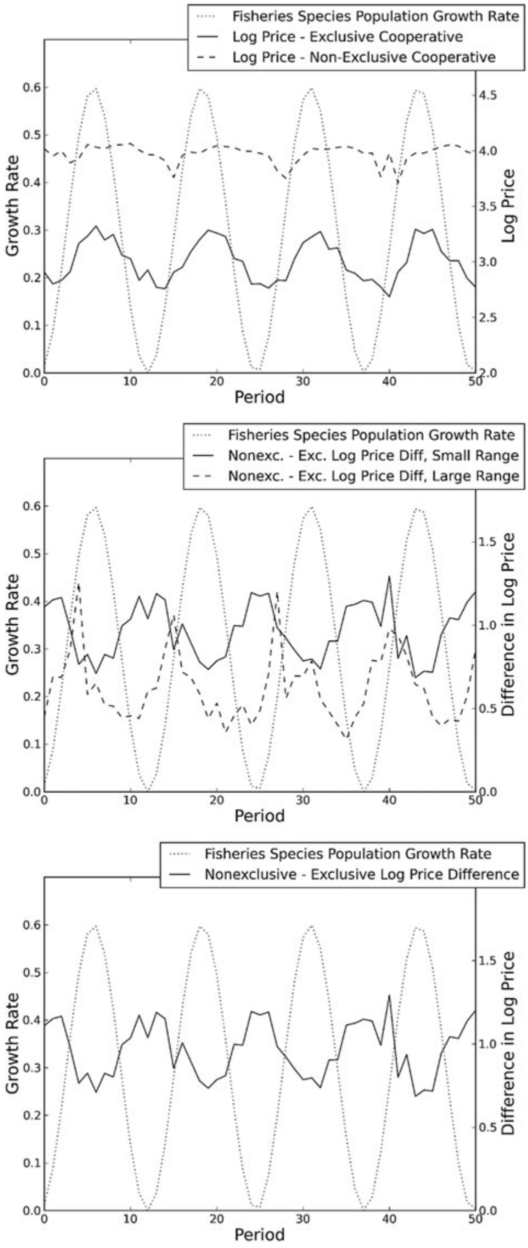
[17] Because of the carrying capacity and initial stock choices, catch is always between 0 and 1. Consequently, the log of catch is negative.

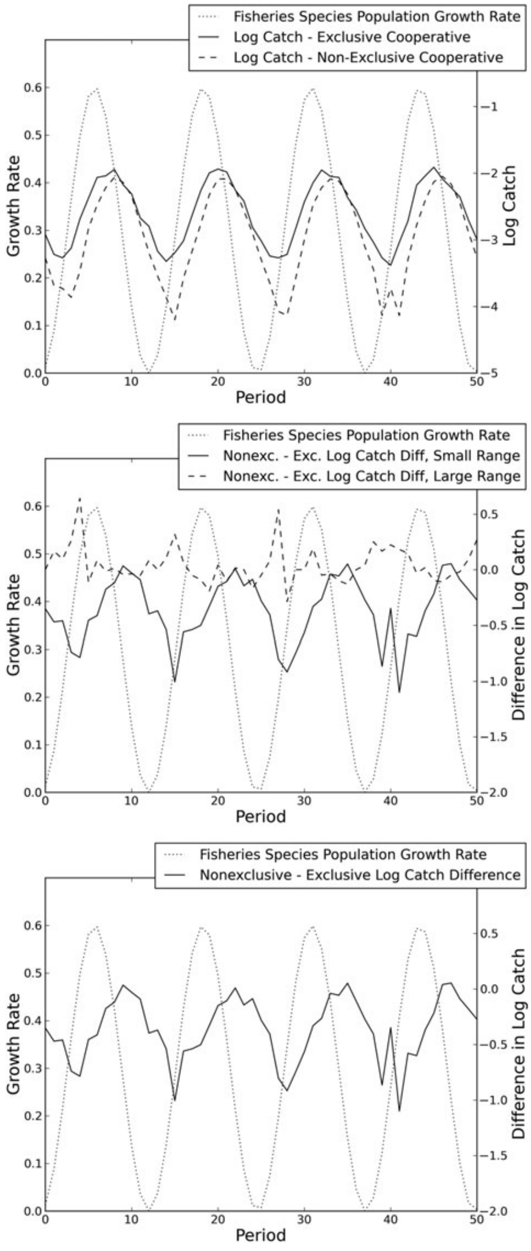
FIGURE 3. Evolution of Cooperative Log Price Over Time



*Notes:* Panel 1 shows the population growth rate r and log price choices for exclusive and nonexclusive cooperatives. Panel 2 shows how species scale—“small range” versus “large range”—affects the difference in log price between the nonexclusive cooperative and the exclusive cooperative. Panel 3 shows how the difference between the nonexclusive log price and the exclusive log price responds to fluctuations in the population growth rate.

*Source: Authors’ analysis based on the theoretical model and simulation methods described in the main text.*

FIGURE 4. Evolution of Cooperative Log Catch Over Time



*Notes:* Panel 1 shows the population growth rate r and log catch for exclusive and nonexclusive cooperatives. Panel 2 shows how species scale—"small range" versus "large range"—affects the difference in log catch between the nonexclusive cooperative and the exclusive cooperative. Panel 3 shows how the difference between the nonexclusive log catch and the exclusive log catch responds to fluctuations in the population growth rate.

*Source: Authors' analysis based on the theoretical model and simulation methods described in the main text.*

sector ("exclusive" cooperative). To operationalize the "exclusive" cooperative model, we simply use the relationship $H_t = H_{ct}$, replace $\alpha^*$ with $\infty$, and solve the model in the same way as described above.

Chosen log prices are strikingly lower for the exclusive cooperative than the nonexclusive cooperative across all periods (figure 3, panel 1). The economic intuition for this result is clear: The exclusive cooperative has more capability of managing stocks and exercises this capability by lowering fishing effort through lower prices. The nonexclusive cooperative, on the other hand, faces fishing pressure from the independent sector and knows that lowering prices could induce members to join the independent sector; for both reasons, the nonexclusive cooperative exerts higher fishing effort by setting higher prices.[18] Since healthier stocks are produced by more aggressive management, the exclusive cooperative tends to have higher log catch than the nonexclusive cooperative (figure 4, panel 1).

### *Implication 2: High Mobility vs. Low Mobility*

In addition, we examine the effect of the extent of species mobility ("species scale") on cooperative decision-making. We use the model described above for species where individuals exhibit relatively little movement. For species where individual organisms exhibit high geographic mobility, we assume the stock in any given period is subject to some amount of catch $H_{et}$ that is external to the given fishery, so that $H_t = H_{ct} + H_{It} + H_{et}$. We calculate $H_{et}$ as in equation (7), assuming that this external effort comes from a population of the same size and skill distribution as the focal population; the only difference is that we assume all fishers operate independently in this external sector.

The difference between the nonexclusive cooperative price and the exclusive cooperative price for species with large scale of movement ("large range") is generally smaller than the difference for small-scale species ("small range") (figure 3, panel 2). For a large-scale species—that is, one that is highly mobile—a local property right has less meaning, as users outside the local area will have an impact on stocks. Accordingly, the exclusive cooperative should behave more like the nonexclusive cooperative—and exert less control on effort by paying a higher price—in cases where the relevant species has a large geographic range. As should be expected from this reasoning, the difference in log catch between the nonexclusive cooperative and the exclusive cooperative is especially large in magnitude for the small range species (figure 4, panel 2).

### *Implication 3: Changes in Population Growth Rates*

Exclusive cooperative prices covary more markedly with population growth rates than nonexclusive cooperative prices (figure 3, panel 1). In fact, the correlation between prices and population growth rate is 0.81 for small-range species fished by exclusive cooperatives, which is statistically significantly different from zero at

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[18] The price level for the exclusive cooperative increases as period 60 nears. As the cooperative nears the final period, it draws down its stocks by increasing the price.

the 1% level. In contrast, the correlation for nonexclusive cooperatives is only 0.03 and is statistically indistinguishable from zero.[19]

Restricting attention to small-range species, where management is most effective, the difference in log prices between the nonexclusive cooperative and the exclusive cooperative oscillates with the population growth rate, so that in times of low projected growth, the exclusive cooperative sets a low price relative to the nonexclusive cooperative (figure 3, panel 3). The intuition is again clear: when low growth is projected, the exclusive cooperative wants to conserve the resource by cutting back on fishing effort; in contrast, the nonexclusive cooperative is confronted with an independent sector and the threat that some of its members will leave to the independent sector if it manages effort too aggressively.

The consequences for differences in catch across the cooperatives are more subtle than in the case of implications 1 and 2. The reason is that catch is a function of both cooperative price and stock, and current and future growth rates affect both price and stock in complicated and potentially offsetting ways. The peaks in catch differences occur prior to the peaks in price differences; this is because price differences are at their highest when growth rates (and hence stocks) are relatively low (figure 4, panel 3). Therefore, we do not have a sharp testable implication for how differences in log catch are correlated with changing growth rates.

### *Influence of Assumptions on Testable Implications*

To summarize, the three testable implications are: 1) An exclusive cooperative will on average pay lower prices to its members than a nonexclusive cooperative but will have higher catch; 2) The gap in prices and catch will on average be smaller in magnitude for species that have a larger scale of movement; 3) The gap in prices will rise when population growth rates fall and fall when population growth rates rise. Here, we briefly speculate about how altering key assumptions of the model would affect our main theoretical results.

First, consider the assumption that low-$\alpha$ (high cost) fishers sort into the cooperative, while others stay out. Suppose instead that fishers with the lowest costs sorted into the cooperative. This could be the case, for example, if high cost fishers do not benefit as much from the equipment, information, and marketing ability provided by the cooperative. In this case, a cooperative without exclusive rights would face a somewhat different problem. An increase in the current buying price would still increase current profits at the expense of future profits, but the marginal fisher that enters the cooperative would now be worse, so that

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[19] Correlations are computed using only periods 10–60. To verify that this pattern has to do with sustainable management and not just the exclusive nature of the cooperative, we also compute this correlation for an alternative model in which the exclusive cooperative cannot predict growth rates. We find that the correlation is statistically indistinguishable from zero in this case. In the case of large-range species, this correlation cannot be distinguished from zero for either type of cooperative.

the marginal profit from that fisher would be less. This suggests that the cooperative has an incentive to manage its stock more aggressively than what we see above. Correspondingly, the differences between an exclusive and nonexclusive cooperative would be less. Any differences we do see in the empirical work could therefore be an underestimate of the influence of mechanisms from our model.

Second, consider the assumption that exiting and entering the cooperative is costless. It may be the case that, instead, when a fisher leaves the cooperative, the cooperative makes it prohibitively costly for them to return. This will affect the results for nonexclusive cooperatives, where the joining decision plays a role. The change will give cooperatives an additional lever with which to keep members from leaving to take advantage of short-term profit opportunities outside the cooperative. This makes the cooperative more willing to manage its stock more aggressively and depress buying prices when it is necessary. This reasoning suggests that, if this assumption were changed, the nonexclusive cooperative would behave more like the exclusive one. Again, any differences we do see in the empirical work could therefore be an underestimate of the influence of mechanisms from our model.

Third, consider the assumption that cooperatives cannot influence the market price. If this were not the case, cooperatives have an additional consideration: an increase (decrease) in the cooperative buying price will tend to decrease (increase) the market price. There is now an incentive to keep production low in order to increase prices. This effect will tend to depress average cooperative buying prices in both exclusive and nonexclusive cooperatives, but if both types of cooperatives are selling into the same market, it is difficult to predict which type would see the larger change. The relationship between this effect and scale or growth rates is even more complicated. For instance, if growth rates are low, the cooperative knows that stocks will be relatively low in the future. With market power, the cooperative will have less incentive to recoup stocks compared to our model above. But again, it is difficult to predict whether this will affect exclusive or nonexclusive cooperatives more. We discuss this assumption again when we explore alternative explanations for our empirical results below.

## IV. EMPIRICAL ANALYSIS

This section develops empirical specifications from the theory in order to test a key assumption of the model and the model's three implications. The theory provides specific guidance as to what methods are appropriate for these tests and how estimated coefficients should be interpreted. In a few dimensions, the theory is too simple to be applied literally to the empirical work. For instance, the theory uses a single-species model, while in reality each cooperative fishes many different species. Moving to a multispecies model would entail adding significant complexity but would be a valuable avenue for future research. Here, we view the cooperative as performing the optimization above independently for each species.

### *Testing Assumption of Members' Response to Cooperative Prices*

To test the assumption that cooperative members increase their catch in response to an increase in the cooperative price, we use the daily transaction data with one observation for each recorded sale by a fishing team. In the model, a cooperative member *i*'s catch in period *t* is given by the following:

$$q^*_{ict} = \frac{P_{ct}(\alpha_i + \beta)}{2} \left[ \frac{(1 - (1 - \theta)^{H_t}) X_t}{H_t} \right]^2 . \tag{15}$$

Taking logs gives the following:

$$\begin{aligned} log(q^*_{ict}) = -log(2) + log(P_{ct}) + 2log(1 - (1 - \theta)^{H_t}) - 2log(H_t) \\ + 2log(X_t) + log(\alpha_i + \beta). \end{aligned} \tag{16}$$

The first two terms on the right-hand side pose no complications for estimation, but the remaining terms do. First, $X_t$, $\beta$, and $\alpha_i$ are unobservable to us. Second, $H_t$ is implicitly a function of other quantities from the model (see equation 8 above). In the case of either a nonexclusive cooperative or the exclusive cooperative with a large range species, $H_t$ is a function of $P_{ct}$, $P_{mt}$, $X_t$, and parameters $\beta$ and $\theta$. For an exclusive cooperative fishing a small-range species, the same is true, except $H_t$ is not a function of $P_{mt}$.

These considerations and equation 16 motivate the following log-linear approximation:

$$log(q^*_{ict}) = \delta_i + \alpha_0 log(P_{ct}) + \alpha_1 log(P_{mt}) + \varepsilon_{ict}, \tag{17}$$

where $\delta_i$ is a fishing-team fixed effect capturing $\alpha_i$, $\beta$, and $\theta$, and $\varepsilon_{ict}$ is a residual. The key identification concern is that the residual is clearly correlated with $P_{ct}$ (and, perhaps, with $P_{mt}$ as well). This is because the residual contains $X_t$, and $X_t$ is chosen in part by the cooperative when it sets $P_{ct}$. In addition, the residual may contain an important factor that is outside the model, time-varying shocks to the cost of fishing.

If one can address this concern, then an estimate of $\alpha_0$ includes two economic items: the direct, positive impact of increasing the cooperative price on an individual's catch; and the negative, indirect impact coming from the resulting increase in $H_t$.[20] The term $\alpha_1$ captures the negative impact of increasing $P_{mt}$ through the resulting increase in $H_t$. Our primary goal is to verify that the net impact of the cooperative price on catch, $\alpha_0$, is positive. This is a necessary prerequisite to the model's assumption that the cooperative can control its members' effort by changing cooperative buying prices.

We use the following idea to address the identification concerns: Unlike in the model, changes in $P_{ct}$ and changes in $X_t$ and fishing costs do not happen at exactly the same point in time. We assume that in reality, when the cooperative changes $P_{ct}$, both individual catch $q^*_{ict}$ and aggregate effort $H_t$ respond to the

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[20] We are very appreciative of an anonymous referee who provided this important insight.

change immediately; however, the stock $X_t$ and unobservable time-varying shocks to fishing do not respond immediately. Under this identifying assumption, if we can examine a narrow enough window around the price change, we can reasonably assume that the expected value of the stock $X_t$ and unobservable fishing costs is similar on either side of the price change.

To operationalize this idea, we estimate equation 17 using fixed effects at the fishing team-species-month level and the fishing team-species-week level. The fishing team is not identified in the Sargento data, so we restrict the analysis to Pichilingue and Abreojos. Unlike in the model, in reality members may not fish for certain species at certain times. Consequently, some members have zero catch for a species in particular periods. The results below first examine the responsiveness of catch to prices including just the intensive margin, and then include both the intensive and extensive margin.

The first set of results appear in table 3, which examines fishers who catch a positive amount of a species. The first panel (columns 1–3) uses the Pichilingue sample, while the second panel (columns 4–6) uses the Abreojos sample. Both panels are structured analogously: the first column estimates equation 17 using fixed effects at the fishing team-species-month level and conventional standard errors, the second column does the same but clusters standard errors at the fishing-team-species month level, and the third column uses fixed effects and clustered standard errors at the fishing team-species-week level. Moving from the first to second column shows the effect of clustering, while moving from the second to third column shows the effect of focusing on a narrower time interval.[21]

The coefficients on log cooperative price are generally positive and statistically significantly different from zero at conventional levels, though the P-value in column 2 increases to 0.103. The estimated elasticities of catch with respect to price range from 0.563 to 0.782, with more stability for Abreojos across specifications. The coefficients on the market price are negative in columns 1–2 as expected given the discussion above, but cannot be distinguished from zero in any of the columns except one. The one exception is column 6, where we see an unexpected positive sign. As noted in the context section above, Abreojos may have nonprice mechanisms with which to induce members to fish; the significant positive coefficient is consistent with this, and may suggest that our model captures only one mechanism through which cooperatives control effort.[22]

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[21] For identification, the fixed effects model does not use fixed effect groups that only have one observation. For Pichilingue, 19–37% of groups have more than one observation (depending on the specification), and for Abreojos 70–77% of groups have more than one observation.

[22] We also estimated these specifications without including the market price, even though this specification is only consistent with the theory in the case of small-range species at Abreojos. In these cases, when standard errors are clustered, the coefficient on log cooperative price is still positive and significant for Abreojos at the 1% level, ranging from 0.718 to 0.739. The Pichilingue coefficient falls to 0.375 (week-level regressions) and 0.205 (month-level regressions), with P-values of 0.141 and 0.335, respectively. Similar qualitative patterns hold when performing the same exercise for the specifications examining both the intensive and extensive margin in table 4.

## Table 3. Responsiveness of Catch to Price: Intensive Margin

| | Dep. variable: log catch | | | | | |
|---|---|---|---|---|---|---|
| | Pichilingue | | | Abreojos | | |
| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
| Log coop price | 0.563** | 0.563 | 0.782** | 0.670*** | 0.670*** | 0.704*** |
| | (0.220) | (0.345) | (0.352) | (0.029) | (0.051) | (0.046) |
| Log mkt price | −0.599 | −0.599 | 0.364 | 0.310 | 0.310 | 1.124** |
| | (1.319) | (1.244) | (1.335) | (0.221) | (0.274) | (0.505) |
| Obs | 2618 | 2618 | 2618 | 23,586 | 23,586 | 23,586 |
| Fixed effects | Sp-M-FT | Sp-M-FT | Sp-wk-FT | Sp-M-FT | Sp-M-FT | Sp-wk-FT |
| Clustering | none | Sp-M-FT | Sp-wk-FT | none | Sp-M-FT | Sp-wk-FT |
| Num. groups | 1493 | 1493 | 2110 | 3169 | 3169 | 7153 |
| Within-R2 | 0.006 | 0.006 | 0.018 | 0.025 | 0.025 | 0.041 |

*Note:* All specifications use linear fixed effects estimation. First three columns use only Pichilingue observations, and next three columns use only Abreojos observations. Columns 1, 2, 4, and 5 include fixed effects at the species-month-fishing team level, while columns 3 and 6 include fixed effects at the species-week-fishing team level. “Num. groups” indicates the number of unique combinations at each level. Standard levels clustered at the level indicated in the “Clustering” row.

The results that incorporate both the intensive and the extensive margin appear in table 4. To incorporate both margins, we consider the exponentiated form of equation 17:

$$q^*_{ict} = exp(\delta_i + \alpha_0 log(P_{ct}) + \alpha_1 log(P_{mt}) + \varepsilon_{ict}). \tag{18}$$

Given that this equation is consistent with the conditional expectation function of the fixed effects Poisson model, and given that a large fraction of observations are zeros, we estimate the model using the Poisson quasi-maximum likelihood estimator with fixed effects at the fishing team-time-species level.[23] As discussed in Wooldridge (2010), ch. 18, and Burgess et al. (2012), the Poisson model is a quasi-maximum likelihood estimator that yields consistent estimates as long as the conditional expectation is correctly specified, regardless of the exact distribution of the underlying error.

Table 4 is structured analogously to table 3. The coefficients can be interpreted as the elasticity of the conditional expectation of catch with respect to price. The coefficient on log cooperative price is positive and significant for every column except columns 2 and 3. This means that the extensive margin effect appears stronger for Abreojos than Pichilingue. Except in one case, the coefficient on market price is negative (and significant in columns 1 and 4).[24]

A complementary empirical approach, presented in the supplemental appendix available at http://wber.oxfordjournals.org/, examines changes in catch at the time of discrete events when there is a large and sustained change in cooperative prices for a species. Such events are difficult to pinpoint in the data. Still, the signs of estimated coefficients are consistent with those above, though not always statistically significant. Therefore, there is evidence that cooperative members respond to cooperative buying prices in the way posited by the model.

### *Implication 1: Price Levels Across Cooperatives*

Next, we test the model's implications for how cooperatives choose buying prices. For this portion of the analysis, we first aggregate the data to the cooperative-week-species level, taking the sum of catch and the average log price across the week. The first implication of the model is if market prices are constant and growth rates and $X_0$ are the same across cooperatives, then on average the exclusive cooperative will pay lower prices to its members than a nonexclusive cooperative but will have higher catch.

To operationalize this comparison, note that in our forward-looking model without uncertainty, the cooperative price in one period $P_{ct}$ will be a function of the exogenous variables for every period, the initial stock $X_0$, and the cost

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[23] The observations row in the table shows the number used for estimation; observations that do not show variation within group are not used. Among the observations used for estimation, 6871 (month specification) and 2480 (week specification) observations are zero for Pichilingue. The corresponding numbers for Abreojos are 36,933 and 18,296.

[24] The exception is again column 6, the week specification for Abreojos, where the coefficient is positive but statistically indistinguishable from zero.

TABLE 4. Responsiveness of Catch to Price: Including Zero Catch

| | Dep. Variable: catch | | | | | |
|---|---|---|---|---|---|---|
| | Pichilingue | | | Abreojos | | |
| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
| Log coop price | 0.441*** | 0.441 | 0.543 | 1.489*** | 1.489*** | 1.500*** |
| | (0.024) | (0.548) | (0.512) | (0.007) | (0.172) | (0.147) |
| Log mkt Price | −2.566*** | −2.566 | −0.791 | −0.455*** | −0.455 | 0.898 |
| | (0.091) | (1.568) | (1.855) | (0.020) | (0.553) | (0.664) |
| Obs | 9341 | 9341 | 4458 | 60,497 | 60,497 | 41,695 |
| Fixed effects | Sp-M-FT | Sp-M-FT | Sp-wk-FT | Sp-M-FT | Sp-M-FT | Sp-wk-Ft |
| Clustering | none | Sp-M-FT | Sp-wk-FT | none | Sp-M-FT | Sp-wk-Ft |
| Num. groups | 1345 | 1345 | 1470 | 3147 | 3147 | 6966 |

*Note:* All specifications use fixed effects Poisson estimation. First three columns use only Pichilingue observations, and next three columns use only Abreojos observations. Columns 1, 2, 4, and 5 include fixed effects at the species-month-fishing team level, while columns 3 and 6 include fixed effects at the species-week-fishing team level. “Num. groups” indicates the number of unique combinations at each level used in estimation. Standard levels clustered at the level indicated in the “Clustering” row.

parameter. Therefore, if we denote the exclusive cooperative by $E$ and the nonexclusive cooperative by $N$, we have for $d$=$E$,$N$: $log(P_{ctd}) = g_d(log(P_{m0}),....,$ $log(P_{mT}), r_0, ..., r_T, X_0, \beta)$, where the $g_d(.)$ are functions. In a more general case, the cost term $\beta$ could also vary by time. A first-order Taylor series approximation of the equations about the expected log market price $\overline{log(P_m)}$ and the expected growth rate $\bar{r}$ yields:

$$log(P_{ctd}) = \bar{g}_d + g_{dp0}(log(P_{m0}) - \overline{log(P_m)}) + ... + g_{dpT}(log(P_{mT}) - \overline{log(P_m)}) \quad (19)$$

$$+ g_{dr0}(r_0 - \bar{r}) + ... + g_{drT}(r_T - \bar{r}) + \varepsilon_{td} \quad (20)$$

where $\bar{g}_d$ is the function evaluated at $\overline{log(P_m)}$ and $\bar{r}$ and contains $X_0$. The terms $g_{dpt}$ and $g_{drt}$ give the derivatives of $g_d$ with respect to $log(P_{mt})$ and $r_t$ evaluated at the mean values of these variables, respectively. Finally, $\varepsilon_{ctd}$ contains both approximation error and period-cooperative-specific shocks to cost (if $\beta$ is allowed to vary by time). If $D_{td}$ is a dummy variable equal to 1 when $d$=$E$ and 0 otherwise, then the two equations can be combined:

$$log(P_{ctd}) = \bar{g}_N + (\bar{g}_E - \bar{g}_N)D_{td} + \sum_{t=0}^{T} \left[g_{Nrt}(r_t - \bar{r}) + D_{td}(g_{Ert} - g_{Nrt})(r_t - \bar{r})\right] \quad (21)$$

$$+ \sum_{t=0}^{T} \left[g_{Npt}(log(P_{mt}) - \overline{log(P_m)}) + D_{td}(g_{Ept} - g_{Npt})(log(P_{mt}) - \overline{log(P_m)})\right] \quad (22)$$

$$+ \epsilon_{tN} + D_{td}(\epsilon_{tE} - \epsilon_{tN}) \quad (23)$$

This motivates the following regression equation:

$$log(P_{ctd}) = \alpha_0 + \alpha_1 D_{td} + u_{td} \quad (24)$$

where:

$$u_{td} = \sum_{t=0}^{T} \left[g_{Npt}(log(P_{mt}) - \overline{log(P_m)}) + D_{td}(g_{Ept} - g_{Npt})(log(P_{mt}) - \overline{log(P_m)})\right]$$

$$+ \sum_{t=0}^{T} \left[g_{Nrt}(r_t - \bar{r}) + D_{td}(g_{Ert} - g_{Nrt})(r_t - \bar{r})\right] + \epsilon_{tN} + D_{td}(\epsilon_{tE} - \epsilon_{tN})$$

Since both the exclusive and nonexclusive cooperative see the same market prices and growth rates in any period, the expected value of $u_{td}$ conditional on $D_{td}$ is just $E(\epsilon_{tN} + D_{td}(\epsilon_{tE} - \epsilon_{tN})|D_{td})$.

Implication 1 of the model for prices is that $(\bar{g}_E - \bar{g}_N) = \alpha_1 < 0$. The above reasoning makes clear what the threats to interpreting $\alpha_1$ in this way are. First, $E(\epsilon_{tN} + D_{td}(\epsilon_{tE} - \epsilon_{tN})|D_{td})$ may not be zero. To take an example, fishing costs $\beta$ may differ between exclusive and nonexclusive cooperatives because of differences in species caught. Another possibility is that, since Abreojos fishes some species that the other cooperatives do not, the two types of cooperatives systematically see different market prices for output. To deal with this important issue, we use species-time fixed effects. The fixed effects permit a comparison of cooperative prices within species-time period. Second, $X_0$ may not be the same across cooperatives within species.[25] In this case, $\alpha_1$ reflects both the mechanism stressed in the model simulations and the difference in initial stocks. We discuss these identification concerns further below.

Finally, we can follow the same reasoning as above to develop an estimating equation for catch:

$$log(Q_{ctd}) = \beta_0 + \beta_1 D_{td} + v_{td} \tag{25}$$

Implication 1 of the model for catch is that $\beta_1 > 0$. The identification concerns noted above are applicable here as well.

We estimate equations 24 and 25 using fixed effects at the species-quarter, species-month, and species-week levels.[26] From the point of view of flexibly capturing time-varying unobservable costs, the species-week specification is most preferable. However, this uses a more limited subset of data for identification. Reassuringly, the results are very similar with all three approaches.

The left panel of table 5 shows the results for log cooperative price, while the right panel shows the results for log weekly catch. Within species and time period, prices are more than one log point lower in Abreojos than the other cooperatives (columns 1–3). The magnitude is quite similar across the columns. This suggests that within a species-quarter combination, omitted determinants of log cooperative prices that vary by week or month are not strongly correlated with the Abreojos dummy. The coefficient on the Abreojos dummy in the catch specifications also has the expected sign (columns 4–6). Within species and time period, log catch is substantially higher in Abreojos than the other cooperatives.

Above, we raised a number of endogeneity concerns. The stability of the coefficient estimates across the columns in table 5 may alleviate some of these concerns. Moreover, some of these concerns are less problematic when one considers both the price and catch results simultaneously. For instance, the catch results could be driven by the fact that initial stocks of all species are exogenously higher on the Pacific side of B.C.S. (near Abreojos) compared to the Gulf of California side (near Pichilingue and Sargento). But this by itself would not explain the negative coefficient in the price regressions. Similarly, differences in the number of members across Abreojos and the other cooperatives could explain the differences in catch but not necessarily the differences in prices. If market prices are systematically lower for Abreojos than for the other

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[25] Coastal ocean productivity varies temporally, due to seasonal and longer-term drivers (e.g., ENSO). Ocean productivity also varies spatially between the Pacific and Gulf coasts of BCS (Lluch-Cota et al. 2010; Leslie et al. 2015), which could create differences in the productivity of fish populations. These effects are still not well understood.

[26] The sample in both regressions uses only weeks in which at least one catch was recorded in the logbooks. Standard errors are clustered at the level of the fixed effect.

TABLE 5. Implication 1: Price and Catch Across Cooperatives

| Variable | Log price (1) | Log price (2) | Log price (3) | Log catch (4) | Log catch (5) | Log catch (6) |
|---|---|---|---|---|---|---|
| Abreojos | −1.095*** | −1.112*** | −1.124*** | 0.984*** | 1.037*** | 1.002*** |
| | (0.029) | (0.023) | (0.016) | (0.183) | (0.148) | (0.125) |
| Constant | 3.180*** | 3.185*** | 3.189*** | 4.059*** | 4.039*** | 4.052*** |
| | (0.009) | (0.007) | (0.005) | (0.070) | (0.057) | (0.048) |
| Obs | 4310 | 4310 | 4310 | 5015 | 5015 | 5015 |
| Num. groups | 626 | 1379 | 3505 | 703 | 1572 | 4081 |
| Within-R2 | 0.790 | 0.840 | 0.916 | 0.035 | 0.047 | 0.081 |
| Fixed effects | Sp-qtr | Sp-month | Sp-week | Sp-qtr | Sp-month | Sp-week |

*Note:* Sample includes observations at the weekly level from Abreojos, Pichilingue, and Sargento. The omitted category is Pichilingue/Sargento. All specifications use linear fixed effects at the species-quarter (sp-qtr), species-month (sp-month), or species-week (sp-week) level. Standard errors are clustered at the level of the fixed effect.

cooperatives even within a species—since Abreojos sells in part to different markets—this could explain the price results, but not the catch results.

Nevertheless, there is still a class of relevant endogeneity concerns: If the area around Abreojos is more productive ecologically, fishing costs could simply be lower for Abreojos; this could lead to lower cooperative prices and higher catch totals. The next subsection shows that, while this effect may be at work, it does not fully capture the patterns in the data.

### *Implication 2: Role of Species Scale in Price Gaps*

Next, we examine the second implication of the model: The gap in prices and catch between cooperatives with exclusive property rights and cooperatives without exclusive rights will be smaller in magnitude for species that have a larger scale of movement. The development of an empirical specification to test implication 2 is similar to the case of implication 1. Instead of allowing the functions $g(.)$ to differ based only on whether the cooperative is exclusive or not, there are now four possible combinations $(d,x)$, $d=E,N$, $x=L,S$: exclusive, large-scale (EL); exclusive, small-scale (ES); nonexclusive, large scale (NL); and nonexclusive, small scale (NS). If $L_x$ is a dummy variable that is 1 for large scale species and 0 otherwise, the Taylor series expansion about the scale-specific expected growth rates and expected log prices yields:

$$\begin{aligned} log(P_{ctdx}) = \bar{g}_{NS} + (\bar{g}_{ES} - \bar{g}_{NS})D_{td} + (\bar{g}_{NL} - \bar{g}_{NS})L_x \\ + [(\bar{g}_{EL} - \bar{g}_{NL}) - (\bar{g}_{ES} - \bar{g}_{NS})]D_{td}L_x + u_{tdx} \end{aligned} \quad (26)$$

where $u_{tdx}$ is a function of prices, growth rates, and $\epsilon_{tdx}$ analogous to the one in the previous subsection, except now including the scale-specific expected growth rates and expected log prices, $D_{td}$, $L_x$, and the interaction of the two.

This motivates the following regression equation:

$$log(P_{ctdx}) = \alpha_0 + \alpha_1 D_{td} + \alpha_2 L_x + \alpha_3 D_{td} L_x + u_{tdx} \quad (27)$$

Assuming again that the two types of cooperatives see the same market prices and growth rate for a given species, the expectation of $u_{tdx}$ conditional on $D_{td}$ and $L_x$ simplifies to the following:

$$E(\epsilon_{NS} + (\epsilon_{ES} - \epsilon_{NS})D_{td} + (\epsilon_{NL} - \epsilon_{NS})L_x + [(\epsilon_{EL} - \epsilon_{NL}) - (\epsilon_{ES} - \epsilon_{NS})]D_{td}L_x | D_{td}, L_x)$$

Implication 2 of the model is that, with all else held equal, $\alpha_3 > 0$. As above, there are two types of threats to interpreting $\alpha_3$ as reflecting the model's mechanisms. First, the expectation in the expression just above may not be zero. This could happen, for instance, if the difference in fishing costs between the exclusive and nonexclusive cooperative varies by the scale of the species. Since one source of this issue is differences in the type of species caught, we again use species-time fixed effects. The second type of identification concern is that the difference in $X_0$ between the exclusive cooperative and the nonexclusive cooperatives could vary depending on scale. For both identification concerns, the crucial issue is whether the difference between the exclusive and nonexclusive cooperatives varies by scale. For example, simply having a difference in fishing costs between exclusive and nonexclusive cooperatives that is invariant to species scale biases the estimate of $\alpha_1$ but not the estimate of $\alpha_3$. In this sense, the test of implication 2 is more robust than that of implication 1 and is analogous to a differences-in-differences approach.

Analogous reasoning leads to an estimating equation for catch:

$$log(Q_{Ctdx}) = \beta_0 + \beta_1 D_{td} + \beta_2 L_{tdx} + \beta_3 D_{td} L_{tdx} + v_{tdx} \tag{28}$$

Implication 2 of the model for catch is that $\beta_3 < 0$.

As in the previous subsection, we estimate equation 27 and 28 using fixed effects first at the species-quarter level, then the species-month level, and finally at the species-week level.[27] The left panel of table 6 shows the regressions for log price, and the right panel shows the regressions for log weekly catch.

There is again stability in the coefficients across the various specifications. As expected, the coefficient on the Abreojos dummy—reflecting the price gap for small scale species—is always negative and significant (columns 1–3). More interesting is the coefficient on the interaction between the Abreojos dummy and the large scale dummy. As predicted by the theory, this coefficient is positive and statistically different from zero. The magnitude suggests that the gap in prices between Abreojos and the other cooperatives is reduced by 15–17% when considering species that are more highly mobile (columns 1–3). The results for catch also confirm the theory: While weekly catch is higher in Abreojos than in the other cooperatives, this difference is cut in half for large scale species (columns 4–6).

This is consistent with the idea that Abreojos exerts less control of effort over large scale species relative to small scale species. These results also narrow the class of alternative explanations that can capture the data. For example, if lower fishing costs near Abreojos than near the other cooperatives are driving the results, then it must be the case that the cost difference is lower for large scale species than for small scale species.

### *Implication 3: Changes in Growth Rates*

The third implication of the model is that the difference in prices between a nonexclusive cooperative and an exclusive cooperative will rise when population growth rates fall, and fall when population growth rates rise. Essentially, the exclusive cooperative acts more aggressively to limit effort when growth rates are projected to be low.

To develop an estimating equation to test the prediction, first consider the cooperative's maximization problem in equation 11 above. Let $\lambda_t$ be the Lagrange multiplier on the constraint for the $X_{t+1}$ stock equation, and note that $H_t$ is an

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[27] The sample in both regressions uses only weeks in which at least one catch was recorded in the logbooks. Standard errors are clustered at the level of the fixed effect.

TABLE 6. Implication 2: Price/Catch Differences by Scale

| | Log Price | | | Log Catch | | |
|---|---|---|---|---|---|---|
| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
| Abreojos | −1.174*** | −1.188*** | −1.187*** | 1.347*** | 1.354*** | 1.240*** |
| | (0.029) | (0.020) | (0.014) | (0.293) | (0.217) | (0.173) |
| Abreojos X large scale | 0.168*** | 0.167*** | 0.149*** | −0.778** | −0.705** | −0.561** |
| | (0.058) | (0.046) | (0.035) | (0.351) | (0.289) | (0.246) |
| Constant | 3.178*** | 3.183*** | 3.185*** | 4.060*** | 4.044*** | 4.062*** |
| | (0.009) | (0.007) | (0.005) | (0.069) | (0.056) | (0.047) |
| Obs | 4309 | 4309 | 4309 | 5014 | 5014 | 5014 |
| Num. groups | 625 | 1378 | 3504 | 702 | 1571 | 4080 |
| Within-R2 | 0.795 | 0.845 | 0.920 | 0.041 | 0.053 | 0.088 |
| Fixed effects | Sp-qtr | Sp-month | Sp-week | Sp-qtr | Sp-month | Sp-week |

*Note:* Sample includes observations at the weekly level from Abreojos, Pichilingue, and Sargento. The omitted category is Pichilingue/Sargento. All specifications use linear fixed effects at the species-quarter (sp-qtr), species-month (sp-month), or species-week (sp-week) level. Standard errors are clustered at the level of the fixed effect.

implicitly defined function of $(X_t, P_{ct}, P_{mt})$ and $\alpha^*$ is an implicitly defined function of $(P_{ct}, P_{mt})$. The first-order condition with respect to $P_{ct}$ can then be written in general as $G(P_{ct}, P_{mt}, X_t, r_{t+1}, \lambda_t; \delta, \beta, \theta) = 0$, where $G(.)$ is a function and $(\delta, \beta, \theta)$ give the discount rate, costs of fishing, and the extraction rate from fishing effort. This means that $log(P_{ctd})$ for cooperative of type $d$=$E$,$N$ can be written in general as: $log(P_{ctd}) = g_d(log(P_{mt}), X_{td}, r_{t+1}, \lambda_{td}, \delta, \beta, \theta)$, where this could be further generalized to allow for time-varying and cooperative-varying costs by substituting $\beta_{td}$ for $\beta$.

We begin again with a Taylor series approximation of this function about the expected values of all arguments:

$$log(P_{ctd}) = \bar{g}_d + g_{dp}(log(P_{mt}) - \overline{log(P_m)}) + g_{dr}(r_{t+1} - \bar{r}) \tag{29}$$

$$+ g_{dx}(X_{td} - \bar{X}_d) + g_{d\lambda}(\lambda_{td} - \bar{\lambda}_d) + \epsilon_{td} \tag{30}$$

where $\bar{g}_d$ is the function evaluated at the expected values and all other bars indicate expected values. The additional subscripts on $g$ indicate derivatives with respect to a variable, evaluated at the expected values. Here, $\epsilon_{td}$ is approximation error and, if $\beta$ is allowed to vary by time and cooperative type, period/cooperative-specific shocks to fishing costs (similarly, $\epsilon_{td}$ could reflect shocks to other parameters). Both cooperatives see the same values of $P_{mt}$ and $r_{t+1}$.

Let $D_{td}$ equal 1 when $d$=$E$ and 0 otherwise. Then, similarly to above, we have:

$$log(P_{ctd}) = \bar{g}_N + D_{td}(\bar{g}_E - \bar{g}_N) + (g_{Np} + D_{td}(g_{Ep} - g_{Np}))(log(P_{mt}) - \overline{log(P_m)}) \tag{31}$$

$$+ (g_{Nr} + D_{td}(g_{Er} - g_{Nr}))(r_{t+1} - \bar{r}) + (g_{N\lambda} + D_{td}(g_{E\lambda} - g_{N\lambda}))(\lambda_{td} - \bar{\lambda}_d) \tag{32}$$

$$+ (g_{Nx} + D_{td}(g_{Ex} - g_{Nx}))(X_{td} - \bar{X}_d) + \epsilon_{td} \tag{33}$$

Implication 3 of the model concerns the difference in the correlation between $log(P_{ct})$ and $log(r_{t+1})$ across exclusive and nonexclusive cooperatives, holding market prices, fishing costs, and initial stock constant. This derivation makes several challenges clear. First, there are items in $\epsilon_{td}$ that are potentially correlated with the observable variables. Time-varying costs, for example, may be related to market prices if these prices are locally determined. Another possibility is that the differential effects of species scale across cooperatives, as shown above. Second, differences in two key unobservables—stock $X_{td}$ and Lagrange multiplier $\lambda_{td}$—reflect differences in market prices, fishing costs, and initial stock. Third, and finally, direct data on growth rates are not available. Instead, we use ONI as a proxy variable. Since ONI increases growth rates for some species and reduces growth rates for others, as discussed above, we must account for species-specific responses to ONI in the specification. Our classification of these responses will introduce measurement error.

To deal with these issues, we estimate the following specification in the empirical analysis using data on the species-week level for each cooperative:

$$log(P_{ctdx}) = \alpha_0 + \alpha_1 D_{td} + \alpha_2 D_{td} L_x + \alpha_3 log(P_{mtx}) + \alpha_4 D_{td} log(P_{mtx}) + \alpha_5 ONI_t \tag{34}$$

$$+ \alpha_6 D_{td} ONI_t + \alpha_7 D_{td} R_x + \alpha_8 R_x ONI_t + \alpha_9 D_{td} R_x ONI_t + \delta_{xp} + u_{tdx} \tag{35}$$

where $x$ is the species subscript and $L_x$ is the dummy for large scale as in the discussion of implication 2. $ONI_t$ is our ONI measure (varying at the month level). Including $D_{td}ONI_t$ allows for baseline differences across geographic areas in response to ONI for species whose recruits have no known response to ONI; the adults of these species may still respond to ONI. $R_x$ is a variable equal to $-1$ if ONI has negative effects on recruitment of species $x$, equal to 1 if ONI has positive effects and 0 if there is no established consensus. Finally, $\delta_{xp}$ is a species-time period-specific fixed effect, where a time period is a month in the preferred specifications below.

Implication 3 of the model is that $\alpha_9 > 0$: the $\alpha_9$ coefficient indicates the difference across cooperatives in responding to other species' positive or negative responses to ONI. Our identifying assumption is that, after controlling for the other observables in equation 34, no factor in $u_{tdx}$ leads to differential effects of ONI across cooperatives. The remaining threats to identification must take a very particular form. For instance, $X_{tdx}$ and $\lambda_{tdx}$ are omitted from the estimating equation. The cooperative dummy $D_{td}$ and the species-time period-specific fixed effect $\delta_{xp}$ capture the components of these unobservables that are additively separable between these items, so the remaining problem comes from components that are cooperative-species-specific. An example that could generate the patterns we see in the data is that the initial stock $X_0$ might be higher near Abreojos only for those species that respond positively to ONI. While we cannot prove an explanation like this is not at work, below we show that our basic results are robust to a number of changes in the specification.

Table 7 shows the results from estimating versions of equation 34. The first column shows the base specification, using fixed effects at the species-month level. The first two rows show the results for the Abreojos main effect and the interaction with the large scale species dummy. These coefficients have the expected signs, given the discussion of implications 1 and 2 above. The third and fourth rows show how the market prices are correlated with cooperative prices for each cooperative. The next two rows contain the interactions of Abreojos with ONI and the Recruit Effect ($R_x$ from above). Finally, the last row contains the estimate of $\alpha_9$. This shows that when growth rates change due to ONI, the price difference between Abreojos and other cooperatives moves in the predicted direction. The coefficient $\alpha_9$ implies a 16% price change in response to a one standard deviation change in ONI.

TABLE 7. Implication 3: Effect of Growth Rates on Price Differences

| | Dep Variable: Log Cooperative Price | | | | | |
|---|---|---|---|---|---|---|
| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
| Abreojos | −0.780*** | −0.835*** | −0.960*** | −1.189*** | −1.181*** | −1.188*** |
| | (0.133) | (0.173) | (0.233) | (0.023) | (0.032) | (0.017) |
| Abreojos X large scale | 0.157*** | 0.139*** | 0.162*** | 0.158*** | 0.162*** | 0.141*** |
| | (0.043) | (0.045) | (0.052) | (0.044) | (0.056) | (0.033) |
| Log mkt price | 0.395*** | 1.022 | −2.440 | | | |
| | (0.117) | (0.845) | (2.406) | | | |
| Abreojos X log mkt price | −0.135*** | −0.114* | −0.085 | | | |
| | (0.050) | (0.060) | (0.075) | | | |
| Abreojos X ONI | 0.056* | 0.071** | 0.047 | 0.065** | 0.064* | 0.064*** |
| | (0.034) | (0.035) | (0.045) | (0.031) | (0.037) | (0.023) |
| Abreojos X recruit effect | 0.793*** | 0.722*** | 0.652*** | 0.393*** | 0.274*** | 0.403*** |
| | (0.176) | (0.198) | (0.232) | (0.063) | (0.085) | (0.049) |
| Abreojos X ONI X recruit effect | 0.211*** | 0.193** | 0.196** | 0.208*** | 0.097 | 0.228*** |
| | (0.074) | (0.075) | (0.086) | (0.074) | (0.090) | (0.055) |
| Estimation method | FE | FE-IV | FE-IV | FE | FE | FE |
| Fixed effects | Sp-mth | Sp-mth | Sp-mth | Sp-mth | Sp-qtr | Sp-week |
| Obs | 2871 | 2600 | 2538 | 2871 | 2871 | 2871 |
| Num. groups | 770 | 575 | 560 | 770 | 340 | 2152 |
| Within-R2 | 0.905 | | | 0.902 | 0.876 | 0.941 |

*Note:* Sample includes observations at the weekly level from Abreojos, Pichilingue, and Sargento. The omitted cooperative category is Pichilingue/Sargento. Columns 2 and 3 treat log market price as endogenous and instrument for it using the one period and two period lag of log market price, respectively. Standard errors are clustered at the level of the fixed effect.

A serious concern with this result is that market prices may be correlated with fishing costs. Above, we saw that our three cooperatives are not dominant players in the La Paz market, so they are unlikely to be able to affect market prices directly with their own actions. Moreover, for at least some species, market prices in La Paz seem to be related to prices in a market that should be relatively unaffected by supply-side issues in B.C.S. Still, if at least some market prices are locally determined, a large positive shock to fishing costs of every player in B.C.S. may cause a large positive shock to market prices as well. Our species-month fixed effect deals with this issue in part; but it could still be the case that a weekly shock in costs relative to the monthly mean is associated with a weekly shock to market prices. This endogeneity could then cause a bias in the coefficient of interest that would be difficult to sign.

We deal with this issue in two ways. First, we instrument for market prices and the interaction of market prices with the Abreojos dummy. As our instruments we use a lag of market prices and the interaction of the lag with the Abreojos dummy. Column 2 uses the one period lag, while column 3 uses the two period lag. The estimates of $\alpha_9$ are quite similar to the estimate in column 1. Nevertheless, this solution has several problems. If weekly shocks to costs from the monthly mean are correlated across time, then the period t shock in the residual could be correlated with the instruments. Even if the exclusion restriction is satisfied, these are not strong instruments. The Kleibergen-Paap LM statistic for column 2 is large enough that we can reject the null hypothesis of underidentification at the 10% level, but we fail to reject with the corresponding Wald statistic. In column 3, we fail to reject with both statistics.

Therefore, we also estimate the standard fixed effects model without incorporating the market prices. While this deviates from the theoretically inspired specification, it is still useful: If the remaining coefficients change dramatically, this suggests that the endogeneity of market prices could cause large biases. The results appear in column 4. Reassuringly, $\alpha_9$ is still positive, statistically different from zero, and of similar magnitude.

Finally, we test the sensitivity of the results to the level of the fixed effect. With a less flexible set of fixed effects (species-quarter), $\alpha_9$ falls in size and becomes statistically indistinguishable from zero (column 5). However, with species-week fixed effects, $\alpha_9$ is again positive and significant, and the magnitude is closely comparable to the baseline specification (column 6).[28]

### *Alternative Explanations*

There are historical and geographic differences between Abreojos and the other two cooperatives. An important concern is that the empirical patterns above

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[28] Throughout, we have used the sample for which we have nonmissing cooperative prices and nonmissing market prices. In specifications not shown here, we show that $\alpha_9$ continues to be positive and significant with species-week fixed effects when this sample is broadened to all observations without nonmissing cooperative prices. However, $\alpha_9$ is smaller and insignificant with this sample when using species-month fixed effects.

reflect these other differences, rather than the difference in property rights. The tests of implications 2 and 3 help greatly in this regard. The empirical specifications testing these implications are essentially difference-in-difference models: while the Abreojos dummy may be endogenous to price and catch levels, the estimated coefficients on the key interaction terms are unbiased as long as the source of endogeneity does not differ by species scale or by species-specific responses to environmental oscillations.

One specific concern, for example, is that Abreojos's distance from La Paz leads to higher costs for selling catch, and this cost is taken out of payments to cooperative members. This explains the negative coefficient on the Abreojos dummy in the buying price regressions above. However, this explanation is problematic. First, the cost difference is unlikely to be large: Abreojos has streamlined methods of transporting, processing, and marketing catch through its operations in La Paz and Enseñada, as well as FEDECOOP's exports. Second, the explanation cannot capture the fact that the price gap between Abreojos and Pichilingue/Sargento is smaller for large-scale species.

One could supplement the above alternative explanation with the idea that, relative to the other cooperatives, Abreojos faces a smaller disadvantage in marketing catch for its exports to the United States and elsewhere. If large-scale species are more often exported, this could explain the fact that the price gap between Abreojos and Pichilingue/Sargento is smaller for large-scale species. However, this explanation is also problematic. Of the species for which we have market price data, Abreojos's most salient exports are lobster and sea bass, and both species are small-scale.[29] Moreover, this alternative explanation cannot explain our third finding, that the price gap is responsive to ONI and the specific effect of ONI (positive or negative) on a particular species.

The geographic differences between Abreojos and the other cooperatives suggest there may be differential stock endowments across the two areas. This could explain our results for differential catch, but such an alternative explanation would have to take a particular form to capture both of our empirical results: specifically, the stock advantage of the Pacific side would have to be relatively larger for small scale species than for large scale species. Existing work suggests the presence of differences in ocean productivity in the Pacific versus Gulf sides of the Baja Peninsula; unfortunately, however, not much is known (as far as we are aware) about how these differences manifest differentially across small scale and large scale species. Therefore, this alternative explanation for our catch results may be plausible, and we do not have evidence to support or refute it at this time. Nevertheless, we believe our model is the most plausible explanation that captures all of the empirical patterns we have seen for price and catch in one unified framework.

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[29] By "salient," we mean products advertised on the FEDECOOP website: http://www.fedecoop.com.mx/. Abalone, another small-scale species, is a key export of Abreojos, but we do not have market price data for this species.

## V. CONCLUSION

In this paper, we set out to understand how cooperatives use property rights to control fishing effort, and how this use is shaped by key characteristics of the targeted fish populations: scale of individual movement and responses to large environmental fluctuations. Using rich logbook data from three cooperatives, including one that enjoys strong property rights, we find support for the implications of our theoretical model. The magnitude of the differences between the cooperative with property rights and the ones without rights—as well as the shrinking of these differences when resources have a large scale or when growth rates are high—are economically significant.

These results highlight the value of linking theory with empirical analysis in order to examine the reciprocal interactions between natural resources and resource users. Our approach focuses on the economic mechanisms underlying these interactions and thereby complements more descriptive, existing analyses of fishery outcomes. Our results are also relevant beyond fisheries, as they illustrate how the decisions of resource users embedded in local institutions are mediated by characteristics of the resource and external dynamic factors. However, given that our logbook data are restricted to only three cooperatives, our conclusions are necessarily provisional. We hope that our analysis points the way to future investigation with more representative data.

More generally, integration of the connections between resources and resource users may well increase the effectiveness of state policies in coastal areas, whether focused on environmental stewardship, economic development, or both. Indeed, CONAPESCA's recently developed National Program of Inspection and Vigilance (*Programa Nacional de Inspección y Vigilancia*) demonstrates the government's interest in involving the leaders of local user groups in fisheries management; the program calls for the formation of state committees that include representatives of national, state, and local governments, as well as representatives of fisher groups.[30] Our results suggest that even greater devolution of authority to local users—by granting property rights—could be a viable management strategy in the right circumstances. By recognizing the influence that local institutions like Mexico's fishing cooperatives may have on both ecological and economic outcomes, policymakers will be better able to craft proactive, ecosystem-based policies that sustain both marine resources and the human communities that rely on them.

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[30] For details, see http://www.conapesca.sagarpa.gob.mx/wb/cona/programa_nacional_de_inspeccion_vigilancia_

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