CHICAGO JOURNALS

The University of Chicago
The Booth School of Business of the University of Chicago
The University of Chicago Law School

Reforming Fisheries: Lessons from a Self-Selected Cooperative
Author(s): Robert T. Deacon, Dominic P. Parker, and Christopher Costello
Source: *Journal of Law and Economics*, Vol. 56, No. 1 (February 2013), pp. 83-125
Published by: The University of Chicago Press for The Booth School of Business of the University of Chicago and The University of Chicago Law School
Stable URL: http://www.jstor.org/stable/10.1086/667864
Accessed: 01/07/2013 15:00

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at http://www.jstor.org/page/info/about/policies/terms.jsp

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

The University of Chicago Press, The University of Chicago, The Booth School of Business of the University of Chicago, The University of Chicago Law School are collaborating with JSTOR to digitize, preserve and extend access to *Journal of Law and Economics.*

http://www.jstor.org

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Reforming Fisheries: Lessons from a Self-Selected Cooperative

Robert T. Deacon *University of California, Santa Barbara*
Dominic P. Parker *University of Wisconsin—Madison*
Christopher Costello *University of California, Santa Barbara*

We analyze a policy experiment in an Alaskan commercial fishery that assigned a portion of an overall catch quota to a voluntary co-op, with the remainder exploited competitively by those choosing to fish independently. Unlike the individual quota system advocated by many economists, the policy encouraged coordinated fishing and did not require a detailed assignment of rights. We model the decision to join and behavior under cooperative and independent fishing. The data confirm our key predictions: the co-op attracted the least skilled fishermen, consolidated and coordinated effort among its most efficient members, and provided shared infrastructure. We estimate that resulting gains in rent were at least 33 percent. Some independents were disadvantaged by the co-op's formation, however, which prompted them to oppose it in court. We analyze the source of their disadvantage and provide guidance for designing fishery reform that leads to Pareto improvements, enabling reform without losers.

1. Introduction

It is widely accepted that the design of property rights plays a key role in determining the value of natural resource stocks.[1] On one end of the property

Deacon is also University Fellow at Resources for the Future. Costello is also Research Associate at the National Bureau of Economic Research. We gratefully acknowledge comments from an anonymous referee, Wolfram Schlenker, Randy Rucker, Quinn Weninger, and seminar participants at the University of California, San Diego, the University of Hawaii, the University of Maryland, Montana State University, North Carolina State University, the University of Oslo, the University of Ottawa Property and Environment Research Center, Resources for the Future, the American Economic Association annual meeting (San Francisco, January 3–5, 2009), and the National Bureau of Economic Research conference Environmental and Energy Economics (Stanford University, April 8–9, 2011). We also thank Ray Hilborn and the Alaska Salmon Program, based at the University of Washington. Finally, we thank the National Science Foundation's Dynamics of Coupled Natural and Human Systems Program for financial support.

[1] Two seminal contributions are Gordon (1954) and Scott (1955).

[*Journal of Law and Economics,* vol. 56 (February 2013)]
© 2013 by The University of Chicago. All rights reserved. 0022-2186/2013/5601-0003$10.00

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

rights spectrum is open access, the regime under which complete dissipation of the stock's value may ensue. On the other end is sole ownership, which provides ideal conditions for maximizing the value of the stock. Most of the world's natural resources are governed by property rights regimes that lie between these extremes.

In the modern regulatory state, with its emphasis on resource management by regulatory agencies, the predominant property rights regime for fisheries is limited entry. Limited entry, which is pervasive in the United States, Canada, and Europe, caps the number of individuals permitted to fish but fails to assign property rights to the stock. In this system, fishermen compete for an administratively determined fishery-wide quota, or total allowable catch (TAC). Typically, permit holders are constrained by rules on open seasons, gear types, and areas fished. Although the cap on licenses can keep the profits of fishermen above the open-access zero-profit equilibrium, permit holders nevertheless have strong incentives to invest in socially wasteful capital racing to the fish.[2] These investments shorten fishing seasons, raise costs, and impair the quality and timeliness of harvests relative to what single ownership would induce.

The recent literature on fishery regulation has sought to reform limited-entry rights, with the goal of engendering incentives that resemble what a sole owner would face while also recognizing that sole ownership is seldom a practical option in the modern regulatory state. Adoption of individual tradable quotas (ITQs), which assign each permit holder a secure share of the annual TAC of a fishery, is the reform most commonly advocated by economists. Where ITQs have been adopted—for example, in Iceland, New Zealand, Canada, and the United States—the race to fish has moderated and rents have increased. Yet despite these economic successes, as well as clear evidence that ITQ management can facilitate the recovery of collapsed fish stocks, less than 2 percent of the world's fisheries use systems that assign quantitative catch rights to harvesters.[3] Apparently, implementation of property rights in fisheries and in other mobile natural resources has been hindered by the transactions costs and political obstacles involved in shifting away from an existing regulatory regime.[4] In the fishery, individuals who

[2] The race and its consequences have been extensively documented in the literature (Wilen 2005).

[3] For recent empirical evidence on economic successes, see Grafton, Squires, and Fox (2000), Hannesson (2004), Leal (2002), Lian, Singh, and Weninger (2010), Deacon, Parker, and Costello (2008), and Newell, Sanchirico, and Kerr (2005). Costello, Gaines, and Lynham (2008) present evidence on the reduced probability of collapse for stocks under catch share management regimes, systems that grant some form of quantitative catch rights to harvesters, of which individual tradable quota (ITQ) systems are one variant. The collapse of fisheries is documented in several studies (Halpern et al. 2008; Myers and Worm 2003; Jackson et al. 2001; Worm et al. 2007). While pollution, climate change, and habitat damage can play important roles, ineffective management strategies are widely believed to be the root cause (Beddington, Agnew, and Clark 2007; Hilborn, Orensanz, and Parma 2005; Wilen 2005).

[4] Libecap and Wiggins (1984) and Wiggins and Libecap (1985) show that contracting over common oil reservoirs also suffers from scant implementation resulting from transactions costs.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

are well suited to competing under an existing regime have incentives to block the transition (Libecap 2008).[5]

Using game-theoretical analysis and exploiting a unique fishery management experiment from the Chignik sockeye salmon fishery in Alaska during 2002–4, we examine an alternative path for fishery reform. This alternative system assigns a secure portion of the aggregate catch to a cooperative (co-op) group of harvesters, formed voluntarily, to manage as the group decides. Those who choose not to join the co-op continue to fish independently under the prior regime and are permitted access to the remainder of the aggregate catch. This novel approach can diminish the incentive to block and, at the same time, engender incentives that closely resemble what a single firm or sole owner would face. Under conditions that we spell out, the transition from limited entry to this alternative regime can be Pareto improving, which eliminates opposition to the change.[6]

To fully capture the efficiencies resulting from coordinating input use, the entity that receives the catch allocation must be empowered to manage the fishing effort of its members in a unified way—that is, it must be structured as a firm. Managing inputs centrally via contracts with a manager, rather than across markets, allows an enterprise to capture gains from coordination without incurring excessive transactions costs (Coase 1937).[7] Coordination gains are likely to be important when several inputs share the use of a single input (Alchian and Demsetz 1972); this clearly is the case in the fishery, where individual harvesters jointly exploit the same stock of fish (Scott 2000). An ITQ management system will not generally accomplish the coordination needed to optimize the spatial and temporal deployment of fishing effort across an entire fleet (Costello and Deacon 2007).

We contribute to the literature on property rights reforms by developing a model of this alternative regime and testing its implications with data from the Chignik fishery. Before 2002, the Chignik fishery was managed by limited entry, and the key policy innovation was to assign a secure portion of the allowed catch to a single entity, the Chignik Salmon Cooperative, to manage as it saw fit. Fishing with the co-op was voluntary. Permit holders who joined signed a contract with the co-op before the season started, and the bylaws of the co-op empowered it to manage each member's fishing effort. The co-op also claimed the resulting profit, which was distributed among members at the end of the season. Given this structure, we model the co-op as a profit-maximizing organization constrained by a limit on its allowed catch. Permit holders who opted

[5] Obstacles include contention over the initial allocation of quota among fishermen, as well as the objections of the fish processor and local community to institutional change. Compounding the problem, inefficient fishery regulation can induce excessive investment in vessels and processing plants. Owners of this capital have incentives to resist regulatory change that would eliminate or impair its value.

[6] The result is reform without losers in the sense of Lau, Qian, and Roland (2000), who argue that designing reform to be Pareto improving can minimize political opposition. Participants may still resist change, however, as part of a strategy to obtain a larger share of the gains from reform.

[7] In fact, Coase (1937) refers to the manager of the firm as an entrepreneur-coordinator.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

out were free to fish competitively under the preexisting rules. The regulator accommodated the two sectors by announcing separate fishing times for each. We use this rare circumstance, with the two fishing sectors operating in tandem, to observe the coordination that the co-op practiced and to measure the resulting efficiency gains. To set the stage, we first place the Chignik experiment in the progression of fishery management institutions and examine how and why this singular institution arose where and when it did.

2. History of the Chignik Co-op Experiment

Commercial salmon fishing began in Alaska during the 1870s and was unregulated until 1924, when the White Act (ch. 272, 43 Stat. 464 [1924]) imposed catch limits linked to spawning goals (Colt 1999; Crutchfield and Pontecorvo 1969). During the latter part of this unregulated phase, most of the catch was taken by large stationary fish traps. When Alaska gained statehood in 1959, it immediately banned stationary fish traps despite their acknowledged efficiency, which caused employment in the fishery to swell by 6,000 entrants and prompted rents to fall.[8] The resulting regime was essentially open access, but with a limitation on the gear allowed.

In 1973, Alaska adopted the limited-entry system that is still used today in most of Alaska's fisheries. Under limited entry, the number of licenses is fixed, and individual license holders compete for a fishery-wide catch limit set by regulators. A political motive for fixing the number of licenses was to prevent entry by fishermen from Washington State and elsewhere, where fishing opportunities were being eroded by court decisions and declining stocks.[9] Alaskan limited-entry licenses are transferable, and positive license prices indicate that rents were generated. Fish ownership was still governed by the rule of capture, however, encouraging fishermen to compete in an inefficient race to harvest a share of the allowed catch before competitors. It is well established that these racing behaviors dissipate rents (Wilen 2005).

Although ITQs are now used in several important Alaskan fisheries, they have not been implemented for salmon either in Alaska or, to our knowledge, elsewhere. This dearth of implementation arguably has several causes. Presumably, the political obstacles that have so severely limited ITQ implementation elsewhere have worked to hinder implementation for salmon as well. Further, because of the migratory nature of salmon and the pulse nature of salmon runs, complete rent capture requires extensive coordination of the spatial and temporal deployment of effort and of public input provision. Our model outlines this argument in more detail. Individual tradable quotas alone fail to accomplish these

[8] According to Colt (1999), the rent reduction was equivalent to 12 percent of the ex-vessel price.

[9] For example, the court decision in *United States v. Washington* (384 F. Supp. 312 [W.D. Wash. 1974]) decreased by 50 percent the salmon allocation to fishermen who were not members of Native American tribes (Nickerson, Parker, and Rucker 2010).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

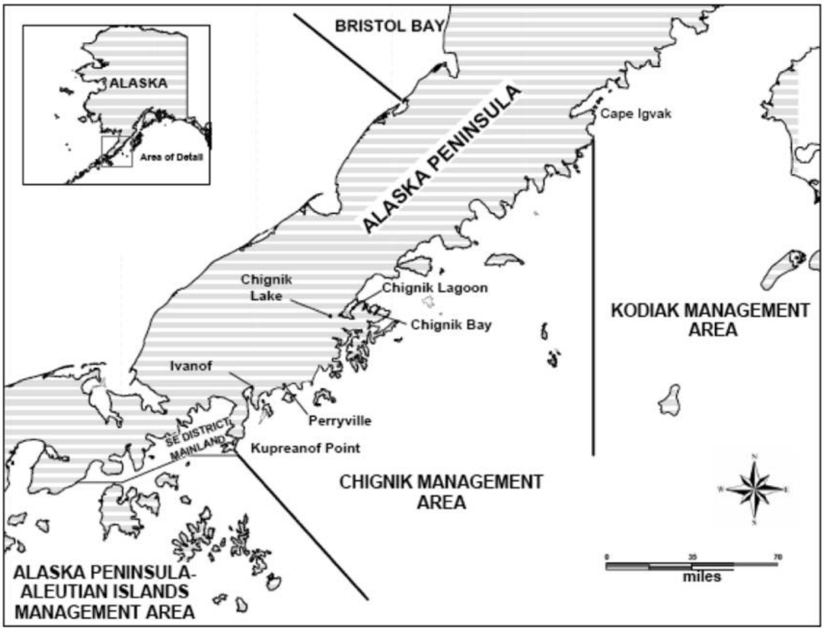

Figure 1. Chignik management area on the Alaskan Peninsula (Stichert 2007a)

tasks and thus will forgo these potential gains unless individual quota owners can collectively agree to coordinate their actions (Costello and Deacon 2007).[10]

Chignik (Figure 1) is one of Alaska's oldest and most important commercial salmon fisheries. The gear used is the purse seine, a large net deployed in the water like a curtain and then cinched from the bottom to prevent fish from escaping when the net is hauled.

Sockeye salmon migrate toward only one river (the Chignik River) in the Chignik system and are funneled into relatively dense concentrations as the migration proceeds from open ocean, through Chignik Bay, into Chignik Lagoon, and finally into Chignik River (Figure 2). Processing facilities are located and purse seine vessels are moored near the final destination.[11]

In 2002, the Alaska Board of Fisheries approved a request by a group of

[10] Other authors have identified potential efficiency advantages for user-based organizations that coordinate the activities of individual members. Scott (1993, 2000), for example, relies on this basic reasoning in arguing that fishery governance by harvester-based organizations represents a logical next step—beyond ITQ regulation—in the development of fishery management. Sullivan (2000) discusses transaction-cost and enforcement advantages that harvester co-ops may have over ITQ policies, but he concludes that harvester co-ops may be less durable than ITQ systems because they exist at the pleasure of their members.

[11] A more detailed map of the area can be found at MapQuest Maps (http://www.mapquest.com/maps?city=Chignik Lake&state=AK).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

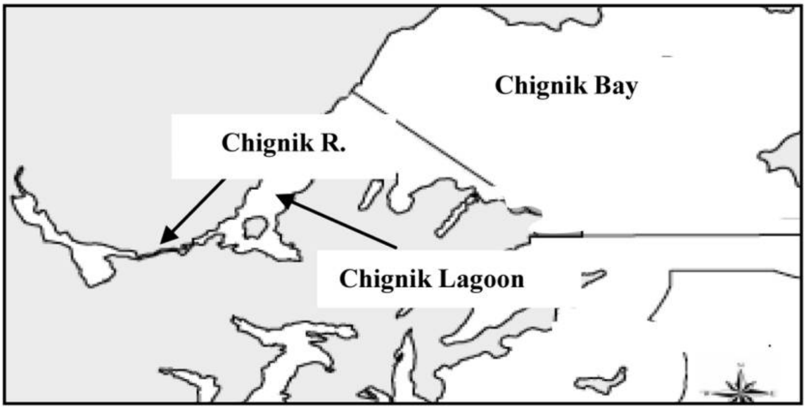

Figure 2. Chignik Lagoon and the nearby vicinity (Stichert 2007a)

Chignik permit holders to form annual co-ops for voluntary joiners; this arrangement continued through 2004. The number of fishermen who joined ranged from 77 in 2002 and 2003 to 87 in 2004, with the total number of permits equaling 100 throughout the period. Each year, the co-op was allocated a share of the TAC to harvest as it saw fit, with the remainder designated for traditional, competitive harvest by the independent sector. The two sectors fished at different times, which were determined by the regulator, and each sector's season was closed when its TAC share was reached. The TAC share of the co-op in a given year was determined by the following rule: (1) if less than 85 percent of the permit holders joined, the co-op received an allocation equal to nine-tenths of a per capita share for each joiner, and (2) if 85 percent or more of the permit holders joined, the co-op received a full per capita share for each joiner. This rule allocated 69.3 percent of the TAC to the co-op in 2002 and 2003 and 87 percent to the co-op in 2004. When the co-op was shut down by an Alaska court ruling in 2005, the regime reverted to the pre-co-op system with competitive fishing for all 100 permit holders.

This history raises several questions. First, why did the co-op form, and why at Chignik? One plausible reason is that Chignik fishermen had prior experience with the benefits of co-op management because of a 1991 strike aimed at securing higher prices from local processors. During the strike, the Chignik Seiners Association, a lobbying organization for local fishermen, negotiated an agreement in which local fishermen rotated efforts to bring predetermined volumes of catch to alternative processors who offered higher prices. Experience with this rotational scheme convinced participating fishermen that effort coordination could

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

yield a much higher catch per unit of effort than conventional fishing (Knapp 2007).[12]

Second, what accounts for the time lag between the promising experience with coordinated fishing in 1991 and the eventual launch of the co-op in 2002? Plausible reasons for the delay include the questionable legality of a co-op under Alaskan law, hesitance by some fishermen to join a co-op, and disagreement over how any catch quota granted to the co-op would be divided among members.[13] The launch in 2002 was evidently precipitated by a second strike against processors in 2001, which once again demonstrated the advantages of coordination and consolidation.

Third, how did the co-op policy affect fishing practices and the level and distribution of rents, and why was it dismantled after only 3 years? We address these questions in detail in the remainder of the paper. Given the contractual structure of the co-op, we model it as an organization motivated to maximize profit subject to a catch limit. We model the independent sector as a group of independent harvesters participating in a noncooperative game. Because fishing with the co-op was voluntary, our model allows for heterogeneous skills and examines the decision to join the co-op or fish independently. This leads to empirical predictions on how different skill levels will sort between the two sectors, as well as to subsequent empirical tests. Finally, our model considers the question of whether the with-co-op equilibrium represented a Pareto improvement over the equilibrium in which all participants competed in limited-entry fishing. This leads to both a close examination of the rule used to allocate the allowed catch between sectors and a discussion of the Alaska Supreme Court decision that overturned the co-op. The model's presentation in the text stresses intuition; proofs and detailed derivations appear in the Appendix.

3. Model

Our model is structured to highlight possibilities for coordinating the actions of inputs that share the use of a single resource—in this case, a stock of fish (Coase 1937; Alchian and Demsetz 1972; Scott 1955). This consideration is introduced in two ways. First, it is well known that harvesting efficiency can be enhanced by coordinating the spatial deployment of fishing effort if the unit value of the stock varies over space (Costello and Deacon 2007). In Chignik, cost per unit of effort declines as the stock migrates toward a port where fishing

[12] Strike participants found that the most cost-effective fishing method involved the use of guiding barriers to direct salmon within Chignik Lagoon (memorandum from Chuck McCallum, executive director of the Chignik Seiners Association, to Gunnar Knapp, professor of economics, University of Alaska, July 21, 1997). This reduced the number of seiners required to harvest the allowed catch and saved on transportation costs by concentrating effort near processing sites. The strike also demonstrated the economic advantages of collectively bargaining with processors over price.

[13] On the continuing concern about allocation, see the July 21, 1997, memorandum from Chuck McCallum (executive director of the Chignik Seiners Association) to Gunnar Knapp (professor of economics, University of Alaska).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

vessels and processing facilities are based. A single firm coordinating the effort of all harvesters will rationally intercept the stock at the most advantageous location, typically near the port. Independent fishermen have an incentive to intercept the stock before rivals do, however, to exploit an unfished stock, and this can result in excessive costs. Our model incorporates this coordination problem by dividing the fishing grounds into two zones, regarding the distance to each as a single value (0 or $\overline{d}$), and specifying that fishing at the greater distance raises the cost per unit of effort. We refer to these zones as inside and outside zones, respectively, and compare the co-op's choice of fishing location with the equilibrium locations of independent fishermen.

Second, gains can be achieved by coordination in the provision and use of nonrival public inputs. Fishery-related examples include shared information on stock locations and shared harvesting infrastructure (up to the point of congestion). A standard free-rider argument indicates that public inputs will be underprovided by independent agents contributing to their provision.[14] Efficiency in public input provision can be promoted, however, by placing the agents who use them under the direction of a single manager empowered to claim the resulting net revenue. Our model includes a nonrival public input, G, that reduces the cost per unit of effort. We assume that the public input is available only to harvesters in the sector that provides it.[15]

These two opportunities for coordination are assumed to affect the cost per unit of effort. Effort, in turn, is represented by the product of time spent fishing, T, and an individual skill parameter, γ, interpreted as the rate at which the individual can apply fishing effort. This specification implies that effort can be managed by controlling time spent fishing, which agrees with the way effort was managed in the fishery we study. When the subscript h refer to an individual fisherman, the individual's total cost is

$$c_h = [\alpha + d_h - G(\Sigma_i x_i)]\gamma_h T_h + \phi_h T_h + x_h. \tag{1}$$

The expression in brackets incorporates all cost components that are proportional to h's effort. We include a common cost parameter, α, and measure distance, d_h, in units of cost. The term x_h is h's contribution to the public input, and $G(\Sigma_i x_i)$ is the amount of public input provided by h's sector. We assume that $G(0) = 0$, $G' > 0$, $G'' < 0$, and $\alpha + d_h - G(\cdot) > 0\ \forall h$. We also include the opportunity cost of h's time spent fishing, $\phi_h T_h$. If h has an attractive opportunity either in another fishery that operates at the same time or in an entirely different occupation, ϕ_h will be large.

[14] If individuals are unwilling to share information on stock locations with other fishermen, effectively underproviding public information, the result could be an excessive or redundant search in the aggregate, because locations searched and found to be unproductive by one individual might be repeatedly searched by others (Costello and Deacon 2007).

[15] Because the two sectors fish at different times in the Chignik case, this is an assumption that shared inputs are not permanent or durable. This applies to the key public inputs that the Chignik co-op provided: day-to-day information on stock densities and removable infrastructure.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Total catch, Q, is linked to aggregate effort, E, and the stock, Z, by a linearly homogeneous fishing technology,

$$Q = ZF(E/Z), \tag{2}$$

where $F' > 0$, $F'' < 0$, $F(0) = 0$, and $F(E/Z) < 1$. The regulator imposes a biologically determined catch limit, expressed in what follows as a fraction of the stock $Q \leq \beta Z$. This catch constraint implies an upper limit on effort, $E \leq ZF^{-1}(\beta)$. Each season's allowed catch and the available stock are determined by the actions of the regulator in the current and prior years. These terms are fixed from the industry's point of view, so we treat them as parameters in what follows and focus on within-season fishing activities.[16]

In the fishery that we study, the migratory behavior of the stock enabled the regulator to divide the catch in such a way that one sector's catch did not interfere with the fishing opportunities of the other. Salmon predictably migrate through the fishing grounds toward their spawning stream during a known part of the year. Each sector was allowed to fish during a separate part of this migration period.[17] The portion of the annual run arriving during the independent sector's open season was a stock available to that sector alone. Once the independent sector's season closed, the uncaught portion of its stock escaped up river. The same process could then be implemented for the co-op sector by opening its season for a period of time and effectively dedicating a portion of the annual run to the co-op.[18] We denote the independent and co-op groups by I and J, respectively, their assigned stocks by Z_{I} and Z_{J}, and the numbers of harvesters in each group by $n(\mathrm{I})$ and $n(\mathrm{J})$. We specify that the run was partitioned in proportion to the number of permit holders in each group—that is, $Z_{\mathrm{J}} = Zn(\mathrm{J})/n(\mathrm{K})$ for group J, where $n(\mathrm{K})$ is the total number of harvesters in both groups. We later relax this allocation rule.

The total effort of the independent sector is $\Sigma_{h\in \mathrm{I}}\gamma_h T_h$. The regulator can ensure that this sector meets its catch limit by closing the independents' fishing season after T_{I} periods, where

[16] A firm assigned a secure catch quota could, in principle, choose to harvest less than what the regulator allows in a given year to increase future stocks, in which case its total catch would be a choice variable rather than a fixed quantity. We regard this possibility as remote in the case that we study and ignore it in what follows. We have two main reasons for this choice. First, if one sector reduced its harvest to generate a higher return in the future, part of that future return would be captured by the other sector and thus be external to the sector making the sacrifice. Second, biologically determined catch limits imposed by regulators often are lower than what a profit-maximizing manager would choose.

[17] We treat the regulator's choice of total allowable catch (TAC) as exogenous, independent of the behavior or composition of the two sectors. This assumption is appropriate for Chignik and other salmon fisheries in Alaska, as explained in Section 4.1

[18] For a sedentary species that does not redistribute itself over the fishing grounds as fishing proceeds, a similar stock division could be achieved on a spatial basis by allocating portions of its habitat to each sector. A spatial division would not work if the target stock redistributes while fishing occurs because harvests by one sector would subtract from the stock available to the other, setting off a race to fish.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

$$\sum_{h \in \mathrm{I}} \gamma_h T_{\mathrm{I}} = Z_{\mathrm{I}} F^{-1}(\beta). \tag{3}$$

The co-op faces a similar catch limit but is free to meet it by choosing distinct fishing times for individual members. In addition, the co-op's fishing times logically cannot exceed the duration of the salmon run minus the length of the independent sector's season. We express this upper limit by $\overline{T}$.

It remains to specify how the location of fishing affects catch. To simplify, we treat the stock available to a given sector as a dimensionless mass, Z, which moves along a migration route. Given the harvest technology, applying E_T units of effort to this stock will yield a catch of $ZF(E_T/Z)$. If this effort is applied sequentially, with E_0 units applied first and with $E_T - E_0$ units applied subsequently, the first batch of effort yields a catch of $ZF(E_0/Z)$, and the second yields a residual catch of $Z[F(E_T/Z) - F(E_0/Z)]$. Concavity of $F(\cdot)$ implies that the catch per unit of effort for the first application of effort is greater than that for the second. Because the migration route of the stock takes it toward port, the first batch of effort is necessarily applied farther from port than the second. Consequently, catch per unit of effort is higher for those who fish outside than for those who fish inside.[19] This creates an incentive for the independent fisherman to fish at a distance. Offsetting this is the fact that fishing at a greater distance increases cost per unit of effort.

There are two kinds of decisions to examine: the initial joining decision and subsequent decisions on effort deployment. We model these as a two-stage entry game and identify subgame-perfect Nash equilibria by backward induction.[20]

3.1. *Effort Deployment by the Co-Op*

Because total catch is fixed by the regulator, profit can be maximized by solving the following cost minimization problem:

$$\min_{d_i,\, T_i\; i \in \mathrm{J};\, x_{\mathrm{J}}} \sum_{i \in \mathrm{J}} [\alpha + d_i - G(x_{\mathrm{J}})]\, \gamma_i T_i + \sum_{i \in \mathrm{J}} \phi_i T_i + x_{\mathrm{J}}, \tag{4}$$

subject to $\Sigma_{i \in \mathrm{J}} \gamma_i T_i = Z_{\mathrm{J}} F^{-1}(\beta)$, $d_i \in \{0, \overline{d}\}$, and $T_i \in [0, \overline{T}]$ for all $i \in \mathrm{J}$, where x_{J} is the co-op's expenditure on the public input.

The profit-maximizing policy is straightforward.[21] First, it sets $d_i = 0$ for each member that spends positive time fishing. This is obvious because equation (4) is nondecreasing in $d_i T_i$, $\forall i \in \mathrm{J}$. Second, public input provision satisfies a Samuelson condition for optimal public good provision; for an interior solution, this is $G'(x_{\mathrm{J}}) F^{-1}(\beta) Z_{\mathrm{J}} = 1$. Both results reflect the gain from solving coordination problems. Third, the profit-maximizing policy assigns positive harvest times to

[19] Costello and Deacon (2007) apply similar reasoning to the harvesting of a nonmigratory stock that inhabits patches at varying distances from port.

[20] Consistent with positive permit values in the fishery examined, we assume that each firm is capable of earning positive profit by fishing independently, regardless of the composition of the independent and co-op fleets.

[21] Because any co-op member could have earned positive profit from fishing as an independent, the maximal profit of the co-op is necessarily positive.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

a subset of members who have the lowest values of the ratio ϕ_i/γ_i and limits the number of members who fish so that these efficient members fish as long as possible, $\overline{T}$ periods. Other members do not fish at all (but still share in the profits of the co-op). Concentrating effort among this group is intuitive because ϕ_i and γ_i are i's cost per unit of time and effort per unit of time, respectively, so the ratio ϕ_i/γ_i is i's cost per unit of effort. Slowing the rate of fishing to extend the season concentrates effort among these efficient harvesters to the greatest extent possible.

These results are summarized as follows:

Proposition 1. The co-op's profit-maximizing policy requires that

i) all active members fish as close to port as possible,

ii) provision of the public input equates the co-op's marginal benefit from provision to marginal cost, satisfying a Samuelson condition, and

iii) fishing is restricted to members who have the lowest cost per unit of effort (ϕ_i/γ_i), and effort is slowed to allow fishing to continue for as long as possible, $\overline{T}$ periods.

As a means of comparison, it is worth noting what would be the profit-maximizing behavior of a social planner who is unconstrained by the institutional structure on which this paper focuses. It is straightforward to show[22] that the planner adopts precisely the same set of actions that are outlined in proposition 1.[23] In other words, the profit-maximizing solution is equivalent to the solution achieved by a co-op of size $n(\mathrm{J}) = n(\mathrm{K})$ and an independent group of size $n(\mathrm{I}) = 0$.[24]

3.2. Stage 2 Choices by Independents

Fishermen choosing to fish independently face a set of decisions similar to that faced by the co-op manager. In this case, each fisherman must independently decide how much time to spend fishing, how much to contribute to the public good, and where to fish. Because profit is linear and increases with time spent fishing, each independent fisherman will fish the entire season. Recognizing this fact, the regulator must set the season length to meet the desired catch (see equation [3]). The highest skilled fisherman is the only fisherman who might be motivated to contribute to the public good; thus, it is insufficiently provided by the independent fleet.

Finally, we find that the equilibrium fishing location choices of independent fleet members depend on a complex interplay of model parameters. The trade-

[22] The social planner faces the minimization problem given in equation (4), when we replace J with the set of all fishermen in the fishery.

[23] To make proposition 1 relevant for a social planner, simply strike the word "co-op" and replace the word "members" with the word "fishermen."

[24] We do not explicitly consider coordination or contracting costs within the co-op. An explicit treatment of this would reveal an additional tension, possibly reducing the socially optimal co-op size.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

off involved has a straightforward intuition, however. Fishing outside is costly, but it enables an individual to contact the stock before all those who fish inside do and, consequently, obtain a higher catch per unit of effort. If the cost per unit of effort of fishing outside is relatively low, all fishermen will fish outside in equilibrium, and nobody will find it in his best interest to save on costs by deviating inside. On the other hand, if the cost per unit of effort of deviating outside is very high, it is in the best interest of all fishermen to fish inside; in this case, the benefit of intercepting the stock earlier never outweighs the high cost of fishing outside. Intermediate cases, in which some fishermen fish inside and some fish outside, can also be equilibria for intermediate values of the distance cost. This decision calculus is based on our model's predictions of the consequences of deviating in location, derived from the average and marginal catch per unit of effort (see the Appendix). These results are summarized below.

Proposition 2. In the subgame involving the independent sector's choice of time spent fishing, public input contributions, and fishing locations, a Nash equilibrium strategy profile requires that

i) each independent harvester fishes the entire time that the regulator leaves the independents' season open,

ii) the independent sector underprovides the public input relative to what is efficient, and

iii) for sufficiently low cost of fishing at the outside location (relative to the gain in catch per unit of effort), some or all independents will choose to fish at the inefficient outside location.

We also note that TAC constraint (3) and the regulator's stock assignment, $Z_{\mathrm{I}} = Zn(\mathrm{I})/n(\mathrm{K})$, imply that the independent sector's season length equals

$$T_{\mathrm{I}} = \frac{ZF^{-1}(\beta)/n(\mathrm{K})}{\Sigma_{i\in \mathrm{I}}\gamma_i/n(\mathrm{I})}. \tag{5}$$

It is therefore inversely proportional to the group's average skill, a result that will become useful later.

3.3. The Stage 1 Decision of Whether or Not to Join

Having determined the equilibrium behavior of the two fleets (independent and co-op), we now turn to the stage 1 decision of which fleet to join. We adopt the convention that fishermen are indexed in increasing order of their γ terms, so low-skilled fishermen have low index numbers. To obtain clear identification of the attributes of those who join the co-op, we assume that high-skilled harvesters (high γ) have a low cost per unit of effort (low ϕ/γ). This will be true if the ϕ terms are constant, if ϕ and γ are inversely ordered, or if ϕ does not increase more than proportionately as γ increases.

We start by examining the second-stage profit shares of successive co-ops in which new members are added in order of their γ parameters. In the Appendix,

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

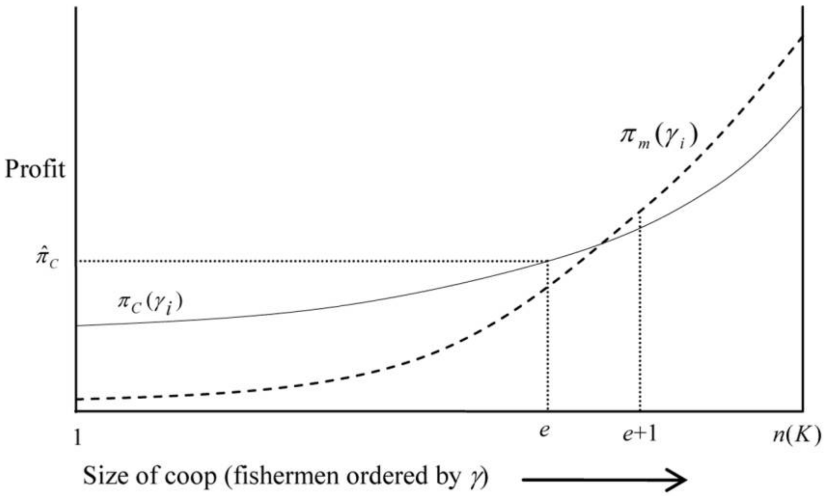

Figure 3. Equilibrium co-op size

we focus on the marginally skilled fisherman and his motivation either to join (and thus contribute to) an existing co-op or to fish independently. Figure 3 illustrates our analysis and identifies the equilibrium co-op size, independent fleet size, and the skill composition of members in each sector. The vertical axis is the profit per member. The horizontal axis is the size of the co-op (from one to all fishermen, n(K)), ordered by skill γ. We first show the intuitive result that, when new members are added in order of increasing skill, co-op profit per member increases monotonically with co-op size. The upward-sloping solid line, $\pi_c(\gamma)$, shows the profit per member of the co-op for co-ops of successively larger size (that is, those formed by accumulating additional members with greater skill).[25] The left intercept of this curve corresponds to the profit of a single-person co-op; although this case strains the definition of a co-op, it really just represents a secure catch allocation and separate fishing period for the lowest skilled fisherman in an amount that equals a per capita share of the entire TAC. This intercept is positive for two reasons: (1) by assumption, all fishermen could earn positive profit by fishing independently, and (2) the per capita catch allocation exceeds what this (least skilled) harvester would catch as an independent. The same reasoning also implies that the profit of the single-person co-op exceeds what the same lowest skilled fisherman could earn by fishing independently with all other harvesters; this result is useful shortly.

Next, we examine the marginal profit from independent fishing for indepen-

[25] This solid line is a smooth curve connecting a set of discrete points indicating the per-member profits for co-ops of different sizes.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

dent fleets composed of successively lower skilled fishermen. This is illustrated by the dashed line, $\pi_m(\gamma)$, in Figure 3. When read from right to left, this line indicates that as successively lower skilled fishermen are added to the independent fleet, the lowest skilled individual's profit monotonically declines. The left intercept of this curve necessarily lies below the solid curve that shows profit per co-op member, as was just explained. If the right intercept lies above the solid curve, then the two must cross at least once, in which case there is at least one equilibrium in which some harvesters join the co-op and some fish independently. Figure 3 illustrates this possibility. Fishermen with skill ranks between 1 and e earn more by joining the co-op than by fishing independently, and the reverse is true for all fishermen with skill ranks between $e + 1$ and $n(\mathrm{K})$. Skill rank e thus corresponds to the marginal, or highest skilled, co-op joiner; skill rank $e + 1$ corresponds to the lowest skilled nonjoiner. The crossing point for the two curves determines both the equilibrium co-op size and the allocation of skills. If the solid line lies everywhere below the dashed line, all fishermen choose to join the co-op.

These results are summarized as follows:

Proposition 3. Under our assumption regarding the relationship between effort rate and time cost parameters, a subgame-perfect Nash equilibrium strategy profile satisfies the conditions in propositions 1 and 2 and, in addition, has the following property: the group choosing to fish independently consists of highliners (highest skilled fishermen); more precisely, all independents have skill levels greater than those of any co-op member.

3.4. Characterizing Pareto-Improving Catch Allocations

The above discussion characterizes the membership and economic behavior of heterogeneous fishermen composing the two fleets. Here we focus on whether all fishermen are likely to support the formation of the co-op. In particular, we examine whether allowing formation of the self-selected co-op can be Pareto improving.

The answer hinges on the allocation of catch between the two sectors. We have assumed thus far that the regulator assigns catch in proportion to membership: $Z_\mathrm{J} = Zn(\mathrm{J})/n(\mathrm{K})$. To explore this issue more completely, we generalize the allocation formula to allow for disproportionate assignments: $Z_\mathrm{J} = Z\theta n(\mathrm{J})/n(\mathrm{K})$, where the scalar θ controls the proportional assignment to the co-op sector. For example, if $\theta = .9$, then the co-op is assigned a stock allocation that provides nine-tenths of a per capita share for each co-op joiner. Intuitively, it would seem that co-op members would be advantaged and independents disadvantaged by larger values of θ, but the endogeneity of self-selected membership may blur this intuition. We start by deriving the profit for an arbitrary fisherman, h, in a completely independent fishery, a term we use to refer to the counterfactual situation in which no co-op is allowed to form. We then compare this profit to what h would earn when the co-op is allowed to form. Naturally,

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

we must simultaneously solve for whether fisherman *h* fishes independently or as a member of the co-op fleet and for the associated season length and fishing locations in equilibrium; these choices will depend on θ.

We characterize our results relative to the benchmark allocation value, θ_c, at which each independent is equally well off whether or not the co-op is allowed to form. Our earlier results (that the joiners are relatively less skilled and the independents more skilled) allow us to show that $\theta_c < 1$. When the co-op receives a larger allocation (given by some $\theta > \theta_c$), independents are made worse off (indeed, so are the more productive co-op members), so this cannot be Pareto improving. On the other hand, if the co-op's allocation is too low (given by some $\theta < \theta_L$), the incentive to join the co-op is insufficient for any co-op to form at all. However, we find that for intermediate values of θ, fishermen of all skill levels (joiners and independents alike) are all advantaged by the ability of the co-op to form. These striking results are summarized below.

Proposition 4. The formation of a self-selected co-op has the following distributional consequences:

i) If $\theta_L \leq \theta \leq \theta_c$, the institutional design is Pareto improving: fishermen of all skill levels are made weakly better off by allowing the co-op to form.

ii) If $\theta > \theta_c$, the institutional design is not Pareto improving: all would-be independents and some would-be co-op fishermen are made worse off by allowing the co-op to form.

iii) If $\theta < \theta_L$, then no co-op forms.

These results are established in the Appendix.

4. Empirical Evidence

We employ a mix of quantitative and qualitative data to test the theory and to analyze related effects of the co-op policy at Chignik. We compare fishery-wide outcomes in the Chignik fishery during three distinct time periods: before the co-op (pre-2002), during the co-op years (2002–4), and after the co-op was shut down (post-2004).[26] We also compare outcomes in the Chignik fishery to outcomes in Alaska's other purse seine fisheries, all of which fished competitively with a TAC limit. Finally, we compare the behavior of Chignik permit holders who fished for the co-op to the behavior of Chignik independents.

After summarizing the quantitative data, we present the evidence in four sections that roughly follow the sequence of decision making at the Chignik fishery. Section 4.2 focuses on the decision to join the co-op. It tests the proposition that highliners will remain independent while less skilled fishermen will

[26] The availability of data over three distinct time periods (before, during, and after the co-op) helps us isolate the casual effects of the co-op from fishery-specific time trends (Meyer 1995, p. 158). The three distinct periods also help mitigate potential serial correlation in our panel regression models (Bertrand, Duflo, and Mullainathan 2004, p. 251).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

opt into the co-op (proposition 3), using data on the catch share histories of fishermen before 2002 to measure relative skill. Section 4.3 compares the consolidation and coordination decisions of the co-op and the independents. It begins by testing the proposition that the co-op will consolidate effort among its most skilled members and that this will necessarily lengthen fishing seasons (proposition 1iii), using data on catch share histories to measure relative skill and data on the number of active licenses and days fished to measure consolidation and season length. We test the proposition that the co-op will fish closer to port than will the independents (proposition 1i and proposition 2iii), using spatial data on fish caught in inside and outside zones. We conclude Section 4.3 by testing the proposition that the co-op will contribute more toward public inputs when compared to independent fishermen (proposition 1ii and proposition 2ii), using qualitative comparisons of infrastructure provision and the coordination of fishing effort. Section 4.4 examines the effects of the co-op policy on ex-vessel prices of salmon and on license values. Section 4.5 assesses the proposition that co-op stability requires that it be Pareto improving for joiners and independents (proposition 4), using data on the historic catch of co-op joiners and independents, the regulator's TAC allocation rule, and the timing of the lawsuit challenging the co-op.

4.1. Data Description

To test the predictions that co-op joiners will be less skilled fishermen than nonjoiners and that the most skilled co-op members will actively fish on behalf of the co-op, we use data on the catch share history of fishermen during the pre-co-op period to proxy fisherman skill. Although individual catch shares are not disclosed because of confidentiality laws in Alaska, we were able to obtain catch share data that are aggregated in groups of three fishermen.[27] The procedure for carrying out these aggregations was designed to minimize catch share heterogeneity among the observations that were grouped. Because some harvesters changed status during the co-op period, different aggregations were formed, using the same procedure, for 2002, 2003, and 2004. For 2002 aggregations, individual fishermen were first partitioned in three groups depending on their 2002 co-op status: co-op joiners who fished, nonfishing co-op joiners, and independents. All fishermen in a given group were ordered according to the average sockeye catch share over the historic 1995–2001 period.[28] Successive fishermen were then clustered in groups of three, and the average historic catch share within each cluster was reported to us. This procedure was then repeated for groups formed on the basis of 2003 and 2004 co-op status.

The end result is a set of roughly 100 observations on co-op status each year

[27] We are indebted to the Alaska Commercial Fisheries Entry Commission for performing these aggregations for us. In a few cases, it was necessary to aggregate over four firms.

[28] We do not consider more distant catch histories because vessel attributes and skill levels can change over time; we do not consider other salmon species because the co-op targeted sockeye salmon.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

during 2002–4 and the average historic per-fisherman catch share during 1995–2001. The mean catch share is 1.01 percent, which indicates that the average fishermen caught about 1 percent of the TAC. This statistic makes sense because there were approximately 100 permit holders at Chignik in each year preceding co-op formation. The maximum and minimum catch shares imply that highliners in the fishery caught 2.22 percent of the TAC, and the least successful fishermen caught .42 percent.

We rely on panel data, with each observation representing a fishery-year outcome, to test the effect of the co-op on fishery rents, consolidation, and salmon prices at Chignik. The panel data help control for the impacts of regionwide, annual shocks to all Alaskan purse seine salmon fisheries that may have also had an impact on outcomes at Chignik during the co-op years. The panel data set consists of 78 fishery-year observations ($i = 6$ fisheries; $t = 13$ years). The six fisheries are Chignik and the other five purse seine salmon fisheries in Alaska. We focus on 13 years of data (1997–2009), because this time span affords 5 years of data before and after the co-op was active. Table 1 gives summary statistics for the panel data. The dependent variables are the average price of a fishing permit that was permanently transferred to another fisherman, the proportion of licenses owned that are actively fished, and the price received by fishermen (from processors) per pound of salmon. Note that we use the sale prices of fishing permits to proxy expected rents from the fishery; permits are permanent rights to compete for a share of the TAC of each season.[29] The key independent variable is binary; it takes a value of one during the 2002–4 co-op years at Chignik. The other independent variables are fishery-specific fixed effects, year effects, and the total allowable catch.

To test the predictions of season length and spatial deployment of effort, we use annual time-series data from the Chignik fishery rather than panel data. We use time-series data because we were unable to find comparable data on season length and spatial location of harvest for the other purse seine fisheries. For season length, we use annual observations of the number of days fished at Chignik during 1980–2008, the years for which we have data. For the co-op years, season length gives the number of days fished by either the independent or co-op fleet; with minor exceptions, these fleets fished on different days. For spatial deployment of effort, we designate Chignik Lagoon (Figures 1 and 2) as the inside location and catches from elsewhere to be outside. We examine annual time-series data from Chignik to see how the proportion of sockeye caught inside deviated during 2002–4 from longer time trends during 1973–2008, the entire period that a limited-entry system has operated in Alaska fisheries. Table 1 gives summary statistics for the time-series data. We also examine daily catch data

[29] The TAC for sockeye salmon in Chignik is likely exogenous to the institutions governing capture. As with most salmon fisheries in Alaska, the sockeye TAC is set annually to achieve an exogenous predetermined escapement level (for example, see Pappas and Clark 2003).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Table 1
Summary Statistics of the Panel and Time-Series Data

	N	Mean	SD	Min	Max
Panel data:					
Dependent variables:					
Average permit price (2009 $)	78	65,823	69,304	10,062	252,510
Proportion of permits actively fished	78	.519	.194	.159	1.000
Price per pound (2009 $)	78	.397	.25	.126	1.095
Independent variables:					
Co-op policy (one if in place, otherwise zero)	78	.038	.193	.000	1.000
Fishery-wide TAC (1,000s of pounds of salmon)	78	66,336	69,612	1,619	295,817
Time-series data:					
Dependent variables:					
Number of days fished	28	68.89	11.60	50.0	102.0
Proportion caught inside	36	.787	.151	.450	1.000
Independent variables:					
Co-op policy (one if in place, otherwise zero)	36	.083	.280	.000	1.000
Fishery-wide TAC (1,000s of sockeye salmon)	36	1,381	593.4	399.6	3,116

Sources. The data are from Bouwens and Poetter (2006), Pappas and Clark (2003), Bouwens and Stichert (2006), Stichert (2007a, 2007b), Stichert, Anderson, and Dann (2009), and Jackson and Anderson (2009).
Note. There are 78 fishery-year observations with $i = 6$ fisheries and $t = 13$ years. The six purse seine fisheries are Alaska Peninsula, Chignik, Cook Inlet, Kodiak, Prince William Sound, and Southeast. The years are 1997–2009. The data come from the fishery participation and earnings statistics of the Alaska Commercial Fisheries Entry Commission (Fishery Statistics—Participation & Earnings (www.cfec.state.ak.us/fishery_statistics/earnings.htm) and summarize 36 years of Chignik fishery data for proportion caught inside, co-op policy, and fishery-wide total allowable catch (TAC) (1973–2008). The table summarizes 28 years of data for number of days fished (1980–2008).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Table 2
Comparison of Mean Catch Histories for Ranked and Sorted Clusters of Fishermen

	N	Catch Share Mean	Catch Share SD	t-Statistic for Difference in Absolute Value
Independents versus co-op joiners:				
Independents	18	1.29	.0036	2.90**
All co-op members	78	1.00	.0045	
Co-op fishermen versus nonfishermen:				
Co-op members who fished	18	1.11	.0030	1.83*
Co-op members who did not fish	59	.90	.0036	

Note. Allowing for unequal variance, the t-statistic for the comparison for the independents versus co-op joiners is 2.53, and the t-statistic for the comparison for co-op fishermen versus nonfishermen is 2.02. The data are pooled for 2002–4.
* Significant at the 5% level (one-tailed t-test with equal variance).
** Significant at the 1% level (one-tailed t-test with equal variance).

from Chignik during 2002–4 and compare the location of the catch during days fished by the co-op versus the independent fleet.

4.2. Relationship between Skill and the Decision to Join the Cooperative

Our model predicts that highliners will remain independent while less skilled fishermen will opt into the co-op (proposition 3). The model also suggests that an individual's historic catch share under independent fishing is a good proxy for the critical skill parameter, γ. Accordingly, we test skill-related predictions with the ranked and clustered data on individual catch shares during the pre-co-op period.

Table 2 shows that the historic catch shares of those who fished independently during 2002–4 significantly exceeded catch shares of co-op joiners (1.29 percent compared with 1.00 percent), which agrees with the theory. Tests for first-order stochastic dominance in the empirical distribution functions provide further corroboration. Figure 4*A* plots cumulative density functions (CDFs) for the historic catch shares of joiners and independents. From visual inspection, the empirical CDF for independents stochastically dominates that for joiners, which indicates greater skill for the former group. A Kolmogorov-Smirnov test (available from the authors) confirms that the differences in the CDFs are statistically significant. We discuss the findings for co-op fishermen versus nonfishermen in Table 2 and Figure 4*B* shortly.

4.3. Consolidation, Spatial Deployment of Effort, and Public Input Provision

The model predicts that a profit-maximizing co-op will consolidate fishing effort among its most skilled members. In order to make maximal use of its most efficient harvesters, the co-op limits the number of members who actually fish, which slows the rate of fishing and lengthens the fishing season. By contrast,

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

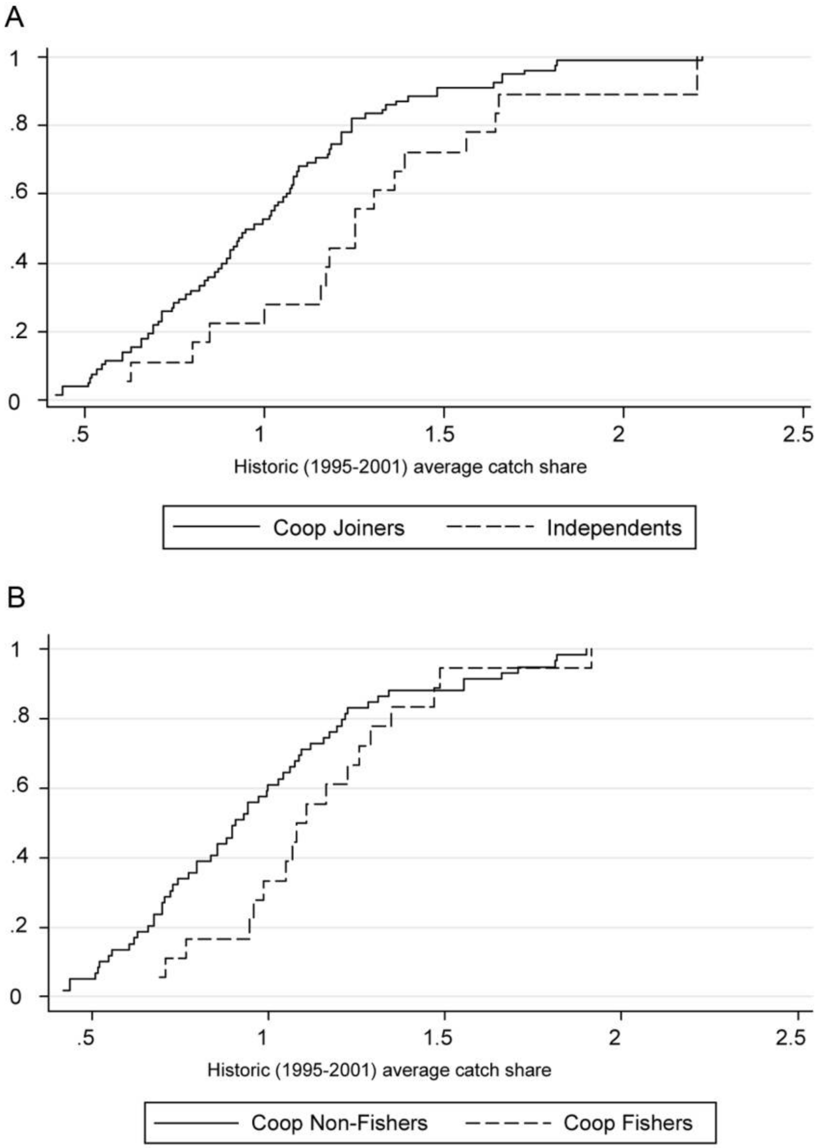

Figure 4. Cumulative density functions of 1995–2001 average catch shares

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

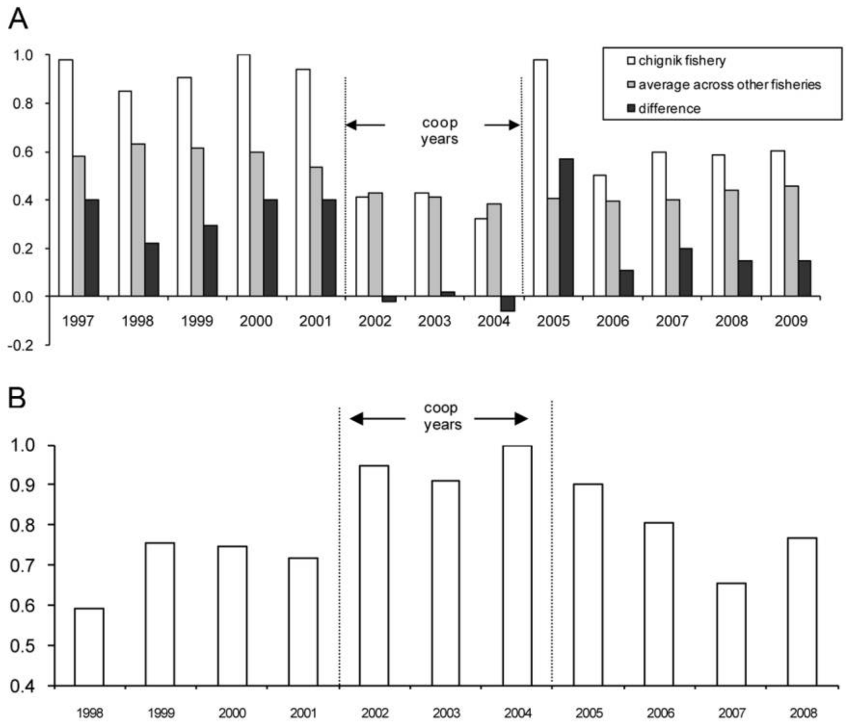

Figure 5. *A*, Comparisons of permits fished and inside catch; *B*, comparisons of inside catch.

all independents are predicted to fish each day their season is open, which causes the regulator to shorten their season to meet the TAC constraint. Thus, we expect to see the following patterns in the data: a decline in the proportion of permits actually fished at Chignik during 2002–4, an extension in the number of days fished during this period, and a concentration of fishing effort among the co-op's more efficient members.

We test the first of these predictions by examining the effect of the co-op on the proportion of licenses actually fished, using the panel data summarized in Table 1. Figure 5*A* shows simple and transparent evidence that the co-op policy dramatically consolidated the Chignik fishery. The proportion of permits actively fished in Chignik decreased from .94 in 2001 to .41 in 2002, when the co-op first operated, and then increased after the co-op was effectively dissolved in 2005.[30] The darkest bars show the difference between Chignik and the average

[30] In Figure 5*A*, the mean differences for the three time periods are .34 for 1997–2001, −.02 for 2002–4, and .23 for 2005–9. In n Figure 5*B*, the means for the three time periods are .70 for 1998–

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Table 3

Panel Regressions of Permits Fished, Ex-Vessel Prices, and Permit Values

	Proportion of Permits Fished (1)	Price per Pound (2)	Permit Value (3)
Constant	.441**	.581**	69,028**
Co-op policy	−.311**	.238**	59,130*
Fishery-wide TAC	3.79E−08	−1.25E−06*	−.093
Adjusted R^2	.855	.818	.820

Note. The permit value data are adjusted by the consumer price index and are presented in 2009 dollars. For all regressions, year dummies and fishery dummies are included. The five control fisheries are the other purse seine fisheries Alaska Peninsula, Cook Inlet, Kodiak, Prince William Sound, and Southeast, and the year dummies span 1997–2009. The omitted observation is the Cook Inlet fishery during 1997. $N = 78$. TAC = total allowable catch.

* Significant at a 5% level (one-tailed t-test).

** Significant at the 1% level (one-tailed t-test).

across the other purse seine fisheries. This difference was strictly positive before and after the co-op years but approximately zero during 2002–4.

Table 3 shows our estimate of the effect of the co-op policy on the proportion of active licenses using the panel regression model in equation (6):

$$\text{proportion of permits fished}_{it} = \delta_t + \alpha_i + \beta(\text{co-op policy})_{it} + \text{TAC}_{it} + u_{it}. \quad (6)$$

Identification of β, the co-op policy effect, comes from within-Chignik annual changes in the proportion of permits fished, controlling for annual shocks (δ_t) that could affect the proportion of licenses fished in all purse seine salmon fisheries (for example, fuel prices and the price of farm-raised salmon) and time-invariant differences in the proportion fished across the six fisheries (α_i). The model also controls for time-variant differences in salmon runs as reflected in the fishery-specific annual TAC. The result indicates that the co-op policy reduced the proportion of permits fished by .31. The direction of the effect, a reduction, is consistent with expectations, and the coefficient estimate is economically and statistically significant.[31] The result is particularly striking because it pertains to consolidation across the entire fishery, not just within the co-op. Consistent with our theory, annual Chignik area management reports indicate that almost all of

2001, .95 for 2002–4, and .78 for 2005–8. The spike to .98 in 2005 is worth explaining. In early 2005, shortly before the start of the fishing season and after the co-op was already formed for the 2005 harvest, the Alaska Supreme Court ruled that the co-op violated an Alaska law prohibiting permit holders who did not actively fish from accruing profits. The state's remedy for the 2005 season was to allow the co-op to fish but to require that all co-op members actively fish for a small part of the season. In 2006, the co-op was entirely dissolved. We discuss the court decision in more detail later.

[31] To correct for possible serial correlation of errors within each fishery, we conduct a robustness check recommended by Bertrand, Duflo, and Mullainathan (2004). We collapse the data into averages for each fishery during three periods: before, during, and after the co-op years. We next run a panel regression using the 18 observations (six fisheries and three time periods) and include fishery and time-period fixed effects along with the average fishery-wide TAC. This generates consistent standard error estimates (Bertrand, Duflo, and Mullainathan 2004). The resulting coefficient on the co-op policy for the collapsed data is of −.311, with a t-statistic of 4.15.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

the consolidation occurred within the co-op; during 2002–4, the proportion of permits actively fished was .25–.28 for the co-op and .92–1.0 for independents.[32]

We test the prediction that the co-op consolidated effort among its most skilled members by comparing mean historic catch shares for fishing versus nonfishing co-op members. The comparison, shown in Table 2, indicates that those who fished for the co-op had higher historic catch shares than those who did not (1.11 percent compared to .90 percent), which agrees with our prediction. Figure 4*B* plots the harvest share CDFs for co-op members who fished and co-op members who did not fish, using the ranked and clustered data described above. From visual inspection, the empirical CDF for co-op members who actively fished dominates the CDF for those who did not fish (except for a single exception near the right tail), and a Kolmogorov-Smirnov test (available from the authors) confirms that the difference is statistically significant.

To test the prediction of season length, we employ time-series data on the annual number of sockeye salmon fishing days at Chignik during 1980–2008 (see Table 1 for summary statistics). The time-series regression model is

$$\begin{aligned}\text{days fished}_t = {} & \alpha + \beta(\text{co-op policy})_t + \pi_1 t + \pi_2 t^2 + \pi_3 t^3 + \pi_4 t^4 \\ & + \mu_1 \text{TAC}_t + \mu_2 \text{TAC}_t^2 + \mu_3 \text{TAC}_t^3 + \mu_4 \text{TAC}_t^4 + u_t.\end{aligned} \tag{7}$$

The time-series model accounts for the cyclical nature of the time-series data by including a fourth-order polynomial time trend and controls for variation in harvest by including a fourth-order polynomial in the annual allowed catch. The regression estimate in column 1 of Table 4 indicates that, on average, the presence of the co-op lengthened the season by 32 days, for a 48 percent increase in season length from the long-run average of 67 days in non-co-op years.[33]

To summarize, the empirics to this point show that the co-op consolidated effort among its most efficient members, and this consolidation lengthened the fishing season (and presumably lowered costs), as the model predicts. The model further predicts that the co-op will coordinate on the location of harvest to reduce costs. Because the co-op secures a guaranteed allocation of catch, co-op harvesters should wait until fish migrate inside into Chignik Lagoon, at which time the harvest will be more efficiently executed (proposition 1.i). In contrast, some or all of the independent sector's harvest is expected to take place outside (proposition 2.iii). We use data on the spatial location of catch to test these propositions in two different ways. First, we examine fishery-wide annual time-series data to see how the proportion of sockeye caught inside deviated during 2002–4 from longer annual time trends. We then use within-fishery data on

[32] Members who fished on behalf of the co-op were paid salaries to compensate for their costs. All co-op members were then paid equal shares of the profit remaining after these salaries and other co-op costs were deducted (Knapp and Hill 2003).

[33] The trend variables are included to control for possible nonstationarity in the mean number of days fished. Dickey-Fuller and Phillips-Perron tests for unit roots, however, support the assumption of stationarity in the annual data. The test results are available from the authors.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Table 4
Time-Series Regressions of Season Length and Inside Catch

	Number of Days Fished (1)	Proportion of Catch from Inside (2)
Constant	509.7*	.994*
Co-op policy	32.15**	.284**
Fishery-wide TAC	.4006	−1.03E−06
Fishery-wide TAC^2	−3.17E−10	1.45E−12
Fishery-wide TAC^3	1.04E−16	−7.47E−19
Fishery-wide TAC^4	−1.19E−23	1.23E−25
Year	−114.65*	.045
Year^2	7.649*	−.004
Year^3	−.217*	.0001
Year^4	.002*	−5.86E−07
N	28	36
Adjusted R^2	.533	.642

Note. The data come from Chignik management area annual management reports and are summarized in the co-op fishermen vs. nonfishermen section of of Table 2. We lack data on season length before 1980, so the data for column 1 span 1980–2008. The data for column 2 span 1973–2008.
* Significant at the 5% level (one-tailed t-test).
** Significant at the 1% level (one-tailed t-test).

daily catch to assess how the proportion of inside catch differed between co-op and independent fishermen during 2002–4.

Figure 5*B* shows the fishery-wide proportion of sockeye caught inside over an 11-year period that includes 2002–4, the co-op's years of operation and provides transparent visual evidence that the proportion caught inside peaked during the co-op years. We employ a time-series regression model to more rigorously test for the effect of the co-op on inside catch. The time-series model is the same as equation (7), except that now the dependent variable is the proportion of sockeye salmon caught inside. The regression results shown in column 2 of Table 4 indicate that the co-op policy increased the proportion caught inside by .28.[34] Note that this proportion applies to the entire fishery (including both co-op fishermen and independents) and, in that sense, understates the behavioral change the co-op implemented.[35]

Table 5 compares the location choices of co-op and independent fleets during

[34] The trend variables are included to control for possible nonstationarity in the mean of the proportion of inside catch. Dickey-Fuller and Phillips-Perron tests for unit roots, however, support the assumption of stationarity in the annual data. The test results are available from the authors.

[35] The time-series regression does not control for marine fuel prices, which could influence the decision to fish inside or outside. Data on fuel prices have been collected since 1999 through the Fisheries Economics Data Program, EFIN Monthly Marine Fuel Prices (http://www.psmfc.org/efin/data/fuel.html#REPORTS). The data show that the mean price of a gallon of fuel in Alaska (in 1999 dollars adjusted for the Anchorage consumer price index) during the summer months of the 3 co-op years was $1.36, and the mean price during the summer months of the 7 non-co-op years was $2.00. Therefore, the proportion of fish caught inside was higher during the co-op years, despite the relatively low fuel prices that should have otherwise encouraged more outside fishing.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Table 5

Proportion of Sockeye Caught Inside by Co-op and Independent Fleets

	Co-op	Independent
2002:		
Number harvested	576,757	162,979
Proportion caught inside	1.00	.82
2003:		
Number harvested	757,974	334,330
Proportion caught inside	1.00	.79
2004:		
Number harvested	541,400	61,446
Proportion caught inside	1.00	1.00

Sources. Bouwens and Poetter (2006); Bouwens and Stichert (2006).
Note. In a few instances, each fleet fished on the same day but at different times. Because the data on spatial catch are reported on a daily basis, the comparison is restricted to those days reserved exclusively for one of the two fleets.

2002–4 using detailed daily catch data from the 2002–4 annual Chignik management reports. As the model predicts, the co-op harvested its entire allocation inside Chignik Lagoon in each year.[36] By comparison, the independent fleet harvested from both inside and outside in 2002 and 2003, which is consistent with the possibility of a mixed equilibrium (proposition 2.iii). During 2004, when there were only 13 independent fleets, all independent harvests took place inside the lagoon.

Our evidence of provision of shared or public inputs by the co-op is qualitative, gleaned from trade press accounts and annual management reports of the Alaska Department of Fish and Game (Pappas and Clark 2003, pp. 10–14). The most prominent shared inputs installed by the co-op were fixed leads, stationary nets placed along the fish migration route to funnel the stock toward waiting purse seiners (Pappas and Clark 2003). The fixed leads altered the style of fishing and dramatically reduced the number of vessels required to achieve a given catch. This sort of shared infrastructure was not employed by the independent fleet (Ross 2002a).[37]

Other actions that we characterize as public input provision by the co-op amount to very precise coordination of members' actions. One important form of coordination was a finely tuned temporal allocation of its members' effort

[36] The following account from a co-op founder makes clear that fishing inside was a conscious operating policy: "We had originally planned to employ a couple of large . . . seiners to fish out on the capes [outside], but we realized that the extra running time would increase costs and reduce product quality. Harvesting in the close proximity and concentrated harvest area of the Chignik Lagoon [inside] was simply the most efficient and quality conscious method to pursue" (Ross 2002a, p. 31).

[37] The use of shared infrastructure was also a hallmark of Native American salmon fishing in the Pacific Northwest before commercialization. Certain types of fishing gear required co-op effort in handling and construction, and ownership of this gear was reportedly shared among individuals and tribes (Higgs 1982).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

(Stichert 2007a). During low tides, Chignik Lagoon, the inside location where the co-op harvested, shrinks to a fraction of its size at high water. This concentrates the fish and reduces harvest cost. A prominent co-op member described how the co-op coordinated effort to exploit this phenomenon: “Instead of [a coop member] making four or five sets . . . during the flood [high tide] for 200 to 300 [fish] a haul, he now could wait till the Lagoon drained out. At low tide . . . [the channel] became a slow, meandering river of concentrated sockeye. And now, fishing for the entire co-op, he could make one giant drag for 3,000 to 5,000 fish” (Ross 2002b, p. 47).

This strategy required that co-op harvesters allow fish to escape up river during high tides, even though it was legal to catch them. Given the co-op’s secure catch allocation and its ability to coordinate, however, the incentive to do this was present. We know of no instances of independent fishermen intentionally allowing fish to swim up river.

The co-op also coordinated its members’ actions to improve the quality of fish delivered to processors. It received permits to hold live fish in net pens for up to 3 days, which allowed it to better match deliveries to processing capacity. On occasion, the co-op even released live fish from capture when processing capacity was insufficient.[38] Independent harvesters have no incentive to engage in such practices, and we are aware of no evidence indicating that they did. The co-op also coordinated information on stock locations from all of its active members and used this information to dispatch vessels and crews to the most advantageous locations. We are aware of no evidence that the independent fleet followed this practice; indeed, fishermen are notorious for hiding such information from their competitors.

Finally, the co-op’s ability to coordinate benefited the fishery manager by enabling precise control of a day’s catch. With independent fishing, the fishery manager must forecast the rate of catch and announce a closing time calculated to meet the overall catch target, an imprecise process at best. On days that the co-op fished, the manager could hit the target precisely simply by requesting that the co-op cease fishing when the desired number of fish was caught (Pappas and Clark 2003).

4.4. *Salmon Prices and License Values*

In this section, we estimate the effect of the co-op policy on both ex-vessel salmon prices and license values. These outcomes are related to our theoretical model but are not explicitly addressed by it. For example, the model does not predict higher ex-vessel prices, but it does provide a rationale for why prices paid to fishermen should be higher under the co-op regime. The rationale is that the consolidation and coordination induced by the co-op should naturally lead to higher quality fish being delivered to processors and a price premium

[38] The preceding two examples are from Stichert (2007a).

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

for co-op fishermen.[39] Indeed, the possibility of exercising greater care in harvesting to deliver a higher quality product was prominent in initial discussions on forming a co-op. In addition, the co-op may command a higher price as a result of having greater leverage in negotiating prices with the small number of fish processors operating at Chignik. It is widely believed that processors extract most of the rents from negotiation with independent fishermen; presumably, a coordinated harvester group could wield its own market power. Both considerations indicate that the co-op's formation might lead to higher prices to co-op fishermen.[40]

We cannot separate these two effects empirically, but we can test for a price increase with the panel regression format in equation (6), using the ex-vessel price per pound of salmon as the dependent variable. The regression results (shown in column 2 of Table 3) indicate that formation of the co-op was accompanied by an average price increase of \$.24 (in 2009 dollars) per pound in the Chignik fishery. This represents a 32 percent increase from the Chignik average of \$.75 outside of the co-op years during 1997–2009.[41] Note that this is a lower bound estimate of any price premium that the co-op achieved because nearly one-third of the sockeye caught at Chignik were harvested by independents during 2002–4.[42]

The evidence thus far indicates that the co-op policy lowered fishing costs and raised ex-vessel prices, which suggests that the policy also increased profits. We lack data on individual firm-level profits, but we do have data on the value of fishing permits. The value of a Chignik fishing permit should reflect the expected present-value profit that a marginal (low-skilled) fisherman could earn in this fishery. The marginal fisherman's profit, rather than the highliner's profit, is relevant because (ignoring differences in nonpecuniary returns) the marginal fisherman would have the lowest reservation price for selling a permit and would therefore determine the transaction price to potential buyers.

Table 3 shows our estimate of the effect of the co-op policy on permit value, using the panel regression format in equation (6). The result indicates that the

[39] There is strong evidence for longer seasons, higher quality, and higher value product in fisheries with secure catch allocations. Concrete data from Alaskan halibut, New Zealand snapper, and Australian bluefin tuna show an increase in quality and ex-vessel value (Leal 2004). Emerging qualitative evidence from newly formed individual fishing quota fisheries on the west and east coasts of the United States show similar outcomes.

[40] We chose not to incorporate the market power feature explicitly in the model in part because its effect seems obvious and in part because this seems specific to Chignik. The co-op's incentive to coordinate to guarantee higher product quality is similar to its incentive to provide club goods and in that sense is consistent with our model. The difference is that enhanced product quality raises price, while we treat the effect of club goods as decreasing costs.

[41] The price data are adjusted for inflation and are in 2009 dollars. As before, we estimated a version of the regression in Table 3 by collapsing the data into averages for each fishery during three time periods: before, during, and after the co-op years. This approach generates consistent standard error estimates (Bertrand, Duflo, and Mullainathan 2004). The resulting coefficient on the co-op policy for the collapsed data is .238, with a *t*-statistic of 2.66.

[42] We lack cross-sectional data during 2002–4 that would allow us to compare output prices between the co-op and independent sectors.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Table 6
Proportionate Profit Increase (ϕ) from Allowing Co-op to Form

Co-op Operating Horizon (Years)	$r = .10$	$r = .07$
3	1.03	1.38
5	.75	.98
10	.50	.62
∞	.33	.33

Note. The increase in license value is $59,130, and the baseline license value is $181,004.

co-op policy increased the value of a permit by $59,130 in 2009 dollars. This implies that the option to join a voluntary co-op substantially increased the amount that buyers would pay for a permanent right to fish at Chignik. This is a 32.6 percent increase relative to $181,004, which was the mean value of a Chignik permit over 1997–2009, excluding the co-op years.[43]

The permit value difference presumably reflects the co-op's effect on the present value of expected future annual profits, but the implied annual profit effect is complicated because the co-op's life span was unknown. We deal with this uncertainty by estimating a range of values for the implied annual profit effect, each based on a different assumption about the co-op's expected life span. The lawsuit that eventually ended the co-op was filed in April 2002 (*Grunert v. State,* 109 P.3d 924 [Alaska 2005]), just before its first year of operation. We therefore set the lower bound of life expectancy at 3 years, its actual period of operation. We set the upper bound at infinity, which corresponds to an expectation that it would persist in perpetuity. To calculate the profit effect, let π indicate the expected annual profit before the co-op formed and assume that it is constant, let V indicate the pre-co-op license value, and let r be the interest rate. Under the assumption that license values observed before the co-op formed did not incorporate expected profits from the co-op's possible formation, the preceding variables are linked by $V = \pi/r$. Let ΔV be the change in license value resulting from the co-op's formation, which we estimate, and let T indicate the number of years in which the co-op was expected to operate. We wish to estimate the proportionate change in profit resulting from allowing the co-op to form, or ϕ. The appropriate present-value formula gives $\Delta V = \{\Phi\pi/r\} \times \{1–[1/(1 + r)^{T+1}]\}$. The term of interest, ϕ, can now be found by combining the two preceding expressions: $\Phi = \Delta V/V \times \{1–[1/(1 + r)^{T+1}]\}^{-1}$.

Applying this formula to the data yields the results in Table 6. The lower bound of the estimate of the annual gain in the marginal fisherman's profit due

[43] As before, we estimated a version of the regression in column 3 of Table 3 by collapsing the data into averages for each fishery during three time periods: before, during, and after the co-op years. This approach generates consistent standard error estimates (Bertrand, Duflo, and Mullainathan 2004). The resulting coefficient on the co-op policy for the collapsed data is 59,115, with a t-statistic of 1.46.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

to the co-op's formation is 33 percent. If parties bidding for Chignik licenses thought the co-op would last for 5 years, the implied proportionate effect on the marginal fisherman's annual profit is a 75–98 percent increase, and other entries in Table 6 have similar interpretations. This profit gain includes both an efficiency component resulting from the co-op's fishing policy and a component that results from the low-skilled member's opportunity to share profits with more efficient co-op joiners.

4.5. Stability of the Cooperative

Our empirical evidence regarding the question of co-op stability and Pareto improvements consists of data on the historic catch of co-op joiners and independents, the regulator's TAC allocation rule, and the lawsuit that challenged the co-op. Our model (proposition 4i) indicates that dividing the TAC between the co-op and independent sectors in proportion to aggregate skill, corresponding to $\theta = \theta_c$, would make those who choose to join the co-op better off and would leave those who choose to fish as independents indifferent. This is a knife-edge Pareto improvement, however; even a slight deviation from this TAC division that disfavors the independents ($\theta > \theta_c$) would make all independents worse off and would presumably cause them to oppose the co-op's formation.

The allocation rule set forth when the co-op was first authorized (described in Section 2) resulted in a TAC share of .693 for the co-op in 2002, its first year of operation. This share resulted from having 77 joiners and a nine-tenths per capita share ($\theta = .9$) for each ($77 \times .9 = .693$). The co-op's assigned catch share was within 1 percentage point of the aggregate historic catch share of fishermen who chose to join the co-op, and the outcome in 2003 was essentially identical. Using historic pre-co-op catch share as a measure of skill (as we argue is appropriate), our model implies that the 2002–3 allocation was right on the knife's edge for a Pareto improvement—that is, it was set almost exactly at our critical value, θ_c. Any deviation that worked against independents would create a situation in which all independents would gain if the co-op was abolished.

In 2004, the co-op's membership increased to 87. To ensure a Pareto-improving outcome as the size of the independent fleet declined, the TAC allocation granted for each independent permit holder would need to be increased (in other words, θ would need to decline). This is true because those leaving the independent sector to sign on with the co-op would be the least skilled independents (proposition 3), while those continuing to fish independently would be the most skilled. The allocation formula put in place by the regulators did just the opposite. Once co-op membership reached 87 in 2004, the allocation rule reduced the TAC share of the independent sector to coincide with the proportion of permit holders that chose to fish independently. This corresponds to an allocation based on $\theta = 1$, which our model suggests will disadvantage all independents. Rough calculations indicate that it would have been necessary

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

to increase the independent sector's per capita TAC allocation by at least 10 percent to ensure a Pareto improvement; instead, it was reduced by 40 percent.

The lawsuit challenging the co-op policy was filed by Michael Grunert and Dean Anderson (*Grunert,* 109 P.3d 924). Consistent with the model's predictions, both were among the highest earning Chignik permit holders and neither joined the co-op. The fact that Grunert and Anderson filed the lawsuit in 2002 suggests that they assigned a positive probability to the number of joiners growing over time, to the point where highliners would become disadvantaged by the TAC allocation rule, which clearly seems to be what happened by 2004.

All those who participated in the Chignik fishery during the co-op years, joiners and independents alike, seemed to agree that coordinated fishing as practiced by the co-op could yield substantial efficiency gains from both reduced harvest costs and enhanced catch quality. As noted above, experience with coordinated fishing at Chignik during two strikes against processors that occurred in 1991 and 2001 left no doubt that strategies such as keeping some vessels idle, concentrating effort near processing facilities, and using stationary nets to guide salmon toward awaiting purse seiners would pay off (Knapp 2007). Even Anderson, one of the two highliners who filed the suit that ended the co-op, argued (shortly after filing the suit) in favor of organizing all effort in the fishery through harvester co-ops, to raise efficiency (Anderson 2002).

The key to the co-op's demise, therefore, was not disagreement or uncertainty over efficiency effects. Rather, the problem was disagreement over dividing the fishery's rents. This problem took two forms: (1) conflicts over how the co-op and independent sectors should share the TAC and (2) disagreements over how the co-op should divide profits among its members. Controversy regarding the between-sector TAC division plagued discussions of prospects for forming a co-op at least as far back as 1997[44] and continued until the time that the co-op was authorized. Disagreements as to how co-op profits should be divided among members were voiced in early discussions among the co-op's founders. While alternative sharing proposals were considered, these negotiations proved difficult, and in the end a simple equal-division rule was adopted. Our model, which treats historic catch share as a proxy for fishing skill, suggests a way to soften these disagreements: make both the between-sector TAC division and co-op members' profit shares proportional to historic catch shares. This would ensure that all permit holders could gain if the co-op formed; it also ensures that all would earn higher profit from joining the co-op than from fishing independently. While this rule might not end the debate over rent shares, one piece of evidence suggests that it could have lowered the volume: the key component of Anderson's (2002) proposal for managing salmon harvests entirely through co-ops was to base the distribution of profits on historic catch shares.

[44] Memorandum from Chuck McCallum, executive director of the Chignik Seiners Association, to Gunnar Knapp, Professor of Economics, University of Alaska, July 21, 1997.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

5. Conclusions

The state's prominent role in managing shared natural resources stems from the difficulty of establishing property rights for assets, such as stocks of fish, subsurface reservoirs of water and oil, and clean air. Stylized treatments of the management problem often recommend price or quantity instruments that mimic the outcomes that markets for these assets would achieve if property rights were well defined. These solutions often prove difficult to implement, however, and their performance in practice is sometimes disappointing. This is not entirely surprising. The theoretical treatments that prescribe these solutions often rely on top-down intervention by a benevolent government, often only implicit in the analysis, to observe what needs to be observed and to make wise choices. A different approach is gaining favor in recent years: assigning rights to certain aspects of resource use and then relying on rights holders' incentives to solve detailed management problems.

Despite evidence of potential gains from management reforms based on assigning rights, progress in this direction has been relatively slow. Less than 2 percent of the world's fisheries currently employ the most prominent rights-based regime, the individual catch share, and pollution control based on assigning quantitative emission rights to individual polluters remains relatively rare. One key holdup is at the stage at which the initial allocation of rights is assigned, a process that invariably invites rent-seeking contention. A second is that, without additional contracting, individually held rights will not capture gains from coordinating the actions of different users.[45] The short-lived experiment with a self-selected co-op in the Chignik sockeye salmon fishery, with its voluntary membership and group-held harvest rights, offers valuable lessons on both counts.

First, co-op membership was voluntary, and the task of devising an acceptable division of the co-op's allocation (or the resulting rents) among members was internalized within this self-selected group. This arguably reduced the initial allocation problem by taking the difficult task of assigning shares to individuals out of the regulatory arena, where political power and lobbying could have amplified transactions costs. The only role of the regulator was to make the gross division of catch between sectors. Sullivan (2000) reports evidence from the Pacific whiting and Alaskan pollock co-ops that this structure can ease the quota assignment problem. Once the catch shares for these co-ops were determined by the regulator, the groups internally negotiated sharing arrangements among members in a matter of a few hours to a few weeks.

Second, rights were assigned to a group rather than to individual harvesters.

[45] Coordination can improve on the use of shared resources whenever ownership is determined by the rule of capture—for example, for groundwater, oil, and gas—but achieving this outcome contractually can be difficult. In the United States, oil is nominally owned by land owners with property above reservoirs, and gains from coordination can, in principle, be captured by unitization agreements. As Libecap and Wiggins (1984) document, however, the transactions costs involved in forming such agreements are most often prohibitive.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

This made it easier for the rights-holding sector to coordinate actions of its individual members. The co-op achieved coordination by adopting bylaws that required all joiners to sign a contract before the start of a season that placed their fishing effort under the direction of a manager. The manager was responsible to a board of directors, elected by the members, and charged with promoting the interests of the membership. This contractual structure is not fundamentally different from that of a worker-owned corporation. In Chignik, coordination substantially increased rents, making the shift away from the old race-to-fish regime a more lucrative positive-sum game than it otherwise would have been. While individual rights holders could, in principle, achieve the same coordination gains by contracting with one another, the transaction costs would plausibly be prohibitive.[46]

Our theoretical analysis of behavioral and distributional effects of a self-selected fishery co-op corroborates the economists' intuition that assigning property rights can reduce costs, enhance efficiency of capture, and ultimately increase rents. We were also able to empirically verify these predictions using a mix of time-series, cross-sectional, and qualitative data. These results provide guidance on the management of fisheries, where lessons from the Chignik experience suggest that reforms enabling self-selected co-ops can be Pareto improving, provided that they are designed with care. However, the Chignik lessons may also inform the management of mobile natural resources more broadly. During this age of global transition from regulated open access to forms of property rights, policies that encourage co-op extraction should provide economic benefits not easily captured by individual rights allocations.

Appendix

Proofs and Detailed Derivations

Proposition 1: The Cooperative's Optimal Policy

The co-op's optimal allocation solves

$$\begin{aligned}\min_{d_i, T_i i \in \mathrm{J};\, x_\mathrm{J}} \; & F^{-1}(\beta) Z_\mathrm{J}\alpha + F^{-1}(\beta) Z_\mathrm{J} \sum_{i \in \mathrm{J}} d_i \\ & - [F^{-1}(\beta) Z_\mathrm{J} G(x_\mathrm{J}) - x_\mathrm{J}] + \sum_{i \in \mathrm{J}} \phi_i T_i, \end{aligned} \tag{A1}$$

subject to $\Sigma_{i \in \mathrm{J}} \gamma_i T_i = F^{-1}(\beta) Z_\mathrm{J}$, $d_i \in \{0, \bar{d}\}$, $T_i \in [0, T_\mathrm{J}]$ for all i, and $T_\mathrm{J} \leq \bar{T}$. Since equation (A1) is strictly increasing in d_i, the optimal policy sets $d_i = 0$ for each member. The term in brackets is the net benefit that the public input

[46] Allocating dedicated catch shares to harvester groups to manage (within broad constraints) is a growing trend in fishery management. Recently formed sector allocations for groundfish in New England and co-op allocations for Alaskan pollock and Pacific whiting are prominent U.S. examples. The reasons cited for this trend include the relative political ease of assigning rights among a few sectors, rather than scores of individual users, and the gains from coordinating effort.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

provides. Given assumed properties of $G(x_J)$, and assuming an interior solution, the following first-order condition is necessary and sufficient for minimizing equation (A1) with respect to x_J:

$$F^{-1}(\beta)\, Z_J G'(x_J) - 1 = 0. \tag{A2}$$

This is the Samuelson condition for efficient public input provision.

It remains to find an assignment of member fishing times that minimizes the fourth term in equation (A1), subject to the catch constraint. The catch constraint for group J implies the following constraint on effort:

$$\sum_{i \in J} \gamma_i T_i \leq Z_J F^{-1}(\beta). \tag{A3}$$

We index co-op members in increasing order of the ratio ϕ_i/γ_i. Since ϕ_i and γ_i are i's cost per unit of time and effort per unit of time, respectively, this ratio is i's cost per unit of effort. Consider a policy, denoted Λ, which assigns fishing time $\overline{T}$ to successive co-op members in order of their index, until the constraint (A3) is violated or satisfied with equality. If constraint (A3) is violated, let $\hat{i}$ indicate the highest indexed member in this low-indexed subset and assign this member a fishing time that satisfies equation (A3) exactly; all higher indexed members are assigned zero fishing time. This assignment satisfies the catch constraint by construction. To see that this assignment is cost minimizing, write the fourth term in equation (A1) as $\sum_{i \in J} (\phi_i/\gamma_i)\gamma_i T_i$. The term $\gamma_i T_i$ is the fishing effort assigned to i, and the ratio is i's cost per unit of effort. Any alternative to policy Λ would require reducing $\gamma_i T_i$ by a lower indexed member and increasing $\gamma_i T_i$ in the same amount by a higher indexed member. Since the index orders members in terms of the ratio ϕ_i/γ_i, this alternative assignment would necessarily result in higher total cost. Therefore, the assignment of fishing times in policy Λ is cost minimizing.

Proposition 2: The Independent Fleet's Behavior

The independent fleet's catch per unit of effort at any location d depends on the effort levels and locations of all independents. We denote by $H(d;\, d_i,\, \gamma_i,\, T_i,\, i \in I,\, Z_I)$ the catch per unit of effort from fishing at location d and assume that each independent takes it as given. Independent h's profit when the set I fishes independently is

$$\begin{aligned}\pi_h = {} & H(d_h;\, d_i,\, \gamma_i,\, T_i,\, i \in I,\, Z_I)\gamma_h T_h \\ & - [\alpha + d_h - G(\sum_{i \in I} x_i)]\gamma_h T_h - \phi_h T_h - x_h.\end{aligned} \tag{A4}$$

Independent h's profit is linear in T_h and, by assumption, maximal profit is positive. Firm h's maximal profit is therefore increasing in T_h. This implies that $T_h = T_I$ for all $h \in I$ (that is, all independents fish the entire time their season is open).

Independent h's optimal public input contribution satisfies the first-order

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

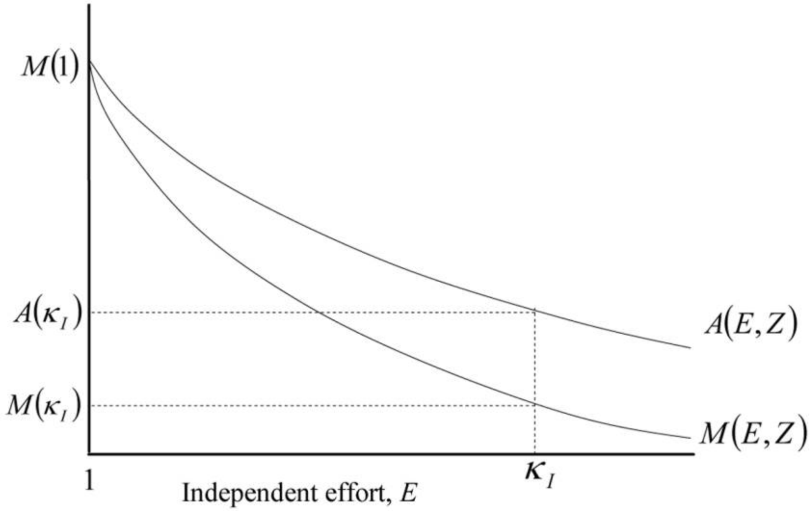

Figure A1. Independent fisherman h's catch per unit of effort, depending on where other independents fish.

condition

$$G'\Big(\sum_{i\in J} x_i\Big)\gamma_h T_I \leq 1, \tag{A5}$$

where $x_h \geq 0$ and constraint (A5) holds with strict equality if $x_h > 0$. The left-hand and right-hand sides of constraint (A5) are h's private marginal benefit and marginal cost for contributing. Let i^* be the independent with the highest γ among all independents; the private marginal benefit of contributing is greatest for this independent. Assuming that individual fishermen's γ parameters are distinct, if $G'(0)\gamma_{i^*}T_I > 1$, then the unique Nash equilibrium requires this harvester—and only this harvester—to make a contribution; i^*'s contribution in this case satisfies constraint (A5) with equality.[47] Alternatively, if $G'(0)\gamma_{i^*}T_I \leq 1$, then each independent fisherman's optimal contribution is zero. In either case, it is clear (and unsurprising) that independents underprovide the public input.

The choice of fishing distance can be examined using the marginal and average catch effort functions $M(E, Z) \equiv \partial Q/\partial E = F'(E/Z)$ and $A(E, Z) \equiv Q/E = [F(E/Z)/(E/Z)]$. These functions are shown in Figure A1, and their shapes are determined by the monotonicity and concavity of $F(\cdot)$. To meet the catch target,

[47] Given that equation (A5) is satisfied with equality for independent i^*, the inequality must be strict for all other independents, which implies that their optimal contribution is zero. This is a standard free-rider equilibrium.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

the regulator fixes total independent effort according to equation (3), at a level denoted κ_I. If all independents fish at the same distance, all obtain the same average catch per unit of effort, $A(\kappa_I, Z)$, regardless of whether all fish inside or outside.[48] Suppose that independent h chooses to fish inside while all other independents fish outside. In this case, h encounters the stock after other independents have fished, and it obtains the marginal (rather than average) catch per unit of effort from κ_I units of effort, $M(\kappa_I)$. Alternatively, if h fishes outside while all other independents fish inside, h's catch per unit of effort would be the marginal catch from the first unit of effort, $M(1)$ in Figure A1.[49]

If all independents are fishing outside, any individual who deviates to the inside would find that cost per unit of effort falls by $\bar{d}$, but catch per unit of effort falls by $A(\kappa_I) - M(\kappa_I)$. If $A(\kappa_I) - M(\kappa_I) > \bar{d}$, which we refer to as condition i, then no independent will find it profitable to deviate inside.[50] If condition i holds, which is more likely when $\bar{d}$ is small, the Nash equilibrium strategy profile in this subgame is unique and requires that all κ_I units of effort fish outside. Suppose instead that all independents are fishing inside. In this case, any individual who deviates outside will find that cost per unit of effort increases by $\bar{d}$, while catch per unit of effort increases by $M(1) - A(\kappa_I)$. If $M(1) - A(\kappa_I) < \bar{d}$, which we refer to as condition ii, then no independent will find it profitable to deviate outside. If condition ii holds, which is more likely when $\bar{d}$ is large, a Nash equilibrium in this subgame is unique and requires that all κ_I units of effort fish inside.[51]

Finally, suppose that $A(\kappa_I) - M(\kappa_I) \leq \bar{d} \leq M(1) - A(\kappa_I)$ so neither condition holds. This implies that a Nash equilibrium strategy profile for the second-stage subgame cannot have all effort fishing either inside or outside. We illustrate this case in Figure A2. The horizontal axis now indicates outside effort, and the dashed line $A(E) - \bar{d}$ shows outsider profit per unit of effort. To characterize Nash equilibrium choices of distance, suppose that all independent effort was initially fishing outside and that successive units were transferred inside. The first unit transferred inside would earn profit $M(\kappa_I)$, shown by point *c*, which exceeds the profit from fishing outside. Transferring successive effort units inside causes the insider profit per unit of effort to increase toward point *a*, at which point all effort is fishing inside and profit per unit of effort equals $A(\kappa_I)$. In Figure A2, the dot-dashed line traces out one possible locus of insider profits.[52] If $\hat{E}$ units of effort fish outside and all others fish inside so all earn equal profit,

[48] We henceforth suppress the second argument in $A(\cdot)$ and $M(\cdot)$, since it remains unchanged.
[49] Fisherman h's catch equals h's catch per unit of effort times the effort that h applies, $\gamma_h T_I$. Catches from the same location will therefore differ among fishermen in proportion to their γ parameters.
[50] The common cost term $\phi_h T_I$, which appears in both profit comparisons, has been ignored.
[51] In both cases, uniqueness follows from concavity of $F(\cdot)$. Details are available on request.
[52] It can be shown that the dot-dashed line is monotone and continuous.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

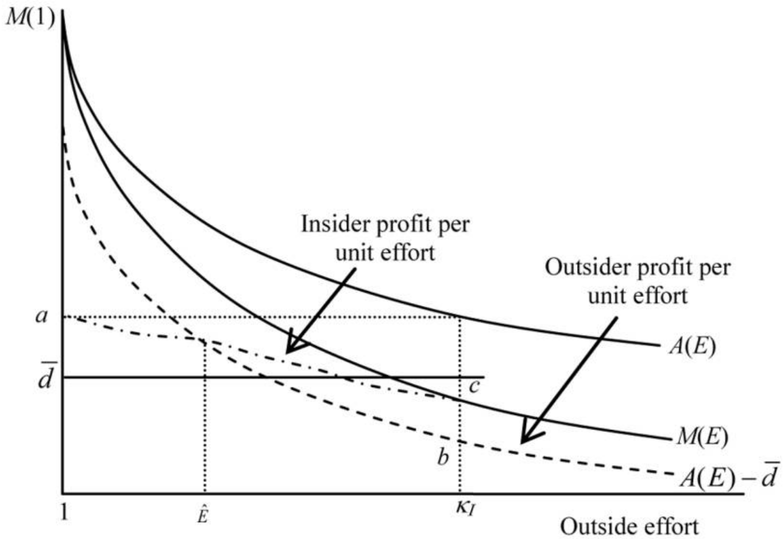

Figure A2. A Nash equilibrium strategy profile in which some independents fish outside, whereas others fish inside.

no one has an incentive to deviate.[53] Accordingly, a Nash equilibrium strategy profile in this case is described by this division of inside and outside fishing.

Proposition 3: Independents Are Highliners

First, we demonstrate that larger co-ops formed by adding successively higher skilled members necessarily have higher profit per member. Writing out the co-op's profit share equation and incorporating both its optimal policy choices and the regulator's TAC assignment yields

$$\pi_{\mathrm{J}}(\mathrm{J}) = \frac{Z}{n(\mathrm{K})}[\beta - \alpha F^{-1}(\beta)] + \frac{1}{n(\mathrm{J})}\left[G(x_{\mathrm{J}}^{*})F^{-1}(\beta)\frac{Zn(\mathrm{J})}{n(\mathrm{K})} - x_{\mathrm{J}}^{*}\right] - \frac{1}{n(\mathrm{J})}\sum_{i\in \mathrm{J}_{\min}} \phi_i \overline{T}, \tag{A6}$$

where $\mathrm{J}_{\min}$ indicates the set of co-op members selected to fish and x_{J}^{*} is the co-op's optimal public input contribution. The right-hand side consists of three components. The first component is catch per member minus the common cost term involving *a*. Given the TAC allocation formula, this does not depend on

[53] Figure A2 is drawn so that these curves cross only once; we have not excluded the possibility that they cross more than once.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

co-op size. The second component is the co-op's maximal net public good benefit per member, which necessarily is increasing in $n(\mathrm{J})$.[54] The third component is the opportunity cost of time spent fishing divided by the number of co-op members. It decreases with co-op size for the following reason. If a new member is added, the TAC allocation rule causes a proportionate increase in the co-op's effort, so effort per member remains unchanged. Consequently, the effect of a new member on the third component in equation (A6) coincides with the new member's effect on the co-op's average time cost per unit of effort. Given the order in which members are added, the new member's time cost per unit of effort (ϕ/γ) is necessarily less than that of existing members. Therefore, the new member will be designated to fish, and the co-op's average time cost per unit of effort decreases.

Next we explore the effect of a larger independent fleet on the profit to the marginal independent. To simplify, we assume that the independent fleet's equilibrium public input provision is 0, which is always approximately true. We also make use of the convention $G(0) = 0$ and the fact that catch per unit of effort equals $\beta/F^{-1}(\beta)$ due to the TAC constraint. Incorporating these simplifications into equation (A6), we see that independent harvester h's profit in the case in which all independents fish outside is

$$\pi_h(\mathrm{I}) = \left\{\left[\frac{\beta}{F^{-1}(\beta)} - \alpha - \overline{d}\right]\gamma_h - \phi_h\right\}T_{\mathrm{I}},$$

which we write as

$$\pi_h(\mathrm{I}) = \left[\frac{\beta}{F^{-1}(\beta)} - \alpha - \overline{d} - \frac{\phi_h}{\gamma_h}\right]\gamma_h T_{\mathrm{I}}. \tag{A7}$$

Our earlier assumption implies that ϕ/γ falls as γ increases, so independents with higher skill parameters have higher profits. The marginal (least profitable) independent in any group is therefore the one with the lowest γ, and forming a sequence of independent fleets by successively adding lower skilled fishermen causes marginal profit to decline. The same conclusion applies in the case where all independents fish inside because h's profit in this instance is found by replacing the constant $\overline{d}$ in equation (A7) with zero. This result also extends to the case where some independents fish inside and others fish outside because equilibrium in the second stage requires that each independent earns the same profit per unit of effort at either location. This implies that the inside versus outside differential in catch per unit of effort exactly matches the differential in cost per unit of effort, $\overline{d}$, so once again independents with higher skill parameters have higher profits.[55]

[54] A demonstration of this is available on request.

[55] The $\beta/F^{-1}(\beta) - \alpha - \overline{d}$ term is replaced by one of two expressions in this case, depending on whether the individual involved fishes inside or outside, but these two expressions take on the same value.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

The dashed line $\pi_{\mathrm{m}}(\gamma_i)$ in Figure 3 in the text illustrates the marginal profit in a group of independent fishermen who have efficiency parameters greater than or equal to a given level γ_ι. The left vertical intercept of $\pi_{\mathrm{m}}(\gamma_i)$ lies below the $\pi_{\mathrm{c}}(\gamma_i)$ intercept because, as explained in the text, a one-member co-op's profit exceeds what the same fisherman could earn by fishing independently with all other harvesters. The right vertical intercept of $\pi_{\mathrm{m}}(\gamma_i)$ is shown to lie above the corresponding intercept for the co-op, which indicates that the highest skilled fisherman could earn more by fishing as a lone independent than by joining an all-inclusive co-op, but this is not the only possibility. If both conditions on intercepts are met, then $\pi_{\mathrm{m}}(\gamma_i)$ must cross $\pi_{\mathrm{c}}(\gamma_i)$ from below at least once.

Such a crossing point identifies a threshold skill level that separates co-op joiners from independents. In Figure 3, the threshold is index value e, referring to a fisherman with skill level γ_e. If all harvesters with skill less than or equal to γ_e are in the co-op, then all those in the co-op earn $\pi_{\mathrm{c}}(\gamma_e)$, which exceeds what they would earn by fishing independently, and all those who fish independently earn more than they would in the co-op, since $\pi_{\mathrm{m}}(\gamma_i) > \pi_{\mathrm{c}}(\gamma_e) \quad \forall i > e$.[56] This allocation of fishermen to groups, together with Nash equilibrium strategy profiles in stage 2, is therefore a subgame-perfect Nash equilibrium. If $\pi_{\mathrm{m}}(\gamma_i)$ lies entirely below $\pi_{\mathrm{c}}(\gamma_i)$, the allocation in which all harvesters join the co-op is the only Nash equilibrium. If the two curves cross more than once, there is an equilibrium for each occasion where $\pi_{\mathrm{m}}(\gamma_i)$ crosses $\pi_{\mathrm{c}}(\gamma_i)$ from below. The generic stage 1 prediction—that fishermen with high values of γ choose to fish independently—is not surprising. By definition, highliners compete most successfully in the race to fish, and joining the co-op would necessitate sharing their harvest profits with less skilled fishermen.[57]

Proposition 4: Distributional Effects of a Self-Selected Cooperative

In a completely independent fishery (that is, if the co-op were not allowed to form), h would earn the following profit from independent fishing:

$$\tilde{\pi}_h = \left[\frac{\beta}{F^{-1}(\beta)} - \alpha - \overline{d} - \frac{\phi_h}{\gamma_h}\right]\gamma_h \tilde{T}, \tag{A8}$$

where $\tilde{T}$ is the season length in the absence of a co-op, given by $\tilde{T} = ZF^{-1}(\beta)/\sum_{\forall i}\gamma_i$.

When the voluntary co-op is allowed to form, h's profit depends on whether he or she decides to join or to fish independently. Suppose that h chooses to fish in the independent fleet. The resulting profit is

[56] We assume that a fisherman joins the co-op if profits from the two choices are equal. The condition stated in the text is equivalent to the internal and external stability conditions for cartel formation developed by d'Aspremont et al. (1983).

[57] We have not demonstrated that $\pi_m(\gamma_i)$ increases monotonically. As the average skill level of the independent fleet increases, the season length falls, which works against the profit increase from greater skill.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

$$\pi_h = \left[\frac{\beta}{F^{-1}(\beta)} - \alpha - \overline{d} - \frac{\phi_h}{\gamma_h}\right]\gamma_h T_{\mathrm{I}}. \tag{A9}$$

Here T_{I} is the season length for the independent fleet, given by $T_{\mathrm{I}} = Z_{\mathrm{I}}F^{-1}(\beta)/\Sigma_{i\in \mathrm{I}}\gamma_i$. The stock assignment Z_{I} depends on the allocation rule as follows: $Z_{\mathrm{I}} = \{[1-\theta] + \theta[n(i)/n(k)]\}Z$. Fisherman h gains from the co-op's formation if $\tilde{\pi}_h < \pi_h$ and loses if $\tilde{\pi}_h > \pi_h$, which clearly depends on the allocation parameter θ. Setting the right-hand sides of equations (A8) and (A9) equal, we can solve for the critical parameter value, θ_c, which yields the same profit for independent fisherman h, regardless of whether the co-op forms:

$$\theta_c = \frac{\sum_{i\in \mathrm{J}}\gamma_i/n(\mathrm{J})}{\sum_{\forall i}\gamma_i/n(\mathrm{K})}, \tag{A10}$$

where J is the set who would join.[58] The right-hand side of equation (A10) is the ratio of average skill for those who would join to the average skill of all fishermen. By proposition 3, joiners have below-average skill, so $\theta_c < 1$. Those who would choose to fish as independents are disadvantaged by allowing the co-op to form if $\theta > \theta_c$, and they are advantaged if $\theta < \theta_c$.

Next consider the fate of those who opt to join the co-op if it is allowed to form. Proposition 3 indicates that these individuals are apt to be the lower skilled members of the fleet. Because they coordinate on fishing location and public goods provision (both of which lower costs), their calculus is somewhat different, but it still hinges on how θ compares to θ_c.

If $\theta > \theta_c$, the most skilled members of the co-op are actually disadvantaged by the fact that it forms. Consider the most highly skilled joiner. In the limit, if the number of fishermen is large, this individual earns the same profit as the least skilled independent. We established above that all independents are strictly worse off in the presence of the co-op when $\theta > \theta_c$, so the same is true for the highest skilled joiner.

We next show that if $\theta = \theta_c$, a co-op still forms and all who join are made better off by the opportunity to join. A sufficient condition for the formation of a co-op is that the lowest skilled fisherman can earn higher profit by forming a one-person co-op than by fishing in a completely independent fishery. Revenue in the two situations is the same when $\theta = \theta_c$, because the catch allocation of a one-person co-op equals what the individual would have caught by fishing completely independently. Cost for the one-person co-op is lower than that noted for independent fishing, however, because the co-op coordinates on fishing location. Therefore, this individual would benefit by forming a one-person co-op.

[58] In a situation in which all are fishing the same amount of time per season, as was the case with independent fishing before the co-op was allowed to form, this ratio would equal the ratio of average catches for co-op joiners to the average catch for the entire fleet. It follows that the critical parameter θ_c can be estimated from information on average catch shares of joiners and independents in a pre-co-op period.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

How does the highest skilled joiner in a multiperson co-op fare? Given the decision to join, this person's profit as a co-op member is at least as great as what he or she could have earned by opting into the independent fleet. In turn, since $\theta = \theta_c$, the profit that would have been earned by choosing to fish as an independent equals what this individual would have earned in a completely independent fishery. Thus, all joiners are at least weakly advantaged by the ability to join a co-op.

Finally, a co-op may or may not form if $\theta < \theta_c$. Clearly, if θ is sufficiently near zero, then the loss from a low-catch allocation more than offsets the gains from coordination for a co-op of any size, so no co-op will form. Let $\theta_L < \theta_c$ be the lowest value of θ for which a co-op of some size will form. Then, for θ values in the interval $\theta_L \leq \theta < \theta_c$, a co-op forms, and all fishermen, including independents and joiners, benefit from its formation. To see this, first note that if the independent fleet contains $n(\mathrm{I})$ fishers, then even the least skilled of these individuals is advantaged by a co-op's formation, because an allocation satisfying $\theta < \theta_c$ gives advantage to those who opt to join the independent fleet. Next, consider the highest skilled joiner. Given the decision to join, the individual's co-op profit necessarily exceeds what he or she could have earned by opting into the independent fleet. This potential independent fleet profit, in turn, necessarily exceeds what he or she would have earned in a completely independent fishery because $\theta < \theta_c$. Therefore, the highest skilled joiner is better off as a result of the co-op's formation. All lower skilled joiners earn the same profit as the highest skilled joiner and would have earned less in a completely independent fishery, so they are all advantaged as well.

References

Anderson, Dean. 2002. There's More than One Way to Craft a Coop. *Alaska Fisherman's Journal*, December, pp. 52–57.

Alchian, Armen A., and Harold Demsetz. 1972. Production, Information Costs, and Economic Organization. *American Economic Review* 62:777–79.

Beddington, John R., David J. Agnew, and Colin W. Clark. 2007. Current Problems in the Management of Marine Fisheries. *Science* 316:1713–16.

Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan. 2004. How Much Should We Trust Differences-in-Differences Estimates? *Quarterly Journal of Economics* 119: 249–75.

Bouwens, Kenneth, and Aaron Poetter. 2006. *2002 Chignik Management Area Annual Management Report.* Juneau: Alaska Department of Fish and Game. http://www.sf.adfg.state.ak.us/FedAidPDFs/fmr06-21.pdf.

Bouwens, Kenneth, and Mark A. Stichert. 2006. *2004 Chignik Management Area Annual Management Report.* Juneau: Alaska Department of Fish and Game. http://www.sf.adfg.state.ak.us/FedAidPDFs/fmr06-69.pdf.

Coase, R. H. 1937. The Nature of the Firm. *Economica* 4:386–405.

Colt, Steve. 1999. Salmon Fish Traps in Alaska: An Economic History Perspective. Working

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

paper. University of Alaska, Institute of Social and Economic Research, Anchorage. http://www.iser.uaa.alaska.edu/iser/people/Colt/FISHTRAP.PDF.

Costello, Christopher, and Robert T. Deacon. 2007. The Efficiency Gains from *Fully* Delineating Rights in an ITQ Fishery. *Marine Resource Economics* 22:347–61.

Costello, Christopher, Steven D. Gaines, and John Lyhnam. 2008. Can Catch Shares Prevent Fisheries Collapse? *Science* 321:1678–81.

Crutchfield, James A., and Giulio Pontecorvo. 1969. *The Pacific Salmon Fisheries: A Study of Irrational Conservation.* Washington, D.C.: Resources for the Future.

d'Aspremont, Claude, Alexis Jacquemin, Jean Jaskold Gabszewicz, and John A. Weymark. 1983. On the Stability of Collusive Price Leadership. *Canadian Journal of Economics* 16:17–25.

Deacon, Robert T., Dominic P. Parker, and Christopher Costello. 2008. Improving Efficiency by Assigning Harvest Rights to Fishery Cooperatives: Evidence from the Chignik Salmon Coop. *Arizona Law Review* 50:479–510.

Gordon, H. Scott. 1954. The Theory of a Common Property Resource: The Fishery. *Journal of Political Economy* 62:124–42.

Grafton, R. Quentin, Dale Squires, and Kevin J. Fox. 2000. Private Property and Economic Efficiency: A Study of a Common Pool Resource. *Journal of Law and Economics* 43: 679–713.

Halpern, Benjamin S., Shaun Walbridge, Kimberly A. Selkoe, Carrie V. Kappel, Fiorenza Micheli, Caterina D'Agrosa, et al. 2008. A Global Map of Human Impact on Marine Ecosystems. *Science* 319:948–52.

Hannesson, Rögnvaldur. 2004. *The Privatization of the Oceans.* Cambridge, Mass.: MIT Press.

Higgs, Robert. 1982. Legally Induced Technical Regress in the Washington Salmon Fishery. *Research in Economic History* Oakland, Calif.: The Independent Institute.

Hilborn, Ray, J. M. (Lobo) Orensanz, and Ana M. Parma. 2005. Institutions, Incentives and the Future of Fisheries. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences* 360:47–57.

Jackson, James V., and Todd J. Anderson. 2009. *Chignik Management Area Salmon and Herring Annual Management Report, 2008.* Fishery Management Report No. 09-59. Anchorage: Alaska Department of Fish and Game. http://www.adfg.alaska.gov/FedAidPDFs/fmr09-59.

Jackson, Jeremy B. C., Michael X. Kirby, Wolfgang H. Berger, et al. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science* 293:629–37.

Knapp, Gunnar. 2007. The Chignik Salmon Cooperative: A Case Study of Allocation to a Voluntary Self-Governance Organization. Unpublished manuscript. University of Alaska, Institute of Social and Economic Research, Anchorage. http://www.iser.uaa.alaska.edu/people/knapp/personal/pubs/Knapp_Chignik_Salmon_Coop--Case_Study_of_Allocation_to_a_Voluntary_Self_Governance_Organization.pdf.

Knapp, Gunnar, and Lexi Hill. 2003. Effects of the Chignik Salmon Cooperative: What the Permit Holders Say. UA Research Summary No. 1. University of Alaska, Institute of Social and Economic Research, Anchorage. http://www.iser.uaa.alaska.edu/Publications/SummaryEffectsChignik.pdf.

Lau, Lawrence J., Yingyi Qian, and Gerard Roland. 2000. Reform without Losers: An Interpretation of China's Dual-Track Approach to Transition. *Journal of Political Economy* 108:120–41.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Leal, Donald R. 2002. *Fencing the Fishery: A Primer on Ending the Race for Fish*. Bozeman, Mont.: Property and Environment Research Center.

———, ed. 2004. *Evolving Property Rights in Marine Fisheries*. Lanham, Md.: Rowman & Littlefield Publishers.

Lian, Carl, Rajesh Singh, and Quinn Weninger. 2010. Fleet Restructuring, Rent Generation, and the Design of Fishing Quota Programs: Empirical Evidence from the Pacific Coast Groundfish Fishery. Staff General Research Paper No. 31428. Iowa State University, Department of Economics, Ames.

Libecap, Gary D. 2008. Open Access Losses and Delay in the Assignment of Property Rights. *Arizona Law Review* 50:379–408.

Libecap, Gary, and Steven N. Wiggins. 1984. Contractual Responses to the Common Pool: Prorationing of Crude Oil Production. *American Economic Review* 74:87–98.

Meyer, Bruce D. 1995. Natural and Quasi-Experiments in Economics. *Journal of Business and Economic Statistics* 13:151–61.

Myers, Ransom A., and Boris Worm. 2003. Rapid Worldwide Depletion of Predatory Fish Communities. *Nature* 423:280–83.

Newell, Richard G., James N. Sanchirico, and Suzi Kerr. 2005. Fishing Quota Markets. *Journal of Environmental Economics and Management* 49:37–462.

Nickerson, Peter H., Dominic P. Parker, and Randal R. Rucker. 2010. The Microeconomics of an Open Access Resource: Evidence from a Natural Experiment in the Washington Salmon Fishery. Working paper. Montana State University, Department of Economics, Bozeman.

Pappas, George, and Kevin Clark. 2003. *Chignik Management Area Commercial Salmon Fishery, Stock Status, and Purse Seine Cooperative Fishery Report*. Report to the Alaska Board of Fisheries. Kodiak: Alaska Department of Fish and Game. http://www.sf.adfg.state.ak.us/fedaidpdfs/RIR.4K.2003.54.pdf.

Ross, Jamie. 2002a. Inside the Co-op, Part I: Radical Surgery Prevents Slow Death. *Alaska Fisherman's Journal*, November, pp. 29–33.

———. 2002b. Inside the Co-op, Part II: The Chignik Fishery and the Aftermath. *Alaska Fisherman's Journal*, December, pp. 47–54.

Schelle, Kurt, Stefanie Carlson, and Nancy Free-Sloan. 2002. *Chignik Salmon Purse Seine Fishery: Summary Data on Issues Related to the 2002 Cooperative Fishery*. Report prepared for the Alaska Board of Fisheries. Juneau: State of Alaska, Commercial Fisheries Entry Commission. http://www.cfec.state.ak.us/research/02_6n/chigcoop.pdf.

Scott, Anthony. 1955. The Fishery: The Objectives of Sole Ownership. *Journal of Political Economy* 63:116–24.

———. 1993. Obstacles to Fishery Self-Governance. *Marine Resource Economics* 8:187–96.

———. 2000. Moving through the Narrows: From Open Access to ITQs and Self-Government. Pp. 1–15 in *Use of Property Rights in Fisheries Management*, edited by Ross Shotton. Food and Air Organization Fisheries Technical Paper No. 404/1. Rome: Food and Agriculture Organization of the United Nations.

Stichert, Mark A. 2007a. *2005 Chignik Management Area Annual Management Report*. Fishery Management Report No. 07-15. Juneau: Alaska Department of Fish and Game. http://www.sf.adfg.state.ak.us/FedAidPDFs/fmr07-15.pdf.

———. 2007b. *Chignik Management Area Salmon and Herring Annual Management Report, 2006*. Fishery Management Report No. 07-56. Anchorage: Alaska Department of Fish and Game. http://www.adfg.alaska.gov/FedAidPDFs/fmr07-56.pdf.

Stichert, Mark A., Todd J. Anderson, and Tyler H. Dann. 2009. *Chignik Management Area*

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions

Salmon and Herring Annual Management Report, 2007. Fishery Management Report No. 09–09. Anchorage: Alaska Department of Fish and Game. http://www.adfg.alaska.gov/FedAidPDFs/fmr09-09.pdf.

Sullivan, Joseph M. 2000. Harvesting Cooperatives and U.S. Antitrust Law: Recent Developments and Implications. http://oregonstate.edu/Dept/IIFET/2000/papers/sullivan.pdf.

Wiggins, Steven N., and Gary Libecap. 1985. Oil Field Unitization: Contractual Failure in the Presence of Imperfect Information. *American Economic Review* 75:368–85.

Wilen, James E. 2005. Property Rights and the Texture of Rents in Fisheries. Pp. 49–67 in *Evolving Property Rights in Marine Fisheries,* edited by Donald R. Leal. Oxford: Rowman & Littlefield Publishers.

Worm Boris, Edward B. Barbier, Nicola Beaumont, et al. 2007. Response to Comments on “Impacts of Biodiversity Loss on Ocean Ecosystem Services.” *Science* 316:1285.

This content downloaded from 128.104.1.219 on Mon, 1 Jul 2013 15:00:12 PM
All use subject to JSTOR Terms and Conditions