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Community Impacts of Fishery Privatization

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Abstract:

The adoption of secure, transferable property rights to a natural resource have efficiency properties appealing to economists, but faces opposition justified by concerns over potential negative impacts on rural communities. Major concerns include the consolidation of vessel ownership, job losses, and changes in community participation, but empirical evidence is limited. This paper examines the impact of the creation of individual transferable quotas (ITQs) to fish for Alaskan halibut and sablefish on rural fishing ports. Using data from the state of Alaska on fish landings, production, and community characteristics, we establish that the expected consolidation occurs in aggregate, and then examine the differential impact on rural communities. Although vessel consolidation is less pronounced in rural communities than larger ports with airport access, we do find limited evidence of reduced taxable sales revenue in rural ports. We examine whether two policies aimed at protecting rural economies—quota transfer restrictions and community development quota—were partially responsible for the limited consolidation in rural ports.

JEL Codes: Q22, Q28, R10

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1. Introduction

Secure, transferable property rights to a natural resource have efficiency properties appealing to economists. They provide incentive to invest in the long-run health of a resource, economize production to take advantage of economies of scale, and make explicit the opportunity cost of resource use (Keohane and Olmstead 2007; Sanchirico and Wilen 2007; Costello et al 2008). Often, however, a transition to property rights moves resource distribution from a broad to narrow group of users (Baland and Platteau 1998; Bromley 1991). The holders of the newly created property rights to the resource increase economic efficiency through consolidation, closure of inefficient facilities, and changes in supply chains and distribution channels (Grafton et al. 2000). Small, rural communities whose local economies are reliant on resource extraction may be affected by this change.

Two natural resources where the issue of rural community impacts of transferable property rights have received attention are water and fish. Trades of water property rights from agricultural to urban uses may affect local economies, including job losses following water transfers (Ge et al 2019; Holcombe and Sobel 2001). In California, rural counties have elected to restrict the transferability of water rights to higher-value uses with the overriding aim of keeping the water in use in the local agricultural economy (Hanak and Dyckman 2002; Hanak 2003 p.viii; Edwards and Libecap 2017). Similar concerns about the impact on rural communities have been raised in the adoption of individual transferable quota (ITQs) in fisheries (Grainger and Parker 2013; Young et al 2019). ITQs are often exclusive, permanent, secure, and transferable property rights to fish, allowing harvesters to adjust effort and fishing capital to capture their allocated quota at minimum cost (Arnason, 2005). However, these adjustments may lead to unwelcome impacts on rural fishing ports (McCay 1995; 2004; Carothers et al 2010). When the Canadian halibut fishery adopted ITQs, efficiency increased, but landings shifted and dropped as much as 12% in some ports as their freezing facilities became unnecessary, and the number of crew-members employed dropped by 32% (Casey et al., 1995). Like water, opposition to property rights in fisheries has coalesced around the impact to rural communities (Grainger and Parker 2013; Sutherland 2016). One example of the effect of this opposition is exemplified by the resolution passed by the North Carolina senate in 2017 opposing any sort of private property right to fish in the South Atlantic region, citing effects on fishing communities and the coastal economy.[2]

Ex-ante analysis shows cost savings resulting from ITQ programs can largely be attributed to consolidation through the exit of inefficient vessels (Lian et al. 2009, Weninger 2008, Weninger & Waters 2003). These predictions have been confirmed in ex-post analyses that find cost savings achieved through consolidation (Grafton et al. 2000; Schnier and Felthoven 2013; Reimer et al. 2014). Often it is smaller vessels that choose to sell quota and exit. The New Zealand quota management system (QMS), adopted in 1986, resulted in fleet downsizing with exiting vessels being predominantly small-scale fishers (Stewart et al, 2006). A reduction in fleet size concentrates vessel revenue, and results in changes to fishing industry employment (Abbott et al, 2010; 2019).

While the issue of the rural community impact of ITQ adoption has been widely discussed, empirical evidence has typically been limited to surveys (e.g. Casey et al., 1995); uses changes in quota ownership as a proxy for local impact (e.g. Carothers et al 2010; Pálsson and Helgason 1995); or focuses on qualitative or aggregate fishery measures (much of this work is summarized in Olson 2011). In this paper we address the lack of empirical evidence on community-level changes by collecting extensive port-level data on deliveries, boats and owners, processing, population, and taxable sales revenue to examine the effect of the 1995 introduction of individual property rights in the Alaskan sablefish and halibut fisheries. Analysis of nearly 4,000 public comments stating opinions on this program indicates that the loss of fish deliveries and income to rural ports, as well as consolidation, were the key concerns of fishermen, crew, seafood processors, and community leaders and members at the time of their implementation (Sutherland 2016). These concerns led to two policy changes—quota transfer restrictions and the allocation of community development quota—that may have affected outcomes (NPFMC 2016). The comprehensive 20-year review conducted by the Northern Pacific Fisheries Management Council

[2] General Assembly of North Carolina, Session 2017, Senate Resolution 370.

(2016) provides aggregate statistics on landings and quota share changes in rural communities, but no statistical tests.

To describe how the changes associated with ITQs might affect rural ports, we first present an economic framework developed by Homans and Wilen (2005). Extending the model to also include sablefish, we show efficiency gains for both fisheries accrue from (i) additional access to high-value markets; and (ii) reductions in fixed costs. Both channels might affect the economies of rural communities. First, secure access to fish enables ITQ fishers to pursue higher value markets, especially fresh markets, and can reduce the need for processing facilities in rural locations. The benefits from delivering fish to small relative to large ports may decrease under ITQs, as rural ports have less transportation infrastructure, like commercial air freight, to access high-value markets (GAO 2004). Second, high fixed costs in regulated open access fisheries are typically associated with excess capital and related yearly operation and maintenance costs. ITQs may remove fishing capital, especially boats, from rural communities, leading to decreased economic activity (Bromley and Macinko 2007; Soliman 2014).

Our goal is to understand the differential effect ITQ adoption had on rural communities in Alaska. We first use a difference-in-difference approach to first show that the overall organization of the sablefish and halibut fisheries changed after the 1995 ITQ adoption in the manner predicted by the economic framework. Given these aggregate changes, we then look at whether rural communities were differentially affected. We find only limited evidence that the percentage of deliveries, taxable sales revenue, and populations of rural communities declined. Further, while all Alaskan ports undergo consolidation in both number of resident owners harvesting halibut and total vessels docked at port, the decreases in owners and vessels in rural ports is not as large. We examine the policies implemented to prevent negative effects in rural communities, finding that measures aimed at reducing consolidation in fishing were likely not the cause of a lack of rural consolidation, as fishers in rural ports consolidated less than equally restricted fishers in ports with airport access. We also find that while communities receiving community development quota see more residents continuing to own halibut fishing boats, they also see relative reductions in sales revenue. These findings suggest there is reason to doubt some of the more catastrophic assessments of rural-community impacts of ITQS, and motivate further empirical studies on this topic.

2. Background and Economic Framework

The halibut and sablefish fisheries often overlap, as both require similar fishing gear and vessels. However, sablefish are harvested further off the coast at depths of 1300ft, requiring larger vessels and more specialized gear than halibut. Halibut are a flatfish caught in waters as shallow as 90 feet, allowing vessels as small as skiffs to harvest halibut. Sablefish vessels are larger than halibut vessels on average; larger vessels are better able to pursue both halibut and sablefish in deeper waters in less-protected areas, such as the Bering Sea and Aleutian Islands (Willman et al., 2009). Only halibut can be prosecuted in shallow, protected waters by small vessels, and because this fishery is more accessible we expect changes in patterns of halibut landings and product type to be more significant to rural communities.[3]

In some of our analyses, we also use the pacific cod fishery as a counterfactual. Pacific cod is harvested using trawl, longline, and pot gear, which overlaps with the primarily pot gear used to prosecute sablefish in the Bering Sea and longline gear used to prosecute halibut as well as sablefish in the Aleutians and Gulf of Alaska (Witherell and Peterson 2011). Broadly, all three types of fish are substitutes that respond to general changes in market dynamics. However product markets differ, with halibut valued fresh or flash-frozen in the United States, sablefish frozen and exported to the Japanese market, and pacific cod processed and sold worldwide in a variety of products, most ubiquitously as fish sticks.

Commercial harvest of halibut in Alaska can be traced back to the early 1900s, and the fishery mostly produced fresh fish until the 1970s (Homans and Wilen, 2005). Higher halibut prices in the 1970s and the implementation of limited entry programs for salmon fisheries contributed to the growing number of vessels entering the halibut fishery. During the 1980s, the halibut fishery received an influx of larger

[3] In much of our comparison of rural and airport-access ports we focus on variables related to halibut, but all results are also calculated for sablefish and are available in appendix E.

crabbing vessels as crab stocks declined (Shotton, 2001). Even as the total allowable catch stayed steady or increased, the season length shortened due to an increasing number of vessels entering the fishery (Willman et al., 2009). The halibut fishery experienced growth when other fisheries experienced low years, and the relatively low cost of entry into the fishery also made halibut attractive as a supplemental fishery. By 1992, the halibut season had been reduced to two or three 24-hour openings yearly (Pautzke and Oliver, 1997). The number of vessel owners participating in the halibut fishery grew from 2,563 in 1985 to its maximum of 4,405 in 1991.

Likewise, the Alaskan sablefish fishery experienced enormous growth after the creation of the US exclusive economic zones in 1976. Like halibut, sablefish attracted an increasing number of vessels from 1980 to 1990. Allocative measures for sablefish were first adopted in 1985, when the total allowable catch was split between geographic areas and gear types, but the advent of new fishing technology, increasing vessel size, and increased entry led to further growth in number of vessels, with the annual number of vessel owners increasing from 374 in 1985 to 1,271 in 1994. To curb overfishing, season length regulations were implemented, with the eastern Golf of Alaska's season reduced from 180 days in 1984 to only 20 days in 1990 (Pautzke and Oliver, 1997).

ITQ programs for the sablefish and halibut fisheries were debated during the late 1980s and early 1990s and finally implemented starting in 1995, with initial allocation of quota grandfathered based on average fishery landings during the qualifying period 1984 through 1990. Unlike sablefish and halibut, pacific cod was a regulated as an open access fishery throughout the 1990s and its management did not change in 1995. Under an economic model of regulated open access management, the transition from regulated open access to ITQ management increases rents in two ways, through the reduction of costs, i.e. an optimal allocation of effort means the fishery is no longer overcapitalized, and through increased revenue, i.e. the ability to access a high-value market for catch throughout the year. In the case of halibut, the transition to ITQs allows access to the high-value fresh market. While there is a limited fresh market for sablefish, providing high-quality product at the correct time of year still increases revenues—

Warpinski et al (2016) suggest ITQs increased Sablefish ex-vessel revenues in Alaska from $66 to $91 million for this reason.

Homans and Wilen (2005) develop a model of the ex-vessel price paths and harvest effort decisions of fishers under regulated open access, building on parameters from their analysis of the Alaskan halibut fishery (Homans and Wilen 1997). Using this parameterized model, they derive estimates for regulated open access fixed costs, variable costs, and revenues, then run the model "backwards" to find the optimal level of effort to maximize fishery rents, arguing that this would be the outcome of a fully-efficient ITQ scheme in the Alaskan halibut fishery. We adopt this framework to understand the aggregate economics of the fisheries in our study. We replicate their simulation results for halibut, then modify the model parameters to simulate sablefish harvesting before and after ITQ introduction. Based on these simulation results we then discuss the potential differential effects on rural communities.

Fishers commit to a fixed level of harvest, E, prior to the season and then regulators set season length, τ, to limit fishing to a total allowable catch, TAC, based on stock availability at the start of the season, X_0. Fishers can access the high-value market during the fishing season, from time 0 to τ. After the season, fishers who have caught and stored fish can access the low-value, post-season market, from τ to T. Inventory accumulation for the low-value market takes place in the early part of the season, from 0 to s, where $s \leq \tau$. The period from s to τ entails sale only into the high-value market.[4] Homans and Wilen (2005) demonstrate that as the low-value market expands, the race to fish increases, with harvesters taking fish, beyond the capacity of the high-value market, to store for the low-value market after the season closes. This is the regulated open access outcome and results in a zero-rent condition, high levels of fixed costs, and short seasons.

The introduction of a first-best policy instrument will enable the choice of effort, E, such that fishery rents are maximized. ITQs in reality may not provide the first-best outcome, but should move the

[4] This is the case Homans and Wilen (2005) model in their simulations. However, this is not the case they derive equations for in the paper. The equations we use here, and presumptively those used in the original paper, are shown in the appendix.

fishery towards this outcome relative to regulated open access. To compare the expected changes across the two fisheries, we compare the zero-rent outcome with the maximum rent outcome. The optimization procedure is described in the appendix, as are the parameters used for both fisheries, in Table A1. We utilize the parameters developed by Homans and Wilen (1997; 2005) as the baseline halibut specification. Although sablefish is similar to halibut, we model four key differences. The first two are in terms of the biomass and TAC, which we find by taking the mean of biomass and TAC from 1988-1994 from the Northern Pacific Fisheries Management Council's Species Profiles (NPFMC 2011 pp. 6, 34). We adjust variable cost upwards to reflect the fact that sablefish are located in deeper, less accessible water than halibut. Finally, we adjust the high-value market scale parameter downward, to reflect the high-value market for halibut being a fresh market and the high-value market for sablefish being a frozen market.

As shown by Homans and Wilen (2005), the halibut fishery sees large gains as a result of decreased fixed costs and increased revenues. The sablefish fishery is also characterized by high fixed costs during the regulated open access phase, and as a result of ITQ management, both simulations show reduced overcapitalization, although the halibut fishery was more overcapitalized. While both are predicted to decrease fixed costs in similar percentage terms, 85% for halibut and 89% for sablefish, the reduction for halibut is anticipated to be around $70 million versus $56 million for sablefish. Revenues, meanwhile, are expected to increase for both fisheries, by around $62 million for halibut and $30 million for sablefish.

In aggregate, we expect to see two clear effects of ITQ management: increases in the utilization of high-value markets for fish; and fleet consolidation and decreasing fixed costs. While we document these changes, we are especially interested in how these changes differentially affect rural ports. Here we foresee two potential mechanisms: (i) rural ports lack access to air freight and other transportation infrastructure and will see less change from access to high-value markets; (ii) rural ports see reductions in economic activity as a result of consolidation. While the markets for sablefish and halibut differ in preferred product form and customer base, ITQs were designed explicitly to enhance product quality for both species.[5] Because the Alaskan ITQ programs increased the flexibility of harvesters, they changed the competitive landscape facing sablefish processors (Fell and Haynie 2013). Increased flexibility in the timing of landings was expected to reduce storage time and cost for halibut and sablefish sold frozen (NPFMC 1992), with fishermen and processors able to take advantage of the year-round market for fresh halibut and the seasonal consumption patterns of sablefish (Hartley and Fina 2001). These changes could differentially affect rural ports, which have less transportation infrastructure, like commercial air freight, to access high-value markets (GAO 2004).

Changes in employment may also impact rural economies. While studies of other fisheries suggest total crew hours dedicated to fishing activities remained roughly constant after the adoption of catch shares, these hours are generally more concentrated among fewer crew (Abbott et al. 2010). In addition, crew contracts change over time, with the cost of leasing quota deducted from the value allocated for crew share (Abbott et al. 2019). Consolidation of boats also changes demand for fishing support services, for instance annual repair and maintenance, which for the Alaska fishing fleet are estimated to conservatively range from $80 to $100 million per year.[6] These market shifts may disproportionately affect rural community welfare to the extent that these labor markets harbor frictions not observed in less remote communities (Bromley and Macinko 2007).

Soliman (2014) argues that "[t]he consequences for these communities are profound: loss of employment, emigration, loss of traditional fishing culture and a wide income gap between quota holders and non-holders. (2014)" Wingard (2000) goes further, suggesting severe population disruptions: "Reduction in employment and concentration of harvest privileges in the hands of fewer fishers may lead not only to a reduction in the number of fishers, but also to a reduction in size or even elimination of some fishing communities. (Wingard 2000)" Given that our simulation predicted fixed cost reductions of over

[5] https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/pacific-halibut-and-sablefish-individual-fishing-quota-ifq-program
[6]https://www.commerce.alaska.gov/web/Portals/6/pub/Trends%20and%20Opportunities%20in%20the%20Alaska%20Maritime%20Industrial%20Support%20Sector.pdf

85% in each fishery, rural communities harvesting halibut and sablefish offer a useful test of these types of predictions.

However, because many of these same concerns were raised during the ITQ adoption process (Sutherland 2016), the Alaska halibut and sablefish ITQ programs included provisions to address concerns about redistribution of benefits and maintaining the character of the fishing fleet (Hartley and Fina, 2001). Special provisions to the ITQ program included quota trading restrictions, vessel size classes, ownership caps, leasing restrictions, and restrictions on use of hired masters for harvesting ITQ quota. There were no restrictions on where the catch could be landed or requirements for delivery to specific processors. One important provision provided that some quota could only be traded within, but not between, vessel classes.[7] Another limited the transferability of low quota allocations via block transfer rules.[8] The goal of these restrictions was to ensure the persistence of a small vessel fleet, at the cost of limiting the efficiency gains of the tradeable permit system (Kroetz et al. 2015).

In addition to the quota restrictions, in 1995 the community development quota (CDQ) program was put in place, which allocated a percentage of halibut and sablefish total allowable catch to small coastal communities. The program requires that communities utilizing CDQ use the earnings to "further economic development in the community through investment in fisheries-related industries, infrastructure, and education (National Research Council 1999, p.47)." In the following sections we test the effect of ITQ adoption and the differential impacts on rural communities. Our baseline results are inclusive of the policies intended to protect local communities and so represent a lower bound for the unmitigated effect of ITQ adoption. Subsequently in the paper we examine the direct effect of these community-protection measures.

[7] Vessel classes were defined as less than 35ft, 35ft to 60ft, and greater than 60ft.
[8] Any quota allocations under 20,000 lbs were blocked so that they had to be traded as a unit; owners could only consolidate two blocks and the ownership of two blocks prevented and purchase of unblocked quota.

3. Data

We utilize data from the Alaskan Department of Fish and Game (ADFG) vessel registry and fish ticket reporting programs, the ADFG Commercial Operators Annual Report (COAR), and port tax and population data from the Alaska Taxable database published by the Alaska Department of Community Economic Development to construct a panel of variables covering the ports receiving deliveries of fish for at least one of the "pre-period" years 1990 through 1994.[9] Fish tickets are required documentation for any harvester landing fish in Alaska and provide vessel and catch information including vessel number, port, date, weight, and landed (ex-vessel) value. We aggregate so that each observation is uniquely identified by a vessel-port-year combination.[10]

While we have data on all fisheries, we limit our analysis to sablefish, halibut, and pacific cod, or just halibut or sablefish individually.[11] Data is summed at the port-level in three ways: First, it is aggregated by port delivered to as given in the fish ticket data. Second, we sum by the resident boat owners active in a particular fishery. To do this, we link the fish ticket data with vessel owner information by ADFG vessel number, which is reported on each fish ticket. We then aggregate these measures by the city listed as the home address of the vessel owner.[12] Third, we aggregate data based on the port listed as the location where the boat is docked.[13]

To construct measures of processing at each port, we utilize COAR data, which tracks both ex-vessel landings and price, as well as the wholesale weight and price of products sold by processor. For ex-vessel data, we prefer to use the fish tickets because they are considered to be more reliable than COAR

[9] There was at least one delivery of either pacific cod, halibut, or sablefish from 1990-1994 to 50 ports; 34 sablefish, 42 halibut, 38 pacific cod.
[10] The unit of time for a delivery is not consistent; some fish tickets cover several deliveries in a given time period while others are for a single delivery at a given point in time.
[11] We use the total landed value of other all species as a control in some specifications.
[12] It is important to distinguish here between vessel owners and quota owners. Our approach in this paper does not allow us to examine what happens to quota holders after ITQ introduction, only the boats that harvest that quota.
[13] All the databases contain misspellings of Alaskan ports, and we create a key linking these misspellings to their correct port wherever we match data on port names.

data.[14] However, COAR data is the only source for number and revenue of processors. We aggregate at the port level to track processor revenue and final product mix. We focus on the ratio of revenue from fresh product to total revenue to understand changing product-types within the processing industry. Descriptions of all variables are summarized in table 1.

Table 1: Variable descriptions

Variable Name	Description	Source
Port Value	Total ex-vessel revenue for deliveries to a port	Fish tickets/vessel registry
Population	Port/city population	Alaska Department of Community and Regional Affairs
Taxable Revenue	Total municipality sales tax divided by tax rate	Alaska Office of the State Assessor
Port Percentage	Percent of total fishery catch landed at a port	Fish tickets/vessel registry
Resident Percentage	Percent of total fishery catch by port residents	Fish tickets/vessel registry
Resident Vessels	Number vessels fishing a species who reside at a port	Fish tickets/vessel registry
Percent Fresh	Percent of processor revenue from fresh product	ADFG COAR
Processor Revenue	Total processor sales	ADFG COAR
Percent Home	Percent of landings delivered to port of residence	Fish tickets/vessel registry
Vessel Docked	Count of all vessels docked at a port	Fish tickets/vessel registry
Vessels <35ft	Count of vessels <35ft owned by residents	Fish tickets/vessel registry
Vessels <60ft	Count of vessels <60ft owned by residents	Fish tickets/vessel registry
ITQ	=1 if year>1994	
No Airport	=1 if not within 5 hours of commercial air service to Seattle	Author's Calculation

Measures of port tax revenue and population are constructed using the Alaska Taxable Database produced by the Department of Commerce, Community and Economic Development Department for 355 Alaskan cities.[15] This database includes the sales tax rate and sales tax revenue for each port in Alaska as well as population for each year 1990-2000. Populations are estimated by the state demographer for the express purpose of distributing tax revenues.[16] We calculate sales taxable revenue for a port as the tax revenue divided by the tax rate. Some port cities do not collect sales tax, and are not included because their taxable sales revenue is not observable to us. In addition, two ports that land halibut are not

[14] For our time period and species of interest, COAR data shows consistently fewer landings than fish tickets, suggesting this dataset is missing some landings.
[15] Previously the Department of Community and Regional Affairs.
[16] Because these estimates are used in funding allocations, cities can and often do appeal the numbers using actual headcounts or other methods to override the demographer's estimates. Given this, we take these population estimates to equal or exceed actual populations.

considered cities in the Alaskan Taxable database, so these names do not appear among the 355 in the data set. Cities are dropped in analyses for variables where data is missing, but included otherwise.[17]

We construct three dummy variables to test treatment effects: an ITQ indicator if the year is after 1994; a measure of airport accessibility; and an indicator for a city receiving CDQ. A port is classified as having airport access if it is located in a city with a direct flight to Seattle, within a five hour drive to such an airport, or has direct highway access to the Lower 48. These cities include Anchorage, Ketchikan, Juneau, Kenai, Haines, Seward, Sitka, Valdez, Whittier and Homer and all city classifications are shown in appendix B.[18]

Table 2: Conditional means for halibut port

	Airport Access		Rural	
	Pre	Post	Pre	Post
Population	28,403	29,745	1,320	1,267
	(70,003)	(72,451)	(1,671)	(1,585)
Taxable Revenue per Capita	14,996	17,506	17,425	15,627
	(3,822)	(3,220)	(22,845)	(18,483)
Port Percentage	0.030	0.034	0.018	0.018
	(0.037)	(0.049)	(0.040)	(0.037)
Vessel Docked (log)	5.062	4.669	3.273	3.136
	(1.160)	(1.325)	(1.616)	(1.655)
Resident Percentage	0.025	0.021	0.013	0.013
	(0.027)	(0.024)	(0.033)	(0.037)
Resident Vessels (log)	4.284	3.365	2.637	2.394
	(1.040)	(1.217)	(1.684)	(1.442)
Percent Fresh	0.304	0.545	0.105	0.202
	(0.237)	(0.292)	(0.248)	(0.336)
Processor Revenue (log)	13.795	13.893	8.494	9.480
	(1.911)	(2.483)	(6.899)	(6.366)
Percent Home	0.474	0.513	0.715	0.769
	(0.278)	(0.299)	(0.324)	(0.306)

Notes: This table compares yearly variables for each fishery; pre is the mean conditional on the year being 1990-1994, post is mean conditional on year 1995-1999. 31 ports are classified as rural and 11 cities are classified as non-rural.

Conditional summary statistics are shown in table 2 for the pre- and post-ITQ values, bifurcated on status as a rural or airport-access port. The ports with airport access generally have much larger

[17] We use the subsample of cities that collect sales tax to run all analyses in an apples-to-apples comparison for all specifications with results shown in appendix D.
[18] In appendix F we use an alternative definition of a rural fishing port provided by Carothers et al (2010).

populations and receive larger proportions of landings, before and after 1995. Consolidation in number of vessels owned by residents and vessels docked at the port decrease for both types of port. To determine the relative changes, to the extent they exist, we turn to statistical analysis.

4. Empirical Strategy

We begin with basic tests of overall consolidation of halibut and sablefish using pacific cod as a counterfactual. We employ a difference-in-difference estimation strategy with observations at the city/port level. The identifying assumption is of parallel trends: controlling for covariates, for a given dependent variable the relationship between cod and sablefish and cod and halibut would have stayed constant absent ITQ introduction. Equation 1 provides the general form of the estimating equation: the variable of interest is regressed on dummy variables for fishery type and ITQ while controlling for year fixed effects, τ_t, any variation affecting all ports within a given year:

$$Y_{j,t} = \sum_{f \in \{H,S\}} \left(\gamma^f \cdot I_j^f + \delta^f \cdot I_t^{ITQ} \times I_j^f \right) + \tau_t + p_j + t \cdot p_j + u_{j,t} \qquad (1)$$

Here, the baseline effect of ITQ introduction on pacific cod is absorbed by the year fixed effects. More robust specifications control for city/port fixed effects, p_j, and port specific time trend, $t \cdot p_j$. The dummy variables I^f are indicator variables equal to one when an observation is from a given fishery, where $f \in \{H, S\}$ represents halibut and sablefish fisheries, and zero otherwise. The coefficients γ^f control for the pre-ITQ difference between halibut or sablefish and pacific cod, prior to ITQ introduction. δ^f are the coefficients on the interaction between the indicator of ITQ adoption, I^{ITQ}, and I^f. Estimates of these coefficients offer insight into how halibut and sablefish variables changed at the ports in the sample differentially after ITQ adoption.

Next, we turn to understanding the heterogeneity of consolidation within the treated sample. Here, we employ a difference-in-difference estimation strategy with observations being city/ports that receive halibut deliveries, and with treatment in all cases being rural designation. The identifying assumption is again of parallel trends: conditional on all control variables, the relationship between rural and non-rural ports prior to ITQ introduction would have continued absent the regulatory shock. In these regressions, it is important to note that consolidation, as estimated in equation 1, is taken as given. Our identification strategy here only estimates the change of rural ports relative to ports with airport access. Equation 2 provides the general form of our estimating equation. The indicator variable I^R is equal to one if the port is designated as rural.

$$Y_{j,t} = \beta \cdot I_j^R + \lambda \cdot I_t^{ITQ} \times I_j^R + \tau_t + p_j + t \cdot p_j + u_{j,t} \tag{2}$$

The specification includes optional controls for year, τ_t, an port, p_j, fixed effects, as well as a port specific time trend, $t \cdot p_j$. Because of the panel nature of the data, we cluster the error term at the port level in all regressions. The coefficient β provides the estimate of the effect of being a rural port prior to ITQ implementation. The coefficient λ shows the differential effect of ITQ introduction on rural communities. To test for the differential effect of CDQ designation, we replace the rural dummy with the CDQ dummy and limit the sample only to rural halibut ports.[19]

5. Results

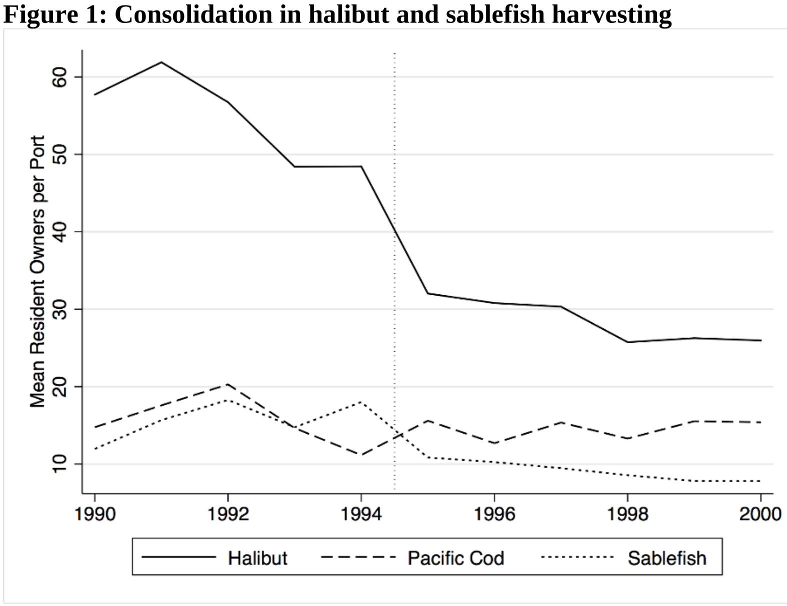
a. Overall Policy Effects

The implementation of ITQs in the Alaskan halibut and sablefish fisheries brought about dramatic changes in the number of participants and distribution of revenue among fishing industry members. Figure 1 shows the change in number of vessel owners prosecuting halibut and sablefish relative to pacific cod. Conditional means pre- and post-ITQ for each fishery are shown in table 3. While the pacific cod fishery sees few aggregate changes in the number of vessels and owners, both the halibut and sablefish fisheries see decreases.

[19] In our baseline regressions each port is treated as an equally weighted observation. In appendix B we provide two alternative weighting criteria based on the importance of halibut and sablefish to overall port revenue and the extent to which the port is important in the total amount of halibut landings. Results for regressions using these alternative weighting schemes are shown in appendix G.

Turning to the regression results from running equation (1), the changes in number of owners and number of vessels docked at the port level can be seen in regression table 4, columns 4-9. Relative to pacific cod, the number of halibut and sablefish owners decreases after ITQ implementation, as does the number of vessels prosecuting halibut and sablefish. The baseline port owner revenue is significantly higher for halibut than pacific cod, but there does not appear to be a relative change in halibut owner revenue after ITQs are adopted. There is an absolute reduction in the average port's owner revenue for sablefish harvesters, which is explained by changes in fishery catch as explained subsequently.

Figure 1: Consolidation in halibut and sablefish harvesting



The consolidation results are as expected from the model, and were anticipated by policy makers. Both fisheries were overcapitalized, and the adoption of ITQs allowed both fisheries to harvest the same amount of fish with fewer vessels. Although the number of owners decreases in both fisheries, the resident owner revenue at a port remains relatively constant in the halibut fishery, and even appears to decrease in the sablefish fishery. As seen in table 1, aggregate sablefish revenue goes up post-ITQ. However, the regression coefficients show a large decrease. This can be explained by sablefish total allowable catch, which decreased for the period between 1996 and 2002. In the regression, this leads sablefish to show a decrease in revenue, post-1995, relative to pacific cod.[20] In reality, the fishery actually earned more revenue per fish, but caught less fish, after ITQ implementation.

Table 3: Summary statistics for comparison of three fisheries

	Halibut		Sablefish		Pacific Cod	
	Pre	Post	Pre	Post	Pre	Post
Port Value	77,632,651	97,434,593	69,192,194	75,117,702	133,829,120	92,194,179
	(19,049,266)	(26,175,730)	(7,200,744)	(15,249,474)	(32,823,249)	(18,489,617)
Total Resident Owners	3,663.41	1,933.29	1,053.04	637.32	1,097.04	1,041.69
	(354.45)	(158.92)	(151.07)	(74.70)	(206.12)	(89.49)
Total Vessels	3,853.25	2,005.68	1,103.17	661.42	1,171.62	1,121.71
	(385.50)	(158.16)	(162.08)	(77.26)	(218.12)	(97.46)
Mean Port Value (log)	10.686	10.747	8.609	7.383	7.085	6.797
	(4.603)	(4.654)	(5.967)	(6.354)	(5.311)	(5.601)
Mean Res. Owners (log)	2.946	2.504	1.704	1.239	1.801	1.604
	(1.653)	(1.404)	(1.481)	(1.344)	(1.442)	(1.466)
Mean Log Vessels	2.983	2.505	1.632	1.219	1.796	1.627
	(1.597)	(1.386)	(1.498)	(1.381)	(1.447)	(1.497)

Notes: This table compares yearly variables for each fishery; pre is the mean conditional on the year being 1990-1994, post is mean conditional on year 1995-2000. The first three measures are aggregate yearly means for the entire fishery, the last three are yearly average port values. The panel consists of 50 ports that land at least one of the species between 1990 and 1994. A total of ports 42 ports receive halibut, 34 receive sablefish and 38 receive pacific cod landings.

The results from this subsection are important to keep in mind in interpreting the relative treatment effects of rural versus airport-access ports provided in the subsequent subsections, which focus specifically on halibut. Results on consolidation in rural ports, of boats and owners, are occurring relative to ongoing, dramatic consolidation across all ports. However, relative changes in port revenues are occurring relative to small changes in port revenues overall.

b. Rural Port Effects

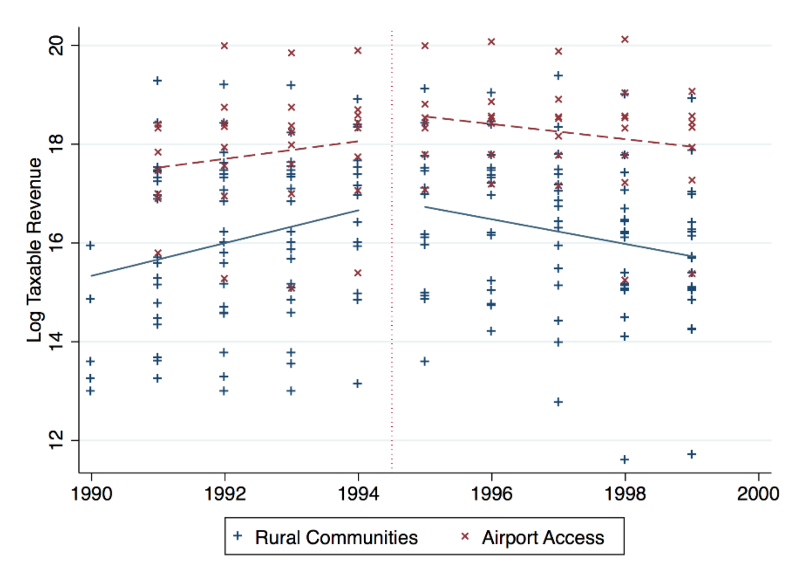
We begin with a discussion of the main results on taxable sales revenue, percentage of deliveries, and population. If ITQs affect rural ports differentially, we expect that they may see fewer deliveries, relative to ports with airport access. As a result of this or other changes, we may also see declines in population or taxable revenue. Figure 2 shows the general trends for taxable sales revenue before and after ITQ implementation. The figure appears to show a relative increase around the 1994 for airport-access ports not observed in rural ports. Both communities with airport access and rural communities

[20] Afsc.noaa.gov/refm/stocks/plan_team/2018/sablefish.pdf

show increasing taxable sales revenue in the pre-period but decreasing post-ITQ implementation, which makes interpretation challenging.

This ambiguity can be seen in the regression table 6, which shows the result of running equation (2). Specifications (7) and (8) show a relative decrease in taxable revenue for rural ports, but when controlling for port linear time trends in (9), there appears to be an increase in taxable revenue. The raw data graphed in figure 2 is consistent with the regressions showing relative decreasing tax revenue in rural ports, and so is suggestive of a differential policy effect, but the results are not definitive. While rural communities have lower populations and landings than large ports, the post-ITQ coefficients, while negative, show no statistical significance. To better understand whether these results suggest there is a small effect on rural communities, or are just indicative of limited statistical power, we explore the channels by which ITQs may differentially impact rural communities in subsequent subsections.

Figure 2: Taxable revenue by port type

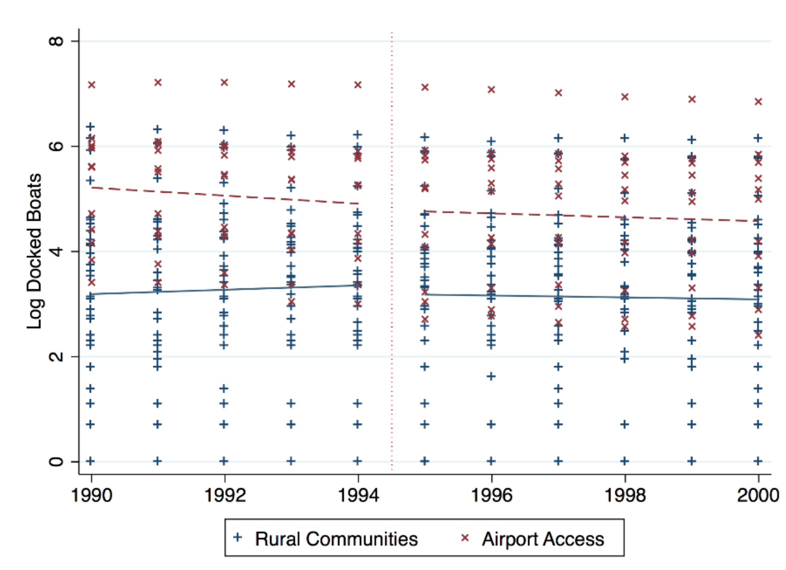


c. Channels

One mechanism through which sales revenue may be impacted is through reduced vessel services. Figure 3 shows general trends for total vessels docked before and after ITQ implementation.

Total vessels docked in rural communities appears to decrease slightly around 1994 while total vessels is decreasing throughout the sample in cities with airport access. The impact of ITQs on total vessels docked can be seen in regression table 6, columns 7-9. When not including a linear time trend, the reduction in vessels docked is less in rural ports, providing some evidence that there is less consolidation in rural ports. The consolidation of resident vessel owners is also relatively less in rural ports than in ports with airport access, as seen in specifications (1)-(3). The coefficient on total resident catch for rural ports is positive but not significant in most specifications. Taken in total, table 6 suggests that rural ports consolidate less and see fewer changes due to ITQs than ports with airport access.[21] We explore in the next subsection whether this is due to policy changes designed to limit impacts on rural communities.

Figure 3: Boats docked in halibut ports



First, we look at whether the nature of deliveries and processing changed for rural ports. Figure 4 shows the change in the amount of fresh product sold from each port. There is a large and growing relative difference between rural and airport ports after the implementation of ITQs. Prior to 1995, declining fresh sales resulted from increasingly short seasons for halibut. After the implementation of

[21] These results are consistent across a number of robustness checks shown in appendices

catch shares, airport-access ports were differentially able to sell fish into the fresh market. Rural ports have a lower baseline percent of fish going to the fresh market, and this difference grows post-ITQs. The impact of ITQs on percentage of catch going to the fresh market can be seen in regression table 7, specifications (1)-(3). The coefficient on percent fresh is negative and significant at the 1% level except for the specification with a port linear trend, although the coefficient is of similar magnitude in all specifications. This results suggests that rural communities miss out on one of the major benefits of ITQs—increased access to fresh market. However, processing revenue results indicate that rural ports see statistically insignificant relative changes in processing revenue. Further, concerns about rural resident vessel owners changing their use of their local port appear unjustified, with the percentage of resident catch delivered to home ports being relatively higher but statistically insignificant in all specifications.

Figure 4: Proportion of halibut sold as fresh after processing at Alaskan Ports

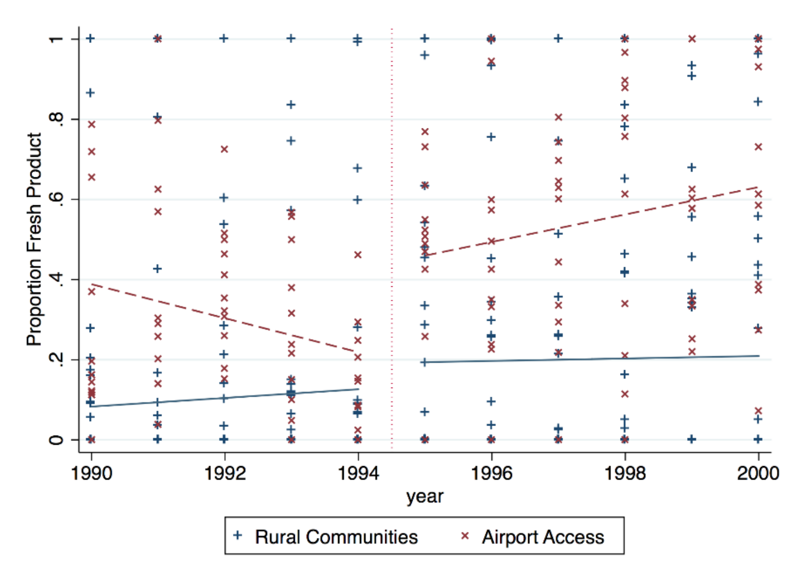


Table 4: Overall ITQ Effects

VARIABLES	(1) Log(Resident Owner Revenue)	(2) Log(Resident Owner Revenue)	(3) Log(Resident Owner Revenue)	(4) Log(Resident Owners)	(5) Log(Resident Owners)	(6) Log(Resident Owners)	(7) Log(Vessels Docked)	(8) Log(Vessels Docked)	(9) Log(Vessels Docked)
Halibut	3.445***	4.031***	4.154***	1.103***	1.245***	1.301***	1.152***	1.309***	1.362***
	(0.588)	(0.484)	(0.484)	(0.140)	(0.112)	(0.109)	(0.144)	(0.108)	(0.105)
Halibut x ITQ	0.299	0.299	0.0754	-0.269**	-0.269**	-0.372***	-0.310***	-0.310**	-0.408***
	(0.393)	(0.399)	(0.381)	(0.119)	(0.121)	(0.108)	(0.114)	(0.116)	(0.104)
Sablefish	1.870***	1.586***	1.560***	-0.0239	-0.102	-0.114	-0.0198	-0.103	-0.115
	(0.542)	(0.505)	(0.512)	(0.112)	(0.0993)	(0.102)	(0.124)	(0.111)	(0.114)
Sablefish x ITQ	-0.989**	-0.989**	-0.942**	-0.276***	-0.276***	-0.254**	-0.264**	-0.264**	-0.244**
	(0.438)	(0.445)	(0.457)	(0.0935)	(0.0950)	(0.0983)	(0.1000)	(0.102)	(0.105)
Observations	1,551	1,551	1,551	1,551	1,551	1,551	1,551	1,551	1,551
R-squared	0.074	0.770	0.784	0.119	0.864	0.882	0.107	0.872	0.888
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on indicator variables for species and ITQ (post-1994). There are 50 ports in the panel. If a port never lands a particular species it is omitted from the regression for that species, but included for other species; occasional landing ports get assigned 0s in years they do not land. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 5: Rural Community Outcome Regressions

VARIABLES	(1) % of Total Landings	(2) % of Total Landings	(3) % of Total Landings	(4) Log(Popula tion)	(5) Log(Popula tion)	(6) Log(Popula tion)	(7) Log (Taxable Rev.)	(8) Log (Taxable Rev.)	(9) Log (Taxable Rev.)
No Airport Access	-0.0118	-0.125***		-1.998***	-3.298***		-1.560**	-6.336***	
	(0.0134)	(0.00285)		(0.604)	(0.0829)		(0.570)	(0.107)	
ITQ x No Airport Access	-0.00449	-0.00449	0.00573	-0.198	-0.194	-0.0448	-0.478*	-0.388**	0.326**
	(0.00499)	(0.00523)	(0.00646)	(0.139)	(0.142)	(0.0419)	(0.256)	(0.164)	(0.149)
Observations	462	462	462	401	401	401	230	230	230
R-squared	0.025	0.929	0.972	0.293	0.943	0.978	0.306	0.942	0.970
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on indicator for airport access. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. Sales revenue and population are not available in all years for all ports and missing observations are dropped from these regressions. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 6: Rural Community Fishing Behavior Regressions

VARIABLES	(1) Log(Resident Vessels)	(2) Log(Resident Vessels)	(3) Log(Resident Vessels)	(4) % Resident Catch	(5) % Resident Catch	(6) % Resident Catch	(7) Log(Docked Vessels)	(8) Log(Docked Vessels)	(9) Log(Docked Vessels)
No Airport Access	-1.652***	-5.591***		-0.0117	-0.00986***		-1.789***	-5.436***	
	(0.437)	(0.0971)		(0.0103)	(0.00113)		(0.455)	(0.0721)	
ITQ x No Airport Access	0.689***	0.689***	0.308**	0.00378*	0.00348	0.00249	0.256**	0.256*	-0.0441
	(0.170)	(0.178)	(0.150)	(0.00222)	(0.00221)	(0.00372)	(0.126)	(0.132)	(0.121)
Observations	462	462	462	445	445	445	462	462	462
R-squared	0.153	0.911	0.957	0.018	0.987	0.994	0.186	0.945	0.968
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut fishers from 1990-2000 on indicator for airport access. Resident vessels include boats used to fish halibut. Docked vessels includes all boats docked in a port. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. The variable percent resident catch has observations dropped in ports where residents catch no halibut in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 7: Rural Community Processing Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	% Fresh	% Fresh	% Fresh	Log(Revenue)	Log(Revenue)	Log(Revenue)	% Home	% Home	% Home
No Airport Access	-0.199***	-0.469***		-5.301***	-12.66***		0.240**	0.348***	
	(0.0498)	(0.0267)		(1.261)	(0.498)		(0.0962)	(0.0235)	
ITQ x No Airport Access	-0.145***	-0.145***	-0.142	0.888	0.888	1.877	0.0162	0.00439	0.0621
	(0.0468)	(0.0490)	(0.138)	(0.872)	(0.913)	(1.669)	(0.0538)	(0.0554)	(0.0900)
Observations	462	462	462	462	462	462	405	405	405
R-squared	0.206	0.555	0.609	0.126	0.734	0.808	0.135	0.729	0.797
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut landings from 1990-2000 on indicator for airport access. Revenue is the total halibut revenue from processors located in a port. Percentage fresh is the port processor's total revenue from fresh product divided by total processor revenue. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

d. Policy Effects

The results in the previous subsection raise key questions about whether rural ports were less affected by ITQ implementation because of policy changes, made during the ITQ adoption process and designed to retain the character of the halibut fishery and provide for economic development in some rural communities. We first look at quota transfer restrictions. Consolidation after quota allocation was limited by vessel transfer restrictions, limiting quota transfers to within vessel class categories. It was also limited by "blocking," which forced allocated quota under 20,000lbs to be sold as blocks and limited ownership of quota to two blocks. We use these vessel categories and blocking rules to explore how consolidation worked differentially in rural and airport-access ports. To identify the effect of these rules, we use the fact that consolidation restrictions are not linked directly to specific cities or city types, although they are designated by regulatory area. This should mean that if the rules are binding in rural communities, consolidation should be similar in rural and airport-access ports within a vessel class category or among blocked quota holders, because quota is still transferable across cities. However, if other factors, such as rural quota holder characteristics or preferences are limiting transfers and consolidation, rural communities will have different outcomes even within a restricted trading class. We take this outcome to mean that the community-protection policies are not the cause of the observed effects of less consolidation in rural ports.

Table 8 shows the size characteristics of the fishing fleets in rural and airport-access ports before and after ITQ implementation. The number of vessels docked at port is split into three categories, small vessels (less than 35 feet), medium vessels (between 35 and 60 feet), and large vessels (greater than 60 feet). Consolidation of quota occurred within these vessel classes, and in percentage and overall reduction in vessels was larger in airport-access ports. This is shown in figure 5 (left panel) for vessels under 35ft in length. Figure 5 (right panel) also shows similar consolidation trends for owners under the 20,000lbs catch threshold.

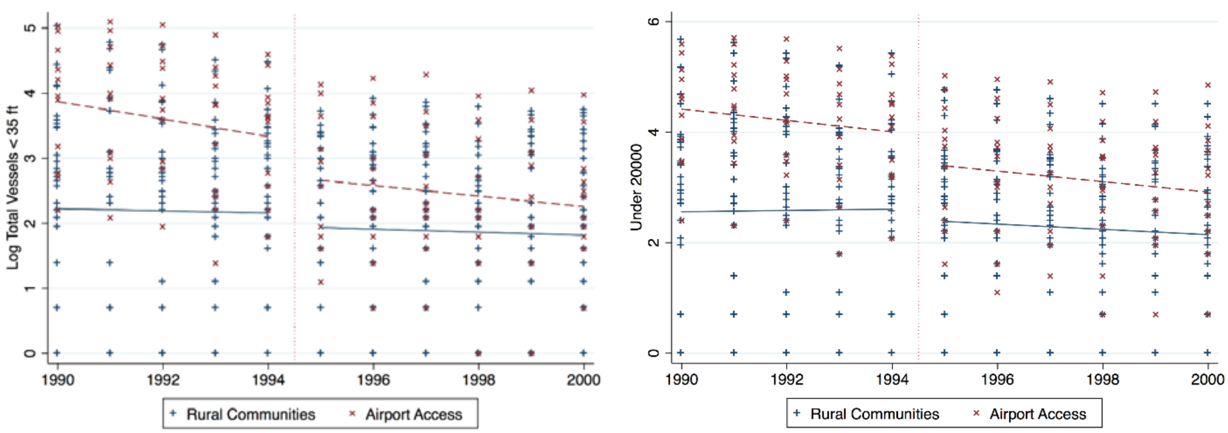
Table 8: Comparison of vessel length changes for rural and non-rural ports

	Non-Rural		Remaining	Rural		Remaining
	Pre	Post	Vessels	Pre	Post	Vessels
Total Vessels Length <35 ft	53	18	33%	20	11	57%
	(44)	(18)		(27)	(12)	
Total Vessels 35 ft<Length<60ft	56	32	57%	40	24	60%
	(50)	(33)		(51)	(32)	
Total Vessels Length >60ft	5.4	2. 8	52%	3.0	1.8	60%
	(6.0)	(4.2)		(10.7)	(6.6)	

Notes: Table shows conditional means for boats catching halibut owned by residents of a city.

Table 9, (1)-(6), shows regression of vessel count (log) of each vessels <35ft and <60ft. The relative reduction in total vessels docked after ITQ implementation is greater in cities with airport access across both vessel class categories, and coefficients on total vessels docked are generally positive and significant at the 5% or 1% level. Looking at a rough measure of the number of blocked owners, we observe similar result, with fewer reductions in the number of vessels harvesting less than 20,000lbs of halibut in rural ports. If, as we assume, small vessels and harvesters in airport-access ports are a good counterfactual for rural ports, there was considerable potential for additional consolidation under the transfer rules in rural ports that did not occur.

Figure 5: Consolidation in Restricted Trading Classes



Next, we examine whether the allocation of CDQ to some rural ports affected their outcomes differentially. Select regression results are shown in Table 10. Changes in taxable sales revenue in these ports relative to other rural halibut ports is ambiguous, and perhaps negative based on specification (3). However, resident owners in these communities retain relatively more vessels to fish halibut but generally do not appear to deliver more fish to their home port. We do not show the results here, but the additional vessels owned by residents in CDQ communities are not more likely to be docked in the CDQ communities themselves, and there is no statistically significant impact of CDQ designation on population changes. It appears that while CDQ quota communities do retain more vessels, they do not provide additional taxable sales revenue, perhaps because they are utilized as assets that fish elsewhere.

6. Conclusion

ITQs often face opposition prior to and dissatisfaction after implementation among certain groups. More broadly, there is an historic record of efforts to maintain traditional practices in the face of changing technology and regulation. In southern England, a series of social disturbances in the 1830s known as the Swing Riots erupted, in part, because laborers feared new mechanization in the form of threshing machines would displace workers (Caprettini and Voth 2017). Likewise, fish traps for salmon harvesting were banned in Alaska in 1960, despite their efficiency advantages, due to the perception they reduced labor opportunities for fishermen (Grainger and Parker 2013).

While there is a general consensus that property rights based management in fisheries offers benefits in terms of cost savings and stock health, social consequences of ITQs are still a highly disputed issue (Thébaud et al., 2012). Do efficiency gains afforded by ITQs result in redistribution of wealth and consolidation in the harvesting sector? This paper confirms the anticipated consolidation resulting from ITQs, but provides evidence that this consolidation is more limited in rural ports. Consolidation and market access are the key drivers of efficiency gains, suggesting that rural communities may be losing *relative* tax revenue because their fishers are not becoming as efficient as those in larger ports

An alternative explanation is that although consolidation is experienced to a lesser degree in small ports, the lack of access to fresh markets and the relative importance of fishing capital and vessel services may explain the decreases in rural community sales tax revenue post ITQ implementation. To prevent distributional impacts on rural communities, policies like community development quota and transfer restrictions are implemented with the intent of reducing consolidation. However, our results suggest that fishers in rural communities are less likely to consolidate, relative to fishers with similar regulatory restrictions who are residents of airport-access ports. While our results offer only a partial evaluation of these policies, the work suggests two key questions for future empirical research: (1) Are rural communities less prone to consolidation under ITQs and why? (2) Are policies aimed at preventing consolidation in rural communities unnecessary or even counterproductive?

Table 9: Vessels docked regressions by vessel size

VARIABLES	(1) Vessels <35ft	(2) Vessels <35ft	(3) Vessels <35ft	(4) Vessels <60ft	(5) Vessels <60ft	(6) Vessels <60ft	(7) Owners <20k lbs	(8) Owners <20k lbs	(9) Owners <20k lbs
No Airport Access	-1.410***	-4.616***		-1.629***	-5.493***		-1.629***	-1.629***	
	(0.380)	(0.104)		(0.433)	(0.0963)		(0.411)	(0.416)	
ITQ x No Airport Access	0.828***	0.828***	0.391**	0.682***	0.682***	0.319**	0.741***	0.741***	0.741***
	(0.182)	(0.191)	(0.148)	(0.168)	(0.176)	(0.151)	(0.165)	(0.167)	(0.175)
Observations	462	462	462	462	462	462	462	462	462
R-squared	0.156	0.857	0.933	0.153	0.909	0.955	0.170	0.897	0.166
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes		No
Port FE	No	No	Yes	No	No	Yes	No	Yes	No
Port Time Trend	No	No	Yes	No	No	Yes	No	No	No

Notes: Regression of logged vessel counts for boats catching halibut, owned by residents of a city, from 1990-2000 on indicator for airport access. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 10: CDQ Regressions

VARIABLES	(1) Log Taxable Rev	(2) Log Taxable Rev	(3) Log Taxable Rev	(4) Resident Vessels	(5) Resident Vessels	(6) Resident Vessels	(7) % Home	(8) % Home	(9) % Home
No Airport Access	-1.281	-3.264*		-1.051**	1.000*		0.193	-0.0511	
	(1.156)	(1.702)		(0.466)	(0.503)		(0.115)	(0.0455)	
CDQ x No Airport	0.0719	-0.143	-0.545**	0.919**	1.030***	0.413	0.0234	0.00377	-0.142
	(0.693)	(0.468)	(0.247)	(0.349)	(0.331)	(0.250)	(0.0718)	(0.0680)	(0.115)
Observations	143	143	143	341	341	341	284	284	284
R-squared	0.190	0.922	0.964	0.051	0.919	0.952	0.123	0.673	0.755
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on indicator for CDQ designation. Sample is of 31 rural ports, of which 10 are designated as CDQ cities. Sales revenue data is not available in all years for all ports and missing observations are dropped from these regressions. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

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Appendix A

Table A1: Simulation Parameters and Sources

Parameter	Halibut	Sablefish	Source
Low-value scale parameter (A)	10	10	
High-value scale parameter (B)	15	10	Reduced from halibut to reflect high-value frozen market rather than fresh
Low-value elasticity (α)	1.5	1.5	
High-value elasticity (β)	1.1	1.1	
Biomass	440	365	Average 1998-94 Biomass from NOAA Species Profiles
Quota (TAC)	60	30	Average 1998-94 TAC from NOAA Species Profiles
Fixed cost (f)	1	1	
Variable cost (v)	0.06	0.08	Changed to have a higher MC than halibut due to the deeper depth, harsher seas
Discount rate (r)	0.01	0.01	
Conversion factor (k)	0.87	0.87	
Catchability coefficient (q)	0.001	0.001	

Note: All halibut numbers are from Homans and Wilen (2005)

Table A2: Simulation Results (in millions of dollars unless otherwise noted)

	Prior Halibut Results		Halibut		Sablefish	
	Open Access	Optimal	Open Access	Optimal	Open Access	Optimal
Fixed Costs	84.81	12.22	81.77	12.22	62.77	7.15
Variable Costs	8.72	8.29	7.60	8.29	6.17	6.47
Total Costs	93.53	20.51	89.37	20.51	68.94	13.61
Revenues	93.53	173.95	89.37	151.57	68.94	98.45
Rents	0	153.44	0	131.06	0	84.83
τ (months)	1.73	-	1.56	12	1.24	12
s (months)	1.73	-	1.56	0.63	1.24	0.64
% Low-value	74.09	-	66.52	0	75.09	0

Notes: Prior halibut results are from (Homans and Wilen, 2005). Simulations run for this paper are shown on the right.

Details of Table A1

We begin by deriving the four simultaneous equations described in Homans and Wilen (2005) for the simulations we use in this paper. The harvest rate H_t at any time t is assumed to be[22]:

$$\mathrm{H}_t = \mathrm{qE}X_0 e^{-qEt} \qquad \text{(HW1)}$$

[22] This derivation follows from Homans and Wilen (2005). The equations are numbered to agree with the equation numbers in that paper. A "HW" prefix indicates the original equation from the paper, while and "ES" prefix indicates the equation has been modified to address the case at hand.

Where X_0 is the initial biomass, E is fishing effort, and q is the catchability coefficient. Total season catch is $\int_0^{\tau} H(t)dt$, and regulators set season length, τ, to get a target TAC, leading to the first condition:

$$\tau = \frac{1}{\mathrm{qE}} \ln\left[\frac{X_0}{X_o - TAC}\right] \quad \text{(HW4)}$$

The year is divided into three periods: (1) from 0 to s where harvest is both for the high-value market and for inventory accumulation for sale later; (2) from s to τ where only harvest for the high-value market occurs; and (3) from τ to T where no harvest occurs but the accumulated inventory is sold in the low-value market.

The instantaneous wholesale low-value market price is P_t^Z. Because inventory can be sold at any time during this period, the price path between τ and T is determined by a no-arbitrage condition:

$$P_t^Z = P_T^Z e^{-r(T-t)} \quad \text{(HW9)}$$

Where r is the interest rate and P_T^Z is the wholesale fish price at the end of the year, time T. Ex-vessel price is the price paid to fishers prior to processing. Let k be the conversion factor of a fish sold in the ex-vessel market to the amount of fish sold in the wholesale market. Then the ex-vessel price is:

$$P_t^{EV} = kP_t^Z = kP_T^Z e^{-r(T-t)} \quad \text{(HW10)}$$

Instantaneous wholesale demand from the high-value market is:

$$Q_t^F = B(P_t^F)^{-\beta} \quad \text{(HW6)}$$

And from the low-value market is:

$$Q_t^Z = A(P_t^Z)^{-\alpha}$$

Where A and B are scale factors for the two markets. The total ex-vessel demand for high-value fish between 0 and s, D_1^F, is:

$$D_1^F = \int_0^s \frac{B}{k}(P_t^F)^{-\beta} dt = \int_0^s \frac{B}{k}\left(P_T^Z e^{-r(T-t)}\right)^{-\beta} dt$$
$$= \frac{B}{k\beta r}(P_t^Z)^{-\beta} e^{\beta r T}\left[1 - e^{-\beta r s}\right] \quad \text{(ES12)}$$

From s to τ, all harvest enters the high-value market, so the demand, D_2^F, is just the harvest during this period:

$$D_2^F = \int_s^\tau qEX_0 e^{-qet} dt = X_0[e^{-qEs} - e^{-qe\tau}] \quad \text{(ES8)}$$

Ex-vessel demand during the final phase, from τ to T, D_3^F, is:

$$D_3^F = \int_\tau^T \frac{A}{k}\left[P_t^Z e^{-r(T-t)}\right]^{-\alpha} dt = \frac{A}{k(P_t^Z)^\alpha r\alpha}\left(e^{r\alpha(T-t)} - 1\right) \quad \text{(HW13)}$$

The total inventory available for the low-value market, D_3^F, equals the total catch from 0 to τ, minus fresh demand from 0 to s, D_1^F, and s to τ, D_2^F.

$$D_3^F = X_0(1 - e^{-qE\tau}) - D_1^F - D_2^F$$

Substituting and simplifying gives us our second of four simultaneous equations:

$$X_0(1 - e^{-qE\tau}) - \frac{B}{k\beta r}(P_t^Z)^{-\beta} e^{\beta r T}\left[1 - e^{-\beta r s}\right] - \frac{A}{k(P_t^Z)^\alpha r\alpha}\left(e^{r\alpha(T-t)} - 1\right) = 0 \quad \text{(ES14)}$$

Next, we set up a zero-profit condition. There are two revenue streams, from the high-value market and the low-value market; the fixed cost per unit effort is f, and the instantaneous cost of employing a unit of effort is v. The profit function is:

$$\pi = \int_0^\tau e^{-rt}[P_t^{EV} H_t - vE]dt - fE$$

During the harvest period, it must be the case that sales into the fresh market yield no rents, or else the level of effort would be increased. For the period from 0 to s when inventory accumulation occurs, the ex-vessel price must maintain its relationship with the final low-value wholesale price:

$$P_t^{EV} = kP_t^Z = kP_T^Z e^{-r(T-t)} \tag{HW10}$$

In the high-value only phase, from s to τ, the quantity harvested is known, given the chosen amount of effort. The instantaneous quantity harvested and available in the wholesale market is $Q_t^F = k\mathrm{qE}X_0 e^{-qEt}$ from (HW1), and the demand function is $Q_t^F = B(P_t^F)^{-\beta}$ from (HW6). Substituting we arrive at:

$$P_t^{EV} = kP_t^F = k^{(\beta-1)/\beta}\left[\frac{\mathrm{qE}X_0 e^{-qEt}}{B}\right]^{-1/\beta} \tag{HW7}$$

This allows us to write the zero-rent condition:

$$\int_0^s e^{-rT} kP_T^Z e^{-r(T-t)} qEX_0 e^{-qEt} dt + \int_s^\tau e^{-rT} k^{\frac{(\beta-1)}{\beta}}\left[\frac{\mathrm{qE}X_0 e^{-qEt}}{B}\right]^{-\frac{1}{\beta}} qEX_0 e^{-qEt} dt - \int_0^\tau e^{-rT} vEdt - fE = 0$$

Solving gives use our third equation:

$$\frac{B^{1/\beta}(kqEX_0)^{(\beta-1)/\beta}\beta}{qE(1-\beta)-r\beta}\left[e^{(qE((1-\beta)/\beta)-r)\tau} - e^{(qE((1-\beta)/\beta)-r)s}\right] + kP_T^Z X_0 e^{-rT}[1-e^{-qEs}] - \frac{vE}{r}[1-e^{-rt}] - fE = 0 \tag{ES15}$$

Finally, we can set (HW7) equal to (HW10) at s, where the inventory accumulation phase ends.

$$k^{\frac{(\beta-1)}{\beta}}\left[\frac{\mathrm{qE}X_0 e^{-qEs}}{B}\right]^{-1/\beta} = kP_T^Z e^{-r(T-s)} \tag{HW7}$$

Using (HW7), (ES15), (ES14), and (HW4) we can solve for the four unknowns: s, E, τ, and P_T^Z. This is the regulated open access outcome. We can get to the optimal outcome by choosing E to maximize rents. To do this, we find the first-order condition for the left-hand side of (ES15).

Appendix B

Table B1: Port Classifications

City	Carothers Classification	Airport Access	CDQ	Percent of Port Revenue Halibut and Sablefish	Percent of Halibut Fishery Revenue
Adak	None			0%	0.0%
Akhiok	Small			6%	0.0%
Akutan	Small		Yes	93%	0.0%
Anchorage	None	Yes		9%	2.3%
Atka	Small		Yes	99%	0.1%
Chignik	Small			8%	0.6%
Cordova	Medium			8%	1.9%
Craig	Small			31%	1.2%
Excursion Inlet	None			27%	0.0%
Gustavus	Small			29%	0.1%
Haines	Medium	Yes		18%	0.7%
Homer	None	Yes		27%	8.4%
Hoonah	Small			42%	1.0%
Juneau	None	Yes		35%	2.5%
Kake	Small			42%	0.5%
Kenai	None	Yes		16%	1.0%
Ketchikan	None	Yes		21%	2.1%
King Cove	Small			12%	1.4%
Kodiak	Large			14%	15.8%
Mekoryuk	Small		Yes	30%	0.0%
Metlakatla	Small			28%	0.4%
Ninilchik	Small	Yes		9%	0.2%
Nome	None		Yes	2%	0.0%
Pelican	Small			53%	0.9%
Petersburg	Large			30%	7.4%
Port Bailey	None			0%	0.0%
Port Moller	None			0%	0.0%
Sand Point	Small			8%	1.8%
Savoonga	None		Yes	100%	0.0%
Seldovia	Small			31%	0.7%
Seward	None	Yes		8%	1.8%
Sitka	None	Yes		51%	6.5%
St Paul Island	Small		Yes	100%	0.3%
St. George	Small		Yes	99%	0.0%
Togiak	None		Yes	0%	0.0%
Toksook Bay	Small		Yes	1%	0.0%
Tununak	Small		Yes	2%	0.0%
Unalaska	Large			11%	0.2%
Valdez	None	Yes		23%	0.3%
Whittier	Small	Yes		40%	0.0%
Wrangell	Medium			23%	1.4%
Yakutat	Small			24%	0.4%

Notes: Table shows 42 cities that show halibut landings sometime 1990-1994 and are located on the coast of Alaska. Carothers classification refers to the designation from Carothers et al (2010) of small, remote fishing communities. Airport access and CDQ designation are as defined in the paper. The fifth column shows one potential weighting scheme calculated by dividing the total revenue of all landed halibut and sablefish by city residents by the sum of landed value of all fish landed by the city's owners. The sixth column provides an alternative weighting scheme, which is the proportion of all halibut revenue ex-vessel revenue from 1990-1994 landed at the port.

Appendix C

Table C1: Rural Community Outcome Regressions with Controls for Landings of Other Species

VARIABLES	(1) % of Total Landings	(2) % of Total Landings	(3) % of Total Landings	(4) Log(Population)	(5) Log(Population)	(6) Log(Population)	(7) Log (Taxable Rev.)	(8) Log (Taxable Rev.)	(9) Log (Taxable Rev.)
No Airport Access	-0.00157	-0.126***		-1.508**	-2.405***		-1.342**	-1.872***	
	(0.0153)	(0.00526)	(1.766)	(0.562)	(0.314)		(0.525)	(0.122)	
ITQ x No Airport Access	-0.00275	-0.00455	0.00589	-0.138	-0.189	-0.0518	-0.483*	-0.381**	0.363**
	(0.00512)	(0.00523)	(0.00647)	(0.162)	(0.135)	(0.0453)	(0.240)	(0.164)	(0.144)
Observations	462	462	462	401	401	401	230	230	230
R-squared	0.124	0.929	0.972	0.429	0.943	0.978	0.352	0.942	0.971
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on indicator for airport access. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. Sales revenue and population are not available in all years for all ports and missing observations are dropped from these regressions. All regressions include a control for the total value of landings of all other species by port residents. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table C2: Rural Community Fishing Behavior Regressions with Controls for Landings of Other Species

VARIABLES	(1) Log(Resident Vessels)	(2) Log(Resident Vessels)	(3) Log(Resident Vessels)	(4) % Resident Catch	(5) % Resident Catch	(6) % Resident Catch	(7) Log(Docked Vessels)	(8) Log(Docked Vessels)	(9) Log(Docked Vessels)
No Airport Access	-0.829**	-5.199***	-304.8***	-0.00281	-0.00222**	0.889	-0.812**	-4.472***	116.8**
	(0.343)	(0.337)	(43.69)	(0.0125)	(0.00108)	(0.994)	(0.349)	(0.571)	(46.23)
ITQ x No Airport Access	0.829***	0.708***	0.328**	0.00504*	0.00347	0.00248	0.422***	0.302**	0.00430
	(0.186)	(0.186)	(0.148)	(0.00281)	(0.00223)	(0.00373)	(0.152)	(0.135)	(0.121)
Observations	462	462	462	445	445	445	462	462	462
R-squared	0.565	0.912	0.958	0.143	0.987	0.994	0.692	0.949	0.972
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut fishers from 1990-2000 on indicator for airport access. Resident vessels include boats used to fish halibut. Docked vessels includes all boats docked in a port. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. The variable percent resident catch has observations dropped in ports where residents catch no halibut in a given year. All regressions include a control for the total value of landings of all other species by port residents. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table C3: Rural Community Processing Regressions with Controls for Landings of Other Species

VARIABLES	(1) % Fresh	(2) % Fresh	(3) % Fresh	(4) Log(Revenue)	(5) Log(Revenue)	(6) Log(Revenue)	(7) % Home	(8) % Home	(9) % Home
No Airport Access	-0.146**	-0.316***		-3.262**	-10.86***		0.188*	0.403***	
	(0.0600)	(0.0765)		(1.278)	(2.208)		(0.0949)	(0.0796)	
ITQ x No Airport Access	-0.136***	-0.138***	-0.134	1.235	0.975	1.935	0.0120	0.00522	0.0642
	(0.0474)	(0.0502)	(0.138)	(0.905)	(0.913)	(1.688)	(0.0552)	(0.0551)	(0.0903)
Observations	462	462	462	462	462	462	405	405	405
R-squared	0.247	0.558	0.613	0.295	0.735	0.809	0.189	0.730	0.797
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut landings from 1990-2000 on indicator for airport access. Revenue is the total halibut revenue from processors located in a port. Percentage fresh is the port processor's total revenue from fresh product divided by total processor revenue. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. All regressions include a control for the total value of landings of all other species by port residents. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Appendix D

Table D1: Rural Community Outcome Regressions in Cities with Tax Revenue Data

VARIABLES	(1) % of Total Landings	(2) % of Total Landings	(3) % of Total Landings	(4) Log(Population)	(5) Log(Population)	(6) Log(Population)	(7) Log (Taxable Rev.)	(8) Log (Taxable Rev.)	(9) Log (Taxable Rev.)
No Airport Access	-0.0125	-0.0144***		-1.259**	-4.954***		-1.560**	-6.336***	
	(0.0187)	(0.00311)		(0.520)	(0.0139)		(0.570)	(0.107)	
ITQ x No Airport Access	-0.00655	-0.00611	0.0175	-0.139	-0.0493	0.0327	-0.478*	-0.388**	0.326**
	(0.00734)	(0.00662)	(0.0130)	(0.232)	(0.0406)	(0.0454)	(0.256)	(0.164)	(0.149)
Observations	230	230	230	230	230	230	230	230	230
R-squared	0.037	0.941	0.975	0.283	0.996	0.999	0.306	0.942	0.970
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on indicator for airport access. Only year-port observations with sales tax information are included. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table D2: Rural Community Fishing Behavior Regressions in Cities with Tax Revenue Data

VARIABLES	(1) Log(Resident Vessels)	(2) Log(Resident Vessels)	(3) Log(Resident Vessels)	(4) % Resident Catch	(5) % Resident Catch	(6) % Resident Catch	(7) Log(Docked Vessels)	(8) Log(Docked Vessels)	(9) Log(Docked Vessels)
No Airport Access	-1.119**	-2.104***		-0.00864	-0.00113		-1.360**	-3.801***	
	(0.538)	(0.181)		(0.0150)	(0.00101)		(0.525)	(0.101)	
ITQ x No Airport Access	0.363	0.496**	0.162	0.00249	0.00358	0.00375	0.153	0.222*	-0.148
	(0.243)	(0.224)	(0.166)	(0.00466)	(0.00379)	(0.00570)	(0.188)	(0.116)	(0.176)
Observations	230	230	230	223	223	223	230	230	230
R-squared	0.129	0.876	0.952	0.015	0.987	0.995	0.190	0.938	0.962
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut fishers from 1990-2000 on indicator for airport access. Only year-port observations with sales tax information are included. Resident vessels include boats used to fish halibut. Docked vessels includes all boats docked in a port. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. The variable percent resident catch has observations dropped in ports where residents catch no halibut in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table D3: Rural Community Processing Regressions in Cities with Tax Revenue Data

VARIABLES	(1) % Fresh	(2) % Fresh	(3) % Fresh	(4) Log(Revenue)	(5) Log(Revenue)	(6) Log(Revenue)	(7) % Home	(8) % Home	(9) % Home
No Airport Access	-0.185**	0.0663		-4.402**	-9.335***		0.188*	0.0622**	
	(0.0675)	(0.0542)		(1.603)	(0.409)		(0.105)	(0.0227)	
ITQ x No Airport Access	-0.140*	-0.155*	-0.267	1.479**	0.997	0.488	0.0761	0.0566	0.0226
	(0.0765)	(0.0836)	(0.167)	(0.678)	(0.616)	(1.489)	(0.0690)	(0.0725)	(0.0994)
Observations	230	230	230	230	230	230	217	217	217
R-squared	0.198	0.599	0.685	0.149	0.864	0.891	0.158	0.771	0.851
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut landings from 1990-2000 on indicator for airport access. Only year-port observations with sales tax information are included. Revenue is the total halibut revenue from processors located in a port. Percentage fresh is the port processor's total revenue from fresh product divided by total processor revenue. There are 42 ports with 11 years of landings data, 11 with airport-access and 31 rural. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Appendix E

Table E1: Sablefish Rural Community Outcome Regressions

VARIABLES	(1) % of Total Landings	(2) % of Total Landings	(3) % of Total Landings	(4) Log(Population)	(5) Log(Population)	(6) Log(Population)	(7) Log (Taxable Rev.)	(8) Log (Taxable Rev.)	(9) Log (Taxable Rev.)
No Airport Access	-0.00297	-0.0134***		-0.819	-2.445***		-0.308	1.355***	
	(0.0153)	(0.00398)		(0.641)	(0.0640)		(0.912)	(0.0728)	
ITQ x No Airport Access	-0.0143**	-0.0143*	-0.00610	-0.156	-0.0982	-0.0261	-0.601**	-0.320*	0.438**
	(0.00697)	(0.00730)	(0.00951)	(0.0982)	(0.100)	(0.0493)	(0.246)	(0.173)	(0.165)
Observations	374	374	374	321	321	321	184	184	184
R-squared	0.022	0.933	0.963	0.086	0.987	0.998	0.080	0.956	0.980
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for sablefish ports from 1990-2000 on indicator for airport access. There are 34 ports with 11 years of landings data. Sales revenue and population are not available in all years for all ports and missing observations are dropped from these regressions. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table E2: Sablefish Rural Community Fishing Behavior Regressions

VARIABLES	(1) Log(Resident Vessels)	(2) Log(Resident Vessels)	(3) Log(Resident Vessels)	(4) % Resident Catch	(5) % Resident Catch	(6) % Resident Catch	(7) Log(Docked Vessels)	(8) Log(Docked Vessels)	(9) Log(Docked Vessels)
No Airport Access	-0.000645	-0.205***		0.592	-12.60***		0.240*	0.860***	
	(0.0130)	(0.0213)		(2.331)	(0.904)		(0.129)	(0.0186)	
ITQ x No Airport Access	-0.0349	-0.0349	-0.0221	-1.152	-1.152	1.740	-0.0474	-0.0102	0.174
	(0.0374)	(0.0391)	(0.0948)	(1.582)	(1.657)	(1.518)	(0.0779)	(0.0770)	(0.103)
Observations	374	374	374	352	352	352	374	374	374
R-squared	0.121	0.950	0.967	0.014	0.967	0.983	0.059	0.905	0.936
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for sablefish fishers from 1990-2000 on indicator for airport access. Resident vessels include boats used to fish halibut. Docked vessels includes all boats docked in a port. There are 34 ports with 11 years of landings data. The variable percent resident catch has observations dropped in ports where residents catch no halibut in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table E3: Sablefish Rural Community Processing Regressions

VARIABLES	(1) % Fresh	(2) % Fresh	(3) % Fresh	(4) Log(Revenue)	(5) Log(Revenue)	(6) Log(Revenue)	(7) % Home	(8) % Home	(9) % Home
No Airport Access	-0.962*	-4.362***		-0.00672	-0.000992		-0.921	-5.559***	
	(0.485)	(0.0757)		(0.0107)	(0.00167)		(0.559)	(0.126)	
ITQ x No Airport Access	0.238*	0.238*	0.143	-0.000925	-0.000269	-0.000816	0.298	0.298	-0.0143
	(0.132)	(0.139)	(0.231)	(0.00430)	(0.00388)	(0.00391)	(0.221)	(0.231)	(0.292)
Observations	374	374	374	374	374	374	278	278	278
R-squared	0.039	0.238	0.375	0.019	0.684	0.803	0.093	0.781	0.839
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for sablefish landings from 1990-2000 on indicator for airport access. Revenue is the total halibut revenue from processors located in a port. Percentage fresh is the port processor's total revenue from fresh product divided by total processor revenue. There are 34 ports with 11 years of landings data. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Appendix F

Table F1: Carothers Outcome Regressions

VARIABLES	(1) % of Total Landings	(2) % of Total Landings	(3) % of Total Landings	(4) Log(Popula tion)	(5) Log(Popula tion)	(6) Log(Popula tion)	(7) Log (Taxable Rev.)	(8) Log (Taxable Rev.)	(9) Log (Taxable Rev.)
No Airport Access	-0.00282	0.000417		-1.391**	0.611***		-1.304**	-0.752*	
	(0.0121)	(0.00255)		(0.557)	(0.145)		(0.508)	(0.383)	
ITQ x No Airport Access	-0.00161	-0.00161	0.00649	-0.311	0.00390	-0.0119	-0.360*	-0.445***	0.376**
	(0.00447)	(0.00468)	(0.00503)	(0.271)	(0.0425)	(0.0347)	(0.192)	(0.150)	(0.165)
Observations	462	462	462	342	342	342	210	210	210
R-squared	0.002	0.929	0.972	0.549	0.997	0.999	0.334	0.944	0.973
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on alternative rural port treatment from Carothers et al (2010). There are 42 ports with 11 years of landings data, 15 non-remote and 27 remote. Sales revenue and population are not available in all years for all ports and missing observations are dropped from these regressions. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table F2: Carothers Fishing Behavior Regressions

VARIABLES	(1) Log(Resident Vessels)	(2) Log(Resident Vessels)	(3) Log(Resident Vessels)	(4) % Resident Catch	(5) % Resident Catch	(6) % Resident Catch	(7) Log(Docked Vessels)	(8) Log(Docked Vessels)	(9) Log(Docked Vessels)
No Airport Access	0.597	3.979***		-0.00434	0.00328***		-0.0627	3.623***	
	(0.637)	(0.138)		(0.00983)	(0.000872)		(0.634)	(0.105)	
ITQ x No Airport Access	-0.0382	-0.0382	-0.0647	0.00187	0.00290	0.00257	0.237	0.237	0.131
	(0.241)	(0.253)	(0.222)	(0.00250)	(0.00209)	(0.00325)	(0.184)	(0.193)	(0.198)
Observations	462	462	462	445	445	445	462	462	462
R-squared	0.050	0.902	0.956	0.003	0.987	0.994	0.006	0.945	0.968
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut fishers from 1990-2000 on alternative rural port treatment from Carothers et al (2010). Resident vessels include boats used to fish halibut. Docked vessels includes all boats docked in a port. There are 42 ports with 11 years of landings data, 15 non-remote and 27 remote. The variable percent resident catch has observations dropped in ports where residents catch no halibut in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table F3: Carothers Processing Regressions

VARIABLES	(1) % Fresh	(2) % Fresh	(3) % Fresh	(4) Log(Revenue)	(5) Log(Revenue)	(6) Log(Revenue)	(7) % Home	(8) % Home	(9) % Home
No Airport Access	-0.0179	0.368***		-0.638		3,114***	0.206**	0.679***	
	(0.0573)	(0.0331)		(1.970)		(528.4)	(0.0919)	(0.00995)	
ITQ x No Airport Access	-0.00127	-0.00127	0.108	2.196*	2.196*	3.002	-0.0359	0.0227	0.190*
	(0.0579)	(0.0607)	(0.126)	(1.231)	(1.290)	(1.946)	(0.0664)	(0.0636)	(0.105)
Observations	462	462	462	462	462	462	405	405	405
R-squared	0.055	0.545	0.609	0.016	0.740	0.810	0.080	0.730	0.800
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut landings from 1990-2000 on alternative rural port treatment from Carothers et al (2010). Revenue is the total halibut revenue from processors located in a port. Percentage fresh is the port processor's total revenue from fresh product divided by total processor revenue. There are 42 ports with 11 years of landings data, 15 non-remote and 27 remote. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Appendix G

Table G1: Rural Community Outcome Regressions Weighted by Sablefish/Halibut Revenue

VARIABLES	(1) % of Total Landings	(2) % of Total Landings	(3) % of Total Landings	(4) Log(Population)	(5) Log(Population)	(6) Log(Population)	(7) Log (Taxable Rev.)	(8) Log (Taxable Rev.)	(9) Log (Taxable Rev.)
No Airport Access	-0.0198	-0.0852***		-2.304***	0.362***		-1.633**	-3.381***	
	(0.0135)	(0.00307)		(0.627)	(0.0329)		(0.730)	(0.158)	
ITQ x No Airport Access	-0.00549	-0.00437	0.00533	-0.0126	-0.0681	-0.00167	-0.917**	-0.353	0.214
	(0.00550)	(0.00563)	(0.00988)	(0.0857)	(0.0555)	(0.0395)	(0.398)	(0.221)	(0.169)
Observations	422	422	422	385	385	385	223	223	223
R-squared	0.082	0.917	0.965	0.369	0.995	0.998	0.347	0.939	0.972
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on indicator for airport access using weighted regression. Weights are the percentage of port residents' total revenue coming from halibut and sablefish, 1990-1994. There are 42 ports with up to 11 years of data, 11 with airport-access and 31 rural. Observations are dropped in ports with no landings in a given year or when the weight is 0. Sales revenue and population are not available in all years for all ports and missing observations are dropped from these regressions. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table G2: Rural Community Fishing Behavior Regressions Weighted by Sablefish/Halibut Revenue

VARIABLES	(1) Log(Resident Vessels)	(2) Log(Resident Vessels)	(3) Log(Resident Vessels)	(4) % Resident Catch	(5) % Resident Catch	(6) % Resident Catch	(7) Log(Docked Vessels)	(8) Log(Docked Vessels)	(9) Log(Docked Vessels)
No Airport Access	-1.364**	-1.118***		-0.0213*	-0.0213***		-2.010***	-0.642***	
	(0.532)	(0.101)		(0.0121)	(0.00137)		(0.538)	(0.0708)	
ITQ x No Airport Access	0.367*	0.432**	0.245*	0.00370	0.00453*	0.00264	0.0494	0.161	0.0273
	(0.190)	(0.184)	(0.140)	(0.00251)	(0.00252)	(0.00470)	(0.176)	(0.130)	(0.116)
Observations	422	422	422	422	422	422	422	422	422
R-squared	0.208	0.921	0.958	0.083	0.984	0.993	0.312	0.965	0.980
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut fishers from 1990-2000 on indicator for airport access using weighted regression. Weights are the percentage of port residents' total revenue coming from halibut and sablefish, 1990-1994. There are 42 ports with up to 11 years of data, 11 with airport-access and 31 rural. Observations are dropped in ports with no landings in a given year or when the weight is 0. Resident vessels include boats used to fish halibut. Docked vessels includes all boats docked in a port. The variable percent resident catch has observations dropped in ports where residents catch no halibut in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table G3: Rural Community Processing Regressions Weighted by Sablefish/Halibut Revenue

VARIABLES	(1) % Fresh	(2) % Fresh	(3) % Fresh	(4) Log(Revenue)	(5) Log(Revenue)	(6) Log(Revenue)	(7) % Home	(8) % Home	(9) % Home
No Airport Access	-0.180***	-0.275***		-5.151***	-16.16***		0.257**	0.423***	
	(0.0591)	(0.0284)		(1.633)	(0.740)		(0.108)	(0.0254)	
ITQ x No Airport Access	-0.196***	-0.183***	-0.125	1.453	2.208	4.245*	-0.0226	-0.0542	0.00472
	(0.0496)	(0.0520)	(0.157)	(1.482)	(1.357)	(2.345)	(0.0481)	(0.0466)	(0.0899)
Observations	422	422	422	422	422	422	405	405	405
R-squared	0.201	0.534	0.576	0.107	0.737	0.804	0.130	0.772	0.820
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut landings from 1990-2000 on indicator for airport access using weighted regression. Weights are the percentage of port residents' total revenue coming from halibut and sablefish, 1990-1994. There are 42 ports with up to 11 years of data, 11 with airport-access and 31 rural. Observations are dropped in ports with no landings in a given year or when the weight is 0. Revenue is the total halibut revenue from processors located in a port. Percentage fresh is the port processor's total revenue from fresh product divided by total processor revenue. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table G4: Rural Community Outcome Regressions Weighted by Proportion of Catch

VARIABLES	(1) % of Total Landings	(2) % of Total Landings	(3) % of Total Landings	(4) Log(Popula tion)	(5) Log(Popula tion)	(6) Log(Popula tion)	(7) Log (Taxable Rev.)	(8) Log (Taxable Rev.)	(9) Log (Taxable Rev.)
No Airport Access	0.0513	0.0115		-1.029*	2.663***		-0.711	2.630***	
	(0.0540)	(0.00762)		(0.590)	(0.0142)		(0.455)	(0.0576)	
ITQ x No Airport Access	-0.0296**	-0.0296**	0.0216	-0.0698***	-0.0694***	-0.00118	-0.852***	-0.841***	0.941***
	(0.0116)	(0.0122)	(0.0196)	(0.0228)	(0.0222)	(0.0246)	(0.138)	(0.149)	(0.184)
Observations	422	422	422	385	385	385	223	223	223
R-squared	0.062	0.940	0.972	0.181	0.998	0.999	0.428	0.842	0.931
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables from 1990-2000 on indicator for airport access using weighted regression. Weights are the percentage of port residents' total revenue from halibut relative to the total fishery halibut revenue, 1990-1994. There are 42 ports with up to 11 years of data, 11 with airport-access and 31 rural. Observations are dropped in ports with no landings in a given year or when the weight is 0. Sales revenue and population are not available in all years for all ports and missing observations are dropped from these regressions. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table G5: Rural Community Fishing Behavior Regressions Weighted by Proportion of Catch

VARIABLES	(1) Log(Resident Vessels)	(2) Log(Resident Vessels)	(3) Log(Resident Vessels)	(4) % Resident Catch	(5) % Resident Catch	(6) % Resident Catch	(7) Log(Docked Vessels)	(8) Log(Docked Vessels)	(9) Log(Docked Vessels)
No Airport Access	-0.0719	-0.696***		0.0403	-0.00965**		-0.358	-0.699***	
	(0.430)	(0.0570)		(0.0375)	(0.00443)		(0.358)	(0.0264)	
ITQ x No Airport Access	0.0893	0.0896	-0.0375	0.0179**	0.0179**	0.0148	0.0824*	0.0829	-0.0198
	(0.106)	(0.111)	(0.0918)	(0.00786)	(0.00824)	(0.0110)	(0.0481)	(0.0505)	(0.0360)
Observations	422	422	422	422	422	422	422	422	422
R-squared	0.157	0.976	0.991	0.141	0.988	0.995	0.051	0.991	0.997
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut fishers from 1990-2000 on indicator for airport access using weighted regression. Weights are the percentage of port residents' total revenue from halibut relative to the total fishery halibut revenue, 1990-1994. There are 42 ports with up to 11 years of data, 11 with airport-access and 31 rural. Observations are dropped in ports with no landings in a given year or when the weight is 0. Resident vessels include boats used to fish halibut. Docked vessels includes all boats docked in a port. The variable percent resident catch has observations dropped in ports where residents catch no halibut in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table G6: Rural Community Processing Regressions Weighted by Proportion of Catch

VARIABLES	(1) % Fresh	(2) % Fresh	(3) % Fresh	(4) Log(Revenue)	(5) Log(Revenue)	(6) Log(Revenue)	(7) % Home	(8) % Home	(9) % Home
No Airport Access	-0.154***	-0.347***		0.0559	-6.909***		0.210*	-0.598***	
	(0.0543)	(0.0329)		(1.054)	(0.225)		(0.113)	(0.0183)	
ITQ x No Airport Access	-0.128*	-0.128*	-0.115	0.298	0.300	0.306	-0.0664	-0.0665	0.0125
	(0.0634)	(0.0665)	(0.0709)	(0.452)	(0.475)	(0.496)	(0.0777)	(0.0816)	(0.0701)
Observations	422	422	422	422	422	422	405	405	405
R-squared	0.425	0.729	0.771	0.015	0.736	0.782	0.177	0.776	0.879
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Port Time Trend	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Regression of yearly port outcome variables for halibut landings from 1990-2000 on indicator for airport access using weighted regression. Weights are the percentage of port residents' total revenue from halibut relative to the total fishery halibut revenue, 1990-1994. There are 42 ports with up to 11 years of data, 11 with airport-access and 31 rural. Observations are dropped in ports with no landings in a given year or when the weight is 0. Revenue is the total halibut revenue from processors located in a port. Percentage fresh is the port processor's total revenue from fresh product divided by total processor revenue. The variable percent home has observations dropped in ports where residents catch no halibut in a given year or no deliveries are made to a port in a given year. Controls for year and port fixed effects and port time trends are included as indicated. Baseline rural port coefficients are omitted when port time trends are included. Robust standard errors clustered at city/port are in parentheses: *** p<0.01, ** p<0.05, * p<0.1