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Author(s): Joshua K. Abbott, Brian Garber-Yonts and James E. Wilen
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Employment and Remuneration Effects of IFQs in the Bering Sea/Aleutian Islands Crab Fisheries

JOSHUA K. ABBOTT
Arizona State University

BRIAN GARBER-YONTS
NOAA Fisheries, Alaska Fisheries Science Center

JAMES E. WILEN
University of California, Davis

Abstract *This article utilizes a census of vessels before and after implementation of catch shares in the Bering Sea/Aleutian Island (BSAI) crab fisheries to examine the short-run effects of catch shares on employment and remuneration of crew. The number of individuals employed declined proportionately to the exit of vessels following implementation. Total crew hours dedicated to fishing activities remained roughly constant, while employment in redundant pre- and post-season activities declined due to the consolidation of quota on fewer vessels. We find little evidence of substantial changes in the share contracts used to compensate fishermen. Finally, we explore a wide array of remuneration measures for crew and conclude that both seasonal and daily employment remuneration increased substantially for many crew in the post-rationalization fishery, while remuneration per unit of landings declined as a result of a combination of increased crew productivity and the necessity of paying for fishing quota in the new system.*

Key words IFQ, rationalization, crab, Alaska, crew, remuneration.

JEL Classification Codes J24, J33, Q22, Q28.

Introduction

It has now been over 35 years since Francis Christy (1993) first posited that individual tradable quotas might be a workable solution to the biological and economic dissipation wrought by open-access institutions. The intervening years have witnessed a gradual increase in the number of fisheries with some form of catch share management, and the legacy has been widely viewed as positive. Economists and other scientists have noted a wide array of effects including a reduction in excess fishing capacity from pre-rationalization levels, a slower pace of fishing with longer and less intense seasons, a reduction in "input stuffing," improvements in product quality, and safer working conditions for

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Joshua K. Abbott is an assistant professor, School of Sustainability, Arizona State University, PO Box 875502, Tempe, AZ 85287 (email: Joshua.K.Abbott@asu.edu). Brian Garber-Yonts is with NOAA Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4, Seattle, WA 98115 (email: brian.garber-yonts@noaa.gov). James E. Wilen is a professor, Department of Agricultural & Resource Economics, University of California, Davis, One Shields Ave., Davis, CA 95616, and a member of the Giannini Foundation (email: wilen@primal.ucdavis.edu).

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fishermen (Casey 1997; Casey *et al*. 1995; Grafton *et al*. 2006; Homans and Wilen 2005). Incentive-based approaches such as individual fishing quotas (IFQs), may also aid in the conservation and recovery of overfished fish stocks (Chu 2009; Costello, Gaines, and Lynham 2008). An increasing number of formerly skeptical fisheries scientists are beginning to view such institutions as a valuable tool in the ecosystem-based management of marine ecosystems (Branch 2009; Hilborn, Orensanz, and Parma 2005; Rice 2007). This support in the academy has been reflected in the policy world, as in the recent U.S. draft policy statement encouraging the use of catch shares to end overfishing and rebuild fish stocks and fishing communities. This follows similar measures introduced in other developed countries with substantial interest in marine fishery resources.

Despite positive assessments, IFQs and other catch share approaches to fisheries management have had detractors who charge that IFQs are frequently offered as a panacea to the "fisheries problem"—with little regard for the distributional implications of their use (Copes 1997; Degnbol *et al*. 2006). IFQs and other catch share instruments of management have been criticized for distributional effects including consolidation of fishing privileges in the hands of a few operations (McCay *et al*. 1996; Palsson and Helgason 1995), inequities due to windfall gains to vessel owners from gratis allocation of fishing privileges (Copes 1997), or to harvesters at the expense of processors (Matulich, Mittelhammer, and Reberte 1996), the loss of social capital and a traditional way of life due to large-scale sell-outs (McCay 1995), and deleterious effects on the level, nature, and remuneration of crew aboard harvesting vessels.[1]

The post-rationalization position of crew has become especially important in the debates over IFQ systems in recent years. Concerns of crew are complex and multidimensional, yet tend to center around three employment attributes: *i)* the level of employment, *ii)* changes in the level and nature of remuneration, and *iii)* changes in the nature of the work itself. The first concern often focuses on the losses of distinct "jobs" from the fishery. Since the intent of many programs is to reduce vessel numbers and consolidate quota on fewer vessels, these gains in efficiency come with inevitable costs, namely the loss of jobs from exiting vessels. This leads to the second concern, which is how remuneration changes after consolidation and elimination of excess capacity. In many cases, very short-term jobs in "derby" conditions are replaced by jobs stretched out over longer seasons and conducted under less demanding conditions. Important questions arise about total employment and crew remuneration after rationalization. Are short-season and part-time crew job losses from exit and consolidation made up by longer-term jobs for remaining crew? Does total crew remuneration rise or fall? What happens to crew remuneration per season? Per day of fishing? Finally, how does the nature of the work in a fishery change post-rationalization? There may be reduced exposure to physical risk, more protracted seasons, substitution to or away from labor in the fishing process, and changes in the nature of the ideal set of skills for a skipper or crewman (*e.g.*, the ability to work without sleep is less important than under derby conditions). Whether these changes favor a particular crew member or not depends upon labor market preferences and outside employment opportunities. For instance, a longer fishing season may be preferable to crew that wish more consistent patterns of employment or that lack complementary part-time

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[1] These criticisms could also be levied at more traditional measures of management. There are numerous examples of large-scale and extensive fishery closures that have followed failures of conventional methods to contain catches, with consequent impacts on employment, community health, and biological sustainability. Furthermore, few, if any, rights-based systems are implemented without addressing some of these concerns. For instance, fears of consolidation led to strong limits on transferability of quota in Alaskan halibut fisheries. Concerns of windfall profits to vessel owners were addressed by the allocation of share to skippers in the Bering Sea/Aleutian Islands crab fisheries and crew in the Alaskan longline fisheries for halibut and sablefish. The interests of crab processors in the Bering Sea were protected through the allocation of quota to processors as well as harvesters. Finally, concern over native fishing communities has been met through the use of separate allocations to traditional fishing interests in both New Zealand and Alaska (Ginter 1996; Levine 1994).

opportunities in outside fisheries or in non-fishery sectors, but viewed negatively by crew that value employment in the fishery as supplementary income, or to crew sequentially fishing a number of fisheries of short duration.

While a handful of economic (Casey 1997; Casey *et al*. 1995; Wilen and Casey 1997) and anthropological case studies (McCay *et al*. 1996; Palsson and Helgason 1995; Binkley 1989) have touched upon some of these issues regarding crew impacts, there has been little rigorous quantitative evaluation because of the paucity of data. This article utilizes an unprecedented set of annual survey data collected from vessel owners in the recently rationalized Bering Sea/Aleutian Island (BSAI) crab fisheries to address impacts on crew. By utilizing this data for two to three post-IFQ years, as well as selected pre-IFQ years, we gain some quantitative insight into the changes in employment patterns and remuneration in the fishery. The assessment that emerges is complex and multi-faceted, but suggests that IFQs are capable of reducing overcapacity and improving fisheries rents while still providing desirable employment opportunities for crew members.

The article is organized as follows. The next section briefly surveys the theoretical and empirical literature to examine the unique characteristics of employment contracts in fisheries and how the alteration of management toward an incentive-based approach may alter these arrangements. The third section introduces the BSAI crab fisheries, their management history, and the unique data sources employed in this study. The fourth section summarizes empirical trends from the data with respect to employment patterns and productivity, changes in the contractual environment in the post-rationalization era, and alterations in the remuneration of crew using a variety of metrics. The final section summarizes these findings and concludes the article.

The Literature

The thinking of economists on the impacts of rationalization on crew welfare actually predates the first implementation of IFQs. In independent work, Samuelson (1974) and Weitzman (1974) demonstrate that variable factors may earn lower wages after transition to efficient management from open access.[2] Boyce (2004) expands this model to distinguish between fishing captains and input suppliers (including crew) and demonstrates, similarly to Weitzman, that input suppliers may be worse off from IFQs in the absence of wealth transfers. However, these findings are not robust. Demeza and Gould (1987) provide multiple examples of how the Weitzman/Samuelson result can break down under conditions of multiple inputs, where open-access actually drives the marginal product of labor to be negative, or where stock effects attract *more* employment (at a higher wage) in the long run than was employed in open access.

This literature makes a number of abstractions about real world fisheries—most notably ignoring the share system that characterizes most of the world's commercial fisheries. Under this system, captains and crew are not paid a fixed wage but a share of (typically, net) revenues. While initially explained as a risk-sharing mechanism (Sutinen 1979), recent scholarship views the share system as a mechanism to discourage shirking in conditions of high stochasticity, specialized but difficult to monitor contributions of labor and capital, and high transaction costs to the creation of contingent contracts (Casey 1997; Wilen and Casey 1997; McConnell and Price 2006). This explanation for the existence of share contracts began in the literature on sharecropping (Eswaren and Kotwal 1985; Stiglitz 1974) and has received considerable empirical support in applications to agriculture (Allen and Leuck 1992, 1995).

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[2] This follows directly from the fact that a single factor earns its average rather than marginal product in open access.

While the principal-agent framework may be useful in explaining why share contracts exist in fisheries, it has not been widely utilized to predict what might happen to fisheries share systems after the adoption of IFQs.[3] This has much to do with the challenge of modeling changes induced by IFQs in the underlying incentives for economic decision-making, which can modify the production function, alter the relative productivity and bargaining power of some factors of production, and dramatically alter the nature of a "fishing job" in duration, safety, and content. These complexities suggest that simple theories may be useful as reductive analytical tools, but less useful as predictive frameworks.

In the absence of strong theory, descriptive case studies can provide some insight into crew changes wrought by catch shares. There are a number of retrospective analyses, many adopting a qualitative or ethnographic approach, and a common thread of these studies is a finding of initial reductions in crew employment (typically measured in the number of "jobs") after rationalization (Guyader and Thebaud 2001). These reductions have been offset by greater participation of the remaining fishermen so that employment in crew days (or similar measures) may be less impacted than "jobs" or even increase (*e.g.*, in Wilen and Casey 1997). With regard to the remuneration of crew, the (limited) evidence has been mixed, but there has been some tendency toward a lowering of remuneration rates, particularly when the metric is the equivalent of a daily fishing wage or the crew share percentage itself (Guyader and Thebaud 2001). These observations aside, the literature has been uninformative about whether these declines are robust to different methods of measurement. For example, total pay per crew member in a season may increase despite a lower share (or even daily monetary payment) as a result of a combination of a longer period of fishing per vessel and enhanced returns per unit catch due to improvements in catch efficiency, product quality, and smoothing of supply.

To summarize, the literature on the impacts of rationalization on crew is afflicted by a number of shortcomings. First, there is a shortage of empirical work to supplement the relatively extensive qualitative literature—literature which, while useful, is subject to a range of sampling biases and interpretations shaped by the normative frame of the analyst. Second, both the qualitative and quantitative literature has suffered from the lack of adequate data both pre- and post-rationalization—making valid comparisons difficult. Third, these studies have centered upon a relatively small set of metrics for measuring the crew impacts of rationalization (*e.g.*, changes in the crew share) when the complexity of the situation warrants the nuanced comparison of a more exhaustive set of metrics. We address each of these concerns by utilizing data on the rationalization of the Bering Sea crab fisheries.

The BSAI Crab Fisheries: Setting and Data

History

The BSAI crab fisheries encompass a fleet targeting a variety of stocks of five species of king and tanner crabs (in the genera *Paralithodes*, *Lithodes,* and *Chionoecetes*). While each of these fisheries has experienced some historical participation, the fishery is dominated in both volume and landed value by Bering Sea snow crab (*C. opilio*) and Bristol Bay red king crab. In pre-IFQ years, these two species were targeted by a fleet of over 200 vessels that utilize pot gear to harvest crab that are delivered alive to shoreside processors in the Pribilof and Aleutian Islands. The majority of these vessels are based in Seattle, but a substantial minority hails from Kodiak and other Alaskan ports. The BSAI crab fisheries draw from a diffuse employee pool extending well beyond U.S. borders, but

[3] The exception is Casey (1997) and Wilen and Casey (1997).

with substantial concentrations of crew from the Pacific Northwest and Alaskan locales. A typical vessel employs five to six crew members, with a small number of vessels employing slightly larger or smaller crews. Crew, with the exception of the skipper, are typically employed as "deckhands" and perform a wide array of physical labor on the vessel, such as preparing bait, setting and pulling pots, sorting the catch, clearing the deck of ice, etc. In return, they receive a fraction of the ex-vessel value of the catch net of certain costs (*e.g.*, bait, fuel) commonly known as the "share." Less skilled/experienced crew members (commonly known as "greenhorns") are typically paid somewhat less than the full share, while key positions, such as the skipper, may earn a larger percentage of net revenues than a "full share" deckhand.

The crab fisheries are managed on a day-to-day basis by Alaska Department of Fish and Game, but as the majority of fishing occurs in federal waters, a substantial amount of regulation is carried out by the National Marine Fisheries Service (NMFS) and the North Pacific Fisheries Management Council (NPFMC). Historically the fishery has been managed under a limited licensing program with season length regulations aimed at keeping fleet catch below a total allowable catch (TAC) target. This led to a quintessential "derby" fishery, in which a large number of vessels raced to fish during season openings of a few days at the longest. Vessels would fish for red king crab for a few days each October and then idle their vessels (or participate in non-crab fisheries) until January when the fishery for snow crab commenced. They then fished at maximum intensity for a fortnight or less until a closure was again triggered.

Starting in 2005 for the red king crab fishery and in 2006 for snow crab, the fishery underwent a dramatic change in management to reduce the over-capitalized fleet, extend the fishing season, increase safety, and reduce biological and economic waste. License holders were allocated proportional quota share (QS) entitling them to harvest shares of the fishery's TAC in (revocable) perpetuity. Once the TAC is set, owners of QS are allocated IFQ that entitles them to an absolute amount of catch in that fishing season, generally expressed in pounds. Entry and exit is possible by purchase or sale of QS, and short-run imbalances are remedied by the annual leasing of IFQ. The plan also allowed for the creation of cooperatives (coops), the pooling of IFQ within these coops, and the allocation of a small proportion of QS to crew skippers with a qualifying catch history.[4]

Given its recent implementation, judgments on the impacts of the program are only beginning to form. What little published analysis that has appeared focuses on the impacts of allocating quota to the processing sector; *e.g.*, Matulich (2008, 2009). Despite its short track record, there is a need to evaluate the effects of rationalization on crew for multiple reasons. First, the effects of rationalization on crew were, and continue to be, a hot-button issue at the NPFMC. Second, the BSAI fisheries offer an unparalleled opportunity to follow in "real time" the immediate changes after rationalization and the transition path to equilibrium under the new system of management. Finally, managers have implemented an unusually comprehensive before-and-after data collection effort which, as described below, is not seen in most fisheries.

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[4] Besides the allocation of skipper shares, the rationalization of the crab fisheries incorporated a number of other unique features. Perhaps the most important was the allocation of individual processing quota (IPQ) to processors and the attachment of IFQ-IPQ matching requirements and regional landing requirements to 90% of IFQ shares. These preserved existing delivery relationships among vessels and processing plants and communities and avoided geographic redistribution of landings and port employment. While designed to protect the investments of processors and limit impacts to fishery-dependent communities, these measures remain controversial. Some (Wilen 2009) have criticized the "two-pie" system for restricting entry to favor existing processors, while advocates of the policy (Matulich 2008, 2009) counter that harvesters have gained from rationalization despite these provisions.

Data

We draw upon two data sources. The first are E-Landings (fish ticket) records, which record a variety of vessel-specific information on fishing activity, such as dates of landings, quantities of species landed, and the number of crew present at the time of landing. The primary data, however, come from annual Economic Data Reports (EDR) filed by vessel owners. This data collection was mandated of all participants in the rationalized fishery and gathers a wide array of information, including revenue from landings of targeted species, information on the labor contracts of captain and crew, payments to crew members, and many other operating costs. An unusual feature of this data collection effort is the required provision of historical data by all vessels, not merely those that remained after rationalization, for selected pre-rationalization years (1998, 2001, 2004, and, for the snow crab fishery, 2005). These years were selected to capture different conditions of stock abundance and market prices. These data provide a baseline for comparison between years immediately before and after IFQ implementation.

This unprecedented breadth of information is somewhat compromised by the inconsistent quality of some data series. As a relatively new survey, there have been issues of data quality for key variables, as well as a tension between refining the survey instrument to precisely elicit the desired information while maintaining comparability of the resulting data through time. Data collection has been controversial, and the industry has had a substantial voice at the NPFMC in defining its appropriate use. The ultimate outcome of this input was an extensive data audit, resulting in a thorough description of the data and provision of some guidelines and limitations as to how the data should be used (*e.g.*, to what degree a particular series is comparable between vessels and through time). We are mindful of these concerns generated by the audit and limit ourselves to series that are deemed reliable for our purposes. We also utilize the E-Landings data, where necessary, to substitute for questionable or missing data series.

The Effects of Rationalization on Crew

A comprehensive assessment of the effects of rationalization on crew requires the synthesis of a variety of metrics. We organize our presentation as follows. First, we examine *compositional changes* in the fishery in terms of the length of season, numbers of vessels, and inter- and intra-vessel patterns of employment. Second, we utilize data from the EDR to examine *contractual changes* in the fishery via changes in the share accruing to crew and patterns in the evolution of vessel costs in figuring the "base" on which shares are calculated. Third, we take an extensive look at *remunerative changes* in the fishery by examining how the returns to labor in the fishery have changed. While IFQs were extended to multiple species and sectors (including crab processors), we limit our attention to catcher vessels fishing for red king crab and snow crab. Catcher vessels take virtually all of the catch volume in the fishery. We focus on red king and snow crab because they are the economically dominant species, have been fished consistently both before and after rationalization, and because of high participation, can be analyzed without revealing the identities of individual vessels.

Compositional Changes

Number of vessels. One of the primary goals of the program was to reduce over-capitalization, and this is reflected by a dramatic reduction in the number of participating vessels due to quota consolidation. The number of unique vessels operating in either of the two primary fisheries dropped from a peak of 233 in 2004 to 77 in 2007. Pre-rationalization participation peaked at 229 red king crab vessels and 173 snow crab vessels in 2004 but fell in the first full year of rationalization to 85 (–63%) and 73 (–58%), respectively.[5] The pace of consolidation then slowed, with 2007 participation of 70 vessels for red king crab and 63 for snow crab. Current numbers of active vessels in the fisheries are now 31 and 36% of their highest pre-rationalization levels. As before the transition, vessels tend to pursue both of the target species in a fishing year; in 2007 73% of vessels were active in both fisheries, compared to 73–78% before rationalization. Roughly 20% of the fleet specializes by pursuing the more lucrative red king crab exclusively—a pattern that appears unaffected by rationalization.

Season length. An inevitable (and intended) result of this dramatic consolidation was the lengthening of the season for the remaining participants. To measure this, we utilized fish ticket data to measure the time from the first fishing day of the season for each species to the day of final offload for each vessel.[6] This provides a reliable measure of time spent in the fishery that can be compared across vessels and through time.[7] Figure 1 depicts box-whisker plots of the calculated fishing days for all days in the EDR.[8] The reduction in length of the fishing seasons in pre-rationalization years is immediately apparent—seasons less than 10 days were typical for red king crab and 15–20 days for snow crab, while current seasons have been 2–3 times as long since rationalization—an increase in season length roughly commensurate with the reduction of vessels in the fishery. While difficult to distinguish from existing data sources, this comparison likely understates the increase in actual *fishing* days. This is because of the time spent waiting to offload catch to processors in the derby fishery that is captured in our measure. These "queuing losses" (which often totaled several days and increased losses from dead and degraded product) were dramatically reduced due to the reduction of vessels, the spreading of deliveries across a greater number of days, and the coordination of delivery dates facilitated by the creation of processor quota (Poulsen 2009; Stone 2009). This also explains the high variance in calculated season length in the pre-rationalization period, when in reality all vessels fished a season of identical (short) length. Another important phenomenon is the dramatic widening in the distribution of season length in the post-rationalization era, with some vessels fishing seasons of approximately the same length as before rationalization, while others are pursuing seasons substantially longer than the median. The establishment of secure catch privileges decoupled the seasons of vessels from the exhaustion of a common pool of target quota; this allowed a vessel's season to be shaped by individual variations in quota holdings and catch rates plus the flexibility to return to port for critical repairs or to avoid bad weather.

Employment—lost jobs. One measure of changes in employment that is often used in the literature is the change in the number of unique "jobs" on vessels. However, calculating this metric is problematic. Because of missing individuals in the pre-rationalization data, it is difficult for us to identify the precise number of unique individuals employed by a vessel in a fishery/season. Instead, we use information on the average employment through time, which may deviate from total employment due to replacements from either terminations or injury. We then tabulate our total employment figures by fishery and calculate total jobs by multiplying the average crew employment (including the captain) for

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[5] The first full year of rationalization for snow crab was reported in the 2006 EDR due to the splitting of the 2005 season across a derby (early) and rationalized (late) season.

[6] This calculation also accounts for the staggered nature of the fishing year in the Bering Sea, which creates the possibility that the terminus of one season and the beginning of another are both contained in the same calendar year. Our calculations report time in the fishery within the calendar year in order to remain consistent with the calendar year accounting of the EDR.

[7] This measure includes time spent in offload, idle time due to weather and maintenance, as well as steam time to and from offloads. We include these events since they represent time for which the share compensates the crew.

[8] Note that 1998 is censored for the snow crab fishery due to uncharacteristically long calculated seasons. The causes are unclear, but may arise due to a combination of wide-scale icing, crew strikes, and an unusually large TAC.

the fleet (derived through a combination of EDR and fish ticket sources) in that year by the number of active vessels. Table 1 reports the calculated number of "jobs" by fishery. There is a considerable post-IFQ decrease in this measure, with employment falling in almost direct proportion to the attrition of vessels.

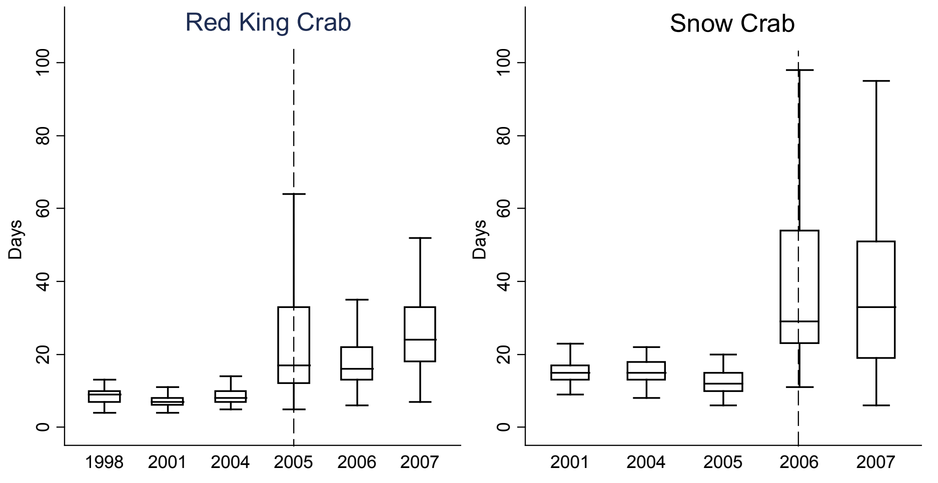

Figure 1. Box-whisker Plot of Season Length for Vessels in Crab Fisheries (dotted line indicates first full year of rationalization)

Table 1
Measures of Employment in Crab Fisheries by Year

Red King Crab Year	TAC (mill. lbs.)	Vessels	Jobs	Crew Days	Crew Days + Non-Fishing	Crew Days/Ton	Crew Days/Ton (post-rat (only)
1998	15.8	201	1,189	10,709	28,636	2.5	2.3
2001	6.6	196	1,089	8,246	25,414	3.5	3.0
2004	14.3	229	1,386	11,918	34,280	2.1	1.8
2005	16.5	85	482	11,181	19,228	1.6	1.6
2006	13.9	77	438	7,968	15,061	1.6	1.2
2007	18.3	70	412	11,538	18,213	1.5	1.5

Snow Crab Year	TAC (mill. lbs.)	Vessels	Jobs	Crew Days	Crew Days + Non-Fishing	Crew Days/Ton	Crew Days/Ton (post-rat (only)
1998	225.9	172	1,064	–	–	–	–
2001	25.3	171	1,046	17,330	34,898	2.6	2.0
2004	19.3	173	979	16,342	32,613	1.7	1.6
2005	19.4	150	849*	11,453*	25,801*	1.2	1.1
2006	33.5	73	415	16,436	23,506	1.1	1.0
2007	32.9	63	366	14,371	20,389	1.0	1.0

* Imputed based upon 2004 avg. crew size.

An important question is whether these reductions in employment have come from vessel-level changes in staffing in addition to changes from exit alone. Table 2 examines this question by summarizing changes in vessel-level employment from 2004–2007 (the final derby year and the last IFQ year in our sample) across both fisheries using only those vessels that persisted until 2007. For red king crab vessels operating in 2004 with a typical crew size (5–6 members including the captain), the dominant pattern is for no change in average employment. However, for vessels with larger pre-rationalization crews, the majority of vessels shed 1–2 crew members by 2007, driving a mean reduction in crew across all size classes of 0.4 jobs.

The reduction of crew on the intensive margin (and its differential effect on vessels with larger pre-rationalization employment) is evidence that vessels were employing labor inputs beyond their most productive level in order to maximize their share of catch (and minimize their risk of *not* obtaining a sufficient share due to crew injuries) under derby conditions. Nevertheless, the effect on employment from these within-vessel adjustments is small—97% of the 2004–2007 job losses in the red king crab fishery arose directly from exit of vessels from the fishery. Unlike red king crab, vessels pursuing snow crab do not reveal a clear pattern in their employment patterns; both nominal growth and reduction of crew occurred with little overall effect (vessels added .13 jobs per vessel, on average).[9]

Table 2
Changes in Crew Employment by Fishery and 2004 Vessel Size

	2007 Change in Crew Size				
Number of 2004 Crew (including captain)	–2	–1	0	+1	+2
Bristol Bay Red King					
5	0	0	9	0	0
% of size class	0	0	100	0	0
6	0	13	21	1	1
% of size class	0	36	58	3	3
7	3	7	7	1	0
% of size class	17	39	39	6	0
8	2	3	2	0	0
% of size class	29	43	29	0	0
All Sizes	5	23	39	2	1
%	7	33	56	3	1
Bering Sea Snow Crab					
4	0	0	0	1	0
% of size class	0	0	0	100	0
5	0	1	11	11	1
% of size class	0	4	46	46	4
6	0	8	14	5	0
% of size class	0	30	52	18	0
7	0	3	2	1	0
% of size class	0	50	33	17	0
8	0	0	1	0	0
% of size class	0	0	100	0	0
All Sizes	0	12	28	18	1
%	0	20	47	31	2

[9] It is difficult to make valid comparisons in this case for the snow crab fishery because of the opening of the concurrent tanner crab fishery in the post-rationalization years after many years of closures. Given the possible jointness of labor inputs to these two fisheries, changes in employment cannot be attributed cleanly to the effects of rationalization itself.

Employment—fishing crew days. "Lost" jobs alone yield an incomplete picture of the employment effects of rationalization, since these losses are offset to some extent by increases in the duration of employment of a smaller cadre of crew members. To account for this, we also provide estimates of total fishing crew days in table 1 by combining vessel-specific estimates of fishing days by fishery and average crew size. Although the magnitude of fishing crew days does vary considerably across seasons as a function of varying TACs, species abundance, and environmental conditions, there is no clear reduction in crew days for either fishery in the post-rationalization era—suggesting that more short-term jobs were replaced by fewer long-term jobs.

Employment—total crew days. Fishing crew days as a measure of employment are deceiving, however, since crew days measured from the first pot-soak to the final offload ignores labor time that is required of many crew members as a condition of their employment. Many crew are required to prepare the boat at the beginning of the season and typically sail back and forth from their home port to Dutch Harbor. While we lack vessel-specific data on these factors, we utilize information on the crew size and home port (and thus steam time) for each vessel combined with knowledge gained from extensive discussions with industry personnel (Poulsen 2009; Stone 2009) to create vessel-specific estimates of the total crew days involved in each crab season, which are shown in the fifth column of table 1. The importance of accounting for this off-fishery employment is immediately apparent; failure to do so underestimates total crew days attached to the fishery (and compensated by the fishery share) by a factor of two or more. This is especially true in the pre-rationalization era where large numbers of vessels fishing short seasons magnify the importance of this fixed (per vessel) "prep time" for the season. The reduction of capacity and lengthening of the season from 2005 onward reduced the proportion of crew time spent preparing for and transiting to and from the fishery. This economizing on redundant fixed costs drives the drastic reductions in this measure of employment after the implementation of ITQs (with 2007 declines of 47 and 42% for red king crab and snow crab, respectively, relative to their pre-rationalization highs).[10]

Crew days/ton landings. While illustrative, it is difficult to assess these changes in jobs and crew hours, since both the number of crew positions and the duration of employment are integrally tied to the TACs and the biomass in the fishery, which may vary dramatically from year to year. Employment trends may be obfuscated if shocks to the fishable biomass led to substantial alterations in vessel landings (table 1). To account for this variability, the sixth column of table 1 reports the yearly average number of crew days per ton of landings. Despite the short time series, there is strong evidence (particularly for red king crab) for a reduction in the labor inputs needed to land a ton of catch after the implementation of catch shares. The relatively stable pattern of crew hours in the post-rationalization era belies the fact that TACs and harvests in both fisheries have typically been higher than in pre-ITQ comparison years (*e.g.*, snow crab TACs in 2006/2007 were about 30% higher than their next highest 1999 value), so employment per unit of output has actually decreased. To ensure that these statistics reflect real changes among a stable cohort of vessels rather than simply arising as a function of quota consolidation on more productive vessels, we calculate the same statistic for only those vessels that persist in the fishery through 2007 (table 1). While these statistics suggest that persistent vessels are consistently more productive in their use of labor, the declining time trend remains robust. Whether these implied employment losses from this increased average productivity were the direct product of rationalization or the unfolding of longer-running exogenous trends in the fishery is unclear.

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[10] While accounting for non-fishing time is likely important in many fisheries, there are unique features of the crab fisheries which exaggerate its importance. Most of the fleet (and crew) hails from distant ports, such as Seattle. There is also a great deal of time involved in rigging pots and securing bait for the season.

Contractual changes. The labor contracts between ownership and crew are individual, complex, and multidimensional arrangements, and it should come as no surprise that we observe only limited information on their content. Nevertheless, data on two aspects with particular relevance are solicited by the EDR: *i)* the share of net revenues paid to captain and crew and *ii)* an accounting of which costs are deducted from revenues prior to calculation of the crew's share.

Share percentage. The "share," as commonly defined by fishermen, is the percentage of revenues (after certain costs are deducted) from which all payments to crew are made. The EDR contains distinct series for owner, crew, and captain share for 2005 forward, but only reports the total of crew and captain share in the historical EDR. Given that both the captain and deckhands are typically considered "crew" (captains are rarely more than partial owners of their vessels) and paid on a share basis, this aggregation still provides a useful measure of the percent of net revenues flowing to the compensation of labor.

Figure 2 displays the mean and 5th and 95th percentiles for the red king crab fishery (snow crab results are similar) in each year for the entire population and the subset of vessels that remained in the fishery through 2007. These show that the pattern of crew shares did not differ markedly before and after IFQ implementation. Mean shares fell approximately 1% immediately following rationalization in 2005, a decrease driven mostly by small adjustments in the share contracts of the vessels that remained in the fishery through 2007.

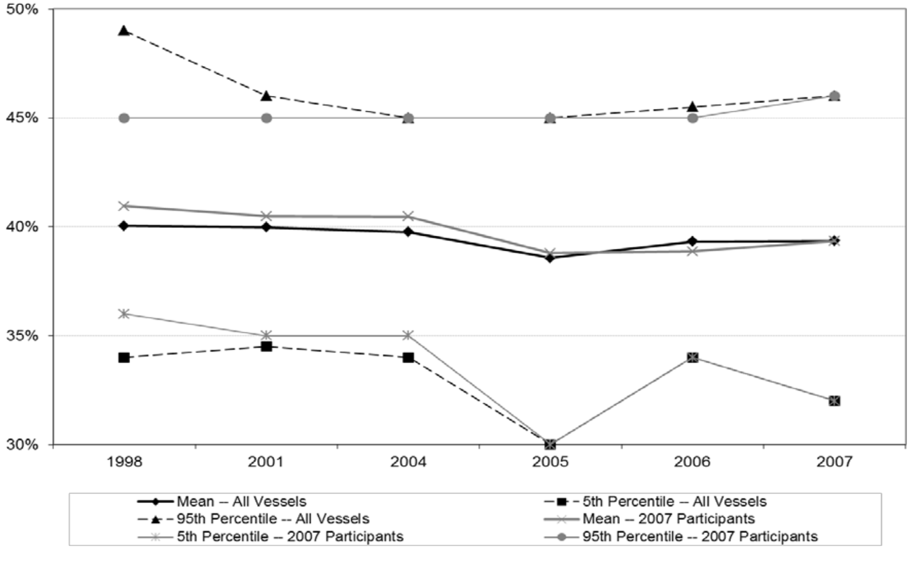

Figure 2. Shares of Captain and Crew in Red King Crab Fishery

While the overall distribution of share arrangements in the fishery remained fairly stable, this was not always the case for individual vessels. Figure 3 demonstrates that over half of the vessels present in 2007 decreased their crew share (25% by 3 points or more), while only 23% reported no change whatsoever.[11] Nevertheless, the majority of vessels have implemented only marginal changes in the crew share.

[11] There is some evidence of a linkage between decreases in crew share and decreases in the number of crew members. A simple linear regression of the 2004–2007 change in red king crab crew share on the change in crew for those same years (not reported) suggests that the reduction of a single crew member is met by a 1.3% decrease (p=.03, R2=.096), on average, in share going to crew. This provides evidence that some proportion of the cost savings from post-rationalization reductions of crew was absorbed by ownership or other factors rather than being passed along in proportionally higher shares to remaining crew.

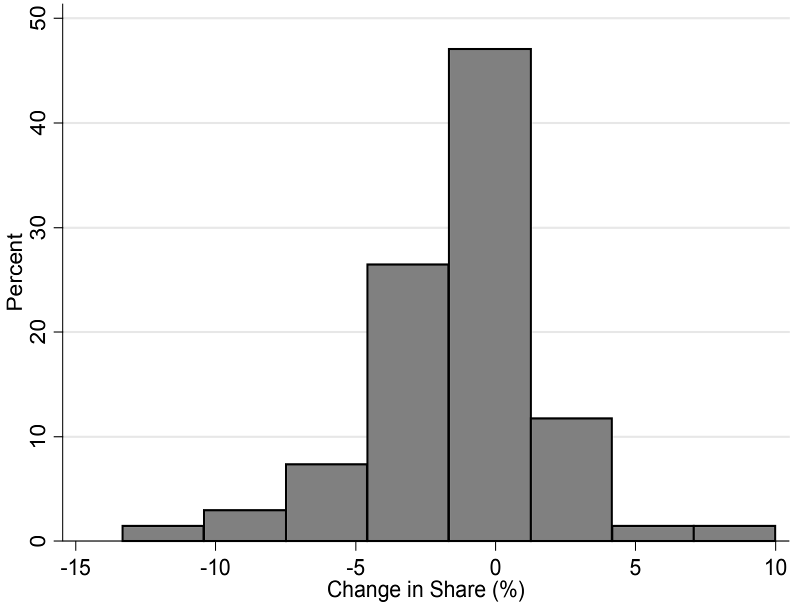

Figure 3. Change in Crew Share from 2004–2007

Cost deductions. Aside from the share percentage, the next most important factor determining a crew member's pay is which costs are deducted from net revenues prior to calculation of the share. The EDR survey solicits whether certain costs are deducted or charged directly (*i.e.,* assessed apart from the calculation of the crew share) to crew members (including the captain). Figure 4 reports the percentage of vessels in each year that indicated that a particular cost category was either deducted or directly charged to crew members for different sub-populations of participants.[12] The graph for "All Vessels" represents all participants in the fishery and showcases a remarkable degree of stability from year to year in the composition of the fleet deduction patterns. Food and tax expenses are assessed from the crew for the vast majority of vessels, as are bait and fuel. Only a minority of vessels charge for lost or damaged gear. Only two cost categories show any temporal trend: gear and the cost of IFQ—with deductions for gear losses slipping in the post-rationalization era and deductions for costs of IFQ increasing from roughly 40% of the fleet in 2005 to 80% in 2006–2007. To investigate to what degree these patterns are the result of reconfiguration of longstanding contracts on vessels versus patterns driven by attrition and entry, we recreate this analysis for three cohorts: *i)* those that never participated in either of the fisheries once they were rationalized, *ii)* those that participated to some degree but were not in the sample by the final year of the sample, and *iii)* those that persisted (or entered) the fishery so that they fished in 2007. These groups are broadly comparable to one another in their treatment of many costs; however, trends in charges for lost gear occur due to the fact that post-rationalization vessels were different from

[12] Note that two cost categories (travel and IFQ) were not elicited until later versions of the EDR (2005, the first year of rationalization for IFQ, and 2006 for travel). Furthermore, this graph does not imply that the remaining fraction of vessels did not charge for a particular cost as respondents have the option to indicate that a particular cost is not applicable (and there are a small number of missing values as well).

those that exited, rather than changes in the designs of contracts per se. Furthermore, the increase in the deductions of IFQ in the calculation of crew share after 2005 is mostly driven by the exit of a substantial number of vessels from the snow crab fishery, which saw its first full calendar year of rationalization in 2006 (although the proportion of vessels deducting IFQ among the cadre of vessels that persisted beyond 2005 did increase substantially in 2006 to encompass 80% of vessels in 2007). A comparison among the vessels with continued participation after three years of rationalization versus those that exited prior to the 2007 season suggests that charging crew for IFQ costs was consistently more prevalent across vessels that persisted in the fishery.

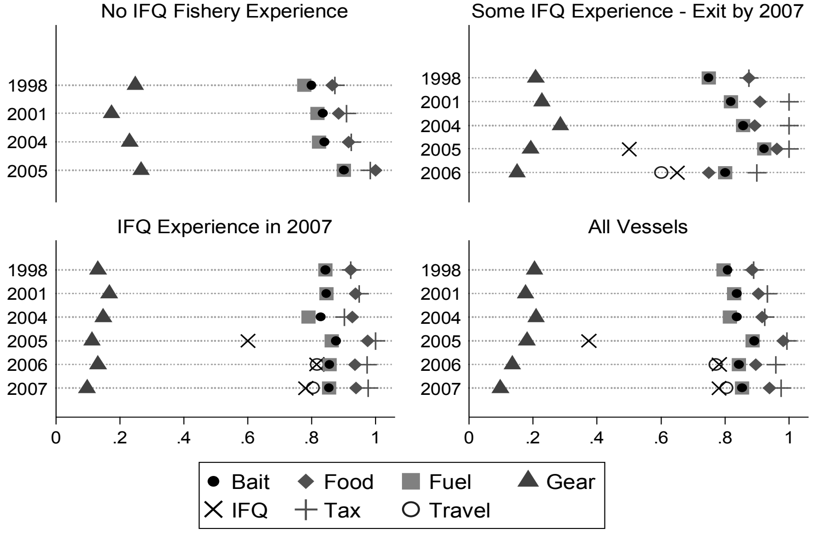

Figure 4. Proportions of Vessels Deducting or Charging Crew by Cost Category

There is an apparent pattern, now persistent for two seasons, where ~80% of the fleet deducts IFQ from crew share while ~20% does not. Nevertheless, the qualitative nature of the data masks strong potential heterogeneity in deduction practices—most importantly whether vessels charge only out-of-pocket costs for leased or purchased quota or also charge for the opportunity cost of quota that is already owned. While the economic rationale for deducting opportunity costs of quota (the foregone value of fishing a unit of quota rather than selling it) is strong (*e.g.*, Wilen and Casey 1997), attempts to deduct opportunity costs have been met by strong resistance in many world fisheries (Palsson and Helgason 1995; McCay 1995). While we lack quantitative data to investigate this question, conversations with knowledgeable owners indicate that deducting for the opportunity costs of quota remains rare and is primarily implemented by a handful of vessels in difficult financial straits (Poulsen 2009).

Remunerative Changes

Understanding remuneration requires understanding factors that govern the supply and demand for crew labor services. On the demand side, consolidation of vessels, elimination of the race to fish, season elongation, and altered fishing practices may change the desired bundle of labor services. In a labor market equilibrium, the marginal crewman will be paid the value of the services they provide to the operation. At the same time, crew must be sufficiently compensated to lure them away from alternative fishing and non-fishing employment. Ideally, we might look at how the attributes of a typical crew job have changed under IFQs, coupled with data on alternative labor markets. Lacking such micro data, we examine per-crew compensation on a seasonal and daily basis and discern how it has varied with respect to the quantity of landings.

Seasonal remuneration per crew member. Table 3 presents the average compensation per crew member in CPI-adjusted 2007 dollars for the two fisheries. These figures do not reflect payments to the skipper, since monetary payments to captain and crew (unlike the share percentages) are available separately for all years of the EDR.[13] The most notable finding for king crab is the substantial and immediate increase in seasonal income in 2005, with incomes rising by roughly 100%; a remarkable finding in light of the contemporaneous decline in king crab prices. In 2006 and 2007, incomes for snow crab were also higher than for 2001 and 2004. However, they are dwarfed by incomes in the 1998 outlier year that preceded the collapse that led to an 83% reduction in the TAC between 1998 and 2000. These lowered TACs persisted through 2007 in spite of some recent signs of recovery (table 1). Altogether, there is evidence of substantial increases in average seasonal income following IFQ implementation.

Table 3
Average Income Measures ($2007) by Fishery

Year	Red King Crab Seasonal	Red King Crab Per Day*	Snow Crab Seasonal	Snow Crab Per Day*
1998	$9,084 ($4,967)	$365 ($203)	$35,353 ($15,492)	$412 ($166)
2001	$10,568 ($6,854)	$432 ($272)	$8,577 ($6,275)	$248 ($174)
2004	$14,466 ($7,153)	$566 ($272)	$13,941 ($6,689)	$414 ($197)
2005	$27,509 ($13,099)	$675 ($283)	– –	– –
2006	$21,523 ($8,677)	$605 ($212)	$16,057 ($8,797)	$283 ($117)
2007	$30,882 ($13,163)	$698 ($268)	$26,029 ($12,713)	$477 ($168)

Note: Standard errors in parentheses. * Includes estimated vessel-specific non-fishing days.

[13] We do not report 2005 estimates for the snow crab fishery because of the lack of reliable crew size data for that year and fishery. Compensation to skippers is not reported here, although the observed trends are quite similar. We avoid this discussion because a substantial (but unidentified) fraction of skippers are at least partial owners of the vessel and thus receive dividends. Many skippers also received crew share under rationalization. These income flows are very difficult to establish with any reliability from the EDR data.

A major part of this increase arose from the selective thinning of the fleet after IFQ implementation. Figure 5 plots empirical densities of the average seasonal pay of crew members in the 2001 and 2004 fisheries for both the vessels that exited the fishery prior to rationalization and those that continued fishing. Each vessel's contribution to the density is weighted by its average crew size to yield the density of pre-rationalization remuneration for crew. There is strong evidence that the vessels that exited the fishery typically offered substantially lower wages prior to rationalization than those that persisted. This concords with the exit of less efficient vessels since remuneration and profitability are tightly linked via the share system.[14]

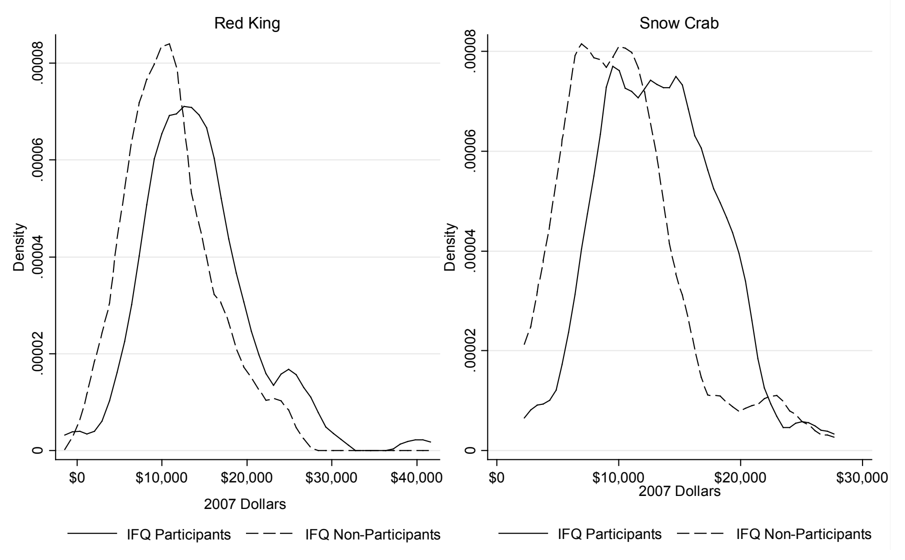

Figure 5. Kernel Density of Average 2001/2004 Crew Pay Stratified by IFQ Participation

There is also evidence of substantial temporal changes in the average remuneration of crew onboard individual vessels. Figure 6 shows the distribution of within-vessel changes in average seasonal pay before and after rationalization, where the contributions to the density of each vessel are weighted by the average crew size in the post-IFQ years. The median "average crew member" on a vessel for king crab earned over 66% (48% for snow crab) more in the three years after IFQ implementation than before, while 87% (75% for snow crab) experience some increase. Again, these increases occur despite substantial reductions in crab prices.

Seasonal remuneration in crab equivalents. Comparisons of seasonal income across these years are problematic since the real prices of crab were highly unstable. Prices fell by over 30% between 2004 and 2007 for reasons generally acknowledged as independent of the management change—the increase in imported Russian crab. To guard against conflating IFQ-driven changes in remuneration with price movements, we construct a simple

[14] A log-regression of seasonal pay on annual dummies and an indicator for IFQ fishery participation estimates that seasonal compensation was 36% higher, on average, for the cohort of vessels that persisted after rationalization than those that exited (robust t-stat = 4.5).

index by dividing remuneration by the average price received by a vessel for its crab—so that remuneration is denominated in pounds of crab.[15] Measured in this manner, the increase in seasonal income is amplified, with the median king crab crew member earning over 122% of the typical pre-IFQ "crab equivalent" salary (109% for snow crab). Failure to account for falling crab prices understates the real increases in seasonal income experienced by crew members (figure 6).

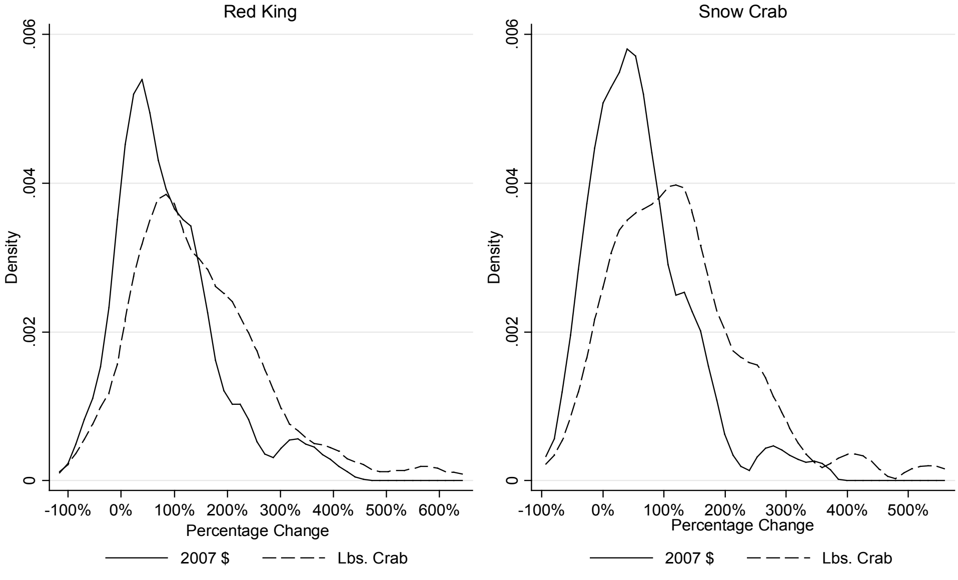

Figure 6. Seasonal Income Change Distribution from 2001/2004 to 2005–2007 using Two Different Metrics

Crab equivalent crew remuneration as a share of output. While seasonal compensation has unequivocally increased for the vast majority of crew within the fishery, the quantity of harvest and landings on vessels has increased as well due to consolidation. This raises the question of whether compensation simply mirrors the increase in productive output of the vessels. To investigate, we examine compensation as a percentage of live landings for the entire crew (excluding the captain) and from the perspective of the individual. Figure 7 presents pre- and post-rationalization kernel densities of average crab equivalent compensation as a percentage of landings. This is useful as a "piece-rate" measure of crew wages and also captures compensation as a percentage of output. These graphs show that, while seasonal compensation rose in the wake of IFQs, landings rose

[15] This index has some desirable properties. First, it has desirable equity properties in that it remains constant if the impacts of price movements are shared proportionally between crew and ownership. Second, since market prices for crab are exogenous to the ownership of individual vessels and the resulting "wage" from a share system is intrinsically variable, it seems wise to compare the state of labor through time by how much of the real output of the enterprise is effectively devoted to its compensation. While labor may be made worse off relative to a reference year from a reduction in output prices, these changes in welfare are not the proper object of a program evaluation of IFQs. Rather, what is desired is a measure with some utility in assessing the compensation of crew labor relative to other factors of production.

more rapidly so that the overall share of real output devoted to crew share fell by half. This broad trend is reflected in compensation per crew member, showing that reductions in crew by some vessels did not substantially offset the effects of increases in output on vessels. From a "piece-rate" perspective, the compensation of crew members has fallen substantially since the advent of IFQs. A similar trend is likely to hold for vessel owners who lease substantial amounts of quota. If leased crab is a large component of expenses, they will also experience reductions in profits per unit of landed crab.

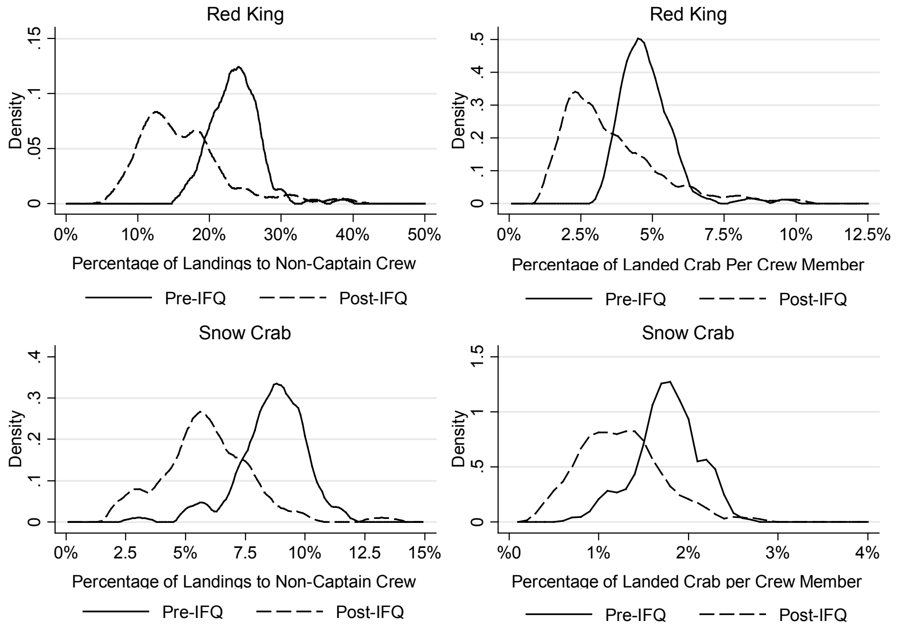

Figure 7. Average Crab Equivalent Compensation as a Percentage of Landings for Entire Deck Crew (left) and Per Crew Member (right)

Daily remuneration. While seasonal remuneration increased onboard most vessels following IFQ implementation, another issue is whether crew members' daily compensation increased or decreased. Table 3 reports the annual mean per-day compensation of crew members. Daily compensation in the king crab fishery has clearly risen, on average, since rationalization, but such a trend is not apparent for snow crab. The daily "wage" increases in the fishery are due in part to attrition of lower-paying vessels. However, as with seasonal pay, there is substantial inter-vessel variation in daily compensation changes straddling IFQ implementation. Figure 8 replicates the information in figure 6 for daily income—measuring change in daily pay both in dollars and in crab equivalent units. The median crew member in the king crab fishery who retained his position before and after rationalization saw his daily dollar denominated income increase by over 12% (46% if changes are measured in crab equivalent units), and over 60% of crew who persisted through the transition saw some increase in daily remuneration (81% in crab equivalent units).[16] The situation is mixed in the snow crab fishery, where the median post-rationalization crew member saw his dollar-denominated daily income shrink by approximately 5% and where only 39% witnessed an increase. However, these conclusions are highly sensitive to the metric used. The median post-rationalization crew member actually saw an *increase* of 29% in their daily "wage," with over 71% experiencing some increase when crab equivalent units are used. The precipitous decline in real snow crab prices from 2005 onward explains much of the daily wage reductions to crew from rationalization. While price declines may have reduced the daily remuneration of a substantial part of the snow crab fleet in terms of their purchasing power, normalizing these wages to the price of the real output of the operation suggests that crew, far from sharing disproportionately in this decline, actually saw their hourly (and seasonal) wages *rise* at the expense of payments to other factors (*e.g.*, capital, quota) and/or reductions in the returns to ownership. Since these price movements were independent of management decisions, it is this *internal* criterion for measuring remuneration change that seems most relevant for judging the effects of rationalization.

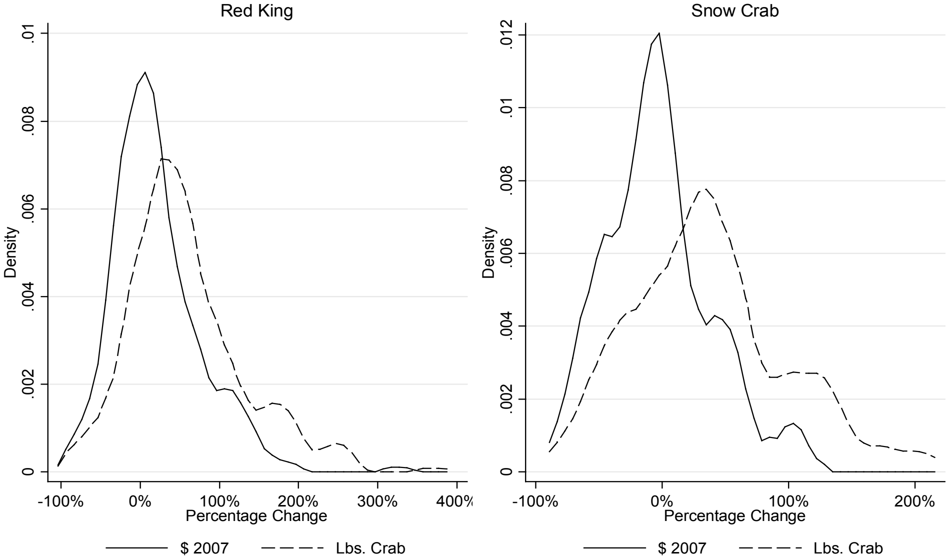

Figure 8. Daily Income Change Distribution from 2001/2004 to 2005–2007 Using Two Different Metrics

Summary and Conclusions

Some of the effects of IFQs on the crab fisheries have been predictable and inevitable consequences of management's intent to reduce the inefficiencies and redundancies as-

[16] Of course this does not imply that crew who persisted in the fishery actually experienced these increases, since the cross-sectional unit of analysis from the EDR is the vessel, not particular crew members. Hiring of new crew with potentially different skills and opportunity costs (perhaps from recruitment of a new segment of workers enticed by changes in the wake of IFQs) can explain some of these within-vessel changes in remuneration.

sociated with the pre-IFQ derby conditions. The attrition of vessels from the fishery has caused a roughly commensurate decrease in the number of individuals with some degree of employment in the fishery. Nonetheless, the overall level of employment in crew hours spent fishing has stayed roughly constant. The amount of time spent in onerous non-fishing activities—including time in transit to the grounds and gearing up/down for the season—has unequivocally fallen, as the consolidation of quota on fewer vessels has reduced the need for this redundant employment.

Remuneration has *increased* (often substantially) on both a seasonal and daily basis for the majority of crew positions relative to before rationalization. This finding is sharper when program-independent reductions in crab prices are accounted for in the calculation of the wage. Given that the share formulas used to pay crew have remained fairly stable, this implies that the base on which the share is calculated (essentially revenues net of most variable costs) has increased substantially on a daily basis for many vessels—a consequence of IFQ-induced cost reductions and/or increases in live landings per day. While a precise breakdown of these causes is not possible due to weaknesses in the EDR cost data, increased live landings per day (through improvements in catch per day and reduced landings of dead crab from improved handling and more timely deliveries) has played a substantial role, with average within-vessel increases of 16% for snow crab and 38% for king crab in the post-rationalization era.

While there have been increases in daily and seasonal remuneration, there have also been increases in average labor productivity. Since productivity increases have been larger than remuneration increases, labor payment per unit of crab output has declined.[17] This is predictable in light of accepted models of wage determination in fisheries (Wilen and Casey 1997; McConnell and Price 2006), which generally prescribe that the effective wage of the marginal crew member (although not the details of the share contract by which that wage is achieved) is determined by their "opportunity wage" in outside employment. Unless this opportunity wage (which is not directly controllable by ownership in the crab fishery) shifts upward sufficiently after rationalization to compensate for increases in productivity per crew member, compensation per unit of catch will inevitably decline.[18] An important question for future research is to understand the mechanisms by which output or revenues are distributed to labor, capital, and ownership, and how these distributions to various productive factors have adjusted under the IFQ system. Before IFQs, crab revenues were allocated to crew, skippers, and owners of vessel capital in a manner that reflected their relative contributions to production under "race to fish" conditions. In the post-IFQ period, these same factors must be compensated under less intense, more prolonged, and more efficient production conditions. These changes in the process of fishing alone would be likely to initiate some changes in the distribution of revenues to crew, skipper, and vessel capital; but now, in addition, revenues must also cover IFQ costs. More complete analyses must deal with the fact that precise measures of the cost of IFQ is made difficult by the hidden nature of many transactions through cooperatives and partnerships and the problematic quality of IFQ cost data in the EDR.

In conclusion, our findings raise an empirical counterexample to some of the more extreme charges levied at IFQs by their critics, who have faulted them as harmful and inequitable to not only the crew displaced by the reduction of overcapacity but also to those

[17] Pay per crew member divided by crab per crew member yields pay per crab. If productivity (crab per crew) rises faster than pay per crew member, pay per crab will necessarily decline.

[18] It is not clear how (or if) the opportunity wage of outside employment changed as a result of rationalization. If the cessation of the race to fish and a reduction in labor demand relative to supply encourages vessel owners to seek out professional, skilled crew, then this may correspond to a crew with greater productivity in outside occupations. While our conversations with owners suggests this may be the case (Poulsen 2009; Stone 2009), it is also possible that the cessation of the derby may induce some owners to staff their vessels with a greater proportion of inexperienced, younger crew who may have lower opportunity wages (Sepez, Lazrus, and Felthoven 2008).

who remain employed in the fishery (Pinkerton and Edwards 2009). Our methodology is based upon an unprecedented dataset that effectively offers a census of the fishery before and after catch shares were implemented. These data allow us to test the assertions of the ethnographic literature in a quantitative manner without the sampling and reporting biases that are likely to plague these studies. Our post-rationalization period is short; hence questions remain about the long-run trajectory of crew outcomes in the fishery (questions that can be addressed in due time with updated versions of these data). The lack of systematic data on displaced crew members after rationalization also limits our ability to ascertain the full impacts on employment and remuneration. Nonetheless, our initial findings suggest that most fishermen have seen their remuneration rise significantly by most measures compared to what they earned or would likely have earned in the fishery before rationalization. Furthermore, independent of average remuneration, the creation of secure access to catch has had several other effects which are generally perceived to be positive for crew including: *i)* reductions in physical risk; *ii)* a smoother, less seasonable pattern of employment; and *iii)* a reduction in financial risk due to the reduction in uncertainty over vessel revenues as a consequence of secure privileges to a percentage of allowable catch (Poulsen 2009; Sepez, Lazrus, and Felthoven 2008).

Finally, our work demonstrates the utility of gathering comparable employment, remuneration and other data both before and after the implementation of major fisheries policy changes. Gathering such data requires considerable foresight and political will. In this case, the data reporting requirements were a non-negotiable element of the management itself. Such efforts are costly to both managers and fishermen and fraught with challenges of survey design and data management, but they are imperative if policy is to be assessed and adapted based upon objective criteria.

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