AN EVALUATION OF COMMUNITY PROTECTION MEASURES IN THE ALASKA HALIBUT IFQ PROGRAM

by

Marysia Szymkowiak

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Marysia Szymkowiak

Approved: ______________________________
Mark A. Moline, Ph.D.
Director of the School of Marine Science and Policy

Approved: ______________________________
Mohsen Badiey, Ph.D.
Acting Dean of the College of Earth, Ocean, and Environment

Approved: ______________________________
James G. Richards, Ph.D.
Vice Provost for Graduate and Professional Education

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: ____
Lee G. Anderson, Ph.D.
Professor in charge of dissertation

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: ____
George Parsons, Ph.D.
Member of dissertation committee

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: ____
Kent Messer, Ph.D.
Member of dissertation committee

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: ____
Sunny Jardine, Ph.D.
Member of dissertation committee

I certify that I have read this dissertation and that in my opinion it meets the academic and professional standard required by the University as a dissertation for the degree of Doctor of Philosophy.

Signed: ______________________________

Ron Felthoven, Ph.D.
Co-chair of dissertation committee

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ABSTRACT

In individual fishing quota (IFQ) programs, fisheries managers often seek to balance efficiency gains with other socioeconomic goals. Although many IFQ programs include such “protection provisions” their impacts are not well understood. This study addresses this literature gap by examining the impacts of protection provisions in the Alaska halibut IFQ program through three analytical chapters examining the costs of quota share trading restrictions, the determinants of hired skipper use, and the impacts of hired skipper use on new entry, wherein hired skipper use serves as a proxy for leasing. The first analytical chapter shows that the efficiency costs of inter-vessel class quota share trading restrictions may be high and showcases linear programming as a potential tool to estimate these costs. The second analytical chapter reveals that the probability of hired skipper use is associated with the residency and the shareholdings of the shareholder. The third analytical chapter shows that the relationship between hired skipper use and entry is complex. Whereas a counterfactual analysis of entry shows that the prohibition on the use of hired skippers in the Southeast Alaska regulatory area may have provided for greater numbers of new entrants into this area relative to the other areas, a discrete choice model of exit shows that hired skipper use is positively associated with the probability of exit for initial recipients. This research provides evidence of the tradeoffs associated with protection provisions in IFQ programs, provides more insight into how participants behave in the fishery, and reveals some attributes of shareholders that could potentially be targeted by policy makers concerned with leasing, entry, and exit rates.

Chapter 1

INTRODUCTION

1.1 Introduction and Objective

Right-based management programs under which a rights-holder is given the privilege to harvest a specified percentage of the total allowable catch (TAC) have been consistently effective at reducing overcapacity, eliminating the race for fish, rationalizing effort, achieving annual catch limits, increasing product quality and profits, and improving safety at sea (Campbell et al., 2000; Grafton, 2000; Rice, 2003; Dupont et al., 2005; Grimm et al., 2012). Rights-based management programs, known alternatively as catch shares, individual transferable quotas (ITQs), and individual fishing quotas (IFQs), are becoming increasingly popular in fisheries management. Under these programs, an initial rights-holder is usually freely allocated quota shares, which are equivalent to a specified percentage of the total allowable catch (TAC). These quota shares are translated into annual fishing pounds, either IFQs or ITQs, based on the annual TAC.

Under these programs, less efficient operators may find it more profitable to sell or lease their shares than to fish them, reducing capacity. With the exodus of operators, costs in the fishery should decrease due to both the removal of capital and the reduction of variable costs associated with that capital. Eventually this should lead to rationalized effort, wherein the number of boats and the amount of effort they can produce is the appropriate level of effort for the fishery (Anderson and Seijo, 2010).[1] Furthermore, in theory, the total cost for producing that level of output is minimized, because all participants are operating at the same marginal costs (Anderson and Seijo, 2010).

The efficiency gains realized under rights-based management programs in fisheries may, however, have negative socioeconomic impacts on some communities. The exodus of less efficient operators could mean a loss of associated employment for crews, dockside workers, processors, etc., with potential domino effects on the rest of the community. The extent of these losses depends on the degree of overcapacity in the fishery and the degree to which the community is dependent on fisheries and cannot supplement the losses with employment in other industries. In the U.S., these impacts were especially significant in the initial quota programs, including the Halibut and Sablefish IFQ (1995), the South Atlantic Wreckfish ITQ (1991), and the Mid-Atlantic Surf Clam and Ocean Quahog ITQ (1990) programs, the latter of which saw crew employment decrease by as much as 80% (Gauvin et al., 1994; McCay, 1995; Hartley and Fina, 2001; Brandt and Ding, 2008; Carothers et al., 2010). The rationalization of the Bering Sea Aleutian Islands crab fisheries in 2005 led to the loss of nearly two-thirds of the fleet in some of these crab fisheries, with seasonal crew employment decreasing by as much as 65% (NPFMC, 2010; Garber-Yonts and Lee, 2013). Although there was a significant increase in the average crew compensation for those remaining in these fisheries (Abbott, Garber-Yonts, and Wilen, 2010), the

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[1] Reimer, Abbott, and Wilen (2012) show that as vessels move out of the fishery, the average scale of operations increases for the remaining vessels, which may not always balance out with the effort reductions associated with changed incentives under secure

average share of a vessel's revenue paid to crewmembers and captains decreased from approximately 35% to about 20% (Garber-Yonts and Lee, 2013). Similar impacts were experienced in various international ITQ programs, with fleet reductions of 40% or more witnessed in Canada's sablefish and halibut and offshore scallop fisheries and in all of Iceland's sectors managed under a quota system (Aslin et al., 2001).

Consolidation resultant from the implementation of rights-based management may also have disproportionate geographic effects. Without restrictions on trading between vessels of different size classes, quota can become consolidated on larger vessels and with larger business owners (Stewart et al., 2006), which tend to be tied to larger population areas (Copes and Charles, 2004). Larger operations benefit from economies of scale and, as businesses, from access to capital and information on quota share transaction trends in the fishery (Aslin et al., 2001). Small operators may also get non-viable amounts of quota with the implementation of a rights-based program, as the institution of this type of program is often concurrent with TAC reductions (Aslin et al., 2001). This viability problem has been documented in Denmark, the U.S. surf clam fishery, and the Icelandic cod fishery (Aslin et al., 2001). Landings can also become regionally consolidated, as quota owners concentrate their fleets in larger ports, which provide ready access to processors and distributors (Copes and Charles, 2004). For example, in Iceland, the exodus of quota out of small regional municipalities led to some local authorities entering the quota share market to try to reverse the outflow; however, they were consistently outbid by those from larger centers in the same region (Aslin et al., 2001). Quota based management programs have also been associated with geographic redistribution of quota, including in the Southern Bluefin Tuna fishery (Aslin et al., 2001), the British Columbia halibut ITQ fishery (Butler, 2008), and the Alaska halibut and sablefish IFQ fishery (Carothers, 2008; Carothers, 2010; Carothers, Lew, and Sepez, 2011).

Managers seek to balance efficiency gains and the potentially adverse impacts of rights-based management on some participants and communities through various restrictions, including restricting who may purchase quota shares and how quota can be harvested and traded. For example, in the U.S., in developing management programs regional fisheries management councils and the National Marine Fisheries Service (NMFS) are required to consider the potential benefits and costs and the vulnerabilities and risks to fishermen and fishing communities resulting from the implementation of the management program. Managers employ a variety of mechanisms intended to achieve goals other than efficiency, including vessel class and area designations for quota shares and limitations on transferability across these classifications, owner-on-board requirements, individual and vessel accumulation and leasing limits, geographic landing restrictions, crew and processor shares, limitations on corporate ownership of quota shares, direct allocations to communities, community set-asides, or subsidized loan programs for communities or new entrants. In fact, these kinds of protection provisions are common, if not ubiquitous, throughout rights-based programs.

Despite the proliferation of protection provisions in rights-based management programs, there is limited literature on the impacts of specific provisions. McCay (2004) discussed how in the Nova Scotia under 65 foot dragger ITQ system despite numerous community protection measures including quota share transferability limits, ownership caps, and the separation of ownership of the fishing fleet from the ownership of processing firms, there was still pronounced consolidation, geographic redistribution of quota shares, and employment loss after the program was implemented. Dawson (2006) showed that several fleet protection measures in the Alaska halibut and sablefish IFQ program have been effective at minimizing vertical integration in the fishery.

Although research is limited with respect to assessing the intended goals of the protection provisions, there is a growing body of literature evaluating the costs of protection provisions in rights-based management programs. Others have looked at the impacts of allowing trading of quota between species groups (Anderson & Bogetoft, 2007), attenuating vessel length restrictions (Grafton et al, 2000), and accumulation limits (Lian et al., 2008), and vessel class quota trading restrictions (Dupont, 2000). Sanchirico and Kroetz (2010) provide an overview of these studies and look at the potential impacts of restricting inter-sector trading or eliminating a particular sector from the ITQ program in the West Coast groundfish fishery. Researchers have looked at the costs of provisions in the Alaska halibut IFQ program as well, including Wilen and Brown (2000) and Kroetz et al. (2014). See Chapter 2 for more details.

The following study addresses this gap in the literature by evaluating the impacts of specific provisions in the Alaska halibut IFQ program, which were intended to maintain a diverse fishing fleet, provide for a transition of the fleet to becoming fully individual-owned and owner-operated, and facilitate entry into the fishery for second-generation shareholders. The first essay in this study presents a linear programming assessment of the costs of inter-vessel class quota share trading restrictions in the halibut IFQ fishery. The second essay presents a discrete choice model analysis of the determinants of hired skipper use, as a proxy for leasing. The third essay is a compilation of three distinct analyses of the impacts of hired skipper use, again as a proxy for leasing, on entry into the fishery. The results of these analyses are described in more detail below.

1.2 Background on the Halibut IFQ Program

In the decades prior to the implementation of the Alaska halibut IFQ program participation in the Alaska halibut fishery had been increasing for several reasons. Halibut inhabit areas close to shore, which are generally accessible to many coastal residents with small boats (NMFS, 1992). Throughout the 1980s, there was an influx of fishermen into the halibut fishery due to the implementation of limited entry programs in the salmon fisheries and decreases in crab stocks. The former led to increasing participation by small vessels, while the latter led to an influx of larger vessels, both of which contributed to increasing pressure on the resource. At that time, the North Pacific Fishery Management Council (NPFMC), the management body for the federal fisheries in the North Pacific, was regulating the TAC in the fishery with a seasonal restriction so that when the TAC was harvested the fishery would close. These seasonal restrictions led to a classic race for fish wherein fishermen increasingly invested in fishing capacity and seasons became increasingly shorter, with resultant gear conflicts and abandoned gear issues (NMFS, 1992). The NPFMC recognized the need to implement a management regime that would fundamentally alter the incentive structure in the fishery, reduce overcapacity and overharvesting, and address gear conflicts.

In response in 1995 the NPFMC implemented the halibut IFQ program. Although this research focuses only on the halibut fishery, halibut and sablefish are managed together under the same IFQ program because the two fisheries are often harvested by the same participants and were subject to the same issues during the period when the NPFMC was developing the program. Management of the halibut fishery is conducted in accordance with catch recommendations of the International Pacific Halibut Commission (IPHC), which was established by a Convention between the governments of Canada and the U.S. in 1923. The IPHC sets the TACs in the fishery, while the NPFMC and the NMFS are responsible for the development, amendment, and enforcement of the IFQ program. Under the IFQ program, the NPFMC granted participants quota shares based on previous catch history, which is translated into a pound equivalent IFQ on an annual basis.

In developing the halibut IFQ program, the NPFMC focused on incorporating provisions targeted towards maintaining diversity in the fleet, limiting consolidation, providing for an eventual transition of the fleet to becoming individually-owned and owner-operated, and facilitating entry for second-generation shareholders. Amongst these provisions are quota share categorizations, individual and vessel use caps, quota blocks for quota shares below a certain size which could only be transferred as a block (with limits on the number of blocks that can be owned), an owner-on-board mandate for second-generation shareholders, and a limit on quota share acquisition by second-generation shareholders.

Quota shares in the program are both vessel class and area specific, with eight management areas (Areas 2C, 3A, 3B, 4A, 4B, 4C, 4D, and 4E) (see Figure 1.1) and four vessel classes. The vessel classes are designated on the basis of how they can operate, as either catcher processors (designated as Class A shares) or catcher vessels (designated as Class B shares for vessels greater than 60 feet, Class C shares for vessels 36 to 60 feet, and Class D shares for vessels under 36 feet). Catcher processor, or Class A, shares are associated with an onboard processing privilege, whereas catcher vessel quota must be landed at a shoreside processing facility. Areas 2A and 2B are not part of the IFQ program, because the former is managed by the states of Washington, Oregon, and California, while the latter is in Canadian waters. Quota shares in Area 4E were wholly allocated to the Community Development Quota (CDQ) program, a fisheries and economic development program for Western Alaskan communities. The NPFMC prohibited quota share transferability by area, to limit localized pressure on any one part of the halibut stock, and by vessel class, to maintain fleet diversity (NMFS, 1992). The removal of small vessels, which were the most closely tied to communities and which provided the most opportunities for people to participate in the fishery, was viewed as potentially socially and economically detrimental to some participants and communities (NMFS, 1992). Catcher processors, which comprise a small portion of the total shares in the fishery, were already largely corporate-owned when the IFQ program was developed; therefore, these shares are not subject to restrictions on the length of the vessel upon which they can be harvested or the use of hired skippers, described in more detail in Chapter 3 (NMFS, 1992).

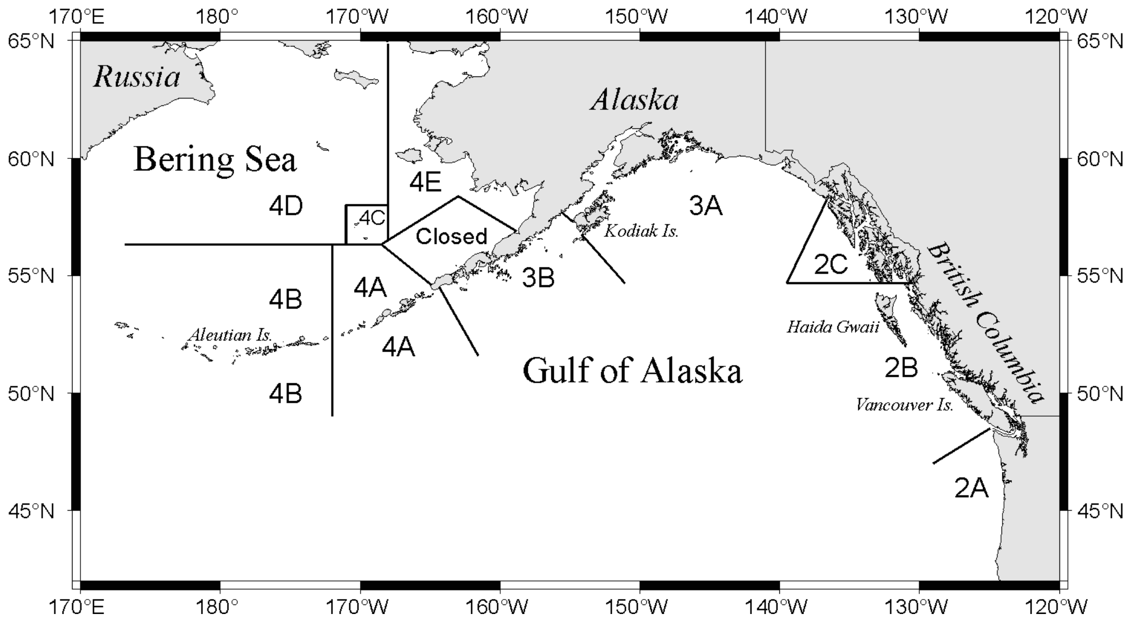

Figure 1.1: International Pacific Halibut Commission (IPHC) halibut regulatory areas. Reproduced from www.alaskafisheries.noaa.gov

The NPFMC implemented numerous other provisions with social objectives. The individual and vessel use caps were instituted to prevent consolidation in the fishery. In order to maintain an owner-operator fleet, the NPFMC implemented a ban on leasing (except for the catcher processor class) and developed an owner-on-board mandate for second-generation catcher vessel quota shareholders. Initial quota share recipients are allowed to use hired skippers (someone designated to fish a shareholder's annual IFQ allocation), except in Area 2C. The NPFMC also sought to prevent excessive consolidation, maintain the diversity of the IFQ fleet, and facilitate entry into the fishery by blocking quota share units that resulted in less than 20,000 pounds of initially issued IFQ from being divided for transfer purposes. In other words, quota share blocks that resulted in less than 20,000 pounds of IFQ were transferred as a block and shareholders could not own more than two blocks of quota shares per area or one block and any unblocked shares in that area (Federal Register, 2007). Individual blocks of less than 1,000 pounds could be "swept up" into a block of 1,000 pounds or less. The NPFMC also added a "buydown" of "fish down" provision in 1996, wherein catcher vessel quota shares for larger size vessel classes could be used on smaller class vessels (e.g. Class B quota shares could be fished on Class C or D vessels and Class C quota shares could be fished on Class D vessels). This provision was implemented to address the scarcity of large to medium size quota share blocks in some areas and to help maintain smaller vessels in the fishery (Dawson, 2006).

Many of these provisions have been amended over the nearly two decades since the implementation of the IFQ program due to the evolution of the fleet and the changing needs of stakeholder groups. Early on in the program, it became apparent that the block program was too restrictive and that the amount of quota shares that were allowed to be swept up was too small to provide economically fishable amounts of quota shares. The NPFMC amended the provision to allow sweep ups of quota shares up to 3,000 pounds (Pautzke and Oliver, 1997). In 2003, the NPFMC implemented an amendment to the halibut IFQ program allowing Area 4C quota shares to be fished in Area 4D, due to issues with localized depletion in Area 4C and issues with the capacity of quota shareholders in Area 4C to harvest their full allocation. The NPFMC has also increased the number of blocks that quota shareholders can own, increased the sweep up levels in some areas, and allowed larger vessel classes to fish the quota shares from smaller classes in some areas. For the most part, amendments in the halibut IFQ program have been toward loosening restrictions, largely in response to industry proposals and testimonies that certain provisions in the program were too restrictive. One exception to this has been a recent amendment to place some restrictions on the use of hired skippers by initial quota share recipients in the program, which is explained in Chapter 3.

1.3 Summary of Dissertation Findings

Chapter 2 presents a linear programming model of the economic costs of quota share trading restrictions between vessel classes in the halibut IFQ fishery. This study adds to a growing body of literature examining the costs of quota share trading restrictions in rights-based management programs. The costs of the inter-class trading restrictions are estimated as lost potential economic rent from 2007 through 2011. The quota trade restrictions are simulated as constraints in the linear programming models, with the maximized objective function representing the rent generation possible under less restrictive regulations. Regulatory vessel use caps (simulated as constraints in the models) are applied as a proxy for capacity limits of the vessel classes constraining potential rent gains. The results of this study indicate that rents in the halibut IFQ fishery could increase by as much as 8% to 28% if restrictions on inter-class trades were less restrictive. There are several limitations to this analysis including the use of average quota share prices for vessel classes as opposed to prices from individual transactions and the inherent limitations of linear programming, which provides a corner solution. Nevertheless, this study does provide some evidence of the costs of the quota share trading restrictions in the IFQ program and should be considered within a broader context that includes other studies of these costs.

Chapter 3 presents a discrete choice model of the determinants of hired skipper use for catcher vessel shareholders, as a proxy for leasing. Individual initial recipients of catcher vessel quota shares in the halibut IFQ program are allowed to use hired skippers to harvest their annual IFQ allocation, with the exception of Area 2C, which corresponds to Southeast Alaska. Since the implementation of the halibut IFQ program there has been an increasing reliance on hired skippers by initial quota share recipients in relationships that are often functionally equivalent to leasing, with hired skippers harvesting quota for shareholders who have only nominal stakes in vessels. This has frustrated the NPFMC's efforts to transition the IFQ catcher vessel fleet to a group of owner-operators. This study shows that the probability of hiring a skipper is statistically significantly related to the residency and shareholdings of shareholders and identifies potential attributes of shareholdings, including quantity and diversity, which may contribute to greater hired skipper use. These attributes are identified within a context of increasing research showing that leasing may result in the diminishment of some of the benefits associated with implementing a catch share program, especially with respect to safety and a stewardship ethic for the resource. This information may allow fishery managers to both predict the degree of such practices and customize regulations to lead to their preferred outcomes in program design or modification.

Chapter 4 addresses the ongoing debate amongst researchers about the impacts of leasing upon entry by empirically assessing the role of hired skipper use, as a proxy for leasing, in facilitating or impeding entry into the halibut IFQ fishery. This study is comprised of three parts, each of which applies a different methodology and examines a different aspect of the impacts of hired skipper use upon entry. In the first part of this study, shareholders and hired skippers are characterized, over the 2000 through 2013 timeframe of the dataset, with respect to whether they are initial recipients or second-generation shareholders, their shareholdings, and how they fish their IFQ. This analysis shows that second-generation shareholders now comprise the majority of hired skippers for initial recipient shareholders of catcher vessel quota shares and that despite an increasing reliance on hired skippers by these shareholders, there has not been an increase in hired skippers, who do not own quota shares. This analysis is extended with a relational contingency table assessment of hired skipper and shareholder networks in the fishery, which does provide some evidence of homophilic networks between these actors especially with respect to both residency and the amount of shareholdings. In the second section of this study, a counterfactual analysis is used to examine the impacts of the prohibition on individual use of hired skippers and corporate ownership of catcher vessel shares upon entry in Area 2C, showing that the number of new entrants into this area is greater than would have otherwise been expected given average conditions across the other areas. The higher actual number of new entrants into Area 2C is attributed to the regulations limiting hired skipper use and corporate ownership of shares. The third section of this study applies a discrete choice model analysis to assess the determinants of exit for shareholders in the IFQ fishery, showing a very weak but positive relationship between hired skipper use and exit from the fishery. In summary these analyses show that prohibiting hired skipper use completely may facilitate entry into a fishery, but, wherein hired skipper use is already allowed, acting as a hired skipper may provide new entrants with the additional income necessary to be able to purchase quota shares.

In summary, these three chapters provide greater insight into the impacts of specific provisions in the halibut IFQ program. Chapter 2 shows that quota share trading restrictions are likely costly in terms of affecting the economic efficiency gains that could be expected with unrestricted quota shares. However, the benefits of these kinds of restrictions, with respect to providing employment opportunities are not quantified. Given that the halibut fishery provides employment opportunities in isolated coastal communities throughout Alaska with few alternative employment prospects, the benefits of quota share trade restrictions should be considered. Chapters 3 and 4 assess the hired skipper provision, which is an increasingly contentious issue in the halibut IFQ fishery. Both of the analyses in these last two chapters indicate that consolidation is a significant factor in how shareholders operate, as shareholders with larger holdings are more likely to use hired skippers and to stay in the fishery. Furthermore, the degree of consolidation in an IFQ area is associated with fewer new entrants. Given that the NPFMC intended to provide for a transition of the catcher vessel halibut IFQ fleet to becoming fully owner-operated and that it has expressed frustration at the slow transition to a class of second-generation owner-operators in the fishery, the potential impacts of consolidation should be understood in any future regulatory considerations, especially as some shareholders in the fishery continue to push for an increase in the individual and vessel use caps. However, restrictions on consolidation are likely to impede potential economic efficiency gains, as shown in the first analysis of this dissertation. Therefore, the NPFMC and managers facing similar challenges in other rights-based managed fisheries should consider the potential trade-offs in economic efficiency and other social objectives with limiting consolidation, allowing hired skipper use, and facilitating entry into the fishery.

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Chapter 2

ESTIMATING THE COSTS OF QUOTA SHARE TRADING RESTRICTIONS IN THE ALASKA HALIBUT IFQ FISHERY

2.1 Introduction

In fisheries, rights-based management programs have been consistently effective at reducing overcapacity, eliminating the race for fish, rationalizing effort, achieving annual catch limits, increasing product quality and profits, and improving safety at sea (Campbell et al., 2000; Grafton et al., 2000; Rice, 2003; Dupont et al., 2005; Grimm et al., 2012). The fundamental idea is that providing participants with a privilege that in essence guarantees them a portion of the TAC will provide them with the incentive to maximize the value of their allocation, and thereby lead to more economically efficient behavior. These types of programs, however, may have adverse impacts on coastal communities as many of these gains are realized through the exodus of less efficient operators and the associated loss of employment from these communities (Gauvin et al., 1994; McCay, 1995; Hartley and Fina, 2001; Brandt and Ding, 2008; Carothers et al., 2010; Abbott, Garber-Yonts, and Wilen, 2010). Managers, therefore, often implement provisions into rights-based programs to minimize adverse impacts on coastal communities, which in turn restrict the capacity of the shareholder in the fishery to optimize the value of his privilege, and thereby restrict economic efficiency gains.

The focus of this paper is on the economic costs associated with these types of protection provisions in rights-based management programs. Specifically, the paper examines the quota share (QS) trading restrictions in the Alaskan halibut IFQ program. Recall from Chapter 1 that the NPFMC classified quota shares by area and vessel class and prohibited trading between these categories. The categorization of QS by four vessel classes and eight management areas, and the prohibition of QS transfers between these categories, led to the emergence of 32 separate QS markets in the halibut IFQ program.[2] The focus on trading restrictions is important because of their use in many rights-based management programs. This paper explores the potential efficiency gains that could be possible with less restricted QS trading and what trading in this modified QS market would likely look like. In other words, how does the maximum rent in the fishery change when inter-class trading is allowed, given an annual total allowable catch (TAC), and a set of production choices with varying marginal values of production? Regulatory use caps, which limit the amount of quota that can be landed on a vessel, are applied as proxies for capacity limits of the vessel classes, restricting the potential efficiency gains and providing a lower bound for the range of economic costs.

The chapter is organized as follows. The first section reviews the literature on studies of the costs of QS trading restrictions in other programs, the economic tradeoffs of various regulatory goals, and the costs of other provisions in the Alaskan halibut IFQ program. This is followed by a definition of the problem in terms of the incentives that exist under rights-based management programs, an overview of linear programming as the empirical tool used in this analysis, and a section on the data and the data manipulation to estimate IFQ prices. The next sections present the linear

[2] Area 2B is in Canadian waters and Area 2A is shared by the states of Oregon, Washington, and California. These areas are, therefore, not included in the halibut IFQ program. The TAC in Area 4E is strictly allocated to the Community Development Quota (CDQ) program.

programming models and analyses of the results. The final section interprets the results within the broader context of fishery management policy and presents the potential limitations of this linear programming approach.

2.2 Literature Review

Several studies have looked at the costs of QS trading restrictions in rights based managed fisheries. Dupont (2000) conducted an ex-ante study of inter-sector trading restrictions in the British Columbian salmon fishery, showing that total resource rent could increase by as much as 1% if inter-sector trading were permitted. Lian et al. (2008) estimated the losses of inter vessel class quota trading restrictions in the West Coast groundfish fishery at 10% of the reduction in costs that could be expected with the implementation of an IFQ program. Kroetz and Sanchirico (2010) estimated the costs of restricting quota trading between gear types in the West Coast sablefish fishery could be as much as 40% of ex-vessel revenue.

Researchers have also evaluated the costs of quota trading restrictions specifically within the Alaskan halibut and sablefish IFQ program. Using quota prices in the halibut IFQ fishery, Wilen and Brown (2000) estimated the efficiency losses of blocking quota in the program at \$55 million of net present value. (See Chapter 1 for an explanation of the blocking program). Researchers have also evaluated the costs of inter-class trading restrictions. At the time the halibut IFQ program was being implemented analysts for the Environmental Impact Statement (EIS) estimated that the total annual benefits of the program would range from \$30.1 to \$67.6 million and that the costs of restricting trading between the vessel classes would be between \$11 to \$13.9 million, or 16% to 46%, of the estimated benefits (Pautzke and Olivier, 1997). The researchers used models of the harvesting costs across the vessel classes to estimate the costs of the quota share trading restrictions. Kroetz, Sanchirico, and Lew (2014) used reduced form regression models to evaluate the costs of restricting quota trade in the halibut IFQ program, including inter-class restrictions, blocked quota, and accumulation caps. They found that the costs of the restrictions ranged from 25 to 41% of the value of the halibut fishery from 2000 through 2011 (ibid.).

In comparison, the analysis in this chapter estimates the costs of restricting trading between vessel classes at 6 to 8% of the estimated rent. The differences in these estimates may be attributed to several factors. First, the EIS analysts were looking at differences in operating costs between participants in the early 1990s. It is likely that because the program has been in existence for nearly 20 years, the less efficient operators have left the fishery, and, therefore, that the differences in the operating costs between the vessel classes have decreased. Second, regulatory changes in the program now allow QS of different vessel classes to be harvested on vessels of smaller or larger classes depending on the area. Although this does not mean that inter-class QS trading is allowed, it could affect the price differentiations between the classes. Differences in the estimates between the study below and that of Kroetz, Sanchirico, and Lew (2014) may be due to their inclusion of other trading restrictions (blocked quota and accumulation caps), which would presumably raise their estimates of the total costs of the restrictions. Furthermore, they included Class A shares in their analysis, which have significantly higher quota share prices than the catcher vessel classes because of the processing on board allowance.

2.3 Problem Definition

The basic concept of rights-based management programs is that owners of the production rights will have incentives to organize their production such that the value of their rights is maximized. Recall that the rights holder is allocated quota shares (QS), a guaranteed percentage of the TAC that is annually translated into fishable pounds, known as individual fishing quota (IFQ). As long as the rights are transferable, the rights holder has the choice to either harvest his IFQ or sell his QS. This analysis is limited to quota share sales, because leasing (selling IFQ) is technically not allowed in the IFQ program. The basic rule is that the rights holder will harvest his own IFQ as long as he can earn more from doing so than from selling his QS on the market. Rights holders with lower marginal operating costs will have higher willingness to pay for IFQ. Through this process, there will be a tendency for the production rights to end up with the most efficient operators and the value of production in the fishery will be maximized. Although this may not always be the case, these are the incentives that are created by a rights-based management program.

The IFQ price represents the value of a unit of harvest, or the resource rent attributable to the scarcity value of the fish. Total rent in the fishery, therefore, can be estimated as the product of the IFQ price and the TAC. In order to maximize rent in the fishery, the TAC should be allocated to those with the highest willingness to pay for the IFQ, or trades should be allowed such that these shareholders can purchase IFQ from those with lower willingness to pay for the IFQ. In this study, these concepts are applied on a vessel class level. That is, the value of production in the fishery is maximized by allocating the production rights (the IFQs) to the vessel class with the highest willingness to pay for them (the highest IFQ price).

Out of the 32 IFQ markets in the halibut fishery, this study is limited to 15 due to data issues described below. Five years were modeled in this study, 2007 through 2011. For each of these years, there is a set of 15 possible production choices (for three vessel classes in five areas) corresponding to a set of 15 IFQ prices and a given amount of harvest available each year for the fishery as a whole, the total allowable catch (TAC). Currently, the TAC is allocated amongst the production choices mostly on the basis of initial program allocations. The problem is to identify how much should be harvested by each production choice in order to maximize the rent in the fishery, when these choices are constrained by the TACs. The linear programming model uses the IFQ prices of the production choices to allocate the TAC such that rent is maximized.

2.4 Summary of the Linear Programming Approach

In this study, linear programming (LP), a mathematical modeling tool, is used to assess how to maximize rent in the halibut IFQ program. Given 15 production choices with 15 corresponding IFQ prices and a set annual TAC, LP is used to maximize rent in the fishery subject to a set of constraints. These constraints mimic several different IFQ trading scenarios between the production choices.

In brief, in a LP problem, the optimization of a linear objective function is subject to a set of linear equality and inequality constraints, which define the feasible region, or the production possibility set, from which an optimal solution is determined. The optimal solution is the point where this function has the largest or smallest value, an extreme point on the feasible region. The basic structure of a LP problem is:

$$\text{Max: } Z = cx$$

$$\text{s.t.: } Ax \leq b$$

$$x \geq 0$$

where c is a defined vector of coefficients, x is a vector of decision variables that is to be determined, and cx is the objective function to be optimized.

where A is a known matrix of coefficients and b is a known vector of right-hand side values for the constraints that bind the objective function.

In the LP models in this study, the maximization of the total rent in the halibut fishery is the linear objective function to be optimized. The harvests by the production choices are the decision variables (the vector x). The IFQ prices are the coefficients (vector c) of the decision variables. The objective function is to maximize (Z), the total rent in the fishery, which is the product of these two vectors (cx).

The LP modeling technique allows the introduction of constraints on these production choices, such that the constraints capture the conditions imposed by the IFQ trading restrictions in the halibut IFQ program. These restrictions are loosened iteratively in the models through changes to the constraints. The right hand side values of the constraints (vector b) will be the sum of the TACs that can be harvested by the production choices on the left hand side of the constraints. These amounts are decided based upon the IFQ trading scenarios of the model. The matrix A (zeros and ones) defines which production choices on the left hand side are trading with each other. The solutions to the models provide an estimate of the rent generation possible under the various IFQ trading restrictions. A set of constraints that mimic the capacity limits of the vessel classes are added to a second iteration of these models. For these constraints, the right hand side value is the maximum amount that can be harvested by the production choice on the left hand side, given the capacity limit of production for that production choice.

2.5 Data and Estimation of IFQ Prices

2.5.1.1 Data

In order to be able to develop these LP models, three types of data are needed: 1) the vector of the TACs, 2) the vector of the IFQ prices, and 3) the numbers of vessels for each of the production choices. The numbers of vessels for each of the production choices will be used to build the vessel use cap constraints, as described in the Models section below. The TACs and the IFQ prices for the set of production choices will be used to build the LP models. The data for the TAC vector is actually the vector of harvests in the given year. It is assumed that these harvests serve as a good proxy for the TAC allocations for the production choices, since over 95% of the TAC is harvested on an annual basis. The harvest data for the vector of TACs is available. Because IFQ transfers are not allowed between catcher vessel quota shareholders, only QS transfer data are available. Therefore, the vector of IFQ prices is not available, but the vector of QS transfer prices, from which IFQ prices can be estimated, is available. However, some of the values in this QS transfer price vector are missing, due to confidentiality issues. In order to be able to present a more complete picture of what QS transfers would look like when some trading restrictions are loosened and to not bias the results by excluding production choices that did not have prices listed for their QS sales for a particular year, the missing prices for the production choices in each modeled year are estimated using an OLS regression with dummy variables. The data acquisition task is, therefore, twofold: 1) find the missing values of the QS transfer prices, and then 2) estimate the IFQ prices from the QS transfer prices.

The average QS transfer prices and number of trades for the set of production choices, and the area-wide TACs are used in estimating the missing QS transfer prices. The area-wide TACs rather than the harvests for the set of production choices are used in estimating the missing QS transfer prices, because the halibut IFQ program allows vessels of a smaller class to purchase QS and harvest the IFQ derived from it for QS designated for larger class vessels, and in some areas, vice versa. Therefore, it is assumed that QS holders consider the area-wide TACs in making their decisions about QS transfers.

In summary, the dataset used for this study includes the average QS transfer prices, harvests, and number of vessels for the set of production choices, the area-wide TACs, and the number of trades used to calculate the QS transfer prices, for the modeled years, 2007 through 2011. The available QS transfer prices, the area-wide TACs, and the numbers of trades are used to estimate the missing QS transfer prices. The vector of IFQ prices is estimated from the vector of QS transfer prices, and along with the harvests and number of vessels for the set of production choices, is used to build the LP models.

The dataset used to estimate the missing QS transfer prices covers the years from 2000 to 2011, due to changes in reporting requirements in 2000 and other data quality issues, with a total of 140 observations on QS sales. Quota shareholders must submit a QS transfer application to the NMFS Restricted Access Management Office when making QS transfers. The application asks the seller to identify the halibut regulatory area and vessel class of the QS, number of QS units being transferred, the NMFS id's of the seller and of the buyer, and whether the seller wants all of the remaining pounds for the current fishing year to be transferred, since QS has associated IFQ pounds that may or may not have been harvested by the QS holder at the time of the transaction. The QS price estimate used for this analysis is the QS price in dollars per pound of associated IFQ, which is a comparable measure across the regulatory areas.[3]

Table 2.1 shows the QS transfer prices for the set of production choices and modeled years. The QS transfer prices were missing for the production choices, for which QS transfer prices are bolded. Ultimately, 25% of the QS transfer prices utilized in these models were missing and were estimated by the regression results. Table 2.1 also includes the area-wide annual TACs for each modeled year that were used to estimate the missing QS transfer prices. The TACs decreased over the five modeled years, except in Area 2C, where they actually increased during that time.

Table 2.1: Quota share transfer prices by vessel class, area, and year, and area TACs. The area TACs are in million pounds. The QS transfer prices that were missing in the NMFS report and were estimated by the regression are in bold.

Area	Class	2007 QS Price	Area TAC	2008 QS Price	Area TAC	2009 QS Price	Area TAC	2010 QS Price	Area TAC	2011 QS Price	Area TAC
2C	> 60	18.42	8.51	23.38	6.21	**22.57**	5.02	**22.07**	4.4	42.94	2.33
	36-60	20.55	8.51	27.70	6.21	20.49	5.02	23.57	4.4	29.47	2.33
	< 36	15.87	8.51	19.51	6.21	17.02	5.02	19.67	4.4	29.17	2.33
3A	> 60	21.32	26.2	28.31	24.2	25.91	21.7	23.07	19.9	33.52	14.3
	36-60	20.14	26.2	26.60	24.2	24.27	21.7	19.89	19.9	32.06	14.3
	< 36	18.59	26.2	23.02	24.2	18.07	21.7	21.04	19.9	29.69	14.3
3B	> 60	11.34	9.2	25.2	10.9	18.2	10.9	19.45	9.9	25.34	7.5
	36-60	18.35	9.2	27.23	10.9	**17.77**	10.9	18.27	9.9	23.87	7.5

[3] QS prices in dollars per pound of associated IFQ are more comparable across areas and vessel classes than QS prices in dollars per QS unit because the ratio of IFQs to QS differs between areas and years (NMFS, 2011). In other words, because IFQ is determined by dividing the shareholders' QS holdings by the total QS for the area-vessel class combination (the quota share pool), the QS has different values across these different combinations.

	< 36	**11.66**	9.2	**16.62**	10.9	**14.06**	10.9	**13.56**	9.9	**19.13**	7.5
4A	> 60	14.29	2.89	16.92	3.1	**16.91**	2.55	13.16	2.33	15.29	2.41
	36-60	13.98	2.89	16.56	3.1	**17.35**	2.55	11.24	2.33	16.86	2.41
	< 36	9.27	2.89	5.96	3.1	**13.64**	2.55	**13.14**	2.33	**18.71**	2.41
4B	> 60	8.97	1.15	9.96	1.48	10.16	1.49	8.71	1.72	10.76	1.74
	36-60	**10.6**	1.15	**15.55**	1.48	10.8	1.49	12.50	1.72	11.33	1.74
	< 36	**6.89**	1.15	**11.85**	1.48	**9.29**	1.49	**8.79**	1.72	**14.36**	1.74

Several areas and one vessel class had to be omitted from the models in this study. There were not enough data points of priced QS transactions to include Areas 4C and 4D or the freezer class in any area. Because there are very few freezer vessels that participate in the halibut IFQ program, there are confidentiality issues associated with reporting prices of QS or IFQ transfers. It is assumed that the omissions of Areas 4C and 4D and the freezer class from the models will not have a substantial effect on the estimates generated, because these areas account for only 4 to 6% of the total harvest, and the freezer class harvest accounts for about 2 to 5% of the total harvest in each area. The resulting set of QS transfer prices is for 15 production choices (three vessel classes in five areas – 2C, 3A, 3B, 4A, and 4B) for each of the modeled years.

2.5.2 Estimating Missing Quota Share Transfer Prices

To estimate the missing QS transfer prices, the fact that the mean QS transfer price paid will differ by year, area and vessel class needs to be recognized. To accommodate different mean prices for the years, areas, and vessel classes, dummy intercepts for each of these categories are included. Given that there are 5 years, 5 areas and 3 vessel classes there are a total of 13 parameters estimated as intercepts. The reference category is the average QS transfer price for the less than 36-foot vessel class in area 3B for the year 2011, as this is one of the missing values in the dataset.

Therefore, the other missing QS transfer prices are calculated in relation to this reference price. The QS transfer price by year, vessel class, and area is estimated as:

$$P_{QS} = C + \sum_{i=1}^{I} B1_i D1_i + \sum_{j=1}^{J} B2_j D2_j + \sum_{z=2000}^{2010} B3_z D3_z + B4 * SALES + B5 * TAC \quad (2.1)$$

where C is the intercept term,

where I=4 and 1=area 2C, 2=area3A, 3=area4A, and 4=area4B,

where J=2 and 1=the greater than 60 foot vessel class, and 2=the 36 to 60 foot vessel class,

where Z is the fixed effects variable for each of the years 2000 through 2010.

The results of this regression are presented in Table 2.2. With 140 observations and 20 estimated parameters, there are 120 degrees of freedom. The parameters for year, area, and vessel class were statistically significantly different for all of the categories. The parameters for the number of trades and the TAC were not statistically significant likely because the model predicts different mean values for quota share prices among the area, vessel class, and year combinations and there is likely not enough variation in the values for the TAC and the number of trades in order to effect meaningful change in the value of the quota share price, given all these dimensions that are accounted for in the value of the price. Other model diagnostics are included in Table 2.2.

Table 2.2: QS transfer price regression results. Standard errors are in parentheses, where *** p<0.01, ** p<0.05, and * p<0.1.

Variables		Variables	
Area 2C	3.23***	Year 2000	-16.81***
	(0.85)		(1.23)
Area 3A	3.98***	Year 2001	-16.21***

	(0.85)		(1.3)
Area 4A	-3.33***	Year 2002	-17.42***
	(0.91)		(1.28)
Area 4B	-7.08***	Year 2003	-16.39***
	(0.97)		(1.29)
36-60 Feet	3.39***	Year 2004	-12.75***
	(0.8)		(1.31)
> 60 Feet	3.6***	Year 2005	-10.54***
	(0.76)		(1.28)
No. Trades	-0.6	Year 2006	-10.17***
(100K)	(0.0)		(1.29)
TAC (100K)	-0.6	Year 2007	-8.59***
	(0.0)		(1.25)
Constant	22.56***	Year 2008	-3.87***
	(1.15)		(1.22)
		Year 2009	-7.07***
			(1.35)
		Year 2010	-7.55
			(1.26)
Observations	140		
R2	0.87		
Std. Error of Regression	2.94		
F-Statistic	40.88		

2.5.3 Estimating the IFQ Prices

The next step of this analysis is to derive the IFQ prices for all 15 production choices and modeled years from the QS transfer prices. The IFQ price reflects what the commercial sector is expecting to earn in the current year from an extra pound of halibut, after selling the halibut caught and paying marginal costs, and the QS transfer price reflects the expected present value of that extra unit to future production (Wilen, 2000; Newell et al., 2007). Quota share transfer prices reflect expectations about prices, costs, and the TACs in the future, and if those conditions are expected to be similar to the current conditions, than IFQ prices provide information on QS transfer prices. The IFQ prices can be derived from the QS transfer prices due to the relationship between these two values and some assumptions. While IFQ prices reflect information about current profitability, QS transfer prices reflect information about expectations about future profitability. When current conditions can be expected to hold in the future, QS transfer prices can be estimated as a multiple of IFQ prices taking into account the time value of money, such that (Wilen, 2000):

$$P_{QS}(t) = [P_{IFQ}(t)]*k \tag{2.2}$$

where k = (1/r) and r is the discount rate (r) for a comparably risky investment.

Based on lease and transfer prices reported in the Alaskan halibut fishery, the multiple "k" is in the range of 6 to 8, suggesting implied discount rates of 12 to 15% (Wilen, 2000).

In the halibut IFQ program, QS transfer prices are available and IFQ prices have to be estimated. Holding the TAC, ex-vessel prices, and costs constant, the QS transfer prices are discounted to estimate the IFQ prices. (Issues associated with discounting this way are addressed in the conclusions.) The equation predicting IFQ prices from QS transfer prices is then:

$$P_{IFQ}(t) = P_{QS}(t)/k \tag{2.3}$$

A 12 % discount rate is applied in this study (Wilen, 2000). Although such a discount rate may be considered high, this study focuses on the percentage differences between the estimated rents under different IFQ trading restrictions, which would not change with the application of different discount rates. However, it does have implications for comparing the estimated rents under the different trading scenarios to the estimated value of the fishery and to the cost estimates of these trading restrictions of other researchers, which are explored more in the conclusions.

2.5.4 Summary Statistics for the IFQ Prices

In Table 2.3, the summary statistics for estimated IFQ prices are presented. The table shows that there is significant heterogeneity in IFQ prices across the areas, with prices decreasing towards areas 4A and 4B. The mean and median prices across all vessel classes in area 4B are less than half the mean and median prices in areas 2C and 3B. Furthermore, the greatest maximum prices for all the vessel classes occur in areas 2C and 3A. The decreasing IFQ prices towards the Aleutians are likely due to several factors. First, the competition for QS is likely higher in areas 2C and 3A, which are comprised of several population centers. Second, ex-vessel prices are likely higher in these areas because of competition amongst a greater number of processors and because access to roads and airports allows relatively easy shipment outside of Alaska. Processors out in the Aleutians often have to deal with hazardous weather conditions that make shipment unpredictable. The standard deviation for the IFQ prices is the largest for the greater than 60 foot vessel class in Area 2C, where the average IFQ price in 2011 was over double the price for this production choice in 2010 (see Table 2.3).

Table 2.3 also shows the disparity in prices between the vessel classes. The greater than 60-foot vessel class tends to have the highest mean and median IFQ prices, except in areas 3B and 4B, where the 36 to 60 foot vessel class has higher prices. Assuming that the different vessel classes are, on average, selling at the same ex-vessel price, the differences in the IFQ prices can be attributed to differences in marginal operating costs across the vessel classes. The larger vessel classes will tend to have lower marginal operating costs due to economies of scale. This means that when trading is allowed between vessel classes, the reallocated IFQ will tend to go to the larger vessel classes.

Table 2.3: Summary statistics of IFQ prices by vessel class and area, 2007 through 2011 (2009$).

	2C	3A	3B	4A	4B
> 60 Feet					
Mean	3.09	3.18	2.39	1.82	1.17
Median	2.69	3.12	2.36	1.78	1.21
Maximum	5.01	3.91	3.06	2.06	1.26
Minimum	2.28	2.64	1.41	1.60	1.06
Std Dev	1.09	0.51	0.67	0.17	0.08
36 – 60 Feet					
Mean	2.94	2.96	2.57	1.79	1.42
Median	2.86	2.92	2.27	1.87	1.33
Maximum	3.44	3.74	3.31	2.02	1.82
Minimum	2.47	2.42	2.22	1.36	1.27
Std Dev	0.45	0.55	0.47	0.26	0.23
< 36 Feet					
Mean	2.43	2.66	2.06	1.40	1.21
Median	2.37	2.55	1.87	1.42	1.01
Maximum	3.40	3.47	2.64	2.25	1.81
Minimum	1.96	2.18	1.73	0.73	0.85
Std Dev	0.57	0.51	0.38	0.56	0.40

2.6 The Linear Programming Models

2.6.1 The Notation for the Linear Programming Models

To introduce the notation for the study, let TAC_{ij} be the amount of TAC that is allocated to the j^{th} vessel class in the i^{th} area,

where *i* equals 1 to 5, and 1= area 2C, 2=area 3a, 3=area3b, 4=area4a, and 5=area4b, and

where *j* equals 1 to 3, and 1=the greater than 60 foot vessel class, 2=the 36 to 60 foot vessel class, and 3=the less than 36 foot vessel class. There is a vector of 15 possible ways of producing fish corresponding to these five areas and three vessel classes.

Let X_{ij} be the amount of harvest by j^{th} vessel class in the i^{th} area. (In the current case, $X_{ij} = TAC_{ij}$ for each production choice, but this will not be true when trading is allowed between production choices).

Let P_{ij} be the IFQ price for all production choices.

Using the above notation, the LP models can be described in the following way. The decision variables in the LP models (or the vector x) are the harvests by the production choices (X_{ij}). The IFQ prices (P_{ij}) are the coefficients (vector c) of the decision variables. The linear objective function is to maximize (Z), the total rent in the fishery, which is the product of these two vectors (cx). The right hand side values of the constraints (vector b) will be the sum of the TACs (ΣTAC_{ij}) that can be harvested by the production choices on the left hand side of the constraints.

The P_{ij} and TAC_{ij} for the set of 15 production choices and five modeled years are shown in Table 2.4. This is the data used to build the LP models. Using these data, five different trading scenarios were modeled for the halibut fishery.

Table 2.4: IFQ Prices and TACs by production choice and year. TACs are in 100,000 pounds.

Class	Year	2C IFQ Price (ij)	TAC (ij)	3A IFQ Price (ij)	TAC (ij)	3B IFQ Price (ij)	TAC (ij)	4A IFQ Price (ij)	TAC (ij)	4B IFQ Price (ij)	TAC (ij)
>60	2007	2.28	3.55	2.64	96.96	1.41	51.04	1.77	16.53	1.11	8.71
	2008	2.84	2.73	3.44	89.17	3.06	59.30	2.06	17.40	1.21	10.86

	2009	2.69	2.06	3.12	79.71	2.19	59.72	1.90	14.92	1.22	9.67
	2010	2.65	1.91	2.80	74.82	2.36	54.91	1.60	13.46	1.06	11.20
	2011	5.01	.98	3.91	53.33	2.96	40.81	1.78	13.54	1.26	12.36
36-60	2007	2.55	66.07	2.50	139.18	2.27	35.63	1.73	8.13	1.27	1.42
	2008	3.37	48.45	3.22	128.74	3.31	41.27	2.02	8.83	1.82	1.79
	2009	2.47	38.51	2.92	114.33	2.27	40.61	1.87	7.07	1.30	1.74
	2010	2.86	34.50	2.42	107.63	2.22	38.84	1.36	6.64	1.37	1.79
	2011	3.44	18.15	3.74	76.27	2.79	28.19	1.97	6.90	1.33	2.42
<36	2007	1.96	11.63	2.30	16.79	1.73	2.76	1.15	1.96	0.85	0.19
	2008	2.37	8.62	2.79	15.87	2.27	3.24	0.73	2.08	1.41	0.06
	2009	2.05	6.73	2.18	13.94	1.87	3.1	1.46	1.63	1.01	-
	2010	2.39	6.13	2.55	13.32	1.82	2.93	1.42	1.53	0.97	0.07
	2011	3.40	3.27	3.47	9.29	2.64	2.25	2.25	1.56	1.81	0.09

2.6.2 Model 1: Current Quota Trading Restrictions

The operation of the fishery with all of the current IFQ trading constraints can be represented by the following LP problem:

$$\text{Maximize: } H = \Sigma P_{ij} X_{ij} \tag{2.4}$$

The objective function is to find the vector of production choices that maximizes the total rent, subject to the following 30 constraints:

$X_{ij} \leq TAC_{ij}$ For each of the 15 possible production choices (15 constraints) (2.5)

$X_{ij} \geq 0$ For each of the 15 possible production choices (15 constraints) (2.6)

The first set of constraints (2.5) limits the harvest amount for each production choice to its current TAC allocation. The second set of constraints (2.6) ensures that the harvest by each production choice is greater than zero. The solution will involve each of the vessel classes in each of the areas harvesting their current allocations and will provide the maximum rent potential under the current IFQ trading restrictions.

2.6.3 Model 2: Relaxing the Constraint on Quota Share Trading between Vessel Classes

The operation of the fishery with trading allowed between vessel classes within the regulatory areas can be represented by the following LP problem:

$$\text{Maximize: } H = \Sigma P_{ij} X_{ij} \tag{2.7}$$

The objective function is to find the vector of production choices that maximizes the total rent, subject to the following 20 constraints:

$\Sigma X_{ij} \leq \Sigma TAC_{ij}$ For j equals 1 to 3 in each of the areas (5 constraints) (2.8)

$X_{ij} \geq 0$ For each of the 15 possible production choices (15 constraints) (2.9)

The first set of constraints (2.8) allows the amount that can be harvested in each area to be the sum of the TACs of all the vessel classes in that area, thereby allowing trading between vessel classes within each of the areas. The solution will allow a positive level of production for only one vessel class in each of the five areas. Given the linear assumptions of the model, the highest production value will occur if all allowed production is by the most efficient fleet in each area. The solution to this problem provides the maximum rent possible when trading is allowed between vessel classes within areas.

2.7 Results of Models 1 and 2

The next step of the analysis is to compare the solutions of the models, which represent the potential rents under the different trading constraints. For each of the modeled years, the solution from Model (1) serves as the baseline rent against which the estimated rent from Model (2) is compared. The differences in the estimated rents between these two sets of models represent the increases in rent possible if quota trading between vessel classes within regulatory areas were permitted.

2.7.1 Estimated Rents from Models 1 and 2

Figure 2.1 shows the estimated rents for Models 1 and 2 for the modeled years, 2007 through 2011. The estimated rents under Model 1 range from about \$87 to \$135 million and the estimated rents under Model 2 range from \$93 to \$143 million. To put these numbers in context, the total revenues in the fishery (calculated as the product of the total harvest and the average ex-vessel price) for 2007 through 2011 ranged from a high of \$206.7 million in 2007 to a low of \$123.6 million in 2009. That is, the estimated rents under the relaxed quota trading scenarios are on average about 55% of total estimated revenues. This is on par with expectations about the ratio of rent to revenues in healthy fisheries (Sumaila et al., 2012).

The rents decreased from 2007 through 2011 due to changes in the TAC, which decreased by 39% for the whole fishery over this time period. At the same time, average IFQ prices across all modeled areas and vessel classes increased by about 60%. The greatest rent values were estimated for 2008 due to relatively high TACs in comparison to 2009 through 2011 and a spike in the IFQ prices. The cause for this increase is uncertain, but may be attributed to factors that include expectations about increasing halibut prices during this period or continued consolidation and exodus of less efficient operators from the fishery.

As expected, for each of the modeled years, the estimated rent under Model 2 is greater than that estimated under Model 1. That is, the relaxation of the quota trading constraint provides for a consistent increase in the estimated rent. The rates of rent increase range from 5.5% to 8.4%, indicating the percentage by which rent could be expected to increase if quota trading constraints between vessel classes were relaxed. This is also equivalent to the economic loss of not allowing quota trading between vessel classes.

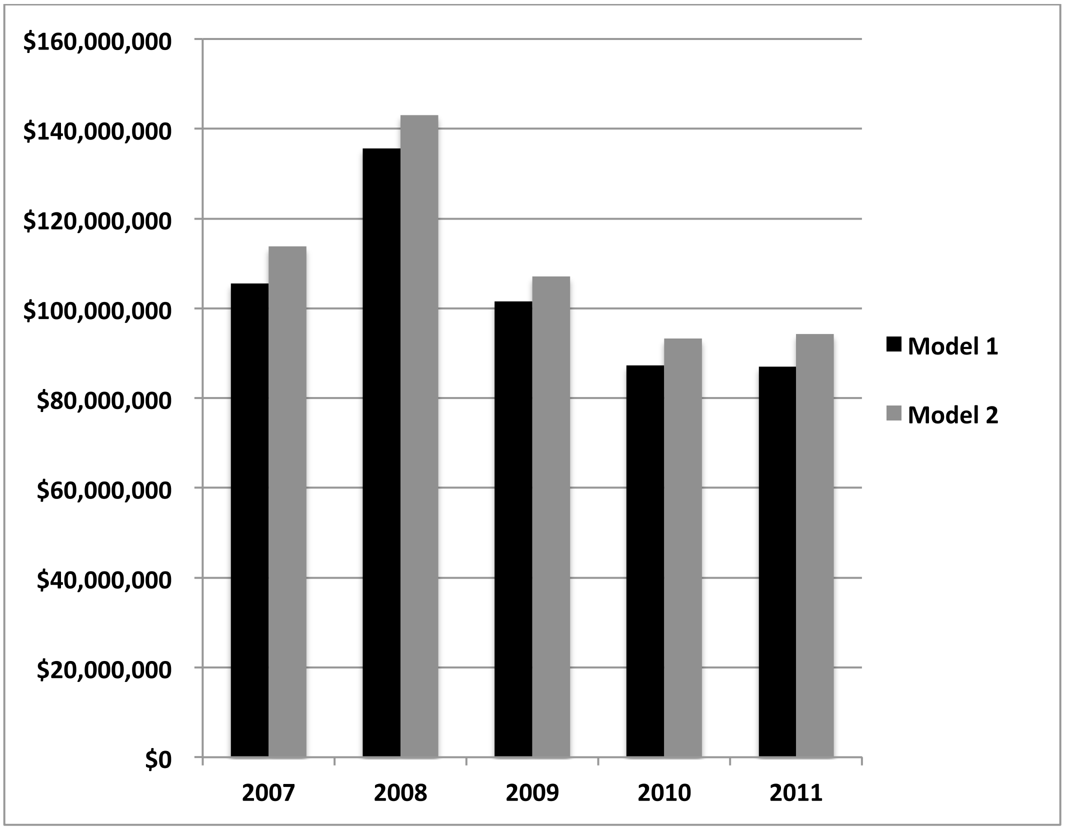

Figure 2.1: Estimated rent under current (Model 1) and relaxed quota share trading (Model 2) (2007 through 2011) ($2009).

There is inter-annual variation in the rate of rent increase under Model 2. This variation is largely a composite of changes to factors that affect IFQ prices across the years, such as current and expected ex-vessel prices, current and expected marginal costs, current and expected TACs, and changes in bank interest rates as QS holders often have to borrow money to purchase QS. These factors seem to affect IFQ prices differently between the modeled years and the production choices, thereby differentially affecting the estimated rents from the models. There is also some inter-area variability in the inter-annual TAC changes. This would change the percentage of the TAC that is being reallocated within the same model between years, thereby affecting the increases in rent under the models.

2.7.2 TAC Redistributions under Models 1 and 2

The increases in rent estimated under Model 2 are a result of the redistributions of the TACs in the regulatory areas to the production choice with the highest IFQ price. Table 2.5 shows the redistributions of the TAC under Model 2 for 2007 through 2011. For each of the modeled years, the redistributed TAC under Model 2 is shown next to the initial TAC allocation for each production choice in the area under Model 1. Under Model 2, the whole TAC for the regulatory area is reallocated to the production choice with the highest IFQ price, such that the redistributed TAC to one production choice per regulatory area under Model 2 is equal to the sum of the initial TAC allocations for each production choice for that area under Model 1. With the exception of two areas in 2011, the TAC is consistently redistributed to the larger vessel classes (greater than 36 feet) across the IFQ regulatory areas. This is evident from the rows with positive shareholdings in the Model 2 columns across the years in Table 2.5. This shift of quota is consistent with expectations of lower operating costs for the larger vessel classes, which can harvest greater quantities of fish on a fishing trip, go out in worse weather conditions, and have more flexibility in where the fish. Furthermore, because larger vessel class quota can be harvested on smaller vessels, this quota is associated with greater flexibility than the quota from the smaller classes. The potential shift of quota towards the larger vessel classes, which could occur with an open trading market is exactly what the NPFMC wanted to prevent in designating shares by vessel class and prohibiting inter-class trading.

Table 2.5: Redistribution of TAC (100,000 pounds) under relaxed quota share trading (Model 2). In bold are the redistributed TACs.

Area	Class	2007 Model 1	Model 2	2008 Model 1	Model 2	2009 Model 1	Model 2	2010 Model 1	Model 2	2011 Mode l 1	Model 2
2C	> 60	3.55		2.73		2.06	**47.31**	1.91		0.98	**22.42**
	36-60	66.07	**81.26**	48.45	**59.81**	38.51		34.50	**42.55**	18.15	
	< 36	11.63		8.62		6.73		6.13		3.27	
3A	> 60	96.96	**252.9**	89.17	**233.79**	79.71	**207.98**	74.82	**195.78**	53.33	**138.9**
	36-60	139.18		128.74		114.33		107.6		76.27	
	< 36	16.79		15.87		13.94		13.32		9.29	
3B	> 60	51.04		59.9		59.72		54.91	**96.69**	40.81	**71.26**
	36-60	35.63	**89.44**	41.27	**104.42**	40.61	**103.34**	30.84		28.19	
	< 36	2.76		3.24		3.10		2.93		2.25	
4A	> 60	16.53	**26.63**	17.4	**28.32**	14.92	**23.64**	13.64	**21.64**	13.54	
	36-60	8.13		8.83		7.07		6.64		6.9	
	< 36	1.96		2.08		1.63		1.53		1.56	**22.01**
4B	> 60	8.71		10.86		9.67		11.2		12.36	
	36-60	1.42	**10.33**	1.79	**12.71**	1.74	**11.42**	1.79	**13.07**	2.42	
	< 36	0.19		0.01				0.007		0.009	**14.88**

The solutions for Model 2 are corner solutions. That is, in each area, for the production choice with the highest IFQ price, the X_{ij} will be equal to the full ΣTAC_{ij} for that area, while the X_{ij} for the other two production choices will be equal to zero. Therefore, Model 2 does not account for potential production capacity limits of the production choices, which may indicate that the estimated increases in rents under this model are overestimates. Also, Model 2 only deals within the set of production possibilities resultant from current regulations. However, an open IFQ trading market could result in the entrance of more vessels into a production choice if more quota was made available. The models in this study do not include the potential for increases in capacity within the production choices.

2.8 Applying Capacity Limits: Model 3

The underlying assumption of Model 2 is that the fleets of each production choice will be able to harvest as much quota as they are given. However, because this may not be the case in reality, Model 3 was developed to allow for the possibility that these fleets have capacity limits. Because the capacity limits of the fleets are not known, the regulatory vessel use caps in the halibut IFQ program are used as proxies for capacity limits, constraining the amount of IFQ that can be harvested by any production choice. The vessel use caps are intended to limit the amount of any IFQ area's TAC that can be harvested by any one vessel. The vessel use caps are utilized as proxies for the capacity limit constraints because the caps represent the maximum that can be harvested by any one production choice. Given that the IFQ program has area-specific TACs, the vessel use caps in the program are also area specific, with one for Area 2C and another for the remaining regulatory areas. In area 2C, the cap is 1% of that area's TAC. The other vessel use cap limits the total amount of the TAC that can be held by any vessel to 0.5% of the whole halibut IFQ program TAC.

Model 3 mirrors the quota trading scenario of Model 2, with the addition of a set of constraints that mimics capacity limits of the production choices. The vessel use caps are applied such that:

For the cap in area 2C, the constraint for each vessel class is:

$X_{ij} \leq Z_{ij}$, where Z_{ij}= (1%* TAC_i) * (V_{ij}), where V = # of vessels, and i=1, for each of the vessel classes (3 constraints) (2.10)

For the cap for the whole IFQ program, the constraint for each vessel class in each area is:

$X_{ij} \leq Z'_{ij}$, where Z'_{ij}=(0.5%* ΣTAC_{ij}) * (V_{ij}), where V = # of vessels, for each of the vessel classes in each area (12 constraints) (2.11)

Constraint (2.11) is not applied for the production choices in area 2C, because the vessel use cap constraints specific to this area (as shown in (2.10) above) will always be more binding than the application of the cap for the whole IFQ program is on these production choices.

Table 2.6 shows the numbers of vessels, the vessel use caps, and the estimated capacity limit constraints (Z_{ij}) for all production choices and modeled years. The estimated capacity limits decrease from 2007 through 2011, in terms of the number of pounds that any vessel class is allowed to harvest. This is because both the TAC and the number of vessels decreased during this time period across nearly all production choices. The fact that the area 2C cap will be more binding than the cap for the whole IFQ program is evident in Table 6, as the area 2C cap is consistently lower than the cap for the other areas. The TAC has changed differentially across the areas from 2007 through 2011, with decreases in area 2C of nearly 73%, compared to 45% in area 3A, and 17% to 19% in areas 3B and 4A. The TAC actually increased in area 4B by 50% over this time period. The vessel use cap, therefore, has decreased by 73% in area 2C but only by 42% in the other areas, from 2007 through 2011. This has resulted in the capacity limit constraints for area 2C becoming increasingly binding throughout the modeled years, in comparison to the other areas.

Table 2.6: Number of vessels, vessel use caps, and estimated capacity limit constraints for all production choices and modeled years. Vessel use caps are measures as 10,000 pounds and capacity limit constraints are measures in 1,000,000 pounds.

		2007			2008			2009			2010			2011		
Area	Class	No. Vsl.	Vsl. Use Cap	Cons-traint	No. Vsl.	Vsl. Use Cap	Cons-traint	No. Vsl.	Vsl. Use Cap	Cons-traint	No. Vsl.	Vsl. Use Cap	Cons-traint	No. Vsl.	Vsl. Use Cap	Cons-traint
2C	> 60	45	8.13	3.57	49	5.98	2.93	44	4.73	2.08	46	4.25	1.95	43	2.24	0.96
	36-60	460	8.13	34.45	443	5.98	26.49	424	4.73	20.05	422	4.25	17.95	406	2.24	9.1
	< 36	203	8.13	12.67	181	5.98	10.62	156	4.73	7.8	168	4.25	7.14	157	2.24	3.52
3A	> 60	192	23.03	43.52	188	21.95	41.27	189	19.6	37.21	184	18.4	34.01	196	13.4	26.41
	36-60	439	23.03	92.81	426	21.9	93.52	403	19.6	79.35	397	18.4	73.39	402	13.4	54.16
	< 36	137	23.03	29.01	134	21.9	29.41	126	19.6	24.8	110	18.4	20.33	109	13.4	14.68
3B	> 60	133	23.03	31,23	137	21.9	30.07	136	19.6	26.77	140	18.4	25.88	137	13.4	18.46
	36-60	188	23.03	41.68	182	21.9	39.95	181	19.6	35.63	181	18.4	33.46	175	13.4	23.58
	< 36	34	23.03	7.36	37	21.9	8.12	32	19.6	6.3	34	18.4	6.28	40	13.4	5.38
4A	> 60	60	23.03	14.27	64	21.9	14.05	62	19.6	12.2	63	18.4	11.64	58	13.4	7.81
	36-60	51	23.03	11.28	51	21.9	11.19	49	19.6	9.64	47	18.4	8.68	46	13.4	6.19
	< 36	20	23.03	3.22	15	21.9	3.29	14	19.6	2.75	14	18.4	2.58	12	13.4	1.61
4B	> 60	29	23.03	6.67	30	21.9	6.58	29	19.6	5.71	36	18.4	6.65	33	13.4	4.44
	36-60	11	23.03	2.76	14	21.9	3.07	12	19.6	2.36	12	18.4	2.21	13	13.4	1.75
	< 36	4	23.03	0.69	3	21.9	0.65	3	19.6	0.59	3	18.4	0.55	4	13.4	0.53

Under Model 3, the capacity limit constraints should decrease the portion of the area TAC that can be harvested by any production choice in the area, relative to Model 2. Given the size of the various capacity constraints, it is possible that production from other vessel classes may be necessary to harvest the full area TAC. These other production possibilities will be added to the set of producing fleets in the area in decreasing order of the value of their IFQ price (P_{ij}).

The capacity limit constraints are not applied to Model 1 because they cannot affect production under the current constrained case. That is, current production in the halibut fishery is already a product of, amongst other factors, the regulatory constraints of the IFQ program, such as the QS trading restrictions and vessel use caps. Therefore, the capacity limits are only binding when the regulations are relaxed and trading is allowed between production choices.

The operation of the fishery when trading is allowed between vessel classes within the regulatory areas and with the application of vessel use caps can be represented by the following LP problem:

$$\text{Maximize: } H = \Sigma P_{ij}X_{ij} \tag{2.12}$$

Subject to the following 35 constraints:

$\Sigma X_{ij} \leq \Sigma TAC_{ij}$ For j equals 1 to 3 in each of the areas (5 constraints) (2.13)

$X_{ij} \geq 0$ For each of the 15 possible production choices (15 constraints) (2.14)

$X_{ij} \leq Z_{ij}$, For each of the vessel classes when i=1 (3 constraints) (2.15)

For constraint (2.15), the harvest by each production choice in area 2C must be less than or equal to its vessel cap for this area as calculated in equation (2.10) above.

$X_{ij} \leq Z'_{ij}$, For each of the 15 possible production choices (12 constraints) (2.16)

For constraint (2.16), the harvest by each production choice in all areas must be less than or equal to its vessel cap in each area as calculated in equation (2.11) above.

The set of constraints (2.15) is the application of the vessel use cap to all three vessel classes in area 2C. The set of constraints (2.16) is the application of the vessel use cap to all production choices.

2.9 Results of Model 3

The capacity limit constraints are only binding in 2011. Because the size of the constraint is a factor of the TAC and the number of vessels, the constraint is only binding in years when the TAC is low and on production choices with small fleets. These conditions are met in 2011, because the TAC is low and under Model 2 the TAC is redistributed to the production choices with the smallest fleets. For the other modeled years, the TAC is higher and redistributed to production choices with larger fleets.

2.9.1 Estimating Rents when Capacity Limits Are Applied

The results of the three quota share trading models for 2011 are displayed in Figure 2.2. The estimated rents under Model 3 (with relaxed trading restrictions but the addition of capacity limit constraints) are lower than those estimated under Model 2 (with just relaxed trading restrictions) because the capacity limits constrain the amount of the TAC that can be redistributed to the production choice with the highest IFQ price. In other words, Model 3 provides a lower bound estimate on the increase in rent estimated under Model 2. The estimated rents under Models 1, 2, and 3 are about

$89.8 million, $94.7 million, and $97.3 million, respectively. These correspond to rent increases of 8.4% and 5.3%, respectively, for Models 2 and 3.

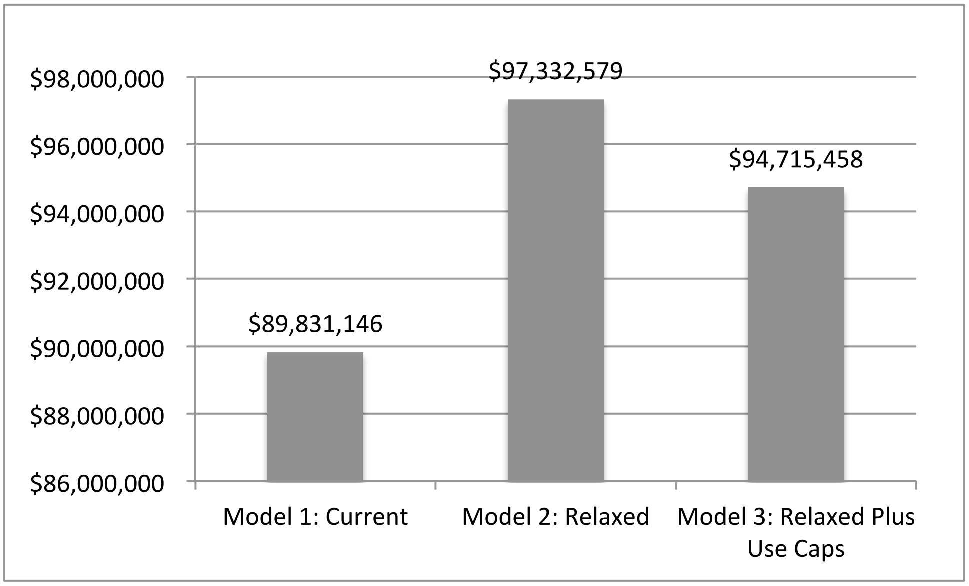

Figure 2.2: Estimated Rents under the Three Trading Models (2011).

The results of Model 3 should be interpreted with consideration of the following caveats. The underlying assumption of Model 3 is that vessels are area-specific, because data on the number of vessels that participate in multiple regulatory areas were not available. This could mean that the area-specific vessel class capacity in Model 3 is overestimated, because if the same vessel participates in the harvest in more than one area it would be closer to its cap for the whole program than is assumed here. Furthermore, as noted for Model 2, there could be an increase in the number of vessels for any production choice resulting from an increase in the availability of the TAC with relaxed trading restrictions. However, Model 3 does not include the potential changes in the capacity constraints that could result from such shifts in vessel numbers across the areas. With such an increase in fishing capacity, the expectation would be that rents would increase and be more in line with those estimated under Model 2.

2.9.2 TAC Redistributions with Application of Capacity Limits under Model 3

Table 2.7 shows the TAC distributions under Models 2 and 3 for 2011. The TAC redistributions under Model 2 are the most efficient allocations of the TAC for 2011 for each of the regulatory areas. In Model 3, some of these optimal allocations have to be redistributed due to the capacity limit constraints. For example, in area 2C, 1.2 million pounds of the 2.2 million pound allocation to the greater than 60 foot vessel class under Model 2 is redistributed to the 36 to 60 foot vessel class under Model 3. The optimal TAC allocation under Model 2 is also redistributed in Areas 4A and 4B under Model 3, to the production choices with the next highest IFQ price for these regulatory areas.

Because the decrease in the TAC in Area 2C over the modeled years has been greater than in other areas, the capacity limit constraints are likely to be binding more frequently. This is especially true for the greater than 60 foot vessel class, which has significantly fewer vessels than the other production choices in this areas. In areas 4A and 4B, the capacity limits are binding on the less than 36 foot vessel class, which also has relatively few vessels.

Table 2.7: Redistribution of 2011 TAC (100,000 pounds) under Models 2 and 3.

Area	Class	Model 1	Model 2	Model 3
2C	> 60	0.98	22.42	9.64

	36-60	18.15	-	12.78
	< 36	3.27	-	-
3A	> 60	53.33	138.90	138.90
	36-60	76.27	-	-
	< 36	9.29	-	-
3B	> 60	40.81	71.26	71.26
	36-60	28.19	-	-
	< 36	2.25	-	-
4A	> 60	13.54	-	-
	36-60	6.90	-	5.84
	< 36	1.56	22.01	16.16
4B	> 60	12.36	-	-
	36-60	2.42	-	9.49
	< 36	0.09	14.88	5.38

2.10 Sensitivity Analysis

A Monte Carlo experiment was conducted to determine empirical distributions of the results from both the restricted and unrestricted quota share trading linear programming models in 2011. A 90% confidence interval for the increase in rent under the unrestricted quota share trading model over the restricted quota share trading model was then calculated. In order to do this, for each of the 15 potential production choices a set of 100 random quota share trading prices was first generated. For each of the 12 production choices for which mean quota share transfer prices were available in the NMFS Halibut Transfer Report, 100 random quota share prices were drawn from the normal distribution, with mean as the mean quota share price and standard deviation, both of which were provided in the report. For each of the three production choices for which quota share transfer prices were estimated using the OLS regression, 100 random draws from the standard normal distribution (with a mean of 0 and a standard deviation of 1) were multiplied by the standard errors for the estimated parameters and then added to the estimated mean quota share transfer prices in order to generate 100 random prices.

The restricted and unrestricted linear programming models were then solved using this set of 100 randomly generated quota share trading prices for each of the 15 potential production choices, providing a range of solutions to the models over the standard normal distribution of the quota share prices. Table 2.8 shows the 90% confidence intervals of the rent values under both the current/restricted and the relaxed quota trading models when these 100 random prices are applied. The 90% confidence interval for the increase in rent under the unrestricted trading scenario compared to the current trading restrictions is 8% to 28%.

Table 2.8: Confidence intervals of rent estimates for 2011.

	90% Confidence Interval
Model 1: Current Trading Restrictions	\$79.9 to \$100.8 million
Model 2: Relaxed Trading Between Classes within Areas	\$91.8 to \$118.8 million

2.11 Discussion and Conclusions

In the Alaskan halibut IFQ program, quota share trading restrictions between vessel classes were implemented to ensure the long-term sustainability of a diverse fishing fleet and communities dependent upon the fishery. There are, however, costs associated with these trading restrictions in terms of the lost potential rent that could be generated from an unrestricted trading market. These trading restrictions hinder the capacity of quota shareholders to optimize the value of their shares, and thereby limit the efficiency gains that could be had under an unrestricted market. This study estimates that for the modeled years 2007 through 2011, the costs of the trading restrictions between vessel classes within regulatory areas range from 6% to 8%. However, the sensitivity analysis for the 2011 results shows that rents could increase by as much as 28% if QS trading restrictions between vessel classes were lifted.

There are several caveats to interpreting the results of this study. First, the linear programming models in this study provide corner solutions whereby all of the IFQ for an area is redistributed to the vessel class with the highest IFQ price. This does not account for the inherent capacity limits of operators to harvest additional quota and likely shifts in IFQ prices, which would occur with an increase of quota on the market. The application of the regulatory vessel use caps in Model 3 only serves as a proxy for the capacity limits, which are not known for the vessel classes. Furthermore, the vessel use caps are not always binding and depend upon the number of vessels in the production choice, which varies significantly across the choices.

The IFQ transfer prices in these models are held constant. In the real marketplace, where supply and demand dictate prices, the flood of IFQ onto the market resultant from the loosening of trading restrictions would likely reduce the market price for IFQ. In order to be able to predict how this would affect market prices, the demand curve for IFQ for the whole fishery would have to be estimated. The demand for IFQ is a function of the price of fish and the marginal costs of producing it, and is an aggregate of all the individual demand curves in the fishery. The marginal costs of fishing for each operator are not known and difficult to predict for the fishery, making a demand curve difficult to estimate.

There are other nuances of the halibut fishery and the effects of loosening quota share trading restrictions that are not accounted for in these models. For example, because these LP models use average IFQ prices, they do not account for the variability in willingness to pay for operators within the same production choice. There are, however, likely operators within the smaller vessel classes, whose willingness-to-pay for IFQ would be equivalent to some of those in the larger vessel class, so that even if trading were allowed between vessel classes, the redistribution of the whole TAC to one production choice may not be realistic. Another limitation of the models in this study is that they are limited to the set of production possibilities defined by the current regulations in the halibut IFQ program. If the IFQ trading market was loosened such that inter-class and/or inter-area trading was allowed, vessels might shift between areas or enter into the fishery in order to harvest any additional allocations. The models in this study, however, hold the capacity limits of the production possibilities constant.

There may also be some issues associated with the IFQ prices used in the models. First, since the start of the program there have been some changes in the reporting formats for quota share transfers. Although using the more limited dataset of quota share transfer prices from 2000 to 2011 is meant to address this issue (since there have been no significant changes in the reporting format since 1999), individual operators may still be misreporting prices in quota share transactions. For example, there have been some issues associated with fishermen including brokerage fees in the recorded transfer prices (NMFS, 2011). Second, the IFQ prices estimated from these quota share transfer prices may be inaccurate due to the assumptions used in discounting. That is, the factors affecting the IFQ price – the ex vessel price of halibut, the TAC, and the marginal cost of fishing – are held constant in the model. In reality, all three of these factors have changed over time.

These models could be substantially improved if they were developed at the individual quota shareholder level, rather than the vessel class level; however, individual quota share transactions are confidential. This would mean that each quota share transaction is priced, and that the model takes into account differentiations between the willingness to pay of individual participants, providing a more realistic picture of the fishery. Running the models on the individual level would also eliminate the issue of a corner solution, if the capacity limits of operators could be included. Using disaggregated data could also allow for the inclusion of other regulatory restrictions in the models, such as individual and vessel use caps. Kroetz, Sanchirico, and Lew (2014) do use individual transaction data for their analysis estimate the costs of restricting quota share trading in the IFQ program at 25% to 41% of the value of the fishery. Comparatively, the losses in potential rents estimated by this study are about 6% to 15% of the value of the fishery. As previously noted, these higher estimates (25% to 41% of the value of the halibut fishery) may in part due to the inclusion of other restrictions in their analysis. Another potential cause of these differences is the 12% discount rate applied in this study, which would provide for comparatively lower estimates in rent as a percentage of the value of the fishery.

Most catch share programs have some provisions associated with social goals that limit the potential efficiency gains that could be had with unrestricted markets. The strength of this LP approach in estimating the costs of quota share trading restrictions is the facility of application, with limited needs for data and understanding of modeling techniques. Although there are significant shortcomings to this modeling approach, it provides a range of cost estimates that managers and stakeholders can use to evaluate the impacts of these trading restrictions in the program.

In developing the halibut IFQ program, the NPFMC wanted to prevent the type of redistribution evidenced by the results of this study, and its associated adverse impacts on coastal communities. The argument that there are economic costs associated with restricting the rights of quota shareholders in order to achieve these broader social goals is clearly evidenced by this and other studies. The Council was aware of these costs during program implementation, as the potential costs were estimated by analysts in the EIS. It remains the purview of stakeholders and managers to decide whether these costs are commensurate with the benefits from maintaining fleet diversity and minimizing adverse impacts on coastal communities. That is, an annual 6 to 8% economic loss may seem significant, but may be equal to or less than what stakeholders deem to be the price of achieving these social goals. Indeed, this study did not attempt to assess the potential benefits of maintaining these quota share trading restrictions. Some would argue that for coastal communities with few alternative employment opportunities the benefits of maintaining a local fishery should be considered and balanced with the losses in efficiency. Most small vessels in the halibut fishery are owned by Alaskan residents, while the ownership of the larger vessels tends to be distributed amongst Washington, Oregon, and Alaska. The potential redistribution of the quota to the larger vessel classes under less restrictive IFQ trading scenarios could, therefore, have detrimental impacts on Alaskan coastal communities.

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Chapter 3

A DISCRETE CHOICE MODEL OF HIRED SKIPPER USE IN THE ALASKA HALIBUT IFQ FISHERY

3.1 Introduction

Catch shares are an increasingly popular fisheries management tool, with demonstrated potential for increasing economic efficiency, improving safety and product quality, and maintaining harvests within a TAC (Dupont, 2000; Arnason, 2005; Newell, Kerr, and Sanchirico, 2005; Hughes and Woodley, 2007; Costello, Gaines, and Lynham, 2008; Schnier and Felthoven, 2013). In catch share programs both permanent and temporary transferability (e.g. leasing quota) are crucial in providing the economic efficiency gains often associated with instituting these programs. Although there is a growing body of literature questioning the potential distributional, safety, and stewardship impacts of leasing in catch share fisheries (Pinkerton and Edwards, 2009; van Putten and Gardner, 2010; Emery et al., 2014a) (examined in more detail below), there is little research on the determinants of the leasing decision itself. This study addresses this critical gap by using a discrete choice model to examine the determinants of the decision to use hired skippers by quota shareholders in the Alaska halibut IFQ fishery, as the hired skipper-shareholder relationship is often effectively analogous to leasing.

One of the lessons learned from the experience in the Alaska halibut IFQ program is that catch share programs, as typically implemented, can create formidable incentives for absentee ownership of quota shares. As fisheries managers increasingly rely on the use of catch shares, these underlying incentives should be better understood. This study shows that the probability of absentee ownership (with the use of a hired skipper serving as a proxy for absentee ownership) is statistically significantly different based on the attributes of the shareholder and their shareholdings. Knowing the characteristics of the parties and the fishery setting that tend to generate greater leasing or hired skipper use, relative to owner-operated vessels, may allow fishery managers to both predict the degree of such practices and customize regulations to lead to their preferred outcomes in program design or modification.

3.2 Active Participation Mandates in the Halibut IFQ Fishery

The NPFMC included several active participation mandates in the halibut IFQ program to provide for an ultimate transition of the catcher vessel fleet to becoming individual-owned and owner-operated (NMFS, 1992). The IFQ halibut fleet consists of both catcher processors, which process their catch on board, and catcher vessels, which deliver their catch to shoreside processors. The NPFMC's active participation efforts focused on the catcher vessel fleet because the catcher processors, which do not deliver to shoreside plants, were already largely corporate owned when the IFQ program was being developed, and comprise a small percentage of the fishery (Pautzke and Oliver, 1997).

The NPFMC's active participation mandates included a prohibition on IFQ leasing after the first three years of the program, a prohibition on entry of new corporations (i.e. non-initial quota share recipients), and an owner-on-board mandate for second-generation (i.e. non initial recipient) shareholders (Szymkowiak and Himes-Cornell, 2015a). In order to provide initial quota share recipients with the flexibility to continue in the business practices that they had had prior to the implementation of an IFQ program, the NPFMC allowed initial quota share recipients to use hired skippers – a person designated by the shareholder to land the shareholder's IFQ. In Southeast Alaska (Area 2C in the IFQ program), the NPFMC limited hired skipper use to corporations and prohibited the acquisition of quota shares by any corporations (including initial recipients of quota in the program) in order to maintain what had historically been an individual-owned and owner-operated fleet in this area. Hereinafter "eligible individuals" refers to individual initial recipients of catcher vessel quota shares, who are eligible to use hired skippers.

Since the implementation of the IFQ program, there has been an increasing reliance on the use of hired skippers (NMFS, 2014; Szymkowiak and Himes-Cornell, 2015a). This can be attributed to both the consolidation of quota by those who had already been using hired skippers and to the aging of previously active eligible individuals who have now switched to using hired skippers. Although age data are generally not available for participants in this fishery, in 2010 the average age of initial recipients in the IFQ program was 60 (NPFMC, 2014). Prior to the implementation of the IFQ program, some vessel owners would hire skippers to fish the halibut fishing seasons, splitting the ex-vessel revenue generated over the season. Now, since many shareholders only nominally own a vessel, per regulatory mandates described in more detail below, many shareholder-hired skipper relationships are functionally equivalent to leasing. The crew and the shareholder split the ex-vessel revenue generated by the landing of the shareholder's quota, but the shareholder's ownership stakes in the vessel and risk in the fishery is minimal (NPFMC, 2014).

Therefore, in this analysis the use of a hired skipper is understood to be a proxy for leasing.

There are several different types of shareholders in the halibut IFQ fishery, designated on the basis of the types of shares that they hold (catcher processor or catcher vessel) and whether they are allowed to use hired skippers. For catcher vessel shareholders, corporations have to use hired skippers, eligible individual shareholders may use hired skippers, and second-generation shareholders may not use hired skippers. Figure 3.1 shows the distribution of halibut IFQ landings across the various types of shareholders in the fishery from 2000 through 2013.[4] Since 2000 there has been a decrease in the percentage of total halibut IFQ landings by catcher processors, corporations (owning both catcher vessel and catcher processor IFQ), and eligible individuals landing their own catcher vessel IFQ. Although the percent of the total IFQ landed by eligible individuals has been decreasing, the percent of these eligible individuals' IFQ landed by hired skippers has increased and now comprises about 20% of the total landings in the fishery.

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[4] Landings are shown instead of IFQ holdings in order to be able to show the changes in hired skipper use amongst eligible individual shareholders. Only landings from 2000 onwards are included, because of potential data accuracy issues associated with database changes in 1999 (NFMS, 2011).

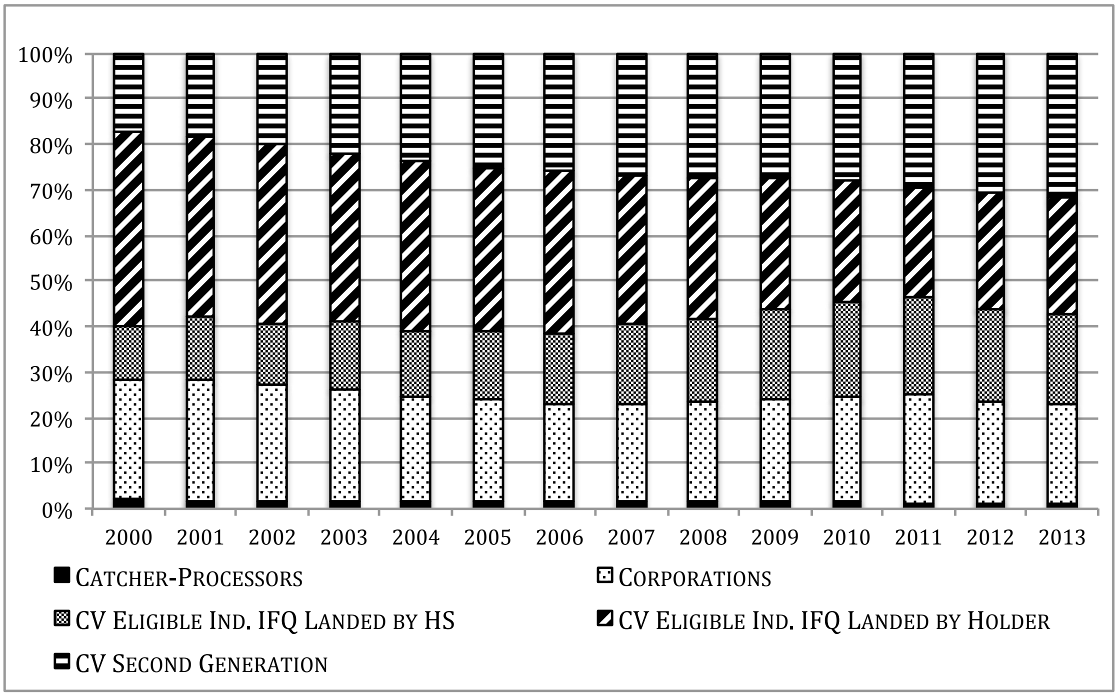

Figure 3.1: Percent of total halibut IFQ landed pounds by user group

The increasing use of hired skippers has occurred despite the NPFMC's repeated amendments to the IFQ program that restrict how eligible individuals can use hired skippers. In 1999, 2002, and 2007, the NPFMC implemented a series of amendments mandating that the shareholder using a hired skipper must own at least 20% of the vessel upon which his IFQ is being fished (NMFS, 2014). In 2014, the NPFMC implemented a rule requiring that shareholders using hired skippers own 20% of the vessel for 12 months prior to their IFQ being fished upon it ((U.S. Office of the Federal Register (USOFR), 2014a). The increasing reliance on hired skippers has also prompted the NPFMC to recently implement a "Sunset Provision" restricting the amount of quota that can be fished by hired skippers to that which was transferred prior to February 12, 2010 (U.S. Office of the Federal Register (USOFR), 2014b).

Given that quota shares are a capital asset with an expected rate of return comparable to relatively risky investments, the reliance on hired skipper use in the halibut IFQ program may indicate that shareholders expect to earn more from using hired skippers now and potentially selling the quota shares in the future than from selling the shares now and investing that money elsewhere in the market. This expectation is supported by the substantial increases in quota share prices since the implementation of the IFQ program. In Area 3A real quota share prices, expressed in 2013 dollars per pound of IFQ[5], increased from $11.23 in 1995 to $31.28 in 2013. In other words, controlling for changes in the TAC, which has decreased sharply since 1995, the price of quota shares in Area 3A has increased by over 178% since implementation of the IFQ program. This increase reflects increased efficiency aboard fishing vessels no longer racing for their share of the catch, but also increased value due to market factors. Another impetus for retaining shares may have emerged due to the several years of discussions at the NPFMC about opening up the IFQ market to the charter sector, which could bid up the price of quota. The catch sharing plan, which allows charter operators to lease IFQ from commercial quota shareholders, was implemented for the first year in 2013, and the NPFMC is currently discussing allowing the charter sector to permanently buy quota shares from the commercial sector (Call and Lew, 2015). Finally, considerations such as capital gains taxes may also be driving the observed decisions to hold rather than sell quota shares.

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[5] As calculated by the Consumer Price Inflation calculator from the Bureau of Labor Statistics.

3.3 Literature on Leasing in Catch Share Programs

Many catch share programs allow quota owners to lease their shares. For lessors, avoidance of the capital gains tax associated with selling an asset and of the physical and financial risks of fishing while continuing to generate income from the quota are commonly cited benefits of leasing (Pinkerton and Edwards, 2009; van Putten and Gardner, 2010). Some researchers argue that leasing can facilitate entry for new participants into a fishery, because leasing allows lessees to build up capital and experience in the fishery, which can be beneficial in qualifying for a loan to purchase quota shares (Wilen and Brown, 2000; GAO, 2004; Stewart and Callagher, 2011). From an economic standpoint, because leasing separates the factors of ownership and production in the fishery, it may provide a means for increasing economic efficiency in a catch share fishery above what can be expected with just permanent transferability (Le Gallic and Mongruel, 2006). Because right holders can choose to outsource their fishing activity and lessees have to compete for quota, there may emerge a class of highly efficient harvest service providers, who will outbid operators with higher operating costs (ibid.). Leasing also allows greater flexibility for fishermen to adjust to inter-annual TAC changes and bycatch rates in multi-species fisheries than is feasible with permanent quota share transfers alone (Pallson and Helgason, 1996). That the volume of lease trades in numerous catch share fisheries often far exceeds quota share transfers may be evidence of the greater flexibility afforded by leasing over long-term quota transfers (Wilen and Brown, 2000; Newell et al., 2005; Putten and Gardner, 2010; Moxnes, 2012).

The effects of rising lease rates in quota markets have also received attention in the literature. Differential impacts occur depending on the degree to which one's catch portfolio is reliant upon leased quota (Szymkowiak and Himes-Cornell, 2015a). In a functional lease market, quota prices are based upon the expected marginal profit one expects to earn in that year. As such, rising lease fees should reflect increased profitability in the fishery, due, for example, to higher ex-vessel prices, increases in catchability, or lower costs of inputs (e.g. fuel). Such conditions are more favorable to recipients of initial allocations whereas those who lease in all or most of their quota may be subject to a profit squeeze, provided that there is still a profit margin to be made (van Putten and Gardner, 2010). This profit margin compression may be problematic because it has been associated with a change in how lessee fishermen operate in the fishery, as the incentives guiding the behavior of lessees may be more likely to differ from those of quota owners (Bradshaw, 2004; Gibbs, 2009). For example, lessees may try to make up some of that profit loss by targeting higher valued catch, resulting in greater highgrading and discard rates (Emery et al., 2014b). Van Putten and Gardner (2010) showed that the implementation of the IFQ program in the Tasmanian rock lobster fishery resulted in the emergence of a class of small lease dependent operators, who operate below normal economic profit, which could negatively influence compliance. Furthermore, when lease prices increase lessees will tend to have less flexibility in when and how they operate making them more vulnerable to numerous timing-related issues, including market prices, labor supply, and inclement marine weather. In fact Emery et al. (2014a) showed that in the Tasmanian rock lobster fishery, lessees have significantly higher risk tolerance levels than quota owners, a pattern that was related to lease quota prices. Finally, if the stakeholder's investment in the fishery is a factor of the duration of his fishing privilege, lessees will tend to have much shorter temporal horizons with regards to the sustainability of the resource than quota shareholders (Scott, 2000; Gibbs, 2009). In sum, some of the benefits often associated with the implementation of a catch share program, in terms of safety improvements and a stewardship ethic, may be diminished when a fishery shifts towards dependence on leasing operations (Szymkowiak and Himes-Cornell, 2015b).

3.4 Research Objective

In light of the NPFMC's expressed frustration at the slow transition to an owner-operated fleet in the halibut IFQ fishery, which has occurred despite a series of amendments intended to minimize hired skipper use, this study reveals potential attributes of shareholders and their holdings that may be targeted for regulations. Furthermore, the growing body of literature on the potentially adverse impacts of leasing provides a broader context for the necessity of this research, especially as the numbers of catch share programs grow in the U.S. and around the world. Understanding the determinants of hired skipper use for shareholders may elucidate other regulatory mechanisms that fisheries managers can use to maintain or transition a fleet to becoming owner-operated, if that is the regulatory goal.

The following analysis applies discrete choice modeling to explore the determinants underlying shareholders' decisions to use (or to not use) hired skippers in the Alaskan halibut IFQ fishery. This study applies a random utility maximizing discrete choice model to analyze these decisions. The analysis is limited to eligible individuals because these are the shareholders in the fishery, who have the option of using hired skippers for IFQ landings.

3.5 Discrete Choice Modeling in the Fisheries Literature

Discrete choice models exploring commercial fishermen's behavior have been applied to predict fishermen's choices with regards to fishing location (Eales and Wilen, 1986; Holland and Sutinen, 1999; Wilen et al., 2002; Hutton et al., 2004), entry-exit decisions (Ward and Sutinen, 1994; Pradhan and Leung, 2004; Tidd et al., 2011; van Putten et al., 2012) and target species selection (Salas, Sumaila, and Pitcher, 2004). Similarly, recreational fisher decisions regarding participation, location, and target species of fishing trips have also been modeled with discrete choice models (Criddle et al. 2003; Carson, Hanemann, and Wegge, 2009; Lew and Larson, 2011). Carothers, Lew, and Sepez (2010) applied a logit analysis to explore how residency in various community sizes effects the likelihood that Alaskan participants will buy or sell quota shares in the Alaska halibut IFQ program.

Researchers have explored leasing as an explanatory variable for fishermen's decisions. Pradhan and Leung (2004) included the use of hired captains as a determinant variable in models of the probability of entry-stay-and-exit of vessel owners in the Hawaiian longline fishery, showing that vessel owners who employed hired skippers were more likely to exit the fishery than those, who fished on their own boats. Emery et al. (2014) developed a discrete choice model of daily participation in fishing to compare the physical risk tolerance between quota owners and those leasing quota, showing that the latter had significantly higher risk tolerance than quota owners in some areas.

Despite this body of literature applying discrete choice models to fisheries research and the growing number of studies on the potential impacts of leasing, to this author's knowledge there has not been any discrete choice analysis of the characteristics of the individual, and/or their shareholdings, that make the individual more or less likely to lease quota. In this light, this study represents a unique application of discrete choice modeling to fisheries management research and an important contribution to the overall understanding of leasing in catch share programs.

3.6 Conceptual Framework

This study applies the model of probabilistic-choice behavior formulated by McFadden (1973) to analyze the discrete decisions of IFQ shareholders to use hired skippers or not for landings. The analysis is limited to eligible individuals (as defined earlier) who have the option of using hired skippers for IFQ landings. The probabilistic choice behavior model is motivated within a random utility maximization (RUM) framework. Under the RUM framework, the decision maker i can be described as facing a finite and exhaustive choice set J of mutually exclusive alternatives, l and j. In this case, there are only two alternatives in J, using a skipper and not using a skipper. Each of the J alternatives has a utility associated with it, and the decision maker is assumed to select the alternative that yields the highest utility. More formally, the decision maker chooses an alternative j at time or choice occasion t if and only if $U_{ijt} > U_{ilt}$ for $l \neq j$. The model involves estimating the probability of observing the decision maker's (the quota shareholder's) choice between these two alternatives.

A fixed effects logit model is applied for this analysis in order to explore the relationship between the predictors and the dependent variable within each entity (Chamberlain, 1980). The entity in this analysis is a unique combination of shareholder, vessel class, and area, as explained further in the Data section below. The "group" that the fixed effects model is estimated upon consists of all the observations for this entity. The underlying assumption of using fixed effects is that something within the entity may impact or bias the predictor or dependent variables. In other words, that there is a correlation between the entity's error term and the predictor variables.

The fixed-effects model controls for time-invariant characteristics of the entities so that the net effect of the predictor variables on the outcome variable can be assessed. This entity-specific heterogeneity is differenced out of the model. In addition, because the fixed-effects model controls for all time-invariant differences between entities, the estimated coefficients of the model cannot be biased because of omitted time-invariant characteristics. In turn, this means that fixed-effects models cannot be used to investigate time-invariant causes of the dependent variable, because technically time-invariant characteristics of entities will be perfectly collinear with the entities.

An alternative to the fixed-effects model is the random effects model. Under the random effects model, the variation across entities is assumed to be random and uncorrelated with the predictor variables. In other words, the assumption is that each entity's error term is not correlated with the predictor variables in the model. As explained in more detail in the Results section, a specification test was performed indicating that the fixed-effects model was more appropriate for this analysis.

3.7 Theory and Variable Selection

This analysis was conducted at the landings level, such that for each landing the shareholder makes the decision to either use or not use a hired skipper. It is assumed that a shareholder makes the decision to use a hired skipper or not based on his relative profits from these two choices. Therefore, if the shareholder makes the decision to use a hired skipper, this should indicate that the hired skipper has a comparative advantage in harvesting the quota. In other words, that the hired skipper is a more efficient harvest service provider than the shareholder, given the shareholder's direct and opportunity costs of participating in the fishery. The hired skipper fee is the percentage of the ex-vessel revenue that the hired skipper is willing to take for landing the shareholder's quota. The percentage retained by the hired skipper should reflect the hired skipper's expectations about the value of the additional pound of fish to current profitability. Unfortunately, hired skipper fees are not reported in the halibut IFQ fishery. However, as discussed in more detail in Section 3.10, hired skipper fees are anecdotally reported to be between 25% to 35% of ex-vessel revenues. Earnings expectations are captured instead by the TAC, the ex-vessel price of halibut, and the marine fuel price, all measured by IFQ area and year.

The TAC (TAC variable) and the ex-vessel price of halibut (Ex Vessel Price variable) are utilized to capture expectations about revenues in the fishery, and the Fuel Price variable is utilized to capture expectations about operating costs. It may be hypothesized that a shareholder will be less likely to use a hired skipper if his earnings expectations are higher. Quota share prices should also theoretically capture current and future earnings expectations in the halibut fishery as a factor of the TAC, the ex-vessel price of halibut, and operating costs. Due to confidentiality issues, quota share price data were not available at the transaction level but rather were provided as an average over the quota type (vessel class and area specific). However, there was not sufficient variation in the observations for halibut quota share prices across the years, areas, and vessel classes to include this variable in the analysis. Table 3.1 shows the list of variables utilized in this analysis.

Table 3.1: Explanatory variables in fixed-effects logit analysis of hired skipper decision

Variable Type	Variable Name	Measured As
Shareholder Residency	Resid Non AK	=1 if shareholder resides outside of Alaska
Holdings (Quantity)	IFQ Pounds 5K	IFQ holdings in 5,000 pounds of fish (for all areas combined in a given year)
Holdings (Diversity)	Multi Class QS Held	=1 if shareholder holds quota in multiple classes in a given year
	Multi Area QS Held	=1 if shareholder holds quota in multiple areas in a given year
Earnings expectations	TAC 100K	Pounds of total allowable catch in 100,000 lbs. (area and year specific)
	Ex vessel price	US dollar (nominal)/pound (area and year specific)
	Fuel price	US dollar (nominal)/gallon (area and year specific)
Attributes of the Year	Year fixed effects	=1 for each year 2000 through 2013

The costs of harvesting one's own quota may also vary based on the residency of the shareholder. Holding all else equal, the direct costs of harvesting their own quota may be higher for non-Alaska residents than Alaska residents. For example, non-Alaska resident shareholders incur the costs of transporting their boat up to Alaska for the fishing season or for maintaining their boat in a distant port and traveling otherwise for the season. A variable denoting whether the shareholder is a resident of a state other than Alaska was, therefore, included in the analysis. A 1 for this variable would denote a shareholder having residence outside of Alaska, whereas a 0 would indicate Alaskan residency. Other researchers have used Alaskan residency as a determinant variable in studies of capital investment and permit migration in the Alaska salmon fisheries (Northern Economics, 2009; Knapp, 2011). In a study of vessel entry, stay, and exit in the Hawaii longline fishery, Pradhan and Leung (2004) showed that most of the vessels entering and exiting were owned by non-residents of Hawaii, who mostly used hired captains. Eija et al. (2011) showed that in Finland landowners living on their farms were less likely to lease their land than those not living on their farms.

The shareholder is also expected to consider the direct, transaction, and opportunity costs of using a hired skipper. As previously discussed, the direct costs of hiring a skipper are not known. Although they are unknown, the transaction costs of hiring a skipper are likely to diminish over time as shareholders establish relationships with hired skippers, and these costs may be defrayed to some degree in social networks of shareholders and hired skippers, as explored in more detail in Chapter 4.

The opportunity costs of using a hired skipper may be lower for those with larger shareholdings (measured with the "IFQ Pounds" variable, which captures the shareholder's IFQ pound holdings in all areas in a given year) and with more diversified shareholdings (measured with the Multi Class QS Held and the Multi Area QS Held variables). Regulatory mandates restrict the amount of quota that can be fished on any one vessel and the size of the vessel upon which shares of different vessel class designations may be fished, which can effectively eliminate the shareholder's capacity to fish his own quota. This is explored in more detail in Section 3.10. However, as Stewart et al. (2006) note, shareholders with larger holdings may also have higher rates of return, which could provide an incentive to harvest one's own shares relative to using a hired skipper. Van Putten and Gardner (2010) suggest that there is a tipping point in the fishery beyond which firms owning more quota would be able to increase profits by leasing some quota. In Iceland, holdings of both small and of large quantities of quota have been associated with increased leasing practices at different stages of the rights-based management program (Palson and Helgason, 1995). Other authors have also shown that small shareholders may also need to lease quota to supplement their holdings (Aslin, 2001). In the agricultural research literature, size of land holdings has been shown to have both a positive (Mabiso et al., 2011) and a negative (Eija et al., 2011) relationship with leasing.

The use of hired skippers has been increasing annually since the start of the IFQ program, which is likely to be associated with the aging of initial recipients, who are no longer willing or able to fish their own quota. The ages of shareholders are considered personally identifiable and sensitive information and were, therefore, not available for this analysis. Researchers have used annual fixed effects variables to model differential changes in the dependent variable over time in discrete choice fisheries models (Wilen et al., 2002; Carothers, Lew, and Sepez, 2010; van Putten et al., 2012). Since 2000, the IFQ program has been subject to several amendments that have relaxed the constraints on how shareholders can operate in the halibut IFQ fishery, which could be expected to alter hired skipper use decisions. For example, in 2005, the IFQ program was amended to allow harvest of 4C allocation in 4D, and in 2007, the “fish up” amendment was implemented, allowing smaller class vessels to fish IFQ designated for larger vessel classes (USOFR, 2008). These kinds of changes allowed shareholders to move their quota across areas and vessel classes, which could provide incentives for hired skipper use. Time fixed-effects for 2000 through 2013 were included in this analysis to capture the potential impacts of these regulatory changes, other annual effects, and the aging of eligible individuals.

3.8 Data

The data for this analysis were provided by the Alaska Fisheries Information Network, which maintains a database of Alaska state and federal fisheries data. The two primary data sources were the fish ticket data from the Alaska Department of Fish and Game (ADF&G), as compiled by the Commercial Fisheries Entry Commission (CFEC), and the IFQ shareholder data from the National Marine Fisheries Service, Alaska Regional Office. The fish ticket data include information specific to the landing, including whose IFQ account is being debited for the landing, whether that permit holder made his own landing or used a hired skipper, the vessel class and area of the IFQ, the pounds landed, and the length of the vessel upon which the landing was made (among other information). This fish ticket data were then linked with the IFQ shareholder data to identify attributes of the shareholder including city and state of residency, total IFQ pounds held in the area in which the landing is being made, and IFQ holdings in other areas. The IFQ shareholder data are collected annually, wherein the IFQ fishable pounds for each shareholder represents the IFQ pounds that were fishable for the IFQ permit in that year as a sum of IFQ derived from quota share, prior-year adjustments, and in/out transfers. Annual area-specific total allowable catches (TACs) were taken from the National Marine Fisheries Service's "Halibut Transfer Report – Changes Under Alaska's Halibut IFQ Program"(NMFS, 2013). Fuel price data were taken from the Pacific States Marine Fisheries Commission (PSMFC, 2013).

A unique identifier was created for each combination of area and permit number (the permit number is specific to the shareholder and a vessel class). This identifier, which is shareholder, area, and vessel class specific, is the entity utilized in the model to group observations. In other words, the observations for each of these entities comprise the group upon which the fixed-effects model was estimated. For some of these entities, there were multiple landings on the same date. A second unique identifier for each combination of permit number, area, landing date, and hired skipper (0,1) was generated. Duplicates of these second identifiers were removed from the dataset, because including these duplicate landings would have effectively resulted in double-counting the decision to use a hired skipper or not in the dataset.

After removing these duplicates, the data for this analysis consist of one observation for each landing specific to a permit number and area combination from 2000 through 2013. Data prior to 2000 were not used for this study because of database and regulatory changes prior to this year that would make inter-annual comparisons difficult. Area 2C was not included in the analysis, because of the prohibition on hired skipper use by all individuals in this area. Areas 4C and 4D were treated as one area because an amendment to the IFQ program in 2005 allowed for landings of 4C IFQ in area 4D. After eliminating landings for IFQ held by corporations, second-generation shareholders, shareholders in Area 2C, landings that were registered as having no IFQ sold or retained and/or the shareholder held no quota share units for that area and vessel class, and duplicate landings on a given date with the same hired skipper use decision, 36,484 observations remained for this analysis. There were a total of 1,838 unique entities (permit number and area combinations) in the data upon which the observations were grouped. As noted in the Results sections, many of these groups and therefore observations had to be dropped because there were no changes in the observed use of a hired skipper over the course of the dataset. STATA 13.1 SE econometric software was used for the analysis, using the *xtlogit, fe* command which produces identical results to the *clogit, group* command.

3.9 Results

A Hausman (1978) specification test was performed, which tests the null hypothesis that the random effects model is the preferred model. With a Chi-squared test statistic of -854.73 and 7 degrees of freedom, the null could be rejected in favor of the alternative hypothesis that the fixed-effects specification for the model was more appropriate than the random effects specification. Therefore, the model was specified as a fixed-effects model.

The estimated results from the fixed-effects empirical model, including both the logit coefficients and the odds ratios, are presented in Table 3.3. A likelihood ratio test for the null hypothesis that the model parameters are jointly equal to zero was conducted. With a Chi-squared test statistic of 2,977 and 20 degrees of freedom, the null hypothesis could be strongly rejected, suggesting that the model is significant. All of the parameter estimates of the variables in the final model were robust to inclusion and exclusion of variables. Over half of the observations (21,442) and 1,316 groups were dropped from the analysis because of all positive or negative outcomes. In other words, these groups had no variation over the dataset in hired skipper use.

Table 3.2: Fixed-effects logit model parameter and odds ratio estimates for probability of hired skipper use. Includes standard errors for logit coefficient (where *** p<0.01, ** p<0.05, * p<0.1) and 95% confidence intervals for odds ratios.

	Logit Coeff	Odds Ratio		Logit Coeff	Odds Ratio
TAC 100K	-0.005***	0.995***	Year 2004	0.847***	2.333***
	(0.001)	(0.993, 0.998)		(0.272)	(1.368, 3.98)
Ex vessel	1.117***	3.057***	Year 2005	0.547	1.728
price	(0.411)	(1.367, 6.836)		(0.465)	(0.695, 4.299)
Fuel price	1.368***	3.929***	Year 2006	-0.695	0.499
	(0.450)	(1.625, 9.497)		(0.741)	(0.117, 2.134)
Resid Non	1.37***	3.934***	Year 2007	-0.935	0.393
AK	(0.175)	(2.792, 5.544)		(0.912)	(0.066, 2.347)
IFQ Pounds	0.045***	1.046***	Year 2008	-2.448*	0.086*
5K	(0.012)	(1.021, 1.072)		(1.302)	(0.007, 1.109)
Multi Class	0.59***	1.804***	Year 2009	0.799	2.223
QS Held	(0.177)	(1.276, 2.551)		(0.699)	(0.565, 8.75)
Multi Area	-0.368***	0.692***	Year 2010	-0.795	0.452
QS Held	(0.149)	(0.517, 0.927)		(1.087)	(0.054, 3.801)
Year 2001	1.257***	3.514***	Year 2011	-3.805**	0.022**
	(0.26)	(2.111, 5.851)		(1.766)	(0.001, 0.709)
Year 2002	1.442***	4.23***	Year 2012	-3.486**	0.031**
	(0.196)	(2.881, 6.21)		(1.654)	(0.001, 0.784)
Year 2003	0.928***	2.53***	Year 2013	-2.029	0.131
	(0.194)	(1.731, 3.697)		(1.485)	(0.007, 2.414)
	Observations	15,037		Log likelihood	-4,936.175
	Groups	522		AIC	9,912.351
	Pseudo R2	0.232		BIC	10, 064.72

In order to test whether time fixed effects were necessary, a joint test of whether all the year dummies are equal to zero was performed. With a Chi-squared test statistic of 443.31 and 13 degrees of freedom, the null that the coefficients for all years are jointly equal to zero could be rejected. Therefore, time fixed-effects were included in the model. The reference year was 2000 in the analysis and only several of the coefficients for the other year dummies were significant in the model. Significant coefficients for three latter years in the dataset (2008, 2011, and 2012) indicate a decreasing probability of hired skipper use, which is not aligned with expectations about the increasing use of hired skippers with the aging of initial recipients nor with the fishery's statistics on increasing hired skipper use. However, the increased probability of not using a hired skipper in 2008 may have been in response to regulations that went into effect in late 2007, which mandated that the shareholder must own 20% of the vessel upon which his quota is being fished for 12 months prior to his quota being landed upon it and required specific documentation of this ownership (NMFS, 2014). This new regulatory mandate would have likely been associated with an adjustment period for shareholders. In addition, as noted in Chapter 4 in this dissertation, the increasing use of hired skippers is mostly due to the consolidation of quota shares by initial recipients in the fishery, who were already using hired skippers, rather than an increase in the number of initial recipients transitioning to utilizing skippers (although this has also happened). The increasing use of hired skippers with respect to the percentage of landed quota for those shareholders who were already using hired skippers would not be captured in this analysis as an increase in the probability of hired skipper use since it would not represent a variation in the hired skipper use decision for these shareholders.

The coefficients of the TAC 100K and the Fuel Price variables are aligned with expectations about the impacts of changes in earnings expectations on the probability of hired skipper use. Holding all else equal, an increase in the TAC should be associated with greater earnings expectations, and a decrease in the fuel price should be associated with greater earnings expectations, holding all else equal. Furthermore, the coefficients of the TAC 100K and Fuel Price variables are aligned with the cost-price squeeze scenario previously described in the literature with respect to the potentially adverse impacts of leasing. The odds ratio of the Fuel Price variable indicates that when the fuel price increases by a dollar the odds of a shareholder using a hired skipper increase by 3.92 times (or 292%), holding all other variables constant at their means. Table 3.4 shows the changes in odds ratios associated with a range of potential increases in the TAC. These odds ratios indicate that, although statistically significant, the impacts of a change in the TAC on the odds of hired skipper use are small. The coefficient of the ex-vessel price of fish is not aligned with expectations that an increase in the ex-vessel price (which, holding all else equal, should reflect an increase in earnings expectations) will be associated with a decrease in the probability of hired skipper use. However, an increase in the ex-vessel price may allow the shareholder to charge a higher lease rate, assuming that the hired skipper's profit margin remains the same, which could provide a further incentive for using a hired skipper.

The IFQ Pounds 5K variable is statistically significant and positive indicating that greater shareholdings are associated with a higher probability of hired skipper use. The odds ratio shows that for every 5,000 pound increase in shareholdings, holding all other variables constant at their means, the odds of using a hired skipper increase by

1.046 (or 5%). Although this does provide some basis for understanding how changes in shareholdings affect the hired skipper use decision, it is also interesting to note how a range of shareholdings may affect the odds of hired skipper use. Table 3.4 shows the odds ratios of hired skipper use under a range of IFQ shareholdings.[6]

Table 3.3: Odds ratios of hired skipper use with different IFQ pound holdings and TACs.

Increases in IFQ Pounds	Odds Ratio	Increases in TACs	Odds Ratio
10,000	1.095	200,000	0.99
15,000	1.145	300,000	0.986
25,000	1.254	400,000	0.981
50,000	1.571	500,000	0.976
100,000	2.469	1,000,000	0.953

The probability of hired skipper use is also associated with the diversity of the shareholder's holdings. A shareholder, who diversifies his holdings portfolio into other vessel classes, increases his odds of hired skipper use by 1.8 times (or 80%). On the other hand, a shareholder who diversifies his holdings into multiple areas actually becomes less likely to hire a skipper. Given the regulatory restrictions on how different vessel class quota may be landed, the switch to using a hired skipper associated with diversifying into multiple vessel classes makes sense. In other words, if a shareholder owns quota shares in multiple vessel classes, he is restricted in whether he can land all of his quota resulting from those shares on his own vessel. There is no regulatory restriction on the same vessel being used across multiple areas,

[6] Holding all other variables constant at their means, the odds ratios under the different IFQ holdings are estimated as an exponentiated multiple of the logit coefficient. For example, the odds ratio for a 100,000 pound increase in shareholdings is calculated as: exp(logit coefficient*20).

however. If a shareholder, who diversifies his shareholdings into multiple areas, becomes more viable as a result, he may become less likely to use a hired skipper. Furthermore, a shareholder who transitions to owning shares in multiple areas may not be able to initially find a skipper to fish his quota in these new areas. If the shareholder ultimately does transition to using a hired skipper, this would not be captured in the analysis, because this transition would not be associated with any variation in the multiple area holdings variable for that shareholder.

With respect to the residency of the shareholder, the coefficient on the Resid Non AK variable indicates that when a shareholder moves out of Alaska he becomes more likely to use a hired skipper. In fact, the odds of a shareholder using a hired skipper are 3.93 times (or 293%) greater when the shareholder moves out of Alaska and holding all the other variables constant at their means. The dataset includes 76 shareholders who changed from Alaskan to non-Alaskan residency, 25 shareholders who changed from non-Alaskan to Alaskan residency and 19 shareholders who changed residency more than once.

3.10 Discussion and Conclusions

This study utilized a discrete choice fixed-effects model to explore the characteristics of shareholders that contribute to the their decision to use a hired skipper. This is a unique and significant contribution to the expanding literature on leasing in fisheries, as it represents the first discrete choice model to assess the attributes of the individual that contribute to the hired skipper use/leasing decision itself. This analysis reveals several potential attributes – the quantity, diversity, and the residency of the shareholder – that may be addressed with regulatory mechanisms by managers concerned with the potential emergence of an absentee owner class of shareholders.

Logistics and regulations are likely to be significant factors in how shareholders with large and diverse shareholdings participate in the halibut IFQ fishery. For example, shareholders with large holdings may hire skippers in order to take breaks during long fishing seasons or because their own vessel operates near the vessel use cap in the IFQ program. For those with holdings in multiple vessel classes, regulatory limitations on the size of the vessel that can be used to fish each class of quota may necessitate shareholders using hired skippers for quota in classes for which they do not have the appropriate sized vessel.

It is worth noting a few ways in which this analysis can be extended. Factors other than those assessed in this analysis could help explain variation in the observed choices over the use of hired skippers. Such factors may include the age of the shareholder, whether they participate in other fisheries, the percentage of their total income that is generated in the halibut fishery, and expectations of earnings in these other fisheries. As previously noted, age data are confidential. An individual's participation across State and federal fisheries may be difficult to establish. Alaska State fisheries data and federal fisheries data are linked by vessel id but not by individuals, although there is the potential for using name-matching software to identify participants across multiple federal and state fisheries.

It would also be of interest to evaluate the potential impacts of commercial IFQ leasing by the charter industry on hired skipper use and the transition of quota to owner-operators. Beginning in 2014, the halibut charter industry in Areas 2C and 3A was allowed to lease IFQ from commercial halibut fishermen in these two areas.

Given that many hired skipper arrangements are functionally equivalent to leasing, opening up the IFQ leasing market to the charter sector, which ostensibly has a higher willingness to pay for IFQ than commercial fishermen (Lew and Larson, 2015), may have some impacts on those commercial fishermen competing to lease IFQ as hired skippers. In the first year of this new policy, average charter lease fees were $5.01 in Area 3A, a 70% to 85% lease rate assuming ex-vessel prices of $6.50 to $7.00 for halibut (Scheurer, 2014). Although the fees charged by hired skippers are not documented in the halibut IFQ program, anecdotal evidence indicates that hired skipper fees in some areas may be as low as 25% (Szymkowiak and Himes-Cornell, 2015a), indicating that perhaps charter lease rates in the Alaska halibut IFQ program are at the upper range of commercial lease rates. However, the charter fleet leased just over 41,000 pounds of halibut IFQ in the first year of this new program, representing a tiny fraction of the over 10 million pounds of IFQ that was landed in Areas 2C and 3A in 2014. Therefore, the largest impact of this new leasing market may not be on hired skippers competing for quota but on fishermen trying to buy quota shares, as the program effectively provides existent shareholders with another alternative to selling their shares. These impacts may be especially problematic if charter fishermen lease small blocks of quota shares that would otherwise go up for sale, as new entrants often initially purchase small quantities of quota shares. The 2014 charter leased IFQ represents about 5% of the total 887,124 commercial IFQ pounds that were permanently transferred in Areas 2C and 3A in 2014 (NOAA, 2014).

Overall, this analysis has provided greater insight into the characteristics of shareholders that contribute to the decision to hire skippers in the Alaska halibut IFQ program, an insight that can be applied more broadly to leasing in catch share programs. In the context of the increasing use of catch share programs in fisheries management and a growing body of literature on the potentially adverse impacts of a lease-based fishery, understanding the attributes of shareholders that contribute to the probability of hiring a skipper/leasing is paramount.

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Chapter 4

EXAMINING THE IMPACTS OF HIRED SKIPPER USE UPON ENTRY INTO THE ALASKA HALIBUT IFQ FISHERY

4.1 Introduction

4.1.1 Background

There is some debate in the fisheries literature about the potential impacts of leasing on the ease of entry or quota share acquisition for second-generation shareholders. Some researchers argue that leasing can enable entry by providing fishermen with quota at a lower cost than would be possible in the permanent quota share market, allowing entrants to build up experience and capital in the fishery in order to eventually buy quota shares (Wilen and Brown, 2000; GAO, 2004; Stewart and Callagher, 2011). On the other hand, other researchers posit that leasing can provide a profitable alternative to selling quota shares for shareholders, which can make quota shares more valuable and, thereby, more expensive for entrants to buy or lease (Pinkerton and Edwards, 2009; van Putten and Gardner, 2010).

Despite this ongoing debate, few researchers have actually empirically analyzed the impacts of leasing upon entry into a catch share fishery. Stewart and Callagher (2011) compared the quota concentration ratio, Herfindahl-Hirschman Index, and number of participating entities before and after the institution of quota leasing in New Zealand's Quota Management System. They showed that the impacts of leasing in a fishery are related to the capital investment requirements of participating in the fishery. For inshore fisheries, which require limited capital expenditures on vessels and gear, the availability of leased quota can facilitate entry, while in fisheries with larger capital investment requirements, leasing may have no impact on entry rates (ibid.). Pradhan and Leung (2004) examined vessel entry, stay, and exit as a factor of whether the vessel was captained by a hired skipper or by the vessel owner. They showed that vessels captained by a hired skipper were more likely to enter and exit, and less likely to stay, than vessels captained by the vessel owner.

In the halibut IFQ fishery, the increasing use of hired skippers by eligible individuals (examined in the previous chapter) may be impeding entry by providing shareholders with an alternative to selling their quota shares. Although initial recipients are continually leaving the fishery, some are shifting towards using hired skippers to land their IFQ, implying that instead of selling their shares and thereby making shares available on the market for second-generation shareholders, these inactive initial recipients may in fact be slowing entry. The ultimate effect of allowing hired skipper use may therefore be a growing number of inactive eligible individuals at the cost of entry. In Area 2C, the NPFMC prohibited hired skipper use amongst all individuals, explicitly in an effort to facilitate entry into the halibut IFQ fishery in this area (NPFMC, 2014). That is, the NPFMC envisioned that the transition to second-generation ownership of quota could be expedited by prohibiting hired skipper use for individual shareholders. In other words, the NPFMC ostensibly viewed hired skipper use as a potential impediment to entry in the IFQ program. The NPFMC also prohibited non-initial recipient companies from purchasing catcher vessel quota shares in the IFQ fishery, which was intended to ensure that individuals were competitive in bidding for quota shares (NMFS, 1992). The combination of these two provisions should have facilitated entry into Area 2C in relation to other regulatory areas.

The following study addresses the ongoing debate amongst researchers about the impacts of leasing upon entry by empirically assessing the role of hired skipper use, as a proxy for leasing, in facilitating or impeding entry into the halibut IFQ fishery. This chapter is comprised of three analyses, each of which applies a different methodology and examines a different aspect of the impacts of hired skipper use upon entry. In the first analyses, shareholders and hired skippers are characterized, over the 2000 through 2013 timeframe of the dataset, with respect to whether they are initial recipients or second-generation shareholders, their shareholdings, and how they fish their IFQ. This analysis is extended with a relational contingency table assessment of hired skipper and shareholder networks in the fishery, with respect to both the residency and the amount of shareholdings of these actors. In the second analysis of this chapter, a counterfactual analysis is used to examine the impacts of the prohibition on individual use of hired skippers and company ownership of catcher vessel shares upon entry in Area 2C. The third analysis of this chapter applies a discrete choice model analysis to assess the determinants of exit for shareholders in the IFQ fishery.

4.1.2 A Brief Note on the Economics of Entry into Quota-based Managed Fisheries

According to economic theory, a well-functioning, well-managed, and enforced ITQ system can give rise to resource rents in a fishery. In the case where quota is freely allocated to initial recipients and there is no attempt to collect some of this rent by resource managers (by leasing, selling, or taxing the quota), most of the resource rent may be captured by the first-generation of quota shareholders when they exit the fishery and sell their shares (Whitmarsh, 1998). The second-generation of shareholders essentially pays initial recipients the value of the rent that result from the implementation of the ITQ system.

In making quota share purchasing decisions, both initial recipients and second-generation shareholders will seek to maximize profits. The economic incentives for buying quota are net of the opportunity costs of both the foregone income that the individual could have expected to earn from alternative work and the foregone returns he could have expected to earn from alternative investments. Transfers are likely to continue throughout the duration of an ITQ managed fishery as quota holders' valuations of their quota change due to changes in expectations about earnings in the fishery and these opportunity costs (Knapp, 2011). For example, as shareholders age, their valuations may decline because they find fishing more difficult, while younger people's valuations may increase as they acquire crewing experience and financial capital (ibid.). Quota transfers will then occur towards individuals in the younger generation whose valuation of the quota is higher than existent quota holders.

In summary, the key difference between initial recipients and second-generation shareholders is that the former can accrue the resource rents that may arise with the institution of an ITQ program. In addition to these potential windfall gains, initial recipients can use the value of their allocated quota as leverage for buying more quota, which theoretically should provide them with an advantage in the quota share market. As ITQ fisheries move towards reducing overcapitalization and increasing efficiency, the value of quota often increases making entry into the fishery more difficult. Indeed, the most frequently cited barriers to entry for second-generation shareholders are the costs of quota shares and the access to capital needed to buy them

(Huppert et al., 1996; Turris, 1997; Dewees et al., 1998; Goodlad, 1999; Copes and Charles, 2005; Carothers, 2008; Aslin, 2009; Pinkerton and Edwards, 2009; Cardwell, 2013).

4.1.3 Entry into the Halibut IFQ Fishery

The NPFMC included several provisions and amendments in the halibut IFQ program to facilitate entry for second-generation shareholders. The block program, which was introduced in Chapter 1, was intended to constrain quota transferability and consolidation so as to preserve the availability of small amounts of quota in the fishery for part-time fishers and new entrants (Hartley and Fina, 2001). The "fish down" or "buy down" provision, also introduced in Chapter 1, was intended to provide a larger pool of quota from which the smaller vessel owners could buy shares, which could facilitate entry since most new entrants buy into the smaller vessel classes (Dawson, 2006). The NPFMC also included individual and vessel use caps to limit consolidation and to ensure the availability of quota for new entrants. Finally, Congress mandated that quota shareholders be charged IFQ fees in order to support a loan program to address the needs of entry level and small boat fishermen (Pautzke and Oliver, 1997). The NMFS has been issuing loans under this program since 1998 (NMFS, 2011).

Quota share ownership by second-generation shareholders has been steadily increasing since the implementation of the IFQ program. By 2013, over 41% of the halibut IFQ shares were held by second-generation shareholders, see Figure 4.1. Figure 4.2 shows the distribution of quota share ownership by initial recipients and second-generation shareholders by vessel class. Second-generation shareholders own the greatest percentage of the total vessel class shares in the smallest vessel class (Class D), which has the lowest capital investment requirements. Large second-generation shareholdings in the Class B vessel class may be due to the "fish down" provision.

The availability of blocked quota shares has been cited as something that has facilitated entry into the halibut IFQ fishery by providing small amounts of quota on the market (NPFMC, 2009). However, the general lack of quota shares for sale on the market and the substantial capital needs coupled with limited access to funding for quota share purchases continue to be often cited obstacles to entry (NPFMC, 2014). The prices of quota shares have increased substantially in all vessel classes and areas since the implementation of the IFQ program (with prices in some areas currently above $40 per pound) (NPFMC, 2014). Furthermore, recent increases in gifted quota shares have put a further upward pressure on share prices (NPFMC, 2014).

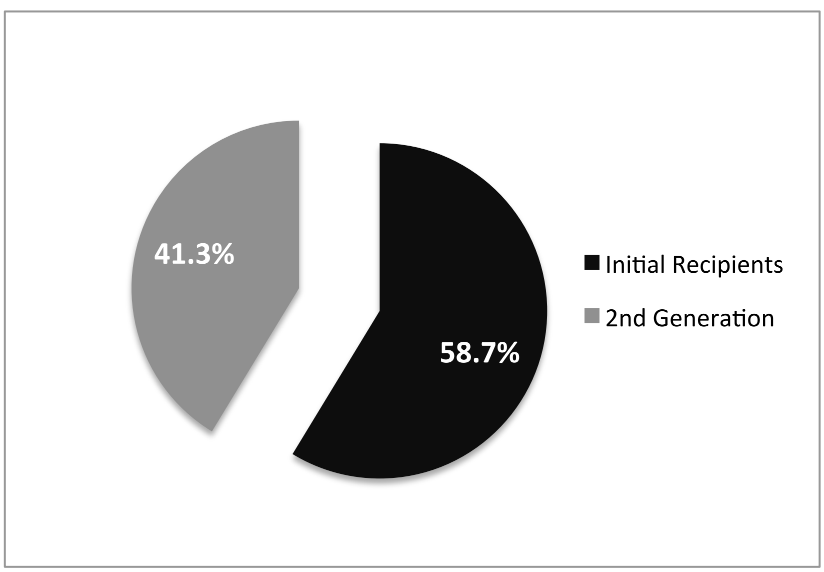

Figure 4.1: Percent of total halibut IFQ held by participant type (2013)

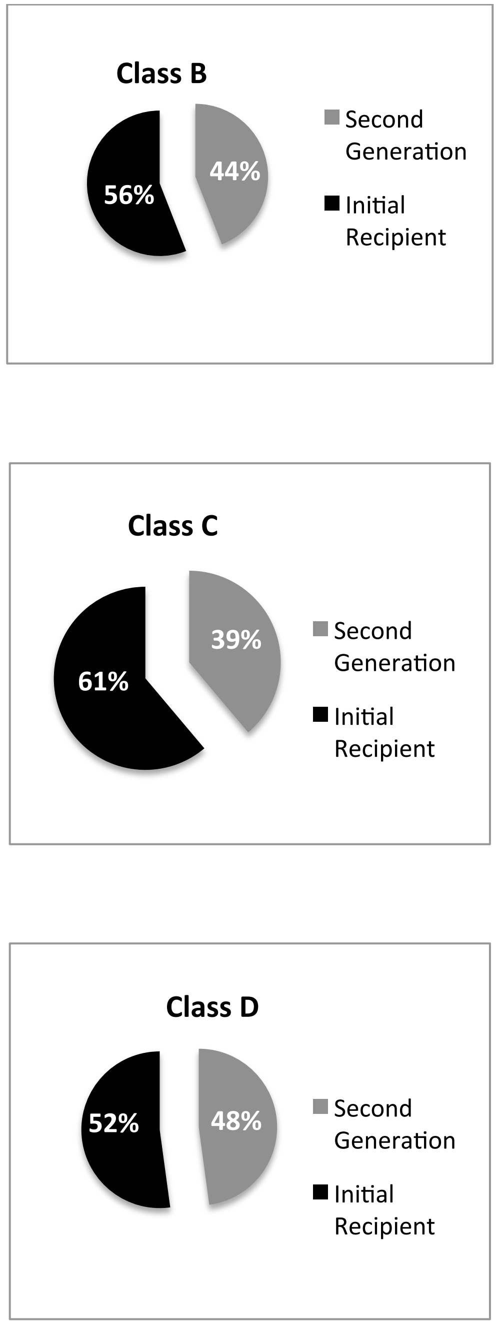

Figure 4.2: Percent of halibut IFQ held by vessel class and by participant type (2013)

4.1.4 Summary of Fourth Chapter Analyses and Findings

In the first analysis in this chapter (Section 4.2), hired skippers and second-generation shareholders are characterized individually and with respect to the networks that exist between them. The analysis shows that most hired skippers are shareholders themselves and that despite a growing reliance on hired skippers by initial recipients, there is no indication of growth in professional hired skippers (i.e. hired skippers who do not own any shares themselves). The networks of hired skippers and shareholders are described with respect to geographic affiliation and amount of quota shareholdings, showing that there is a statistically significant relationship between hired skippers and shareholders with similar characteristics. In other words, shareholders are likely to use hired skippers that reside in the same state and have similar sized shareholdings, indicating that the networks between these actors are homophilic. If second-generation shareholders enter the fishery as hired skippers, homophilic networks may impede new entry by making entry more difficult for those who are "unlike" existent participants (e.g. from the same geographic area and with the same quantity of holdings). However, homophilic networks should also reduce transaction costs between hired skippers and shareholders and thereby facilitate these relationships.

The second analysis in this chapter (Section 4.3) presents a counterfactual analysis of entry into Area 2C, which was subject to different regulations on hired skipper use and corporate ownership of quota shares than the other regulatory areas. This counterfactual analysis shows that if entry into Area 2C approximated the pattern of entry into the other regulatory areas, there would we be fewer new entrants than there actually have been into this area. The higher than expected rate of entry into Area 2C is attributed to the more restrictive regulations on hired skipper use and corporate ownership of shares, which have likely provided a disincentive for initial recipients to consolidate holdings in the area, making more quota shares available for purchase for new entrants interested in buying into the fishery.

The third analysis of this chapter (Section 4.4) presents an assessment of the determinants of exit for eligible individuals (i.e. those who can use hired skippers) in order to understand how hired skipper use affects exit. A shareholder is identified as exiting an IFQ area if he does not own any quota shares in that area by the beginning of the next fishing season. This analysis employs a discrete choice model with a shareholder exiting an IFQ area as the dependent variable and hired skipper use as one of the predictor variables, showing that hired skipper use is weakly positively associated with the probability of exit of a shareholder. The results also indicate that the probability of a shareholder exiting an IFQ area is negatively associated with the diversity and quantity of his shareholdings.

In summary, the three analyses in this chapter provide greater insight into how hired skipper use is affecting entry into the halibut IFQ fishery. The counterfactual analysis provides some evidence that limiting the ability of initial recipients to use hired skippers has facilitated entry into Southeast. The other two analyses in this chapter, however, show a more nuanced picture of the impacts of hired skipper use upon new entry. Despite concerns about the impacts of hired skipper use, networks between shareholders and hired skippers and the continued increase of hired skippers that are second-generation shareholders indicate that quota shares are being transferred to the next generation of shareholders and that acting as a hired skipper likely allows second-generation shareholders to build up their stakes in the fishery. Furthermore, there is indication that acting as a hired skipper is positively associated with the probability of a shareholder exiting from an IFQ area, although the association is weak and redefining exit could change the results.

4.2 Characterization of Hired Skippers and Shareholders and their Networks in the Halibut IFQ Fishery

4.2.1 Introduction

Since the start of the IFQ program, there has been a gradual shift of quota shares to second-generation (i.e. non initial recipient) shareholders and an increasing use of hired skippers by eligible individuals (i.e. initial recipient individual quota shareholders of catcher vessel shares excluding shareholders in Area 2C). Since most second-generation shareholders have to buy their quota shares, they often act as hired skippers in order to build up capital in the fishery. As quota is transferred to these second-generation shareholders and eligible individuals increasingly shift towards being inactive shareholders or exit the fishery altogether, several participant types have emerged in the fishery. The following study characterizes these participant types in the halibut IFQ fishery and uses concepts from social network analysis to assess the relations between these participant groups, in an effort to understand potential impacts on new entry into the halibut IFQ fishery.

Researchers have shown that social networks can significantly increase collaboration amongst stakeholders (Diani, 2003; Hahn et al., 2006; Sandstrom, 2008). With respect to fisheries, van Putten et al. (2012) showed that access to social networks does facilitate entry for new participants into a fishery. However, very tight social networks, or ones with very high tie density (the number of existing ties between actors divided by the number of possible ties), may be problematic because they can lead to homogenization of knowledge and thereby less efficient use of information (Bodin and Norberg, 2005; Little and MacDonald, 2007). Furthermore, tie density may be associated with homophilic networks, ones that are chiefly comprised of people that are similar to each other, with respect to some characteristic (beliefs, age, education, etc.) (McPherson et. al., 2001). Although, as discussed in more detail below, homophilic networks can work to reduce transaction costs incurred in exchanges between actors, the emergence of these types of networks may be problematic if they also serve to exclude potential participants.

In the halibut IFQ fishery, there is anecdotal evidence that some networks facilitate quota share purchases and the development of shareholder-hired skipper relationships (NPFMC Public Testimony, 2011). There is also some indication that most new entrants have to act as hired skippers in order to be able to make economically worthwhile trips to fish their own quota (NPFMC, 2014). In this context, homophilic networks between shareholders and hired skippers may impede entry for new participants, if these entrants are seen as being significantly different from existent participants. As discussed further in Part II below, there is also some evidence that different geographic networks may be better equipped to facilitate new entry than others.

In the first part of this analysis, eligible individuals and hired skippers are characterized with respect to how they participate in the IFQ program. Furthermore, participation rates within these categories are evaluated over the timeframe of the dataset. The analysis is limited to eligible individuals, because corporations are mandated to use hired skippers, and second generation shareholders are forbidden from using hired skippers. Several categories of shareholders and hired skippers are identified in the fishery, with respect to occupation in the fishery and degree of participation. The analysis shows a generally static number of professional hired skippers and an increasing number of second-generation shareholders, while the number of inactive eligible individuals is increasing though not in proportion to the number of eligible individuals leaving the fishery. Similarly, Van Putten and Gardner (2010) characterized five shareholder types in the Tasmanian rock lobster fishery with respect to quota share ownership and leasing.

In the second part of this analysis, contingency tables with appropriate measures of association are developed to assess the relationships between characteristics of the eligible individual shareholder and of the hired skipper, with respect to residency and shareholdings. Contingency tables are joint frequency distributions of two or more categorical variables. First described by Karl Pearson in 1904 (Pearson, 1904), contingency tables and measures of association are amongst the most widely used statistical tools by scientists. Researchers analyzing fishermen's social networks have utilized relational contingency table analysis to assess relationships between actors, comparing the number of actual relations to the number of expected relations given the size of the network and number of ties (Ramirez-Sanchez and Pinkerton, 2009; Barnes-Mauthe et al., 2013; Turner, 2014). There is also emerging research utilizing social network analysis to analyze the roles of participants, geography, and ties between actors in lease quota markets in limited entry and catch share fisheries (MacLauchlin, Larkin, and Adams, 2009; Van Putten et al., 2011; Ropicki, 2013; Ropicki, 2014).

4.2.2 Data

The data utilized in this analysis is Pacific halibut IFQ landings data from 2000 through 2013 provided by the Alaska Fisheries Information Network (AKFIN). The data is comprised only of landings for eligible individuals, who utilized hired skippers for the landing. Each observation includes shareholdings (amount of total annual fishable pounds) and residency attributes (city and state) for both the eligible individual shareholder and the hired skipper. The status of the hired skipper as either an initial recipient of quota shares or not is also flagged. The shareholdings of both actors are also categorized as less than 3,000 pounds (LT 3K), 3,000 to 10,000 pounds (3K to 10K), 10,000 to 25,000 pounds (10K to 25K), and greater than 25,000 pounds (GT 25K). Shareholdings were categorized to reflect regulatory restrictions on holdings and NMFS reporting conventions on consolidation in the IFQ fishery (NMFS, 2012). After omitting all landings for corporate entities, second-generation shareholders, and participants in Area 2C, and landings for eligible individuals in which a hired skipper was not used, the number of observations used for this analysis was 13,831. STATA 13 S.E. software was used for this analysis.

4.2.3 Characterization of Shareholders and Hired Skippers

Eligible individual shareholders can be categorized with respect to how they land their own IFQ and hired skippers can be categorized with respect to their quota share investments. With respect to these characteristics, several types of shareholder and hired skipper groups participate in the halibut IFQ fishery. These groups can be classified as: 1) *Active eligible individuals*– fish all of their own catcher vessel quota; 2) *Part-time eligible individuals* – fish some of their own quota and lease some; 3) *Inactive eligible individuals*– lease all of their quota; 4) *Hired skipper shareholders* – shareholders who act as hired skippers; 5) *Professional hired skippers* – do not own any halibut IFQ shares themselves. The first three categories are mutually exclusive, as types of eligible individual quota shareholders, and categories four and five are mutually exclusive, as types of hired skippers. However, both eligible individuals and second-generation shareholders can be classified as hired skipper shareholders.

Figures 4.3A and 4.3B show the number of individuals in each participant category in the halibut IFQ fishery from 2000 through 2013. Figure 4.3B excludes active eligible individuals in order to show the remaining participant categories at a scale at which trends in these categories can be compared. Since eligible individuals can be included in the hired skipper shareholder category, these numbers should not be considered as additive for the purpose of defining a total number of participants in the fishery. It should also be noted that these counts of participants are taken from the landings data and therefore do not account for any participants, who may not be utilizing their quota shares at all.

The figures show a precipitous decline in active eligible individual shareholders, with a concomitant though not equal increase in inactive eligible individual shareholders, indicating that most eligible individuals exit the fishery once they retire from fishing their own quota. The exodus of eligible individuals is likely due to consolidation in the fishery, aging, and decreases in the TAC, which have likely made some shareholders' holdings too small to fish. After a spike in 2008, the number of part-time eligible individuals has dropped back to levels that existed in 2000. Whether part-time eligible individuals transition into becoming inactive or whether they exit the fishery altogether is not evident from these trend lines. However, annual spikes in inactive eligible individuals are generally correlated with dips in part-time eligible individuals and vice versa (and often in similar quantities), providing some evidence that part-time individuals are the ones that transition to being inactive. Concurrent with an increasing number of inactive eligible individuals, there has been an increase in the number of hired skipper shareholders over the timeframe of the data. Surprisingly, there has not been an increase in professional hired skippers since 2000, which contradicts expectations about an emerging class of professional hired skippers associated with an increasing demand for hired skippers from eligible individuals.

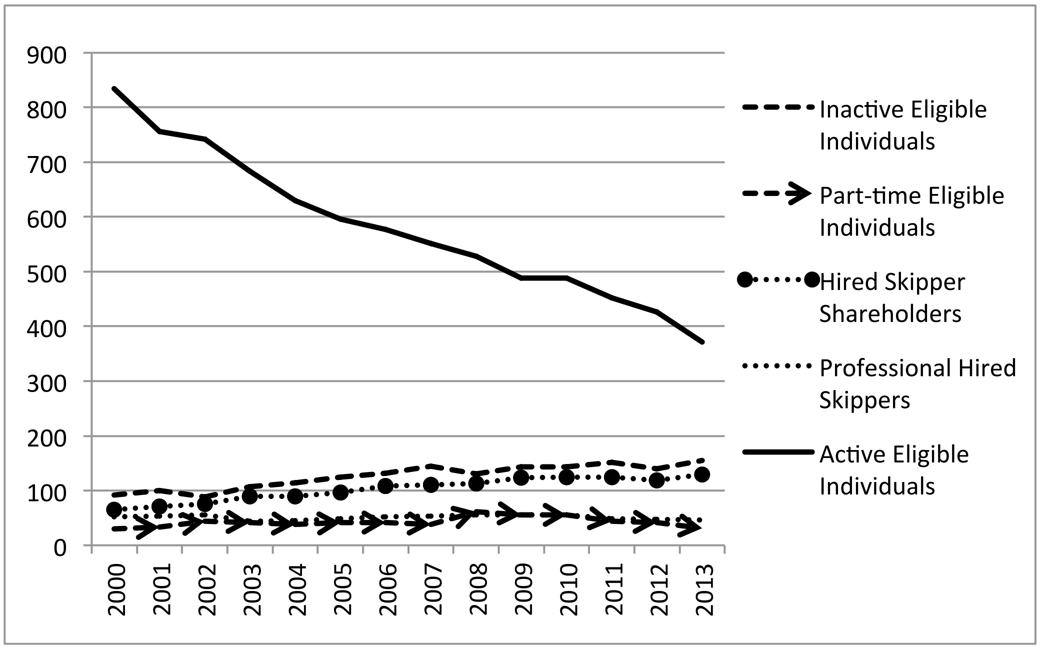

Figure 4.3A: Number of individuals in each halibut IFQ participant category from 2000 to 2013, including active eligible individuals.

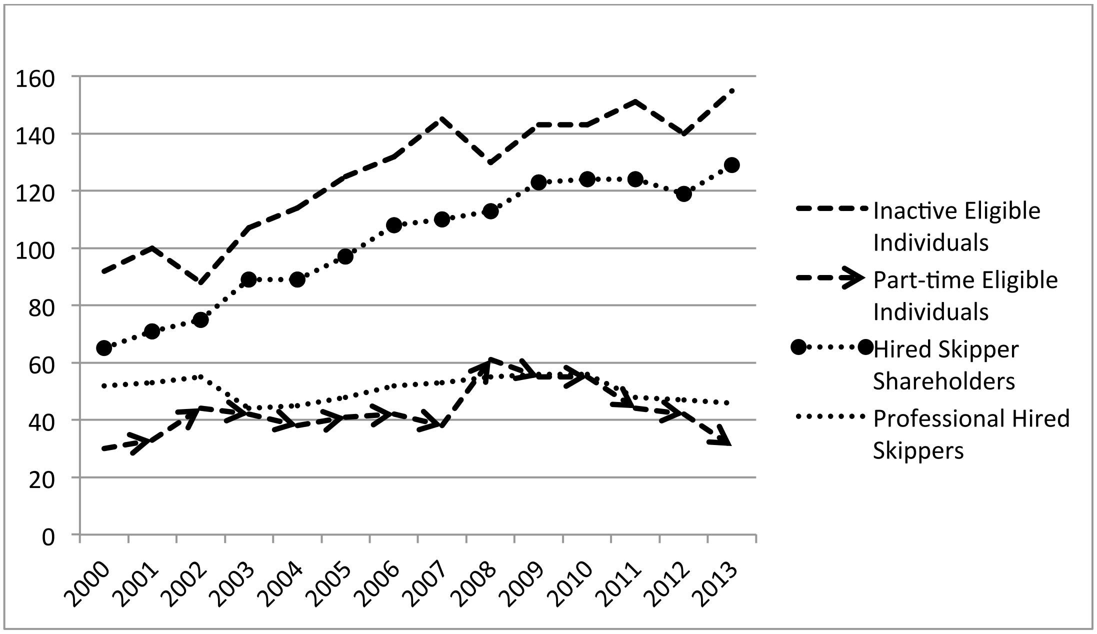

Figure 4.3B: Number of individuals in each halibut IFQ participant category between 2000 through 2013, excluding active eligible individuals.

Figure 4.4 shows the number of hired skippers, who landed quota for eligible individuals, by hired skipper type (e.g., initial recipient or second generation shareholder, or professional hired skipper/ non-shareholder) between 2000 and 2013. The figure shows that the number of hired skippers fishing quota for eligible individuals has been increasing since 2000, with second-generation shareholders accounting for the vast majority of hired skippers in the fishery since 2003. It is interesting to note both the slight decrease in the number of professional hired skippers and the increasing number of initial recipients acting as hired skippers over this time period. The decreasing number of professional hired skippers may be due to a shift of some of these participants into the second-generation shareholder category or out of the fishery, as demand for hired skippers is met by initial recipients and by second-generation shareholders. A decrease in the TAC over this time period has also likely contributed to less demand for hired skippers than would otherwise be expected given the increasing reliance on hired skippers by eligible individuals. The cause for the increase in initial recipients acting as hired skippers may also be due to the decreasing TACs, as leasing in quota would allow these shareholders to make up for some of the loss in harvest.

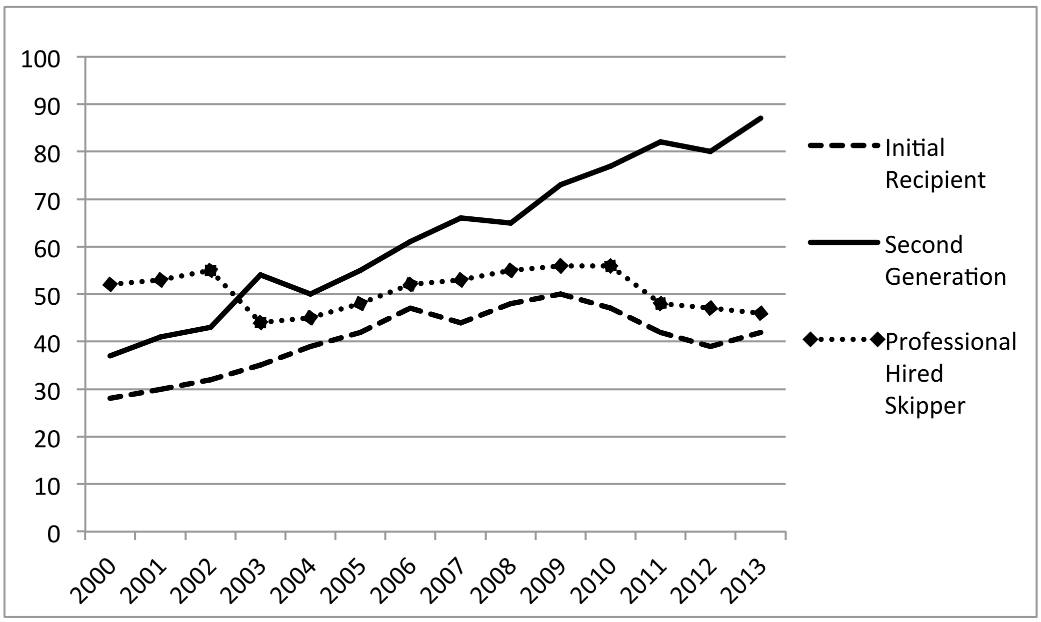

Figure 4.4: Number of hired skippers for eligible individuals by shareholding category

Figure 4.5 shows the percent of total quota landed for eligible individuals that is landed by active, inactive, and part-time eligible individuals. This figure shows that inactive eligible individuals now account for the majority of landed quota for eligible individuals. Given that active shareholders still make up the majority of eligible individual shareholders in the halibut IFQ fishery, Figure 4.5 indicates that as a group inactive eligible individuals have consolidated more quota than active eligible individuals. Furthermore, given their small numbers in the fishery, this landings data indicates that part-time eligible individuals have also consolidated proportionally more quota in the fishery than active eligible individuals.

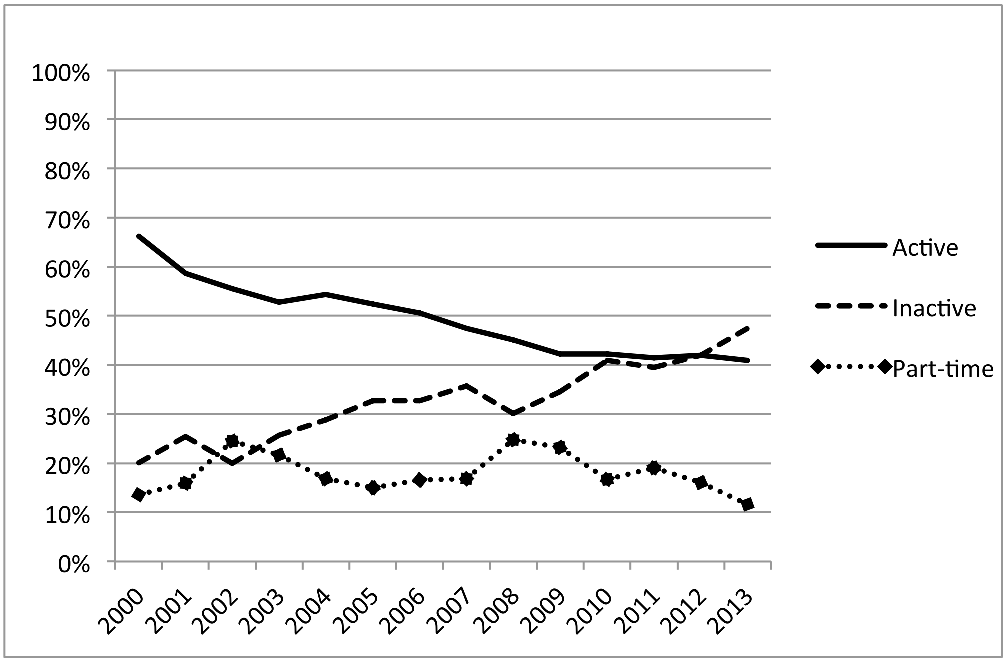

Figure 4.5: Percent of total eligible individual landed quota landed by active, inactive, and part-time shareholders

4.2.4 Analyzing Shareholder and Hired Skipper Networks

4.2.4.1 Introduction

At the February 2011 North Pacific Fishery Management Council meeting, participants in the IFQ program testified about the potential impacts of the hired skipper "Sunset Provision", which provides that hired skippers cannot be used to harvest annual IFQ allocations from quota shares that were transferred after February of 2010. The provision, which was implemented in December of 2014, was developed in response to the increasing use of hired skippers by eligible individuals in the program, which ran counter to the desire of the NPFMC to have an owner-operator IFQ fleet (NPFMC, 2014). Public testimony at the February 2011 meeting provided anecdotal evidence that in the halibut IFQ fishery networks may exist based on age (initial recipients versus second-generation shareholders), occupation (shareholder versus hired skipper) and geography (Alaskans versus Non-Alaskans, and on more micro-levels – towns or IFQ areas, etc.).

Given the differential benefits of hired skipper use in the fishery, age and occupation divisions in public testimony are aligned with expectations. The latitude to use hired skippers affords eligible individuals another means of using their IFQ, whereas second-generation shareholders have to buy into the fishery, which can be delayed by eligible individuals utilizing skippers. Researchers have shown that attributes including age, occupation, experience in an occupation, and socioeconomic status can contribute to the formation of homophilic networks (McPherson et al., 2001; Barnes-Mauthe et al., 2013).

It was also evident from the 2011 public testimony that there is a geographic dichotomy between the Seattle and the Alaska-based fleets with regards to the perception of the role of hired skippers and access to quota shares for second-generation shareholders in the fishery. Furthermore, the Seattle and Alaska networks seemed to cut across generational lines. Hired skippers from Seattle testified that acting as a hired skipper allows them to build up capital and experience in the fishery and that inhibiting the use of hired skippers would inhibit their ability to gain entry into the fishery, while eligible individuals from Alaska testified that the expansion of hired skipper use had never been intended by the NPFMC and that it was necessary to curtail this use and provide for a facilitated entry into the IFQ program for second-generation shareholders. Other researchers have found that geographic affiliation (e.g. village, city, or region) is one of the key underlying attributes that contribute to the formation of homophilic social networks, which can be difficult to penetrate for "outsiders" (McPherson et al., 2001; Ramirez-Sanchez, 2007; Cohen et al., 2012).

The second part of this analysis evaluates the relationships between shareholders and hired skippers, with respect to the attributes of these actors. The analysis addresses whether there is evidence of a probabilistic relationship between shareholders and hired skippers that is a factor of the homogeneity of their shareholdings or the geographic proximity of these actors. A relational contingency table analysis is used to evaluate the strength and statistical significance of these relationships.

4.2.4.2 Economic Theory of Transaction Costs and Homophilic Social Networks

The theoretical underpinnings of this analysis are based in the literature on homophilic networks and transaction costs. Transaction costs are all monetary and non-monetary costs that are incurred when an economic exchange is made (Commons, 1931; Fliaster and Spiess, 2007) and may include search and information costs, bargaining costs, and policing and enforcement costs. Homophilic networks can reduce transaction costs due to the trust, proximity, reciprocity, and social responsibility that these networks foster, which can help to overcome costly information asymmetries, bargaining periods, and monitoring needs (Eckenhofer, 2011). Furthermore, outside of their immediate network, actors are more likely to collaborate with those, who have ties to others in their network, which can help to reduce transaction costs due to greater trustworthiness (Burt, Gabbay, Holt, & Moran, 1994; Burt, 2000; Berardo & Scholz, 2010; Feiock, Lee, Park, & Lee, 2010; Lee et al., 2012; Lubell, Scholz, Berardo, & Robins, 2012).

With respect to the relationships between hired skippers and shareholders, the emergence of homophilic networks could also potentially provide for lower transaction costs. Both hired skippers and shareholders incur transaction costs when they establish new partnerships, due to the search and information costs of looking for new partners, the bargaining costs for new transactions, and the potential for policing and enforcement costs, especially within the initial stages of a relationship. Utilizing their networks to establish these relationships and maintaining those relationships could, therefore, help to reduce these transaction costs. This may be especially pertinent with geographically affiliated social networks, as physical proximity between shareholder and hired skipper can help to reduce search, information, bargaining, and monitoring costs. With respect to quantity of shareholdings, shareholders and hired skippers with similar sized holdings may be more likely to know each other than those with different sized holdings, especially if hired skippers with large holdings are more likely to be initial recipients than second-generation shareholders. Such familiarity could help to lower transaction costs. Furthermore, hired skippers with large shareholdings may be more likely to want to lease only large amounts of quota, since they are less likely to need to append their own holdings to make economically worthwhile trips.

4.2.4.3 Contingency Tables and Measures of Association

Contingency tables with measures of association are used to analyze networks between shareholders and hired skippers, with respect to shareholdings and geographic affiliation of these actors. The contingency table shows the percentages for the response variable (column) within the categories of the explanatory row variable. Contingency tables are used to look at whether the conditional distributions of one variable are the same across the levels of the other variable.

Relational contingency table analysis examines the ratio of observed to expected ties within and between groups, wherein the expected number of ties reflects expectations under a model of independence (Hanneman and Riddle, 2005; Barnes-Mauthe et al., 2013). This type of analysis has been used to examine network homophily (Barnes-Mauthe et al., 2013). Measures of association are used to assess the statistical significance of relationships (Pearson's Chi-squared) and the strength of these relationships (Cramer's V, gamma, Kendall's tau-b). Pearson's Chi-squared and Cramer's V are measures of association for categorical variables, and gamma and Kendall's tau-b (described in more detail in a section below) are more appropriate for ordinal variables.

The Pearson Chi-squared value is used to evaluate whether there is a statistically different relationship between the conditional distributions of the variables. The null hypothesis is that the conditional distributions are independent. The assumptions of the Chi-squared test include independent observations, mutual exclusivity of row and column variables, and large expected frequencies.

The formula for the Chi-squared test statistic is:

$$\chi^2 = \sum_{i=1}^{I} \sum_{j=1}^{J} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \tag{4.1}$$

where O_{ij} is the observed frequency in the i^{th} row and j^{th} column and E_{ij} is the expected frequency in that row and column. The statistic is summed over all rows I and columns J. The expected frequency in each cell is calculated as:

$$E_{ij} = \frac{T_i * T_j}{N} \tag{4.2}$$

where T_i is the total number of counts in the i^{th} row and T_j is the total number of counts in the j^{th} column and N is the total number of counts in the table.

The value of the Chi-squared statistic is large when some of the cells have large discrepancies between the observed and expected frequencies. The critical value of Chi-squared is established with the alpha value corresponding to the significance level and the degrees of freedom, where the degrees of freedom are equal to: (I - 1)(J - 1). When the probability of the Chi-squared test statistic is below a chosen significance level, the null hypothesis of independence can be rejected.

If the null hypothesis is rejected, the next step of the analysis is to identify the cells or parts of the contingency table that contributed the most to the goodness-of-fit statistic, i.e. the parts that contributed the most to rejecting the null hypothesis, and the strength and direction of the contribution of these cells. This is achieved by inspecting the residuals.

Because the size of the residuals will be related to the sample size the residuals are standardized - divided by the root of the expected frequency. These are known as the Pearsonian residuals, which are calculated as:

$$r_{ij} = \frac{O_{ij} - E_{ij}}{\sqrt{E_{ij}}}, i = 1,\ldots,I, j = 1,\ldots,J. \tag{4.3}$$

The use of Pearsonian residuals to examine a contingency table may give conservative indications of cells having lack of fit because the variance of r_{ij} is always less than or equal to one and in some cases considerably less than one. Therefore, the size of these residuals cannot be judged by comparison with standard normal percentage points and evaluation of the cell's contribution may be misleading (Everitt, 1992; Kateri, 2014).

A more precise analysis is afforded by the use of adjusted residuals, which are the Pearsonian residuals divided by an estimate of their standard error (Haberman, 1973). These adjusted residuals are approximately normally distributed with a mean of zero and a standard deviation of one (Haberman, 1973). Therefore, adjusted residuals can be interpreted in a probabilistic way using the standardized normal curve. A critical value of 2.0 is often used, such that if the adjusted residual is greater than absolute 2.0, the residual is considered to be significant at the 5% level (Bakerman and Robinson, 1994).

The adjusted residuals are defined as follows:

$$d_{ij} = \frac{O_{ij} - E_{ij}}{\sqrt{E_{ij}\left(1 - \frac{n_i}{N}\right)\left(1 - \frac{n_j}{N}\right)}}, i = 1, \ldots, I, j = 1, \ldots, J. \tag{4.4}$$

where n_i and n_j are the expected frequencies for row i and column j, so that $\left(1 - \frac{n_i}{N}\right)$ and $\left(1 - \frac{n_j}{N}\right)$ are the expected proportions for the i rows and j columns, respectively (Bakerman and Robinson, 1994).

Evaluation of the Chi-squared statistic and the residuals are useful for determining the significance of relationships between categorical variables, but other measures of association are utilized to evaluate the strength of these relationships, including Cramer's V. Cramer's V varies from 0 (no association) to 1 (complete association) and is a symmetrical measure, meaning that the value will be the same when either variable is considered the independent or the dependent variable. Cramer's V is calculated as:

$$V = \sqrt{\frac{\chi^2}{N * \min(I-1, J-1)}} \tag{4.5}$$

where I and J, as above, are equivalent to the number of rows and columns, respectively, so that the denominator is the sample size multiplied by the smaller of the number of rows minus one or the number of columns minus one.

With two-by-two contingency tables, Cramer's V is equivalent to the Phi coefficient, which takes the square root of the Chi-squared statistic divided by the sample size. Values of 0.15 or more for Cramer's V are considered useful and of 0.4 or more are considered good (Healey et al., 2010; Chakrabrati, 2013; Murgante et al., 2014).

4.2.4.4 Relative Frequencies of Hired Skipper and Shareholder Characteristics

Table 4.1 shows the relative frequencies of hired skipper and shareholder characteristics in the dataset. Included in the table are both relative frequencies of hired skipper and shareholder characteristics and relationships in the fishery and relative frequencies of observations in the dataset. The former are calculated as unique relationships or characteristics of individual hired skippers and shareholders, so that for each year of the dataset no individual or relationship is double counted. The latter are calculated as the frequencies of observations in the dataset, which does allow for double counting of individuals or relationships.

Both sets of frequencies are presented in order to evaluate whether utilizing the landings observations accurately represents actual relationships in the fishery. Comparing the relative frequencies of actual characteristics and relationships in the fishery to the relative frequencies of the observations in the landings dataset reveals some minor differences especially with regards to shareholdings. However, given that there are multiple categorizations of holdings in the dataset (i.e. as Chapter 3 less than 3,000 pounds, 3,000 to 10,000 pounds, 10,000 to 25,000 pounds, and greater than 25,000 pounds), which are not fully represented in the relative frequencies in Table 4.1, it is expected that using the landings dataset will not significantly bias the results. The landings dataset is used for this analysis because shareholders make the decision to use a particular hired skipper each time that they are making a landing; therefore, analyzing the conditional distributions of the variables within the landings data is considered to be more representative of actual decisions in the fishery.

The data shows that although shareholders and their hired skippers are likely to reside in the same state, they are unlikely to reside in the same city, which may indicate that geographic affiliations for networks are state and not city based. Over the timeframe of the dataset, the majority of hired skippers were from Alaska, which is at least in part due to the greater facility of acting as a hired skipper for those in proximity to the fishing grounds. Alaskans represent a majority of shareholders in the dataset as well. Consistent with the information presented in Figure 4.4, initial recipients represent only about 30% of hired skippers in the fishery over the 2000 to 2013 dataset. Also shown are shareholder and hired skipper shareholdings relative to each other, indicating that the majority of shareholders own more quota than the hired skippers that they employ to harvest their annual IFQ allocations. These differences in holdings are expected since most hired skippers are second generation shareholders and are likely still building up their quota share portfolios. It is important to keep in mind that these relative holdings are with respect to the defined categories of holdings and do not reflect absolute differences between actual holding quantities. In other words, a shareholder who has 24,000 pounds of quota and hires a skipper with 11,000 pounds will be categorized as having holdings equivalent to his skipper, because they are both within the 10K to 25K holdings category.

Table 4.1: Relative frequencies of shareholder (QS holder) and hired skipper characteristics where "GT" is greater than and "LT" is less than.

	HS and QS holder Reside in Same City	HS and QS holder Reside in Same State	HS Resides in AK	QS holder Resides in AK	HS is an Initial Recipient	HS and QS holder have Same Holdings Amount	QS holder Holdings GT HS Holdings	QS holder Holdings LT HS Holdings
Relative Frequency of Actual Characteristics and Relationships								
0	64%	32%	28%	42%	70%	72%	40%	88%
1	36%	68%	72%	58%	30%	28%	60%	12%
Relative Frequency of Observations								
0	69%	35%	28%	45%	75%	72%	34%	94%
1	31%	65%	72%	55%	25%	28%	66%	6%

4.2.4.5 Analyzing the Relationships between Shareholders and Hired Skippers – Residency

Given the indication of geographically affiliated networks above, the following section extends the analysis of the residency-based relationships between shareholders and hired skippers by analyzing whether the geographic affiliations are statistically significant and whether there is any evidence of greater homophily in either the Alaskan or the non-Alaskan network. Furthermore, this geographic affiliation is analyzed both with and without the inclusion of professional hired skippers in order to address how professional hired skippers fit within the overall geographic affiliations.

Table 4.2 shows the relational contingency table analysis by residency of the shareholder and the hired skipper. As in Table 4.1 above, Table 4.2 does provide some evidence of geographically affiliated networks of shareholders and hired skippers, as the observed to expected frequency ratios are greater than 1 for cells where hired skipper and shareholder are both from the same region. Furthermore, the Pearson Chi-squared statistics for both analyses, including and excluding professional hired skippers, are highly statistically significant, indicating that the null hypothesis of independent conditional distributions can be rejected above the 99% significance level. The strength of the relationship as measured by Cramer's V is moderate to good (Healey et al., 2010; Chakrabrati, 2013; Murgante et al., 2014).

Table 4.2: Relational contingency table analysis by residency. Values for each cell are the observed frequencies, the ratio of observed to expected frequencies, and each cell's contribution to the Pearson chi-squared statistic.

		Hired Skipper Residency			
		Only Hired Skippers with Shareholdings (excluding Professional Hired Skippers)		All Hired Skippers (including Professional Hired Skippers)	
		Alaskans	Non-Alaskans	Alaskans	Non-Alaskans
Shareholder Residency	Alaskan	4,247 1.23 181.9	559 0.41 464.9	6,687 1.23 286.2	903 0.42 723.8
	Non-Alaskan	2,451 0.76 193.7	2,062 1.62 495.1	3,225 0.72 348.0	3,016 1.71 880.2

Pearson Chi2 (1)	1.3e+03 Pr=0.000	2.2e+03 Pr=0.000
Cramer's V	0.3786	0.4023

The adjusted residuals were omitted from this table because in a two-by-two contingency table the absolute values of the adjusted residuals are equivalent. A better gauge of the contribution of each cell to deviance from homogeneity may, therefore, be the cell's contribution to the value of the Pearson Chi-squared test statistic. In looking at these values, the low frequency of Alaskan shareholders hiring non-Alaskan skippers and the high frequency of non-Alaskan shareholders hiring non-Alaskan skippers contribute the most to rejecting the hypothesis of independence.

Finally, with respect to geographic affiliations of networks, there is no significant difference between the contingency tables that do and those do not include professional hired skippers. The Pearson Chi-squared test statistic increases with sample size for the table that includes professional hired skippers. The value of Cramer's V also increases slightly with the inclusion of professional hired skippers. This result indicates that for the most part geographically affiliated shareholder-hired skipper networks include professional hired skippers. The ratio of observed to expected frequencies of hired skipper use is slightly higher for non-Alaskan shareholders using non-Alaskan hired skippers when professional hired skippers are included, perhaps indicating that the non-Alaskan network of shareholders and hired skippers is more inclusive of professional hired skippers.

4.2.4.6 Analyzing the Relationships between Shareholders and Hired Skippers – Shareholdings

The following analysis presents the relationships between shareholders and hired skippers in relation to the shareholdings of these actors relative to each other. Although the Pearson Chi-squared statistic is used to analyze the independence of these categories, since the categorizations of shareholdings are ordinal data, ordinal measures of association, including gamma and Kendall's tau-b, are also employed in this analysis. These measures describe and test the direction of association between the variables, as well as the strengths of these associations.

Gamma and Kendall's tau-b are proportional reduction in error (PRE) measures, which describe how much error in predicting y is reduced when taking x into account. In this case, the relationship of interest is between the hired skipper holdings (x) and the holdings of the shareholder that hires him (y). Although all three measures of association utilized here (Chi2, gamma, and Kendall's tau-b) are symmetrical and therefore the values of these measures will be identical indeterminate of how the dependent and independent variables are defined.

Gamma is a measure of association that assesses the relationships between pairs of observations, compared in terms of their relative rankings on the dependent and independent variables, or concordance. Concordant or same-order pairs are those in which the member of the pair that ranked higher on the independent variable also ranked higher on the dependent variable. Discordant or inverse order pairs are those in which the member of the pair that ranked higher on the independent variable ranked lower on the dependent variable.

Gamma (γ) is calculated as:

$$\gamma = \frac{N_s - N_d}{N_s + N_d} \tag{4.6}$$

where N_s is the number of concordant pairs and N_d is the number of discordant pairs. This ratio can vary from +1 to -1, indicating the direction and strength of the relationship.

The calculation of gamma excludes tied pairs – paired observations tied on the dependent variable (T_y) and paired observations tied on the independent variable (T_x). Kendall's tau-b (τ_b) corrects for ties. Kendall's tau-b can be calculated as:

$$\tau_b = \frac{N_s - N_d}{\sqrt{(N_s + N_d + T_y)(N_s + N_d + T_x)}} \tag{4.7}$$

Table 4.3 shows the ratio of the observed to expected frequencies, the Pearson residuals, the adjusted residuals, and the Pearson Chi-squared test statistic, gamma, and Kendall's tau-b measures of association for the relationship between shareholders' categories of holdings and the holdings of the skippers whom the shareholders employ. Kendall's tau-b also varies from -1 to +1.

Given the large Pearson Chi-squared statistic of 347.4 and 12 degrees of freedom, the null hypothesis of independence between shareholders and the hired skippers that they use with regards to shareholdings can be rejected beyond the 99% significance level. Values in bold indicate a higher relative frequency than would be expected under complete independence between the two variables and wherein the residuals are statistically significant at the 95% level. If shareholders are likely to use hired skippers with similar sized shareholdings, the expectation is that the ratio of observed to expected frequencies would be greater than one for cells wherein shareholders and hired skippers have equivalent shareholdings and the ratio would be less than one for cells wherein the holdings across these actors are not equivalent. Indeed, there is some indication of this kind of a relationship between shareholders and hired skippers as most of the greater than one ratios appear in a diagonal pattern from the upper left to lower right corners, or across similar holdings between shareholders and hired skippers. The only outlier in this overall trend is cell (4,1), which indicates that large shareholders use professional hired skippers more than would be expected under independence.

Table 4.3: Relational contingency table analysis by shareholdings, including professional hired skippers. Values for each cell are the observed frequencies, the ratio of observed to expected frequencies, and the adjusted residuals.

		Hired Skipper Shareholdings				
		0	LT 3K	3K to 10K	10K to 25K	GT 25K
Shareholder Holdings	LT 3K	85 **1.33** 3.95	30 **3.08** 6.72	42 **1.43** 2.54	15 0.43 -3.74	12 0.24 -6.35
	3K to 10K	249 0.87 -2.74	75 **1.62** 4.47	221 **1.57** 7.70	195 **1.18** 2.66	136 0.57 -8.04
	10K to 25K	556 0.90 -3.35	107 1.06 0.72	375 **1.23** 4.8	461 **1.29** 6.50	400 0.77 -6.5
	GT 25K	3,622 **1.02** 3.33	520 0.90 -5.13	1,575 0.91 -9.31	1,937 0.94 -5.99	3,218 **1.09** 12.00

Pearson Chi2 (12) = 347.4016 P = 0.000
Gamma = 0.0813 ASE = 0.013
Kendall's tau-b = 0.0432 ASE = 0.007

The signs of the residuals indicate how relationships differ from what would be expected under independence, wherein positive or negative values indicate more or less, respectively, of a relationship than would be expected under independence (Kateri, 2014). For example, the sign of the residual and the value of the observed to expected frequencies ratios for cell (4,3) indicate that the frequency of observed relationships between shareholders with GT 25K holdings and hired skippers with 10K to 25K holdings is less than would be expected under independence and the 9.31 absolute value of the adjusted residual indicates that this cell is highly statistically significant in contributing to the rejection of independence. The greatest contribution to deviation from independence is due to shareholders with the largest category of holdings using hired skippers with similarly sized holdings in cell (4,5). All of the residuals for the diagonal line representing the same holdings between shareholders and hired skippers (from cell (1,2) to cell (4,5)) indicate that the values in these cells are highly statistically significant in their contribution to rejection of independence. The residuals analysis indicates that all of the values are significant at the 95% level and above except the (3,1) value, which is not significant.

Also presented are the gamma and Kendall's tau-b values and their asymptotic standard errors as measures of association between these variables. Both the gamma and the tau-b values indicate virtually no association between the categories. The associations evidenced by both the gamma and the Kendall's tau-b measures are related to the type of data used. In general, measures of association will tend to be greater when higher levels of measurement are used, such as ordinal data rather than nominal data. However, individual-level data will tend to produce weaker measures of association compared to those obtained from aggregate data (Clark and Avery, 1976; Korey, 2013). This is due to the noise variance in individual-level data, which can be filtered out when data are aggregated.

The above analysis includes professional hired skippers, which may underestimate the association between shareholders and hired skippers as a factor of their holdings, if professional hired skippers are more likely to lease quota from all types of shareholders. Furthermore, including professional hired skippers does not address the analysis of the shareholder and hired skipper networks as they relate to entry into the fishery, since professional hired skippers do not own quota shares.

Eliminating the relations between professional hired skippers and shareholders is anticipated to positively affect the value of the measures of association, as professional hired skippers may be skewing the results. In this section, professional hired skippers are omitted from the analysis, which leaves 9,319 observations.

Table 4.4 shows the conditional distributions between shareholders' holdings and the holdings of the hired skippers that they use, for just the landings of the hired skippers who own quota shares. The Pearson Chi-squared test statistic is significant beyond the 99% significance level indicating that, as above, the null hypothesis of independence between shareholders and the hired skippers that they use with regards to shareholdings can be dismissed. The values in bold indicate the same as above. The diagonal pattern from the upper left to the lower right corners indicates statistically significantly higher observed to expected frequencies for cells wherein the hired skipper and shareholder own similar amounts of quota. As in Table 4.3 above, the major contribution to deviation from independence, as evidenced by the size of the residual, is due to shareholders with the greatest quantity of holdings using hired skippers, who also have the largest quantity of holdings, cell (4,4).

Table 4.4: Relational contingency table analysis by shareholdings, excluding professional skippers. Values for each cell in descending order are the observed frequencies, ratio of observed to expected frequencies, adjusted residuals.

		Hired Skipper Holdings			
		LT 3K	3K to 10K	10K to 25K	GT 25K
Shareholder Holdings	LT 3K	30	42	15	12
		3.86	**1.79**	0.54	0.30
		8.35	4.39	-2.86	-5.77
	3K to	75	221	195	136

10K	**1.52**	**1.48**	**1.11**	0.54
	3.96	7.01	1.80	-9.89
10K to 25K	107	375	461	400
	1.01	**1.18**	**1.23**	0.74
	0.17	3.89	5.60	-8.58
GT 25K	520	1,575	1,937	3,218
	0.91	0.91	0.95	**1.10**
	-4.58	-8.59	-5.11	14.64
Pearson Chi2(9) = 324.4304		P = 0.000		
Gamma = 0.2693		ASE = 0.016		
Kendall's tau-b = 0.1417		ASE = 0.009		

As expected, eliminating professional hired skippers does not significantly alter the results with respect to observed to expected frequency ratios or the contribution of each cell to deviation from independence, but it does increase the value of the ordinal measures of association. The gamma and Kendall's tau-b indicate that there is concordance between the shareholder's holdings and the hired skipper's holdings, showing that as a shareholder's holdings increase the likelihood increases that that shareholder will use a hired skipper with larger shareholdings.

The test statistics for the significance of this relationship are not provided but can be calculated using the values of gamma or Kendall's tau-b and the asymptotic standard errors (ASE) provided in the output (Acock, 2008), such that:

$$z = \frac{\gamma}{ASE(\gamma)} \tag{4.8}$$

The z-statistics for gamma (0.2693) and Kendall's tau-b (0.1417) are therefore 16.83 and 15.74, respectively, which are significant beyond the 99% significance level. This means the measures of association are statistically significant and that the null hypothesis that there is no ordered relationship between the ordered distributions of the categories can be rejected.

4.2.4.7 Conclusions

This section examines how initial recipients and second-generation shareholders have been changing how they participate in the halibut IFQ fishery from 2000 through 2013. Whereas the total number of eligible individuals participating in the halibut fishery has been decreasing since the start of the IFQ program, likely as a factor of aging and consolidation of quota shares, the number of inactive eligible individuals has increased. Part-time eligible individuals, those that only rely on hired skippers for part of their landings, have not increased significantly and remain a relatively small contingent in the fishery. However, there is both indication that inactive and part time eligible individuals have been more effective at consolidating quota shares than active individuals, given the proportion of total landed pounds by these participant types relative to their numbers in the fishery. This may reflect that those who acquire significant holdings have a greater disincentive to sell their quota when they stop fishing than those with smaller holdings, or that those who consolidate quota do so as part of a business model that ultimately includes using hired skippers. Professional hired skippers accounted for about a third of the landings observations for eligible individuals from 2000 through 2013, indicating that many of those who act as hired skippers do so as part of a transition to owning shares or in order to append shareholdings.

The relational contingency table analysis in this study provides evidence of both geographically-affiliated and holdings associated networks in the halibut IFQ fishery, with shareholders being more likely to use hired skippers from the same state and with similar amounts of shareholdings. There is also indication that these geographically affiliated networks include professional hired skippers, although these skippers may be crewmembers, who have the intent but have not yet been able to buy quota shares themselves. Networks centered on the relative holdings of shareholders and hired skippers are stronger when professional hired skippers are omitted from the analysis, providing some evidence that professional hired skippers lease quota from various types of shareholders. Homophilic networks are common in various social settings and can help to reduce transaction costs for participants. However, given that many second-generation shareholders have to act as hired skippers in order to make economically worthwhile fishing trips, to acquire the capital necessary to buy their own quota shares, and to extend their fishing seasons, homophilic networks may also serve to exclude new participants.

Relational contingency tables and measures of association are based on the assumption of independence of observations. In this analysis that would mean that the decision to use a hired skipper is independent for each of these landings/observations. It is likely that the observations for each shareholder are not completely independent because the shareholder most likely leases a chunk of quota at a time that is then landed by the hired skipper with several landings (i.e. observations). However, it is impossible to discern from the data which observations are for individual decisions to use a hired skipper and which are for the hired skipper making landings on a chunk of quota that he has leased.

This analysis lays the groundwork for a formal social network analysis of hired skipper and shareholder networks. Such an analysis would examine the relations between each of the actors in the fishery in order to better understand the roles of key participants, the ties between the different participant groups, and the degree of homophily in the networks. Given the evidence in the above analysis of geographic and holdings associations between hired skippers and shareholders and the changing characteristics of participants in the fishery, a formal social network analysis could examine changes in these networks over time as well.

4.3 Counterfactual Analysis of Entry into Area 2C

4.3.1 Introduction

The halibut catcher vessel fleet in Southeast Alaska (Area 2C in the IFQ program) has historically been primarily comprised of small boats (less than 60 feet in length), which were for the most part owned and operated by local Alaskan residents (NMFS, 1992). For most participants in this area, the halibut fishery has always been a part-time fishery, supplementing income from the salmon season. In developing the halibut IFQ program, the North Pacific Fishery Management Council (NPFMC) sought to protect the unique character of, and to facilitate entry into, the halibut IFQ fleet in Area 2C. Therefore, the NPFMC included additional restrictions on quota share acquisition and IFQ use for participants in Area 2C, specific to catcher vessel shares only. The two main provisions that impact entry into the halibut IFQ catcher vessel fleet in Area 2C include a prohibition on quota share acquisition by companies and a prohibition on hired skipper use by any individuals. By providing a disincentive for initial recipients to consolidate quota shares in this area relative to other areas, these restrictions may have led to more shares being available on the market for new entrants. The focus of this analysis is to examine the impacts upon new entrants of these additional restrictions by estimating what entry would have been in a counterfactual Area 2C in which conditions approximated those of the other regulatory areas.

In Area 2C only individuals are allowed to acquire catcher vessel quota shares (Title 50, Part 679, 1998). Companies, even if they are initial quota share recipients in the IFQ program, are prohibited from purchasing catcher vessel quota shares (Title 50, Part 679, 1998). This is different from the other regulatory areas, where initial recipient corporate entities may buy additional quota shares. This prohibition was implemented to maintain the competitive position of owner-operated vessels in these areas as there was concern that companies could outbid owner-operators for quota shares (NMFS, 1992). If companies were expected to have higher rates of return than individuals, quota share acquisition could be difficult for new entrants. Furthermore, the eventual attrition of companies, facilitated by the limitation on quota share acquisition, would mean more quota shares being made available on the market for new entrants.

The other additional restriction placed on operators in Area 2C limits hired skipper use to companies. That is, all individuals (including initial recipients) must be on board when their annual catcher vessel IFQ allocation is being fished, except under emergency medical waivers (Title 50, Part 679, 1998). This is different from the other regulatory areas, where initial recipient individuals could use hired skippers to harvest their annual IFQ allocations. This added restriction was intended to facilitate entry by ensuring that aging quota shareholders would have to sell their quota shares once they were no longer willing or able to fish their annual IFQ allocations (NPFMC, 2014).

Table 4.5 shows new entrants across the IFQ regulatory areas from 2000 through 2013. Given that Areas 2C and 3A encompass the population centers of Southeast Alaska and the Gulf of Alaska, it may be expected that these two areas would have the largest numbers of new entrants across the IFQ program. Proximity to fishing grounds, especially for new entrants, who likely own smaller vessels, should facilitate entry. In this vein, however, the close numbers of new entrants across these two areas is interesting given that Area 3A includes a population that over the timeframe of the dataset increased from being approximately three to six times larger than that of Area 2C. Furthermore, Areas 3A and 3B actually have the largest TACs for the IFQ program and Area 3A has ex-vessel prices that on average are equal to those of Area 2C. Given these incentives, the numbers of new entrants into Area 2C may actually be greater than expected, relative to the other IFQ areas.

Table 4.5: New entrants across IFQ regulatory areas from 2000 through 2013 ('00 through '13)

	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
2C	53	46	43	50	35	34	30	27	11	14	22	11	15	20
3A	52	57	47	61	54	27	43	30	20	19	30	25	21	25
3B	11	15	12	20	12	8	10	12	3	7	6	6	3	10
4A	9	4	8	8	6	7	7	9	2	2	5	11	9	2
4B	12	5	5	7	6	5	3	3	6	3	0	4	6	3
4C	3	0	1	1	2	3	0	0	3	4	0	3	1	1
4D	2	1	2	5	1	2	0	2	0	2	0	2	0	1

The following analysis examines whether entry into Area 2C was facilitated by the additional restrictions on hired skipper use and ownership of quota shares by companies. It is hypothesized that entry is a factor of earnings expectations in the halibut fishery, the opportunity costs of buying halibut IFQ shares, the availability of quota, and demand. Proxy variables are used as indicators of these factors and data for these proxies are obtained from 2000 through 2013 for the other areas in the IFQ program (Areas 3A through 4D). In Step 1, the relationships between these proxy variables and entry are estimated in several specifications of a model of entry into the other IFQ regulatory areas using count regression techniques. Model fit diagnostics are used to assess the goodness of fit of these models, showing that the models are a reasonably good fit to the data and can therefore be used to predict entry into Area 2C from 2000 through 2013. This predicted entry approximates entry in Area 2C if Area 2C had not been subject to additional restrictions on company ownership of catcher vessel shares and individual use of hired skippers. For all three specifications estimated in Step 1, predicted entry into Area 2C is less than actual entry into the halibut IFQ program in this area. It is, therefore, surmised that entry was positively affected by the additional restrictions in Area 2C. However, conclusive statements about these impacts should be made with care, given several qualifications to these results.

4.3.2 Counterfactual Analysis Methodology

The methodology applied in this analysis is analogous to a counterfactual analysis in that the underlying question being asked is a what-if question. Counterfactual analysis has been utilized extensively in policy analysis research, to study a broad range of initiatives in taxation, welfare reform programs, education, criminal rehabilitation, and environmental protection (Trescott, 1982; Bourguignon, William, and Melo, 1992; Greenberg et al., 1998; Atherton, 2005; Lankoski and Ollikainen, 2011; He et al., 2013). In the fisheries literature, researchers have applied counterfactual analysis to evaluate the impacts of various management schemes, including marine reserves in the Atlantic Canadian cod fishery (Grafton and Kompas, 2009) and an international management policy for fisheries in the Barents Sea (Stokke, 2012).

Fisheries researchers have also utilized the difference-in-difference (D-I-D) methodology, a type of counterfactual analysis tool, to analyze how participation in different fisheries groups affects participants' behavior (Abbott and Wilen, 2000; Jardine et al., 2014). The D-I-D approach is an econometric tool used to measure the effect of a treatment, where the treatment is applied to one group (the treatment group) and not the other (the control group) at some point in time. The D-I-D estimator subtracts out the initial (pre-treatment) differences between the two groups, so that any differences can be attributed to the treatment.

The D-I-D approach and the standard counterfactual framework could not be applied in this analysis, because the extra restrictions in Area 2C do not meet the basic assumptions of these methodologies. The D-I-D approach could not be applied because the treatment (i.e. the extra restrictions placed on Area 2C) did not meet the exogeneity assumption underlying the D-I-D estimator in that the additional restriction in Area 2C was implemented because conditions in this area are different than those in other areas. A standard counterfactual framework could not be applied because the differentiated provision in Area 2C violates some of the basic assumptions underlying causal inference. First, in the IFQ program many shareholders own quota in multiple areas, so that there is no IFQ area that can be used as a control group in comparison against Area 2C. Second, the treatment group was not randomly assigned since Area 2C was given additional protections explicitly because it was different from the other areas in terms of the types of vessels that operated there and the relationships to local coastal communities.

The methodology used in this analysis, wherein average conditions are applied to Area 2C, was also applied by Rivas et al. (2009) to study the impact of a program intended to limit deforestation in the region of Manaus in Brazil. The researchers used average conditions across the areas surrounding Manaus to develop a counterfactual Manaus. Deforestation in the counterfactual Manaus was compared to deforestation in the actual Manaus providing some evidence for the claim that the program had been effective at reducing deforestation.

4.3.3 Theory and Variable Selection

According to economic theory, entry into fisheries is positively related to expectations of earnings in the fishery and negatively related to the opportunity costs associated with participating in the fishery over the next best alternative. Current and expected earnings in the fishery, which are a factor of expectations about the ex-vessel price, marginal costs and the TACs, should be reflected in the prices of quota shares (Wilen and Brown, 2000). In this analysis expectations of earnings in the fishery are captured with the quota share price, ex-vessel price, marine fuel price, and halibut TAC variables. Other researchers have included stock levels of the target species, ex-vessel prices, and total revenue for a vessel in its first year after entry into the fishery as measures of profit expectations in models of vessel entry decisions in fisheries (Ward and Sutinen, 1994; Pradhan and Leung, 2004; Mardle et al, 2005 and 2006; Tidd et al., 2011). It may be posited that there is a positive relationship between the halibut TACs and ex-vessel prices and entry into the halibut IFQ fishery and a negative relationship between fuel prices and earnings expectations and entry. Although earnings expectations should also be captured by halibut quota share prices, because new entrants have to buy halibut quota shares, higher share prices are likely to be associated with lower entry rates.

Entry and exit behavior in fisheries is a factor of an individual's opportunity costs of fishing, which will change depending upon changes in the potential earnings in other fisheries and other employment opportunities (Ward and Sutinen, 1994; Pradhan, 2004; Knapp, 2011; Tidd et al., 2011). In many Alaskan coastal communities the opportunity costs of entry may be low because of limited employment alternatives. The opportunity costs of buying halibut quota shares are a factor of alternative employment and alternative investment opportunities. In this analysis, alternative employment opportunities are captured by the unemployment rate variable. It can be posited that there is an inverse relationship between unemployment and entry. In other words, fewer alternative employment opportunities may be associated with greater rates of entry into the halibut IFQ fishery. The unemployment rate is calculated as the average of the unemployment rates for the economic regions within each IFQ area, see Table A1 for details.

Average earnings in Alaskan salmon fisheries are used as an indicator of the opportunity costs (or lost earnings) of buying into the halibut IFQ fishery rather than participating in the salmon fisheries. In other words, it may be posited that there is an inverse relationship between average earnings in Alaskan salmon fisheries and entry into the halibut IFQ fishery. The salmon average earnings variable is calculated as the average earnings for all salmon fisheries that are prosecuted within the IFQ area.[7] The salmon average earnings variable is a metric of the opportunity costs of buying quota in the halibut IFQ program because salmon fisheries account for the largest seafood harvesting sector in Alaska, have historically been the major fishery for many fishermen that participate in the halibut fishery part-time, and are managed with limited entry permits many of which now also have a high market value (Warren, 2013). This variable should capture opportunity costs for both Alaskan and non-

[7] Average earnings are calculated as the sum of total earnings for all salmon fisheries (gear type, area, and species specific) in the IFQ regulatory area divided by the total number of participants.

Alaskan entrants because there has been an increasing percentage of salmon permit ownership by non-Alaskan residents (Sethi, 2014).

The limited availability of quota shares on the market has also been cited as an impediment to entry in the halibut IFQ fishery (NPFMC, 2014). Quota share availability in this analysis is captured by the attrition rate of initial quota share recipients and the percent of shareholders in the area with shareholdings that are less than or equal to 10,000 pounds for the given area and year ("Non-consolidation"). The attrition rate of initial quota share recipients is expected to be associated with new entry, because the exodus of initial recipients should mean more quota shares on the market. The prevalence of non-consolidated holdings in an area may facilitate entry for several reasons. First, shareholders with smaller holdings may be more able or willing than large shareholders to divide their shareholdings into smaller chunks for sale. Second, there is anecdotal evidence that the availability of small chunks of "blocked" quota has facilitated entry for new participants (NPFMC, 2009). Third, larger shareholders may be more competitive in bidding for quota if they have higher rates of return than smaller shareholders, as Stewart et al. (2006) note occurred in the New Zealand Quota Management System. Finally, some researchers point to a positive relationship between consolidation of quota shares and leasing (Palsson and Helgason, 1995), so that shareholders with larger holdings in the IFQ program may be more likely to use hired skippers than to sell their shares once they are no longer fishing their own IFQ, a relationship that was evident from the analysis in Chapter 3 as well.

New entry into the fishery is also likely to be driven by the number of people living near the fishing grounds. The population variable is included in this analysis to capture some of the potential differences in demand across the IFQ areas. Other researchers have looked at local population as a determinant variable in buying and selling decisions in the IFQ program (Carothers, Lew, and Sepez, 2010) and in models of salmon permit ownership (Knapp, 2011), showing that population is a significant determinant of quota and permit ownership. The number of people living within proximity to fishing ports varies greatly across the IFQ areas, with the largest total population in Area 3A at just over 477,000 and populations in the Aleutian areas (4A through 4D) at under 10,000. For this analysis the population variable was calculated as the total number of people living within the IFQ regulatory area (measured in 1000 people). See Table A1 in the appendix for more details.

4.3.4 Data

Data for this analysis were taken from multiple sources including the Alaska Fisheries Information Network (AKFIN), the National Marine Fisheries Service, the Alaska Department of Fish and Game, and the Alaska Department of Labor and Workforce Development. The analysis is based upon data from 2000 through 2013 because pre-2000 data does not include many of the fields relevant for this study. The data consists of one observation for each IFQ area (excluding Area 2C) for each year from 2000 through 2013, totaling 84 observations.

The list of variables utilized in the analysis is presented in Table 4.6. Each of these variables is specific to the area and year. The dependent variable in this analysis, entry, is measured as the total number of new entrants into the IFQ regulatory area, specified as the number of new halibut quota shareholders who had not previously owned quota shares in the program. In other words, the permit holder is designated as a new entrant if they did not own any halibut quota shares in any previous year of the IFQ program.

Table 4.6: Independent and dependent variables in analysis of entry.

Variable Measures	Variable Name	Measured As	Source
Number of New Entrants	Total New Entrants	Total number of new entrants into the area. "New entrant" indicates someone who did not own halibut quota shares in any previous IFQ fishing year	AKFIN
Expectations of Earnings in the Fishery	QS Price	Mean IFQ price for all vessel classes	NMFS, Restricted Access Management Division
	Ex Vessel Price	Mean ex-vessel price for halibut for the season	NMFS, Restricted Access Management Division
	Fuel Price	Mean fuel price, averaged across all ports in IFQ area	Pacific States Marine Fisheries Commission, Fisheries Economics Data Program
	Halibut TAC (100Klbs)	Season TAC in 100,000 pounds	NMFS, Restricted Access Management Division
Opportunity Cost of Labor	Salmon Average Earnings	Average earnings for all salmon species and gear types	Alaska Division of Fish and Game – Division of Commercial Fisheries
	Unemployment Rate	Average unemployment rate	Alaska Department of Labor and Workforce

			Development
Availability of Quota	Non-consolidation	Percent of area catcher vessel shareholders (individuals only) whose holdings are less than 10K pounds	AKFIN
	Attrition Rate	Percent of initial recipients that sold all of their quota shares in that area that year.	AKFIN
Demand	Population (1000s)	Total population for the area	Alaska Department of Labor and Workforce Development
Annual Patterns	Year 2000 to 2003 Year 2004 to 2013	Dummies for periods of years	

4.3.5 Summary Statistics

The summary statistics presented in Table 4.7 reveal a substantial amount of dispersion in the data, due to the variability in these variables across both IFQ areas and years. Of particular importance is the dispersion in the total new entrants variable, which informs the choice of the specification of the count regression model, as described below. The largest numbers of new entrants are in Area 3A, which encompasses the biggest population centers in Alaska. There were 12 missing observations for the quota share transfer price data. The statistics reveal a significantly higher dispersion for the quota share transfer price data than the ex-vessel or fuel price data. Since the TAC has actually decreased across many of the IFQ areas over the period of the dataset, this dispersion in the quota share transfer price data may indicate that factors other than expectations of earnings, as measured by the ex-vessel and fuel prices and the TACs are impacting quota share transfer prices.

Table 4.7: Summary statistics.

Variable	Observations	Mean	Variance	Minimum	Maximum
Total New Entrants	84	10	191.91	0	61
QS Price	72	12.51	50.69	3.68	33.34
Ex Vessel Price	84	3.53	1.61	1.48	6.47
Fuel Price	84	2.74	1.20	1.13	4.43
Halibut TAC (100K lbs.)	84	66.53	6109.40	4.3	262
Salmon Avg Earnings	84	80,091	36,949	24,702	206,621
Unemployment Rate	84	.08	.0003	.05	.11
Non-consolidation	84	.59	.0172	.32	.85
Attrition Rate	84	.05	.001	0	0.17
Population (1000s)	84	80.01	25,992.06	4.67	477.84

4.3.6 Background on Count Regression Models

The number of total new entrants per area per year is count data, which is discrete and takes only a finite number of non-negative values. Many social and economic issues can give rise to non-negative integer, or count, data. Count regression models have been applied to study a variety of topics including length of hospital stays (Carter, 2010), medical treatment effects (Baetschmann and Winkelmann, 2013) and healthcare use (Baetschmann and Winkelmann, 2014), recreational demand (Englin and Shonkwiler, 1995; Haab and McConnell, 1996; Ozuna and Gomez, 1996; Shonkwiller and Shaw, 1996; Loomis and Ng, 2012; Parsons et al., 2013) and traffic accidents (Yaacob, 2011; Wah, 2012; Bhat et al., 2014). Several types of regression models are designed to analyze count data including the Poisson, negative binomial, zero-inflated or truncated, and hurdle models, although the Poisson and the negative binomial dominate empirical applications (Greene, 2008). There are several underlying assumptions that are common to both the Poisson and the negative binomial models, including independence of observations, exogeneity of variables, a log-linear relationship between the response and explanatory variables, and a multiplicative effect of the predictors on the response variable (Rodriguez, 2007; Hilbe, 2011). The traditional Poisson and negative binomial distributions assume an expected number of zero counts for a given value of the mean, which can be manipulated with the zero truncated or inflated or with the hurdle models (Hilbe, 2011).

Models of new entry in the halibut IFQ program were estimated as both Poisson and negative binomial distributions. The Poisson and the negative binomial models assume different discrete probability distributions for the dependent variable.

The Poisson distribution is given by the following:

$$\Pr\left[Y_i = y_i\right] = \frac{\exp(-\lambda_i)(\lambda_i)^{y_i}}{y_i!}, \lambda_i > 0, \tag{4.9}$$

where i={1,2….n} observations, Y_i is the i^{th} observation on the count variable of interest, y_i={0,1,2…}are the possible values of Y_i and λ_i is the mean.
Setting $\lambda_i=\exp(\beta x_i)$, where β and x are vectors of exogenous variables and parameters, yields the Poisson regression model (Ozuna and Gomez, 1995). The conditional mean and variance are both equal to λ_i. This relationship, known as equidispersion, is the underlying assumption of Poisson that sets this distribution apart from other count model distributions (Hilbe, 2011).

The negative binomial model does not assume the equality of the mean and the variance but rather accommodates overdispersion in the data (i.e. when the variance is greater than the mean) with an extra parameter, often known as the dispersion or heterogeneity parameter (Hilbe, 2014). The dispersion parameter is a measure of the adjustment needed to accommodate the extra variability in the data and in the case of the negative binomial distribution is log-gamma distributed (Hilbe and Greene, 2008). Continuing with the notation from above, the negative binomial distribution is written as Poisson with log-gamma heterogeneity (a Poisson-gamma mixture) (Hilbe, 2011)[8]:

$$\Pr\left[Y = y_i \mid x_i, u_i\right] = \frac{\exp(-\lambda_i u_i)(\lambda_i u_i)^{y_i}}{y_i!} \tag{4.10}$$

where the log gamma assumption for ε implies that $u_i = \exp(\varepsilon_i)$ has a gamma distribution (Hilbe and Greene, 2008; Hilbe, 2011).

In essence, the Poisson model is a special case of the negative binomial model when the variance is equal to the mean. The equidispersion assumption of the Poisson model is considered to be too constraining for many types of social data, so researchers often use the negative binomial specification (Greene, 2008).

The Poisson and the negative binomial models are generalized linear models, which use a link function to relate the response variable to the model. The link function for the Poisson and negative binomial models is log-linear so that the logarithm of the response variable is linked to a linear function of the explanatory variables (Hilbe, 2011). That is, for a one-unit change in the independent variable, the

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[8] Hilbe (2011) identifies 13 separate derivations for the negative binomial distribution. The negative binomial model used in this analysis is considered to be the traditional negative binomial model, commonly symbolized as NB2.

log of the dependent variable is expected to change by the value of the regression coefficient. The form of the model equation is the same for Poisson and negative binomial regression models.

The log-linear link function used in Poisson and negative binomial regression models can be represented as:

$$\ln(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \tag{4.11}$$

where Y is the count variable being modeled and X is a vector of explanatory variables (Hilbe, 2011). The dependent count variable can then be estimated for any values of the explanatory variables using the coefficient estimates from the model, such that:

$$Y = \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n)\text{ , OR} \tag{4.12}$$

$$Y = (\mathrm{e}^{\beta_0})(e^{\beta_1 X_1})(e^{\beta_n X_n}) \tag{4.13}$$

The parameters of the models are estimated using maximum likelihood estimation (Greene, 2008).

For the counterfactual analysis in this study, equation (4.11) is derived to represent the main determinants of entry into the halibut IFQ fishery in all regulatory areas excluding Area 2C. In this equation Y represents the number of new entrants, X is a vector of determinant variables of new entry, and ε is an error term. Equation (4.12) is used to estimate the count of new entrants into Area 2C, which assumes that average conditions across the other IFQ areas hold for Area 2C. This is described in more detail below.

4.3.7 Results

4.3.7.1 Comparing the Poisson and Negative Binomial Models

The distribution of the total new entrant data has variance nearly 20 times greater than the mean. Such overdispersion points to the negative binomial model likely being more appropriate than the Poisson model for this data. However, the coefficients estimated with the Poisson model do not depend on the assumption of the equality of the mean and variance (Hilbe and Greene, 2008). In other words, the coefficients are consistent even if this assumption is violated. The major impact of the violation of the distributional assumption is on the estimated variances, with the Poisson model underestimating standard errors when the data is overdispersed (Hilbe and Greene, 2008).

Table 4.8 shows the estimates for the corresponding Poisson and negative binomial models. The models are estimated using Stata SE 13.1 statistical analysis software, with the *poisson* and *nbreg* commands. The models have similar results with respect to the signs and values of the coefficients, although the significance of these coefficient estimates varies between the Poisson and the negative binomial models. The Poisson and the negative binomial regression coefficients are interpreted in the same way: for a one unit change in the predictor variable, the difference in the logs of expected counts is expected to change by the respective regression coefficient, holding all other determinant variables constant. As expected, the estimated standard errors are smaller for the Poisson models than the negative binomial models. Table 4.8 also shows the log-transformed over-dispersion parameter, the log of alpha (lnalpha), which is calculated as mean dispersion. The maximum likelihood estimate of the log of alpha is first calculated and then alpha is calculated from this. Under a Poisson model, the alpha value is constrained to be equal to zero.

A likelihood ratio test, which tests the null hypothesis that alpha is equal to zero, is performed to compare the appropriateness of fitting the data to a Poisson versus a negative binomial distribution. For models 1B and 2B, the likelihood ratio tests of alpha equal to zero have probabilities of 0.038 and 0.040, respectively, suggesting that alpha is non-zero and that the negative binomial model is more appropriate than the Poisson model for this data. The goodness-of-fit of the Poisson distribution to this data was also tested using the deviance and the Pearson statistics, which are commonly used test statistics for Poisson models (Hilbe and Greene, 2008). Significant values for both of these test statistics indicated that the Poisson regression model is inappropriate for this data. (See Appendix for results).

Table 4.8: Comparison of Poisson and negative binomial models of entry. Standard errors are in parentheses, where *** p<0.01, ** p<0.05, and * p<0.1.

VARIABLES	1A Poisson	1B Negative Binomial	2A Poisson	2B Negative Binomial
Ex Vessel Price	0.278***	0.274***	0.123**	0.110
	(0.061)	(0.073)	(0.057)	(0.067)
Fuel Price	-0.415***	-0.404***		
	(0.091)	(0.109)		
TAC (100K lbs.)	0.007***	0.008***	0.007***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)

Non-consolidation	2.463***	2.401***	1.972***	1.988***
	(0.447)	(0.510)	(0.498)	(0.567)
Attrition Rate	2.068*	2.761*		
	(1.204)	(1.455)		
Population (1000)	0.001*	0.001	0.001**	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
Year 2004to2013	-0.278**	-0.249	-0.492***	-0.516***
	(0.124)	(0.161)	(0.114)	(0.138)
QS Price			-0.021**	-0.017
			(0.011)	(0.013)
Unemployment Rate			5.979	5.780
			(3.648)	(4.656)
Constant	0.002	-0.070	-0.118	-0.124
	(0.324)	(0.356)	(0.321)	(0.352)
Lnalpha		-3.440***		-3.601***
		(0.814)		(0.827)
Alpha		0.032		0.027
		(0.026)		(0.023)
Observations	84	84	72	72
McFadden’s R2	0.711	0.267	0.695	0.26
AIC	430.171	429.107	390.569	389.424
BIC	449.617	450.985	408.783	409.914

4.3.7.2 Negative Binomial Models of New Entry

Given the evidence above that the negative binomial distribution is the appropriate distribution for this data, the models of entry are re-estimated below only as negative binomial models. Several determinant models of entry were estimated and tested for the IFQ regulatory areas, excluding Area 2C. Three final models were selected. The estimated results from the empirical models are presented in Table 4.9, along with model diagnostics. The probability of alpha equal to zero is 0.001 for Model 3, 0.015 for Model 4, and 0.017 for Model 5 indicating the appropriateness of the negative binomial specification. These three models were also estimated assuming the Poisson distribution, the Deviance and Pearson Chi-squared test statistics for the goodness-of-fit of these models indicated that the data are not Poisson distributed (See Table A2 for details).

All of the variables included in these models jointly contributed statistically significantly to improving the overall fit of the model, as tested by the likelihood ratio test. Likelihood ratio tests are used to analyze the specification of the model by testing restrictions on the parameters (Hilbe and Greene, 2008). For all of the models in the table, the log-likelihood Chi-square test statistics for the null hypothesis that the estimated coefficients are equal to zero had p-values significant at least at the 95% level, indicating that the null hypothesis that taken together the independent variables had no effect on the dependent variable could be rejected.

Table 4.9: Negative binomial models of new entrants. Standard errors are in parentheses, where*** $p<0.01$, ** $p<0.05$, and * $p<0.1$.

VARIABLES	Model 3	Model 4	Model 5
Ex Vessel Price	0.217***		0.269***
	(0.081)		(0.075)
Fuel Price	-0.491***		-0.366***
	(0.093)		(0.107)
QS Price		-0.032***	

		(0.010)	
TAC (100K lbs.)	0.006***	0.006***	0.009***
	(0.001)	(0.002)	(0.001)
Population (1000s)	0.002**	0.002**	
	(0.007)	(0.001)	
Unemployment Rate	8.618*	12.84**	
	(4.900)	(5.532)	
Attrition Rate	4.019***	3.531**	2.936**
	(1.531)	(1.657)	(1.483)
Non-consolidation	2.000***	1.525**	2.762***
	(0.562)	(0.629)	(0.432)
Year 2000 to 2003			0.276*
			(0.165)
Constant	-0.216	-0.327	-0.666**
	(0.376)	(0.401)	(0.321)
Lnalpha	-3.297***	-2.795***	-3.222***
	(0.689)	(0.511)	(0.699)
Observations	84	72	84
McFadden's R2	0.267	0.244	0.263
AIC	428.293	395.39	428.623
BIC	450.171	413.608	448.074

The expected number of new entrants is specified as a factor of earnings expectations, opportunity costs, demand, and quota availability. Since the quota share price should reflect expectations about current and future earnings in the fishery, which is a factor of the TAC, the ex-vessel price of fish, and costs of fishing, it is expected that the quota share price variable will capture some of the variability of the these other three variables (i.e. Ex Vessel Price, Fuel Price, and TAC). Indeed, the Ex Vessel Price and the Fuel Price variables are insignificant when estimated together with the quota share price variable and the coefficients significantly change in value. Therefore, in Model 4, the quota share price variable replaces the other two price variables. In Model 5, the fixed effects variable for the years 2000 through 2003 was added. This variable interacts significantly with the population and the unemployment rate variables likely because of substantial changes in the populations and the unemployment rate between the periods of 2000 through 2003 and 2004 through 2013. Model diagnostics indicate that Models 3 and 5 are comparable in terms of both the McFadden's R2 and the Akaike and Bayesian Information Criteria, although the McFadden's R2 statistic does not correspond to explaining a portion of the variation in the response variable as with linear models (Hilbe and Greene, 2008).

For all three models, the signs of the coefficients in Table 4.9 adhere to expectations about the relationships between these independent variables and the response variable. Expectations of earnings in the halibut fishery as measured by the ex-vessel price of halibut and the TAC are positively correlated with the number of new entrants into the IFQ fishery, while increases in the price of fuel and the price of quota shares have negative influences on new entry. The unemployment rate, which measures the opportunity costs of participating in the halibut IFQ fishery, was positively correlated with entry into the halibut fishery, indicating that fewer alternative employment prospects (as reflected by a higher unemployment rate) are positively correlated with entry into the halibut fishery. The other measure of opportunity costs, the salmon average earnings variable, was not statistically significant in any of the models.

Metrics of quota availability in the program were also statistically significant in the models of new entrants. As expected, the attrition rate of initial recipients in an area was statistically significantly correlated with entry into that area, as greater attrition would indicate increased opportunity for new entrants to buy quota shares. Higher percentages of shareholders in the less than 10,000 pound holdings category ("Non-consolidation") was also positively correlated with entry, which was expected considering that new entrants often initially buy small amounts of quota. Finally, the proxy for demand (population) had a positive coefficient, indicating that the number of people in proximity to the IFQ area is positively correlated with the number of new entrants into the area. There was not enough variation in the number of new entrants between all the modeled years so that fixed effects variables for each of the years 2000 through 2013 were not statistically significant. A variable representing a period of years from 2000 through 2003 was statistically significant in a model that excluded the population and unemployment rate variables. Starting in 2004, entry decreased across the IFQ areas and has largely remained at levels below the pre-2004 level since.

4.3.7.3 Model Fit Diagnostics

In order to be able to use Models 3, 4, and 5 to predict entry into Area 2C, the predictive accuracy of the models for the regulatory areas used to fit the model is first assessed. The following section presents the model diagnostics for Models 3, 4, and 5 using model fit and residual dependence plots.[9] Model fit plots show the observed

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[9] In order to use the predict command in STATA to predict fitted values and residuals for the three models, the models were re-estimated using the generalized linear model (*glm*) function with the (*nbinomial ml*) family and the link (*log*) function specified. This provides the same coefficient and standard error values as the *nbreg* command.

values in the data versus the fitted values for the models. The fitted line on the plots represents the regression line for the observed and fitted values. A good fit for a model would be represented by all of the fitted values falling on a 45-degree diagonal line, which would imply a regression line with a slope equivalent to 1.

Figure 4.6 shows the model fit plots for Models 3, 4, and 5 with the equation for the regression line representing the fit of the models to the data, where n3, n4, and n5 are the predicted numbers of new entrants under these three models, respectively. Given the equations of the fitted lines, with slopes close to 1 and intercepts close to 0, and the distribution of the data around these lines, these plots indicate that all three of the models have an overall good fit for the data, with Model 5 having the best fit.

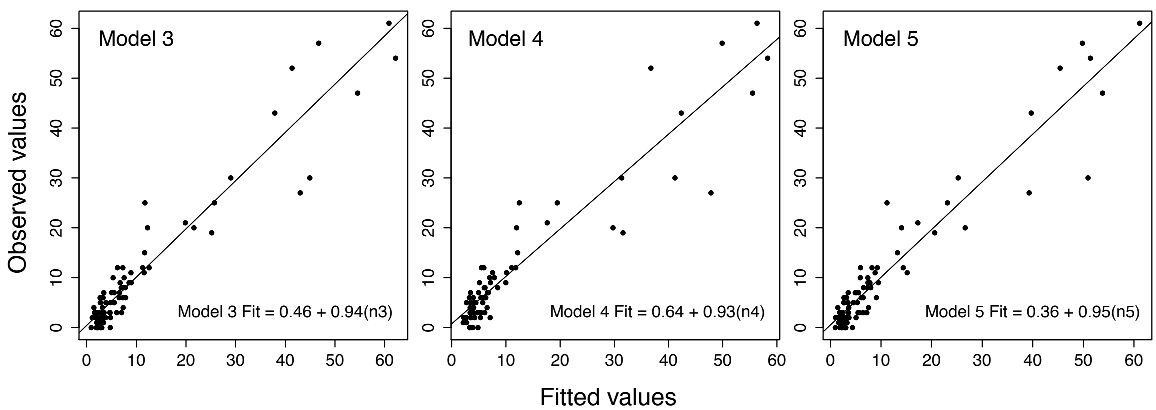

Figure 4.6: Observed versus fitted values for Models 3, 4, and 5.

The models' fit to the data is further assessed with an analysis of the residuals. McCullagh and Nelder (1989) recommend deviance residuals for examining the goodness of fit of general linear models (GLMs). For GLMs, deviance plays an analogous role to that of residuals sum of squares for ordinary linear models (Wood, 2006).

Deviance residuals for negative binomial models are calculated as (Cameron and Trivedi, 2013):

$$d_i = sgn(y_i - \hat{\mu}_i)\sqrt{2\left\{y_i \log\left(\frac{y_i}{\hat{\mu}_i}\right) - \left(y_i + \alpha^{-1}\right)\ln\left(\left(y_i + \alpha^{-1}\right) / \left(\hat{\mu}_i + \alpha^{-1}\right)\right)\right\}} \quad (4.14)$$

where $sgn(y_i - \hat{\mu}_i)$ is the function that makes d_i positive when $y_i \geq \hat{\mu}_i$, and negative when $y_i < \hat{\mu}_i$, $\hat{\mu}_i$ is the fitted mean, and α is the variance.

Because standardized residuals give a reasonable approximation to a normal distribution, deviance residuals are often standardized (Wood, 2006; Carruthers et al., 2008). Standardized deviance residuals are calculated as the deviance residuals multiplied by the factor $(1-h_j)^{-1/2}$, where h_j is the diagonal of the hat matrix.

Figure 4.7 shows the standardized deviance residuals plotted against the fitted values to inspect the models' fits.[10] A trend in the mean of the residuals indicates that the independence assumption is violated and that there may be a missing dependence or the wrong link function has been specified (Wood, 2006). A trend in the variability of the residuals is indicative of an issue with the assumed mean variance relationship, which implies a problem with the assumed response distribution (Wood, 2006).

Figure 4.7 does not reveal trends in the means of the residuals. The fitted line for all three models falls close to zero, indicating that the models do not consistently

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10 Standardized deviance residuals were calculated using the *standardized deviance* option for *predict* in STATA after the *glm* estimation of the negative binomial models.

under or over predict the actual total number of new entrants. There is indication that there may be two potential outliers in the data, which fall close to ± 3 residuals for the data. One is Area 3A in 2013, where the total number of entrants was 25 and the models predicted 11 to 12. The other outlier was in Area 4C in 2001 when entry was 0 and the models estimated 4 entrants. Aside from these two observations, the models have a general pattern of overall constant variance in the data. Although several residuals fall outside of the ± 2 range, which constitutes the 95% probability range for a normal distribution, a normal distribution for standardized deviance residuals can only be approximated with large datasets (Welham et al., 2014). Furthermore, other researchers have noted that residuals greater than absolute 2 should be considered acceptable (Wilson, 2013), and given the other indications of the overall acceptable fit of the models, these residuals are not considered highly problematic. Given that the coefficients in the estimated models are aligned with economic theory, that the models fit the data fairly well, and that the residual diagnostic plots do not reveal any problematic trends, it is concluded that Models 3, 4, and 5 should provide a reasonable prediction of new entrants into a counterfactual Area 2C.

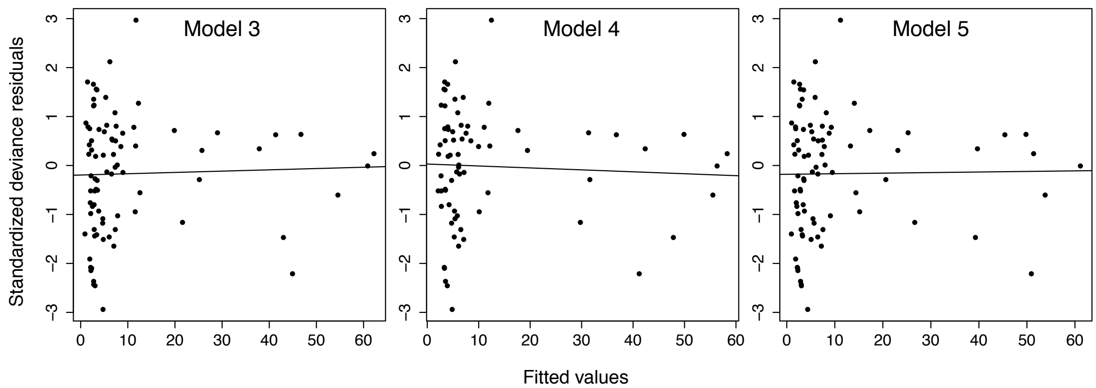

Figure 4.7: Standardized deviance residuals versus fitted values for Models 3, 4, and 5.

4.3.8 Estimating Entry into Area 2C

The coefficients in Models 3, 4, and 5 are estimated as the average effects of these determinant variables upon the log of entry in all IFQ areas except Area 2C. The next step in the analysis is to use the coefficients from these models to estimate entry into Area 2C, assuming entry in this area followed the average conditions across the other IFQ regulatory areas. That is, the idea is to impose on Area 2C the average effects of the determinant variables from Models 3, 4, and 5 to predict a count of new entrants. This is a counterfactual exercise in that it is the predicted entry into Area 2C under the hypothesis that entry in this area was not affected by regulations other than those that affected entry in the other regulatory areas. If the predicted entry is less than actual entry, this provides some context for discussing the benefits of the additional restrictions in Area 2C in terms of positively affecting entry. In other words, the only hypothesized difference between actual and predicted entry into Area 2C is a result of the additional regulations in 2C, which were meant to facilitate entry.

Using the log-linear link function to predict expected counts (see equation 4.12 above), the expected count of new entrants was predicted in Area 2C, such that:

$$\hat{Y}_{Area2C} = \exp\left(\sum_{j=1}^{n} \hat{\beta}_j X_{Area2C_j}\right) \tag{4.15}$$

Where, $\hat{\beta}_j$ are the estimated coefficients of the determinants of entry (*j*) into all other regulatory areas except Area 2C and $X_{Area2Cj}$ represent the explanatory variables for Area 2C. Therefore, $\hat{Y}_{Area2C}$ is the estimated count of new entrants into Area 2C in the counterfactual case that the regulations affecting entry into the fishery (e.g. hired skipper use and corporate shareholdings) were the same as in the other regulatory areas. If $\hat{Y}_{Area2C} < Y_{Area2C}$, this provides some evidence that the extra restrictions on participants in Area 2C were effective at facilitating entry into the halibut IFQ program into this area.

Table 4.10 shows the estimates of predicted entry into Area 2C using Models 3, 4, and 5 for the year 2000. Note that the exponentiated regression coefficient (exp β_j) represents a multiplicative effect of the jth predictor on the expected count, see (4.12) and (4.13). Predicted entry for 2000 was 14 to 22 new entrants, a 58% to 74% decrease over actual entry that year in Area 2C (53 new entrants).

Table 4.10: Exponentiated numbers of new entrants into Area 2C using Models 3, 4, and 5 for the year 2000.

	Model 3	Area 2C (2000)	Predicted Entry (2000)	Model 4	Area 2C (2000)	Predicted Entry (2000)	Model 5	Area 2C (2000)	Predicted Entry (2000)
Ex Vessel Price	0.217	2.62	1.76				0.269	2.62	2.02

Fuel Price	-0.491	1.28	0.533				-0.366	1.28	0.65
TAC (100K lbs.)	0.006	84	1.64	0.006	84	1.65	0.009	84	2.17
QS Price				-0.32	8.2	0.77			
Population (1000s)	0.002	72.27	1.12	0.002	72.27	1.16			
Unemployment Rate	8.62	0.062	1.71	12.84	0.062	2.22			
Attrition Rate	4.02	0.054	1.24	3.53	0.054	1.21	2.94	0.054	1.17
Non-consolidation	2.00	0.841	5.38	1.53	0.841	3.61	2.76	0.841	10.21
Year2000to2003							0.28	1	1.32
Constant	-0.216	1	0.81	-0.327	1	0.72	-0.67	1	0.51
Predicted Number of New Entrants			20			10			22

The count of new entrants into Area 2C is predicted using Models 3, 4, and 5 for all modeled years, 2000 through 2013. Figure 4.8 shows the actual count of new entrants into Area 2C for 2000 through 2013 along with the predictions and the 95% prediction intervals under Models 3, 4, and 5. The prediction intervals are calculated using the bias-corrected bootstrap method to approximate the variance of the estimators.[11] The width of the prediction intervals has considerable variation for Models 3 and 5. This should reflect the distance between the X_i's used for the prediction and the sample mean of X-bar$_i$ with the width of the prediction interval widening when the X_i used for the prediction is further away from the sample mean of X-bar$_i$. Furthermore, the prediction intervals are asymmetric, which is expected given that the data come from a skewed distribution (Smith, 2013).

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[11] The prediction intervals are calculated with the *prvalue* command and the *boot bias corrected* options from the SPost statistical analysis package in STATA 13 SE, with the default 1,000 replications (Xu and Long, 2005).

For every modeled year the predicted count is less than the actual count except in 2011, when the predicted count of new entrants under Model 5 is greater than the actual count of new entrants into Area 2C. On average, the predicted count of new entrants is about 56% less than the actual count of entrants. The count of new entrants in Area 2C of the halibut IFQ fishery has been decreasing over the modeled years, which may be the result of several factors. Participation in the fishery may have stabilized after the first couple years when participants were becoming familiar with the IFQ program and there were high rates of consolidation. Decreasing entry may also be a factor of limited opportunities for crewmembers to build up capital in the fishery. Many new entrants spend several seasons crewing before they buy their own quota shares, building up the financial capital to buy shares. With the decline in the number of vessels participating in the halibut fishery following the implementation of the IFQ program, there are fewer crewing opportunities, so that fewer individuals can feasibly enter the fishery in this way. The steep decrease in actual new entrants in 2011 may have been due to a very sharp increase in ex-vessel value in the Southeast salmon purse seine fishery, which nearly doubled that year (Knapp, 2013). Although the salmon average earnings variable was not a statistically significant predictor of entry in the models, many of the salmon fisheries (which are gear/area/species specific) are appropriate entry-level substitutes for buying halibut quota shares.

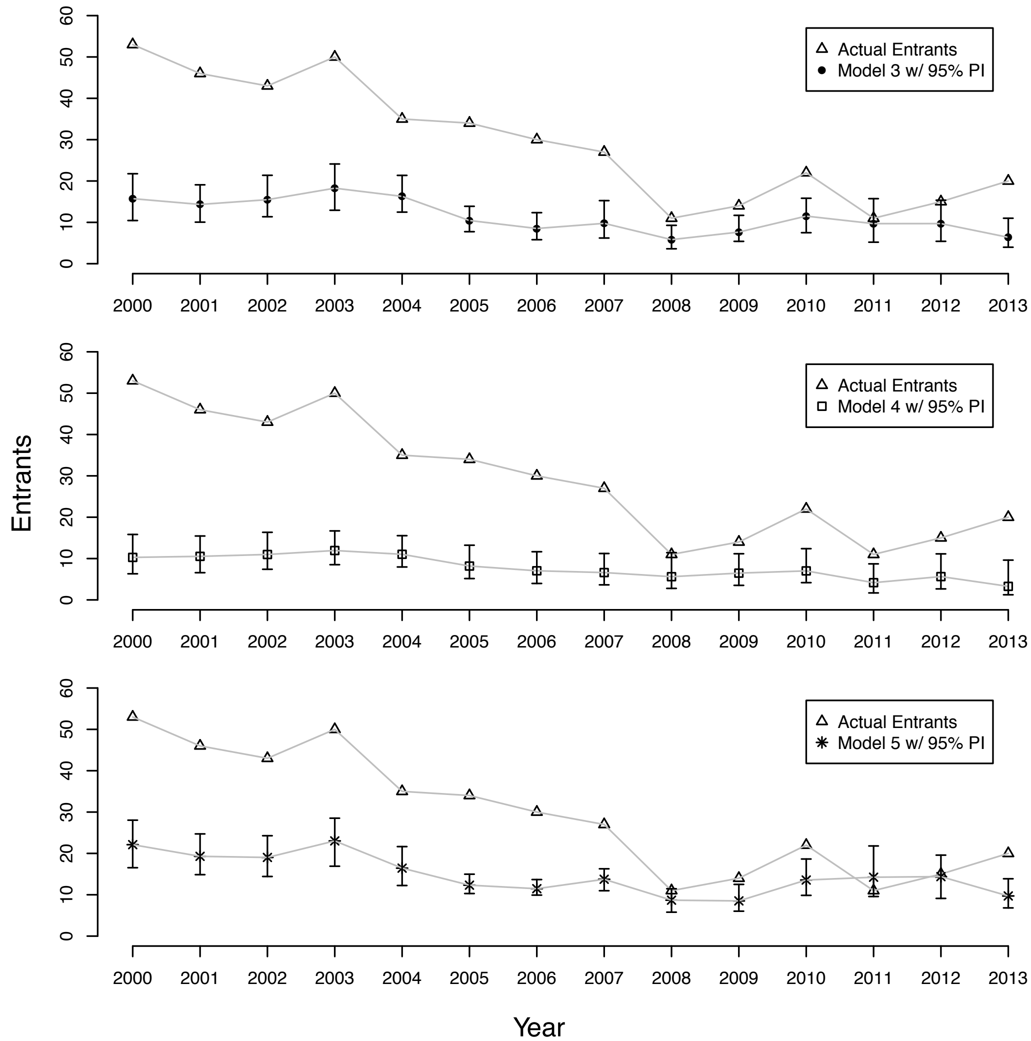

Figure 4.8: Actual versus predicted numbers of new entrants into Area 2C, with bootstrap prediction intervals

As can be seen in Figure 4.8 the pattern of predicted entry under Models 3, 4, and 5 largely follows the trend of actual new entrants into Area 2C from 2000 through 2013, with a general pattern of decreasing entry, slight upticks in 2003, 2009, 2010, and 2012, and dips in 2008 and 2011. Assuming that actual new entrants are responding to the same determinants of entry as described in these models, predicted and actual entry should follow the same general pattern. However, the models do not predict increases in the count of new entrants that occurred in Area 2C in 2013, as many of the other IFQ areas had fewer entrants in 2013 than in the preceding years. Furthermore, decreases in ex-vessel prices, the percent of shareholders with holdings less than 10,000 pounds, and the unemployment rate contributed to lower estimates of new entrants.

4.3.9 Conclusions

This analysis shows that indicators of earnings potential and opportunity costs are significant predictors of entry into the halibut IFQ fishery and that the directions of these relationships are aligned with economic theory. Furthermore, metrics of demand and availability of quota are positively correlated with entry. The model fit and residual diagnostic plots indicate that Models 3, 4, and 5 provide an overall good fit for the data and that, therefore, they should provide reasonable predictions of entry into Area 2C if this area were subject to the same regulations impacting entry as the other regulatory areas. There is only slight variance in the predicted counts of new entrants into Area 2C across these models and the models largely follow the pattern of actual entry into Area 2C.

The results of this analysis confirm the hypothesis that entry into Area 2C from 2000 through 2013 was greater than was predicted based on the other regulatory areas, which were not subject to the same restrictions on corporate ownership of catcher vessel shares and hired skipper use by individual catcher vessel shareholders. Prohibiting individuals from using hired skippers may have facilitated entry by both ensuring that aging quota shareholders have to divest themselves of their holdings instead of using hired skippers to fish their annual IFQ allocations and by providing a disincentive for initial recipients to acquire more quota in Area 2C. That is, in relation to the other IFQ areas, in Area 2C initial recipient shareholders may have had less of an incentive to augment shareholdings because they could not use a hired skipper. The prohibition on quota share acquisition by corporations likely also limited consolidation in the fishery and, by providing that the vast majority of shares were held by individuals ensured that the movement of quota from initial recipients to second-generation shareholders would be faster. The aging of shareholders does not prohibit corporations from participating in the fishery,[12] as it does with individual shareholders, since corporations by definition have to use hired skippers. So a regulation that ensured the vast majority of quota shares remain with individuals would also ensure that quota move from one generation of shareholders to the next more quickly.

Although this analysis can provide some framework for a discussion about the impacts of the extra restrictions on hired skipper use and corporate shareholdings upon entry into Area 2C, this discussion should be couched within a broader understanding of the limitations of this type of counterfactual analysis. First, using average conditions from the other IFQ areas to predict entry into Area 2C is problematic because this area is inherently different from the other regulatory areas. Indeed, the very differences between Area 2C and the other IFQ areas led to the additional restrictions on shareholders that underlie this analysis. The under 60 foot vessel classes together hold about 94% of the quota shares in Area 2C, compared to on

[12] A corporation can maintain its holdings in Area 2C (and in other areas acquire more shares) as long as there is no addition of a partner or new shareholder, which does not include court-appointed trustees acting on behalf of a shareholder (50 CFR 679.42).

average of about 65% across the other IFQ areas. This, coupled with the fact that quota shares remain largely unconsolidated in this area, means there are small chunks of quota available for small boat owners, which is most often exactly what new entrants want to buy. These conditions make Area 2C unique in the halibut fishery and inherently difficult to compare with the other regulatory areas. It is also important to note that this may also mean that the predicted number of new entrants into Area 2C based on average conditions in the other areas is downward biased, because Area 2C has inherent conditions that would make entry into it easier than into the other IFQ areas.

It should also be noted that other measures were implemented to affect entry and limit consolidation in the IFQ program. For example, the "fishing down" provision, which allows shareholders with quota from larger class vessels to fish this quota on smaller class vessels, was not implemented in Area 2C until 2007, although fishing down was allowed in the remaining IFQ areas starting in 1996. Not implementing the fishing down provision in Area 2C was originally intended to limit consolidation by owners of small vessel class quota, which, as previously mentioned, dominate the halibut IFQ fleet in this area. This same amendment in 2007 increased the sweep-up level for halibut in Area 2C and 3A to 5,000 pounds, compared to 3,000 pounds for the other IFQ areas, in order to facilitate the consolidation of shareholdings that were otherwise too small to be fishable. A sweep-up allows the consolidation of small amounts of shareholdings into a larger chunk of quota, which would otherwise be impossible due to the "blocked" nature of shareholdings under 20,000 pounds in the program (described in Chapter 1). Increasing the sweep-up level could facilitate entry if new entrants wanted a larger chunk of quota and if initial recipients consolidating holdings made it easier for initial recipients to sell their shares and exit the fishery.

Finally, there may be some issues associated with using count data regression for this analysis due to the size of the sample. Some studies have shown that maximum likelihood estimation may produce biased results with small samples (Clarke and Perry, 1989; Dean, 1994; Lord, 2006). However, the most problematic results are seen in samples of 20 or fewer observations (Clarke and Perry, 1989) with some authors noting that sample sizes of 60 or above are sufficient for models that estimate few parameters (about 1 to 5) (Eliason, 1993). Other researchers have shown that decreasing sample size with maximum likelihood estimation does not increase the occurrence of Type I errors but does increase Type II errors as the number of independent variables increases (Hart and Clark, 1999). Nevertheless, given that the sample size in these models is 72 for Model 4 and 84 for Models 3 and 5 and that there is ongoing debate in the literature about the impacts of small sample size on maximum likelihood estimates, the estimates from the models of new entrants are assumed to be unbiased and consistent estimates of true parameter values.

Despite the above caveats, this analysis does provide some insight as to the determinants of new entry into the halibut IFQ fishery. Of particular interest is the positive relationship between entry and the variable that indicates consolidation in the IFQ area. If managers are concerned with the number of new entrants into the fishery, they could consider placing further restrictions on quota consolidation by participants. The next section extends this analysis by examining the association between consolidation and exit in the IFQ fishery.

4.4 An Analysis of Exit in the Halibut IFQ Fishery

4.4.1 Introduction

This final section of Chapter 4 examines whether the use of hired skippers has affected the propensity of exit in the halibut IFQ fishery, where exit is demarcated as a shareholder selling all of his quota shares in an IFQ area. The analysis examines the determinants of exit in a fishery, employing a discrete choice model, with hired skipper use as one of the predictor variables for exit. In this analysis, hired skipper use is utilized as a proxy for leasing, since shareholder and hired skipper relationships are often functionally equivalent to leasing, in that the shareholder does not own any part of the vessel and has no financial or personal risk in the landing of his quota (see Chapter 3 for details). Understanding the determinants of exit from the fishery provides some context for discussing how using hired skippers may be impacting exit and the transference of quota shares to an active, second-generation owner class.

At the most basic theoretical level, an individual is expected to enter a fishery when profits are attainable and to exit when losses are sustained. Beyond this most simplistic level, however, the individual would also be expected to consider returns in alternative investments, technological change, compliance costs, changes to competition, and expectations about the health of the resource (Stewart et al., 2006). The drivers of exit are explored in more detail in the Variable Selection section below.

The option of using a hired skipper provides initial recipient shareholders in the halibut IFQ fishery with a profitable alternative to selling their quota shares and exiting the fishery. Aging shareholders can retain their shares and have hired skippers fish the quota derived from those shares, while minimizing their exposure to risk in the fishery. The option of hired skipper use for initial recipients likely also adds value to the shares by providing these shareholders with another option for how their shares may be utilized. As discussed in Section 3.2, the reliance on hired skipper use in the halibut IFQ fishery provides some indication that some shareholders expect to earn more from using hired skippers now and potentially selling the quota shares in the future than from selling the shares now and investing that money elsewhere in the market. However, as shown in Chapter 3, the probability of hired skipper use is significantly different for different categories of shareholders with respect to residency, the diversity and quantity of shareholdings, and the attributes of the quota shares. This is aligned with expectations about divergent direct, transaction, and opportunity costs of hired skipper use and harvesting one's own quota for different types of shareholders, discussed in detail in Section 3.7.

The literature on exit decisions in fisheries dates back to the theoretical work of Smith (1968, 1969), who modeled entry and exit decisions in open-access fisheries, showing that these decisions reflected anticipated levels of returns associated with the prosecution of a given fishery, net of opportunity costs. Others have expanded this theoretical work, for example, adding different catchability models (Mackinson, Sumaila, and Pitcher, 1997) and non-linear investments and stock-dependent harvesting costs (Eisenack, Welsch, and Kropp, 2006). Researchers have also examined fleet restructuring following the implementation of an IFQ program, showing that consolidation is often rapid (Campbell, Brown, and Battaglene, 1999) and may also reflect additional entry into a fishery prior to the implementation of an IFQ program due to speculation and participants anticipating gaining quota claims in the fishery (Brandt, 2007). Nostbaaken, Thebaud, and Sorensen (2011) provide a thorough review of the theoretical and empirical literature on capital adjustments in fisheries.

Discrete choice models have been widely applied to modeling entry and exit in fisheries. Numerous researchers have applied multinomial logit models to examine choices about entering, staying, or exiting a fishery at the vessel level (Ward and Sutinen, 1994; Pradhan and Leung, 2004; Mardle et al., 2006; Tidd et al., 2011; Tidd et al., 2014), with some research on the decommissioning decision as well (Tidd et al., 2011). Many of the variables utilized in these studies inform the predictor variables examined in this analysis, as outlined below. Of note is that most discrete choice models have been employed to examine the exit decision at the vessel level and for open-access fisheries. Although Slater et al. (2013) developed a binary logit model of the willingness to exit a fishery in the Philippines at the individual level and Stewart et al. (2006) conducted a survey of exiting fishermen in New Zealand after the implementation of the Quota Management System there. Other researchers have also conducted extensive surveys of fishermen's potential decisions to exit in the face of declining catch (Daw et al., 2012).

There have been several studies examining exit in the halibut IFQ fishery. In an ethnographic study of the impacts of rationalization on Gulf of Alaska coastal communities, Carothers (2008) highlighted the outmigration of halibut fishing quota from small coastal communities (less than 1500 people), noting that village residents often sell their quota during difficult financial times without then having the capital to buy quota, which is consistently appreciating in value. Carothers (2013) conducted a survey of sellers and buyers in the IFQ program from 1996 to 2004, showing that there are demographic differences between sellers and buyers in the IFQ program.

Carothers, Lew, and Sepez (2010) developed a logit model of the likelihood of selling quota by small, remote Alaskan fishing communities in the first several years of the IFQ program.

Despite this body of literature on exit decisions in fisheries, there is limited research on these decisions at the level of the individual and for catch share fisheries. Furthermore, to this author's knowledge, there is only one study that examines the impacts of leasing in relation to exit from fisheries (Pradhan and Leung, 2004). This study expands on the existent exit literature in fisheries by examining the decision of individual shareholders to exit a halibut IFQ area (by selling all of their quota shares) with respect to whether they use hired skippers, a variety of economic indicators, and attributes of the shareholder and his quota holdings. The analysis is carried out in a random utility framework and the analytical model is estimated by applying the logit model. See Chapter 3 for a full description of this framework and model.

4.4.2 Variable Selection

The discrete dependent variable for this analysis is exit from a given IFQ area in a given year. Exit is demarcated as an individual shareholder selling all of his quota shares in an area (=1) or not (=0) in a given year, from 2000 through 2013. As in Chapter 2, the analysis is limited to eligible individuals (or individual initial recipients of catcher vessel quota shares in all IFQ regulatory areas except Area 2C), because these are the shareholders who have the option of using hired skippers to land their IFQ. The explanatory variables explored in this analysis are shown in Table 4.11. The expected determinants underlying a shareholder's decision to exit an IFQ area are attributes of the shareholder (residency and shareholdings), attributes of his quota holdings, attributes of the year, and economic variables.

Because this study is intended to analyze the impacts of leasing on exit from the fishery, the primary predictor of interest is the use of hired skippers, which functionally mimics the leasing of quota. A shareholder is classified as using a hired skipper if he uses a hired skipper for any landing in the area and year of the observation. Similarly, Pradhan and Leung (2004) utilized a multinomial logit analysis to assess the decision of Hawaiian longline vessels to enter, stay, or exit the fishery, showing that vessels that were captained by hired skippers were more likely to exit the fishery than vessels captained by their owners, which the authors associate with the potentially greater production efficiency of vessels captained by their owners. On the other hand, in their survey of fishermen exiting the New Zealand Quota Management System, Stewart et al. (2006) found that most participants exiting the New Zealand fisheries were small-scale, active fishermen, rather than investors or processors, likely because of differences in rates of return between shareholder types. Inconsistencies across these studies with respect to the impacts of leasing on exit may reflect differences in the status of alternative fisheries and economic conditions in the different regions and countries. Although Pradhan and Leung (2004) do not explore the impacts of these other determinants on exit, Stewart et al. (2006) report that most exiting fishermen in New Zealand were not employed in other paid work at the time they were leaving the fishery.

Expectations of earnings in an IFQ halibut regulatory area will inform shareholders' decisions to stay or exit the area. Earnings expectations in the fishery were captured by the annual total allowable halibut catch (TAC) and the fuel price (Fuel Price) variables, both of which are area and year specific. Researchers have shown that the probability of a vessel exiting from a fishery is negatively correlated with the stock abundance of the target species (Ward and Sutinen, 1994; Pradhan and Leung, 2004; Mardle et al., 2006; Tidd et al., 2011) and positively correlated with operating costs (Ward and Sutinen, 1994). However, other researchers have shown that marine diesel prices are not significant predictors of exit (Tidd et al., 2011) and that vessels are only marginally more likely to exit when fuel prices increase (Tidd, 2014). A shareholder's revenue in an IFQ area (measured with the Area Revenue variable) is also an important indicator of earnings expectations. Researchers have used similar indicators of earnings expectations in modeling vessel exit decisions, including the value of daily catch (Daw et al., 2012) and total revenue of target species (Mardle et al., 2006; Tidd et al., 2011), showing that revenue expectations are negatively associated with exit. Theoretically, shareholders should also consider quota share prices in their decision to stay or exit the IFQ fishery, as these prices should reflect expectations about current and future profitability in the fishery (as a factor of expectations about the TAC, the ex-vessel price of fish, and operating costs) and should inform a strategic exit decision for those shareholders who want to maximize their earnings (Squires et al. 1998; Weninger and Just 2002; Newell, Papps, and Sanchirico 2007; Nostbakken, Thebaud, and Sorenson 2011). Average quota share prices by area and year are included in the dataset (QS Price variable). In a survey of exiting fishermen from the New Zealand Quota Management System, Stewart et al. (2006) found that 60% of respondents had considered quota share prices in the timing of their exit.

Earnings expectations in the fishery may also differ based on the shareholder's quantity and diversity of shareholdings ("Lbs" variables and "Multi area qs held" and "Multi vessel class qs held"), attributes of the quota shares (vessel class and area designations), and proximity of residency to IFQ area of holdings (Resid AK). A shareholder's rates of return may differ based on the quantity and diversity of his shareholdings, such that large and diversified shareholders may expect to earn more in the halibut fishery than small and less diversified shareholders (Stewart et al., 2006). Greater and more diversified shareholdings may also reflect a different conceptualization of the fishery as a long-term investment and not just an employment. With respect to the amount of shareholdings, Stewart et al. (2006) found that most exiting participants in the New Zealand Quota Management System were small-scale fishermen. In a survey of quota shareholders that participated in the halibut and sablefish IFQ fisheries from 1995 to 2004, Carothers (2013) found that 44% of quota sellers from the IFQ program noted that one of the reasons that they sold quota shares was because the amount of quota shares they were issued was "too small" to be fishable. With respect to the diversity of shareholdings, Schnier and Felthoven (2013) showed that specialization (in terms of the percentage of the vessel's Alaska-wide revenues that are derived from the crab fisheries) is associated with vessels exiting the crab fisheries. As explored in the previous chapters, the costs of fishing may differ based on the attributes of the quota shares with respect to the vessel class and area designations, as these are associated with the remoteness of the fishing area and the size of the vessel upon which the quota has to be fished. Researchers have examined vessel mobility as a function of capital outlays, showing that smaller vessels are more likely to enter and exit a fishery (Tidd et al., 2011). Similarly, Stewart et al. (2006) found that 80% of exiting fishermen in New Zealand owned vessels with less than 10 tons of capacity.

The opportunity costs of time may also vary based on the residency of the shareholder, as residents of larger communities may have more opportunities for alternative employment. Therefore, variables for the shareholder's residency with respect to the population of his resident community were included in this analysis (Resid-Rural). Mardle et al. (2006) and Pradhan and Leung (2004) found that locally owned vessels were less likely to exit the fishery than vessels owned by residents of other countries and other states, respectively, Schnier and Felthoven (2013) found that Alaskan ownership of a vessel did not significantly affect the likelihood of exit for participants in the Bering Sea crab fisheries

Variables for the annual attributes of the data are also included, specified as a fixed effects variable for the years 2000 through 2003. This concurs with the annual dummies that were used in the counterfactual analysis of new entrants as well, as there is indication of a differing trend in both entry and exit for the years 2000 through 2003 than for the remainder of the dataset.

Table 4.11: Determinant variables of exit in logit analysis.

Variable Type	Variable Name	Measured As
Leasing Variable	Hired Skipper	=1 if shareholder hired a skipper for any landings that year; =0 otherwise
Economic Variables	TAC (100K lbs.)	Total allowable catch in 100K lbs. (area and year specific)
	Fuel Price	Dollar/gallon (nominal) (area and year specific)
	Area Revenue (100K)	Shareholder's area revenue in $100,000 (year specific)
	QS Price	Mean quota share price (area and year specific)
Attributes of Shareholder	Resid AK	=1 if shareholder resides in Alaska; =0 if shareholder resides outside of Alaska

	Resid Rural	=1 if shareholder resides in community with population of 1 to 30,000; =0 if shareholder resides in community with population greater than 30,000
	Lbs. LT 3K	=1 if shareholder holds 3,000 pounds of quota (year/area specific); =0 otherwise
	Lbs. 3Kto10K	=1 if shareholder holds 3,000 to 10,000 pounds of quota; =0 otherwise
	Lbs. 10Kto25K	=1 if shareholder holds 10,000 to 25,000 pounds of quota; =0 otherwise
	Lbs. GT 25K	=1 if shareholder holds more than 25,000 pounds of quota; =0 otherwise
	Multi Class QS Held	=1 if shareholder holds quota in multiple classes; =0 otherwise
	Multi Area QS Held	=1 if shareholder holds quota in multiple areas; =0 otherwise
Attributes of Holdings	Class B	=1 if landing is of Class B quota (greater than 60 feet); =0 otherwise
	Class C	=1 if landing is of Class C quota (36 to 60 feet); =0 otherwise
	Class D	=1 if landing is of Class D quota (less than 36 feet); =0 otherwise
	Area 3A	=1 if landing is of 3A quota; =0 otherwise
	Area 3B	=1 if landing is of 3B quota; =0 otherwise
	Area 4A	=1 if landing is of 4A quota; =0 otherwise
	Area 4B	=1 if landing is of 4B quota; =0 otherwise
	Area 4CD	=1 if landing is of 4CD quota; =0 otherwise
Attributes of Year	Year 2000 to 2003	=1 for years 2000 through 2003; =0 otherwise

4.4.3 Data

The data for this analysis were provided by the Alaska Fisheries Information Network, which maintains a database of Alaska state and federal fisheries data. The two primary data sources are the fish ticket data from the Alaska Department of Fish and Game (ADFG), as compiled by the Commercial Fisheries Entry Commission (CFEC), and the IFQ shareholder data from the National Marine Fisheries Service, Alaska Regional Office. The fish ticket data include information specific to the landing, including whose IFQ account is being debited for the landing, whether that permit holder made his own landing or used a hired skipper, the vessel class and area of the IFQ, the pounds landed, and the length of the vessel upon which the landing was made (among other information). This fish ticket data were then linked with the IFQ shareholder data to identify attributes of the shareholder including city and state of residency, total IFQ pounds held in the area in which the landing is being made, and IFQ holdings in other areas. The IFQ shareholder data are collected annually, wherein the IFQ fishable pounds for each shareholder represents the IFQ pounds that were fishable for the IFQ permit in that year as a sum of IFQ derived from quota share, prior-year adjustments, and in/out transfers. Population data was taken from the U.S. Census "American Fact Finder," the Canadian Census, and the State of Alaska, Department of Commerce, Community, and Economic Development (U.S. Census, 2010; Statistics Canada, 2011; State of Alaska, 2013). Annual area-specific total allowable catches (TACs) and mean quota share transfer price data were taken from the National Marine Fisheries Service's "Halibut Transfer Report – Changes Under Alaska's Halibut IFQ Program"(NMFS, 2013). Fuel price data was taken from the Pacific States Marine Fisheries Commission (PSMFC, 2013).

The choice occasion being modeled in this analysis is a year. For any given area and year, the shareholder either sells all of his quota shares or he does not. Therefore, the observations for the dataset are year, permit number, and area specific. Permit numbers are specific to a vessel class but not an area, so that a shareholder may be associated with multiple permit numbers. Therefore, using one observation for each year, permit number, and area combination ensures that all choice occasions for the decision to sell or not are represented. Areas 4C and 4D were treated as one area because an amendment to the IFQ program in 2005 allowed for landings of 4C IFQ in area 4D. Since the intent of this analysis is to examine the relationship between hired skipper use and exit from the halibut IFQ fishery, the dataset is limited to landings from 2000 through 2013, omitting the first five years of the IFQ program wherein most exiting participants were adjusting to the implementation of the program. In other words, utilizing the first five years of the data may have confounded the results with respect to relationship between hired skipper use and exit, because shareholders were adjusting to the implementation of the IFQ program. There are 15,454 observations for this analysis.

Only 5.57% of the observations in the dataset are for shareholders exiting an IFQ area. The low frequency of exit in the dataset is likely due to the use of landings data for this analysis and the way in which exit is flagged in the data. Landings data omits those shareholders, who have not been landing their quota. Quota share ownership data would be more representative of exit because it would include all shareholders and not be limited to those making landings. However, the landings data had to be used for this analysis in order to include the flag for use of a hired skipper for a landing by a shareholder. The shareholder is flagged as exiting from an IFQ area if the permit number that he is fishing in that area has quota pounds at the beginning of the current year but none at the beginning of the next year, indicating that the shareholder divested of quota shares sometime in the current year or prior to the start of the next fishing year. This implies that if the shareholder stops landing his quota but cannot sell his shares by the beginning of the following year, he will not show up in the dataset as exiting the fishery. In other words the shareholder is essentially only flagged if he is successful at selling his shares that year. If it takes the shareholder several years to decide to sell or to successfully sell his shares, he will essentially disappear from the dataset without being flagged. This lag time likely accounts for some of the low frequency of observed exit in the dataset. Potential ways of addressing this in future studies are explored in the Conclusions section.

4.4.4 Results

4.4.4.1 Rare Events Logit Analysis Maximum Likelihood Estimates

Researchers have shown that in cases of rare events (i.e. where one of the outcomes of the dependent variable being modeled is infrequent) maximum likelihood estimation may produce biased estimators (Firth, 1993; King and Zeng, 2001). The probability of biased estimators decreases with sample size and with the frequency of the rare event. Furthermore, ordinary logistic regression may strongly underestimate the probability of occurrence of rare events, due to errors in classification, or in determining the probability cut-point at which the observation should be classified as either a zero or a one (King and Zeng, 2001). In effect, the classification is biased towards favoring zeros at the expense of ones with rare events data, so that the model does a better job of classifying zeros than ones. The classification error also affects the estimation of the constant term and thereby any predictions from the model. Although the number of observations in this study and the frequency of exit fall just outside of the most problematic range of potential biased estimations as described by King and Zeng (2001), the model of exit is approximated both with an ordinary logit model and with methods specifically intended to deal with rare events.

There are three general methodologies to deal with rare events in maximum likelihood estimation: exact logistic regression, the bias correction method developed by King and Zeng (2001), and the penalized maximum likelihood estimation method developed by Firth (1993). The exact logistic regression method, which foregoes the asymptotic properties of estimates, is appropriate for small samples (less than 200 observations), as it is a computationally intensive methodology (Leitgob, 2013). Firth's penalized maximum likelihood estimation includes a penalization term that is sensitive to sample size and the number of rare events, which penalizes the log-likelihood with one-half of the logarithm of the determinant and information matrix (Firth, 1993).

King and Zeng (2001) suggest case control sampling, wherein data is collected on all the possible ones in the data and a random sample of zeros, such that there are no more than two to five times the number of zeros as ones. After a model is specified for this whole sample, the coefficients are corrected either by weighting the observations or by "prior correction," which corrects the maximum likelihood estimate of the intercept (ibid.). King and Zeng also suggest correcting for bias in maximum likelihood estimates of coefficients in rare events data with finite samples by using a weighted least-squares expression, which can be applied to logit models that do not use case control sampling. Leitgob (2013) performed Monte Carlo simulation to assess the biasedness of maximum likelihood estimates under different small sample and rare events scenarios, showing that King and Zeng's bias correction method may be overcorrecting bias in maximum likelihood estimates, whereas Firth's penalized maximum likelihood estimates produce consistenly unbiased results.

Statistical corrections for rare events in binary outcome models were tested using both Firth's penalized maximum likelihood logistic model and the King/Zeng bias correction model. The ordinary logistic, Firth's penalized maximum likelihood model, and the King/Zeng bias correction model are estimated using STATA commands *logit*, *firthlogit*, and *relogit*, respectively. The results of the three logistic estimations for Model 1 are shown in Table 4.12. The results for the models correcting for rare events using Firth's penalized maximum likelihood and the King/Zeng bias correction are nearly identical to those of the ordinary logistic model, with respect to both the values of the coefficients and the standard errors. Therefore, the remaining results are reported only for the ordinary logit model.

Table 4.12: Estimation of Model 1 using ordinary logistic, Firth's penalized maximum likelihood, and King/Zeng bias correction method. Standard errors are in parentheses, where *** p<0.01, ** p<0.05, and * p<0.1.

Variables	Logit	FirthLogit	ReLogit
Hired Skipper	0.172*	0.172**	0.172*
	(0.0881)	(0.0880)	(0.0909)
TAC (100K lbs.)	-0.003***	-0.003***	-0.003***
	(0.0005)	(0.0005)	(0.0005)
Fuel Price	-0.265***	-0.265***	-0.265***
	(0.0375)	(0.0375)	(0.0378)
Area Revenue (100K)	-0.152	-0.145	-0.145
	(0.095)	(0.085)	(0.122)
Lbs. LT3K	1.246***	1.252***	1.252***
	(0.191)	(0.190)	(0.214)
Lbs. 3Kto10K	0.946***	0.950***	0.950***

	(0.169)	(0.169)	(0.189)
Lbs. 10Kto25K	0.442***	0.444***	0.444***
	(0.148)	(0.148)	(0.159)
Multi Class QS Held	-0.151*	-0.149*	-0.149*
	(0.0851)	(0.0850)	(0.0818)
Class B	0.764***	0.762***	0.762***
	(0.134)	(0.134)	(0.136)
Class C	0.467***	0.464***	0.464***
	(0.102)	(0.102)	(0.103)
Constant	-2.723***	-2.721***	-2.721***
	(0.223)	(0.222)	(0.243)
Observations	15,459	15,459	15,459

4.4.4.2 Logit Models of Exit from the Halibut IFQ Fishery

Table 4.13 shows the parameter estimates for four specifications of a model of exit from an IFQ area. For each of the models below, the log-likelihood Chi-square test statistic had a p-value significant at the 99.99% level, indicating that the null hypothesis that taken together the independent variables had no effect on the dependent variable could be rejected. Likelihood ratio tests are used to analyze the specification of the models by testing restrictions on the parameters (Hilbe and Greene, 2008). According to the likelihood ratio tests, all of the variables included in these models jointly contributed statistically significantly to improving the overall fit of the models. Although the coefficient was not statistically significant, the Area Revenue variable was included in Models 1, 2, and 3 because it statistically significantly contributed to improving the overall fit of the model, using the likelihood ratio test.

Table 4.13: Parameter estimates from logit models of exit. Standard errors are in parentheses, where *** p<0.01, ** p<0.05, and * p<0.1.

Variables	Model 1	Model 2	Model 3	Model 4
Hired Skipper	0.172*	0.148*	0.133	0.162*
	(0.088)	(0.089)	(0.089)	(0.089)
Fuel Price	-0.265***	-0.207***		
	(0.038)	(0.036)		
TAC (100K lbs.)	-0.003***			-0.003***
	(0.0005)			(0.0005)
QS Price			-0.025***	-0.022***
			(0.005)	(0.007)
Area Revenue (100K)	-0.152	-0.142	-0.157*	
	(0.095)	(0.095)	(0.096)	
Lbs. LT3K	1.246***	1.308***	1.286***	1.473***
	(0.191)	(0.192)	(0.192)	(0.133)
Lbs. 3Kto10K	0.946***	0.989***	0.972***	1.157***
	(0.169)	(0.170)	(0.170)	(0.117)
Lbs. 10Kto25K	0.442***	0.461***	0.461***	0.613***
	(0.148)	(0.149)	(0.149)	(0.117)
Multi Class QS Held	-0.151*	-0.161*	-0.179**	-0.167*
	(0.085)	(0.086)	(0.086)	(0.086)
Class B	0.764***	0.759***	0.760***	0.741***
	(0.134)	(0.134)	(0.135)	(0.134)
Class C	0.467***	0.488***	0.483***	0.457***

	(0.102)	(0.103)	(0.103)	(0.103)
Area 3B		0.258***	0.196**	
		(0.089)	(0.09)	
Area 4A		0.606***	0.457***	
		(0.128)	(0.132)	
Area 4B		0.808***	0.606***	
		(0.191)	(0.205)	
Area 4CD		0.653***	0.585**	
		(0.235)	(0.246)	
Year 2000to2003				0.263**
				(0.114)
Constant	-2.723***	-3.532***	-3.577***	-3.466***
	(0.223)	(0.197)	(0.201)	(0.217)
Observations	15,459	15,459	15,324	15,324
Pseudo R2	0.0362	0.0373	0.0369	0.0364

The results presented in Table 4.13 indicate that shareholders who use hired skippers are more likely than those who do not use hired skippers to exit an IFQ area. However, the coefficients on the hired skipper variable are only significant at the 10% significance level. In Model 3, the hired skipper variable has a slightly higher standard error and is just barely insignificant at the 10% significance level. Overall these models indicate a relatively weak positive relationship between hired skipper use and exit.

The signs of most of the economic indicators variables are aligned with expectations. The signs of the TAC and the QS Price variables indicate that increases in an area TAC and the average quota share price in an area are associated with a decrease in the probability of a shareholder exiting the area. Given that increases in the TAC and the quota share price should be indicative of increasing earnings expectation, the signs of the coefficients of these variables are aligned with expectations. Furthermore, the negative coefficient for the Area Revenue variable also reflects that shareholders with greater earning potential are less likely to exit the fishery. Although net revenue would be more appropriate for this analysis, data on individual shareholders' costs in the fishery are not available. On the other hand, the sign of the Fuel Price variable is not aligned with expectations, as increasing costs in the fishery should theoretically be associated with an increase in the probability of shareholders selling their quota. However, both Tidd et al. (2011) and Tidd (2014) found fuel prices to be of little significance in predicting vessel exit. In this analysis, the negative coefficient on the Fuel Price variable may reflect the increasing fuel prices and decreasing numbers of exiting shareholders in the latter part of the dataset, rather than actual responses to changes in the costs of participating in the fishery. The QS Price should capture expectations about earnings from the halibut fishery associated with the TAC, the ex-vessel price of halibut, and the costs of fishing. Indeed, as with the analysis presented in Section 4.3, the QS Price is too highly correlated with the Fuel Price to be included in the same models, and the Area Revenue and TAC variables cannot be included together in the same model that includes the QS Price variable.

The attributes of the shareholder with respect to his shareholdings are also statistically significant predictors of exit from an area, indicating that the degree of investment in the fishery by a shareholder is negatively associated with the probability of his exiting the fishery. Relative to shareholders with more than 25,000 pounds of quota, shareholders with quota in the other three (smaller) holdings categories (i.e.

Lbs. LT 3K, Lbs. 3Kto10K, and Lbs. 10Kto25K) are more likely to exit an IFQ area. Furthermore, shareholders with diversified holdings (i.e. quota in multiple vessel classes) are less likely to exit than shareholders with holdings in just one vessel class. It is possible that these trends reflect higher rates of return for shareholders with larger and more diversified holdings, as researchers have speculated in other fisheries (Stewart et al., 2006).

The attributes of the quota held by the shareholder are also significant predictors of exit. The coefficients of the Class B and Class C variables indicate that shareholders with larger vessel class quota are more likely to exit the fishery than shareholders with smaller class quota, which is aligned with expectations about the costs of fishing but may also be associated with regulatory provisions in the fishery described in the Discussion section. Relative to a shareholder in Area 3A, a shareholder in each of the other IFQ areas is more likely to exit those areas. There was evidence in the estimations that the Area variables interacted with the TAC and Year variables and could not be statistically significant in the same models. This provides some indication that the Area variables explain both some of the inter-annual and inter-area variation in the probability of exit. The positive coefficient on the Year 2000 to 2003 variable indicates that the probability of exit was higher during the first couple years of this dataset, likely because shareholders were still adjusting to the implementation of the IFQ program during this period, while in the latter years of the dataset exit is likely more associated with other factors, such as aging.

Some variables, which were expected to be significant in explaining the probability of exit in the halibut IFQ fishery, including the residency of the shareholder and the diversity of the shareholder's holdings with respect to multiple

IFQ areas did not have statistically significant coefficients and did not statistically significantly contribute to improving the overall fit of the models, as tested with the likelihood ratio test. Potential reasons for this are discussed in the Discussion and Conclusions section.

The McFadden pseudo R-squared statistic is also reported. Low pseudo R-squared values for logistic regression are common and, therefore, it is often recommended that researchers not report R-squared values with their results (Hosmer and Lemeshow, 2000). In other studies of vessel exit, the McFadden's pseudo R-squared statistic ranges from 0.2 to 0.3 (Pradhan and Leung, 2004; Tidd et al., 2011; Tidd, 2014). The McFadden's pseudo R-squared for the three models presented in Table 3 is very low, potentially indicating limited explanatory power for these models. However, low pseudo R-squared values are sometimes associated with logistic models of rare events (Freund and Rijkers, 2012).

Table 4.14 shows the marginal effects of each of the predictor variables on the probability of a shareholder selling all of his quota/exiting from an area for each of the Models 1 through 4. The marginal effects in this analysis were calculated at the mean values of the independent variables. For the fixed effects predictor variables, the marginal effect of a variable for these models is the change in the probability of hiring a skipper with a change in the fixed effects variable from presence to absence holding all other variables constant. For the continuous predictor variables, the marginal effect represents the change in the probability of exiting the fishery when the predictor variable increases by one unit.

Overall the marginal effects on the probability of exit from an area with a change in each of the predictor variables are very small, although statistically significant. The marginal effects coefficients indicate that the probability of those using hired skippers exiting the fishery is only about 1% greater than those who do not use hired skippers. In comparison to a shareholder that owns more than 25,000 pounds of quota, the probability of a shareholder exiting an area increases by 6% for shareholders with holdings less than 3,000 pounds, by 4% for shareholders with holdings between 3,000 and 10,000 pounds, and by 2% for shareholders with holdings between 10,000 and 25,000 pounds. In comparison to a shareholder with Class D quota, the probability of a shareholder with Class B or Class C quota exiting an area is 3.5% or 2% greater, respectively. Relative to Area 3A, the probability of exit increases by about 1% to 4% for shareholders in Areas 3B, 4A, 4B, and 4CD.

Table 4.14: Marginal effects on probability of exit for Models 1 through 4. Standard errors are in parentheses, where *** p<0.01, ** p<0.05, and * p<0.1.

Variables	Model 1 Marginal effect	Model 2 Marginal effect	Model 3 Marginal effect	Model 4 Marginal effect
Hired Skipper	0.008*	0.007*	0.006	0.008*
	(0.004)	(0.004)	(0.004)	(0.004)
Fuel Price	-0.012***	-0.01***		
	(0.002)	(0.002)		
TAC (100K lbs.)	-0.0001***			-0.0001***
	(0.00002			(0.00002)
QS Price			-0.001***	-0.001***
			(0.000)	(0.000)
Area Revenue (100K)	-0.007	-0.142	-0.157*	
	(0.004)	(0.095)	(0.096)	

Lbs. LT3K	0.0578***	0.061***	0.06***	0.069***
	(0.009)	(0.009)	(0.009)	(0.006)
Lbs. LT3Kto10K	0.0439***	0.046***	0.045***	0.054***
	(0.008)	(0.008)	(0.008)	(0.005)
Lbs. LT10Kto25K	0.021***	0.021***	0.021***	0.029***
	(0.007)	(0.007)	(0.007)	(0.005)
Multi Class QS Held	-0.007*	-0.007*	-0.008**	-0.008*
	(0.004)	(0.004)	(0.004)	(0.004)
Class B	0.0355***	0.035***	0.035***	0.035***
	(0.006)	(0.006)	(0.006)	(0.006)
Class C	0.0216***	0.023***	0.022***	0.021***
	(0.005)	(0.005)	(0.005)	(0.005)
Area 3B		0.012***	0.009**	
		(0.004)	(0.004)	
Area 4A		0.028***	0.021***	
		(0.006)	(0.006)	
Area 4B		0.037***	0.028***	
		(0.009)	(0.01)	
Area 4CD		0.03***	0.027**	
		(0.011)	(0.011)	
Year 2000to2003				0.012**
				(0.005)
Observations	15,459	15,459	15,324	15,324

Binary outcome models are evaluated with regards to how often they correctly predict the occurrence of the event under study. The rates of true positive predictions (sensitivity) and of true negative predictions (specificity) are directly related to the rate of the occurrence of the event in the sample. The sensitivity of models is likely to be low with rare events (Swets, 1988; King and Zeng, 2001). In fact, fisheries researchers have shown that the predictive accuracy of vessel exit is low when there are a relatively small number of exiting vessels (Mardle et al., 2006). The default classification cut-point for binary outcome models is 0.5%. When this cut-point is applied, the models correctly classify about 94.4% of the outcomes, which corresponds to the percentage of observations that are of shareholders not exiting the fishery.

In rare events logit models, the probability of ones will be systematically underestimated (King and Zeng, 2001). A classification cut-point of 0.5% assumes that sensitivity and specificity are of equal importance, and thereby that the error rates associated with each (i.e false positive and false negative) are equally acceptable. Researchers have used cut-point analysis to improve prediction for rare events, utilizing an optimal cut-point based on the intersection of the sensitivity and specificity curves, which improves sensitivity at the cost of specificity (Hein and Weiskittel, 2010). The sensitivity and specificity curves versus the probability cutoffs indicate that a probability cutoff of 0.057% would simultaneously maximize both sensitivity and specificity. Using the 0.057% cutoff, the sensitivity and specificity of the models were both about 61%, with slight variation across the four models.

The receiver operating characteristic (ROC) curve is a plot of the sensitivity (true positive) rate against 1 minus the specificity (the false positive rate) for the different possible cut points of a probability model, which shows the tradeoff for sensitivity and specificity of the model. The area under the ROC curve (AUC) should be equal to one for models with perfect discrimination. Although Hosmer and

Lemeshow (2000) suggest that 0.7 to 0.8 is the AUC range for acceptable discrimination, researchers studying rare events have suggested that lower ranges are acceptable for models of rare events, with AUCs of 0.65 to 0.8 reported with rare weather events (Swets, 1988), AUCs of 0.7 to 0.77 for adverse drug effects (Duke et al., 2014), and AUCs of 0.56 to 0.7 for infrequent gene mutations (Lin et al., 2006). The AUCs are 0.655, 0.657, 0.657, and 0.656 for Models 1, 2, 3, and 4, respectively. Given that an AUC of 0.5 would indicate wholly random prediction, these AUCs for the four models indicate that the models do have some discrimination in predicting exit from an area. Furthermore, although these AUCs are not within the acceptable range for discrimination given by Hosmer and Lemeshow (2000), they are within the range reported by other researchers for rare events.

4.4.5 Discussion and Conclusions

This analysis examines the determinants of exit from the halibut IFQ fishery, with a particular focus on the impacts of a shareholder using a hired skipper. The results of this analysis indicate that although those who use hired skippers are statistically significantly more likely to sell their shares in a given area than those who do not use hired skippers, the marginal effects indicate that the increase in the probability of exit for those using hired skippers is very small. In other words, the relationship between the shareholder using a hired skipper and exiting from an IFQ area is marginally positive. This concurs with findings from Pradhan and Leung (2004), who showed that vessels not captained by their owners were more likely to exit the Hawaiian longline fishery, which was assumed to be a factor of greater production efficiency for vessels operated by their owners. The association between exit and hired skipper use evidenced in this analysis may be interesting in light of concerns about the increasing use of hired skippers and the potential impacts of this use upon entry. However, because the analysis does not take into account the number of years that shareholders stay in the fishery using a hired skipper, this marginally positive relationship should be couched within a broader understanding of the potential impacts of hired skipper use upon entry.

Hired skipper use may be hypothesized to be positively associated with exit if hired skipper use is a factor of aging amongst initial recipients. In other words, healthy shareholders may be less likely to use hired skippers than aging shareholders, who use hired skippers as a step towards selling their quota shares and exiting the fishery altogether. On the other hand, hired skipper use may be hypothesized to be negatively associated with exit if shareholders have large investments in quota shares and lease their quota as a way of making money off of their shareholdings. Because these two hypotheses are consistent with different signs on the hired skipper parameter, this may account for the weakness of hired skipper use as a determinant variable in the models. One potential mechanism of dealing with these differing relationships between hired skipper use and exit would be to include variables that capture these relationships. For example, an age variable may capture some of the association between aging shareholders using hired skippers as a step towards selling out of the fishery. However, as noted in the previous Chapter, age data is not available for individual shareholders. It is also possible that the quota shareholdings variables used in this analysis, with respect to the quantity and diversification of holdings, capture some of the association between the use of hired skippers and quota investment in the fishery.

The associations between the economic variables (the TAC, Quota Share Price, and Area Revenue) and exit in this analysis are aligned with economic theory and previous research that included similar metrics. Individual shareholders who have expectations of greater earnings, as reflected by their area revenue, are less likely to exit, and shareholders are generally less likely to exit when the TAC and quota share prices are greater. Given that the TACs have been decreasing and the quota share and ex-vessel prices (the latter of which is captured in the area revenue variable) have been increasing while the frequency of observed exits has decreased in the dataset, the associations between these three economic variables and exit may to some degree be reflecting changes in the dataset over time. However, there is considerable inter-area variation in these variables as well. The relationship between the Fuel Price variable and exit in this analysis is not aligned with theoretical expectations about the impacts of costs on exit. However, the 1% marginal effect is more aligned with previous research, which showed that fuel prices are insignificant in predicting exit. Furthermore, this relationship may be capturing decreasing demand for quota when costs increase, which would result in fewer shareholders being able to sell their shares.

This analysis indicates that shareholders with more consolidated and diversified shareholdings are less likely to exit the fishery than those with fewer quota shares and non-diversified holdings. The probability of a shareholder exiting from an IFQ area is greater for those with smaller holdings likely in part because it is easier to sell smaller amounts of quota. Furthermore, those with larger holdings are more likely to be participating in the halibut fishery full-time and are less likely to be able to quickly respond to changes in economic indicators in the fishery such as the TAC or the ex-vessel price of fish. The negative relationship between consolidated shareholdings and exit should be considered with other findings in this dissertation that consolidated quota is associated with fewer new entrants into an IFQ area and that shareholders with larger and more diversified holdings are more likely to use hired skippers. Together, these findings indicate that consolidation may delay the transfer of quota to a second-generation class of owner-operators.

The associations between the vessel class and area attributes of the quota shares and the probability of exit may in part reflect regulatory provisions and changes to the stock biomass. The probability of those with larger class quota being more likely to sell out of the fishery may be associated with the regulatory provision that allows larger class quota to be fished on smaller sized vessels, which could mean that the larger class quota shares are easier to sell. The greater likelihood of shareholders exiting the fishery in Areas 3B through 4D relative to Area 3A may be related to the greater operating costs in those areas and to more severe cuts in the TACs in the Bering Sea and Aleutian Islands, which decreased by 60% to 73% from 2000 to 2013, compared to 40% TAC cuts in the Gulf of Alaska during this same time period.

Several variables that were expected to be associated with the probability of exit did not have statistically significant relationships in the models. For example, despite previous research indicating that residents of rural Alaskan communities are more likely to sell their shares than urban residents, this study found no relationship between the residency of the individual, with respect to the population or state, and the probability of exit. This may be because these previous studies were assessing adjustment to the IFQ program while in this analysis this adjustment is assumed to have taken place and exit is a factor of other variables. The Multi Area QS Held variable may not be significant, because the quantity and diversity of shareholdings are sufficiently captured by the other variables in the model.

Although limiting the study to eligible individuals provided that using a hired skipper could be included as a predictor variable, this study excluded a significant portion of halibut IFQ participants (including catcher processor shareholders, shareholders in Area 2C, and corporate shareholders) from the analysis. Including these other participant types would allow for a more comprehensive analysis of exit in the halibut IFQ fishery. This analysis could also be improved by using a different flag for exit in the fishery. In this study, the shareholder is demarcated as exiting the fishery in the current year if he has no shares in the following year, which does not take into account that shareholders may make the decision to exit the fishery but not be able to immediately sell their shares. Given that there is likely often a lag period between when the shareholder decides to exit the fishery and when he actually exits, the demarcation for exit used in this analysis likely omits numerous exiting shareholders. Changing the flag to one wherein the shareholder would be designated as exiting the fishery if he did not own any quota in any following year would account for this potential lag time. Another way to address this would be to use a continuous variable for the percentage of a shareholder's quota share holdings sold in a given area and year (a divestment rate). This would capture what is likely to often be a slow rate of divestment by quota shareholders and create more observations with variability in the variable of interest. For the impacts of hired skipper use on this divestment rate dependent variable to be consistent with the results of this study, higher rates of hired skipper use would be associated with higher rates of divestment.

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Chapter 5

CONCLUSIONS

Fisheries management has been rapidly evolving since the 1970s, when nations worldwide began to declare sovereignty over exclusive economic zones (EEZs) out to 200 nautical miles from their coastlines. Prior to this most fisheries were largely open access, with few regulations on who could participate, how, and when. The last four decades have witnessed a huge shift from a lack of regulations, to controls on inputs (e.g., gear, vessel size, engine power, etc.) and outputs (TACs, trip limits, bycatch limits), and increasingly towards rights-based management programs. Although many lessons have been learned throughout this process and there is increasing evidence that these programs are an effective tool for maintaining catch within a prescribed TAC, decreasing overcapacity and total costs in the fishery, and increasing safety, these benefits are counterweighed by evidence of some potentially adverse social impacts largely associated with consolidation and shifts of quota ownership, landings, and employment opportunities, especially on fishery-dependent and isolated coastal communities.

How to balance economic efficiency gains with some of these adverse impacts is still a challenge for managers. Throughout numerous rights-based management programs, managers have employed a variety of tools, or protection provisions, to try to address and minimize these adverse impacts, but the impacts of these specific provisions are largely not studied. As fisheries managers, especially in the U.S., move towards increasingly relying on rights-based management, the efficacy of provisions intended to balance efficiency and other social goals needs to be better understood. This dissertation addressed this gap by exploring the impacts of protection provisions in the halibut IFQ program.

The three analytical chapters in this study provide greater insight into the impacts of specific provisions in the halibut IFQ program. The findings of each of these chapters are discussed thoroughly within the chapters and are not repeated here. The first analysis shows that quota share trading restrictions are likely costly in terms of affecting the economic efficiency gains that could be expected with unrestricted quota shares. However, the benefits of these kinds of restrictions, with respect to providing employment opportunities are not quantified. Given that the halibut fishery provides employment opportunities in isolated coastal communities throughout Alaska with few alternative employment prospects, the benefits of quota share trade restrictions should be considered. The second and third essays assess the hired skipper provision, which is an increasingly contentious issue in the halibut IFQ fishery. Both of the analyses in these essays indicate that consolidation is a significant factor in how shareholders operate, as shareholders with larger holdings are more likely to use hired skippers and to stay in the fishery. Furthermore, the degree of consolidation in an IFQ area is associated with fewer new entrants. Given that the NPFMC intended to provide for a transition of the catcher vessel halibut IFQ fleet to becoming fully owner-operated and that it has expressed frustration at the slow transition to a class of second-generation owner-operators in the fishery, the potential impacts of consolidation should be understood in any future regulatory considerations, especially as some shareholders in the fishery continue to push for an increase in the individual and vessel use caps. However, restrictions on consolidation are likely to impede potential economic efficiency gains, as shown in the first analysis of this dissertation. Therefore, the NPFMC and managers facing similar challenges in other rights-based managed fisheries should consider the potential trade-offs in economic efficiency and other social objectives with limiting consolidation, allowing hired skipper use, and facilitating entry into the fishery.

Numerous means of improving each of these analyses are explored in each of the previous chapters. A more holistic approach that addressed the potential interactions of these various protection provisions would also be a valuable expansion of this research. However, perhaps the most useful extension would be an examination of similar provisions in other rights-based management programs. Consistency in the impacts of these provisions across various programs, in the predictors of behaviors (e.g., leasing) that may be problematic, and in other decisions of interest such as entry and exit would provide much greater insight for fisheries managers interested in developing or amending a rights-based fisheries management program that more effectively balanced their competing programmatic goals. Indeed, it seems that the next improvement in rights-based management should be a deeper understanding of the impacts of specific programmatic provisions on various stakeholders in the fishery.

Appendix A

APPENDIX TO ANALYSES IN CHAPTER 4

Table A1 shows the cities, boroughs, and economic regions that were included in the calculation of the average earnings, population, and unemployment variables for each IFQ area used in Sections 4.3 and 4.4.

Table A1: Cities, boroughs, and economic regions included in calculation of Salmon Average Earnings, Population, and Unemployment by IFQ Area.

	Salmon Average Earnings		Population	Unemployment
IFQ Area	Fishery	Fishery Description	Cities and Boroughs	Cities and Boroughs
2C	S 01A S 03A S 05B S 15B	SALMON, PURSE SEINE, SOUTHEAST SALMON, DRIFT GILLNET, SOUTHEAST SALMON, HAND TROLL, STATEWIDE SALMON, POWER TROLL, STATEWIDE	Haines, Hoonah, Angoon, Ketchikan, Petersburg, Prince of Wales-Hyder, Sitka, Skagway, Wrangell	Southeast Economic Region
3A	S 05B S 15B S 01E S 01H S 01K S 02K	SALMON, HAND TROLL, STATEWIDE SALMON, POWER TROLL, STATEWIDE SALMON, PURSE SEINE, PRINCE WILLIAM SOUND SALMON, PURSE SEINE, COOK INLET SALMON, PURSE SEINE, KODIAK SALMON, BEACH SEINE, KODIAK	Anchorage, Matanuska-Susitna, Kenai, Kodiak, Valdez-Cordova, Yakutat	Anchorage, Matanuska-Susitna, Kenai, Kodiak, Valdez-Cordova, Yakutat

	S 03E S 03H S 04D S 04E S 04H S 04K	SALMON, DRIFT GILLNET, PRINCE WILLIAM SOUND SALMON, DRIFT GILLNET, COOK INLET SALMON, SET GILLNET, YAKUTAT SALMON, SET GILLNET, PRINCE WILLIAM SOUND SALMON, SET GILLNET, COOK INLET SALMON, SET GILLNET, KODIAK		
3B	S 01L S 01M S 03M S 04M	SALMON, PURSE SEINE, CHIGNIK SALMON, PURSE SEINE, AK PENINSULA SALMON, DRIFT GILLNET, AK PENINSULA SALMON, SET GILLNET, AK PENINSULA	Aleutians East, Lake and Peninsula, Kodiak	Aleutians East Borough, Kodiak Island Borough, Southwest Economic Region
4A	S 01M S 03M S 03T S 04M S 04T	SALMON, PURSE SEINE, AK PENINSULA SALMON, DRIFT GILLNET, AK PENINSULA SALMON, DRIFT GILLNET, BRISTOL BAY SALMON, SET GILLNET, AK PENINSULA SALMON, SET GILLNET, BRISTOL BAY	Aleutians East and West	Aleutians East and West
4B	Same as 4A	Same as 4A	Aleutians West	Aleutians West
4C/D	Same as 4A	Same as 4A	Mekoryuk and Aleutians West	Aleutians West

Table A2 shows the Deviance and Pearson Chi-squared goodness-of-fit test statistics for the Poisson models presented in Table 4.9 and when the Poisson distribution is assumed for the models in Table 4.10. Both test statistics are significant for all of the models indicating that, given the models, the hypothesis that these data are Poisson distributed can be rejected at least at the 1% level.

Table A2: Deviance and Pearson Chi-squared goodness-of-fit statistics for Poisson Models

	Deviance Test Statistic	df	Prob > chi2
Model 1A	137.172	76	0.0000
Model 2A	116.168	64	0.0001
Model 3	138.0258	76	0.0000
Model 4	101.0596	66	0.0036
Model 5	140.1366	77	0.0000
	Pearson Test Statistic	df	Prob > chi2
Model 1A	117.834	76	0.0015
Model 2A	101.531	64	0.0020
Model 3	121.1045	76	0.0008
Model 4	106.2724	66	0.0036
Model 5	122.776	77	0.0007