DISCUSSION PAPER

March 2015 ■ RFF DP 14-32

Efficiency Costs of Social Objectives in Tradable Permit Programs

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A version of this paper was accepted for publication by the *Journal of the Association of Environmental and Resource Economists* on 03/12/2015.
http://www.press.uchicago.edu/ucp/journals/journal/jaere.html

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Abstract

Objectives of tradable permit programs are often broader than internalizing an externality and improving economic efficiency. Many programs are designed to accommodate community, cultural, and other non-efficiency goals through restrictions on trading. However, restrictions can decrease economic efficiency gains. We use a policy experiment from the Alaska halibut and sablefish tradable permit program, which includes both restricted and unrestricted permits, to develop one of the few empirical measurements of the costs of meeting non-efficiency goals. We estimate that restrictions are reducing resource rent in the halibut and sablefish fisheries by 25% and 9%, respectively.

Key Words: tradable permits, created markets, individual transferrable quota, catch shares, Alaskan halibut and sablefish fishery

JEL Classification Numbers: Q22, Q28

Contents

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Introduction

Tradable permit programs (TPPs) are a market-based policy designed to internalize externalities. Examples include management of air pollutants such as CO_2 and SO_2, point and non-point source water pollution, as well as the allocation of catch in commercial fisheries (Boyd et al. 2003). Regardless of their application, TPPs establish a cap (e.g., amount of pollution or resource extraction), then allocate a share of the cap to participants in the form of a permit. In many programs, however, trading of the permits is restricted (Tietenberg 2007).

Restrictions on trade, such as who can trade with whom[1] and whether permits can be borrowed or banked, are often implemented to address cultural, secondary environmental issues, and other non-efficiency goals. Often the justification is based on 'equity' issues and concerns over the 'winners' and 'losers' (Hahn 1984). For example, an oft-stated concern in commercial

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Funding for this research was provided by Resources for the Future and the Alaska Fisheries Science Center, National Marine Fisheries Service. The views and opinions expressed in this paper are the authors' own, and do not necessarily reflect those of Resources for the Future or the National Oceanic and Atmospheric Administration or the U.S. Department of Commerce.

This publication was prepared by Kailin Kroetz, James N. Sanchirico, and Daniel K. Lew under NOAA Grant #NA120AR4170070, California Sea Grant College Program Project #NA120AR4170070, through NOAA's National Sea Grant College Program, U.S. Dept. of Commerce. The statements, findings, conclusions and recommendations are those of the author(s) and do not necessarily reflect the views of California Sea Grant, state agencies, NOAA or the U.S. Dept. of Commerce.

We thank Joshua Abbott, Isabel Call, Ghada Elabed, Harrison Fell, Ron Felthoven, Jacqueline Ho, Larry Karp, Stephen Kasperski, Douglas Larson, Clayton Munnings, Aaron Smith, Martin Smith, James Wilen, Zhongmin Wang, the participants of the AERE conference (Seattle June 2011), the participants at the PERC Lessons Learned in Rights-Based Fisheries Management workshop (Bozeman July 2011), and two anonymous reviewers for helpful comments on earlier drafts of the manuscript. Jessica Gharrett and Terry Hiatt were very helpful in providing and explaining the nuances of the data.

[1] This encompasses many types of restrictions including restrictions on trade between economic agents within the program, including who can trade with whom and the limitations placed on those transactions, as well as the exclusion of potential participants from a program (e.g. the exclusion of some sectors from a program).

fisheries is that larger operators may buy out smaller operators, which could have negative implications for the social fabric of coastal communities and ports (see e.g. Willmann (2000)).

Trading rules are one possible means of addressing non-efficiency goals.[2] While they may produce societal benefits, they may also reduce the cost-effectiveness of a program (Stavins 1995) and/or reduce the potential for increases in revenue to occur through changes, such as increases in product quality and switching to more valuable product forms (see e.g. Wilen (2005) for further discussion and examples of revenue-side gains in fisheries after management changes). The extent to which the benefits outweigh the costs or vice versa is not fully understood. We provide one of the few empirical estimates of the magnitude of the efficiency costs of trading restrictions, thereby enabling policymakers to understand the tradeoffs associated with including restrictions in the design of a TPP (see also Gangadharan (2000, 2004) , Grafton Squires and Fox (2000), and Singh, Weninger, and Doyle (2006)).

In general, we contribute to the set of ex post evaluations of TPPs[3], albeit with a more limited focus on measuring the costs of restrictions. Our analysis is similar to Gangadharan (2004) who obtains an estimate of the variation in permit price by geographic area in the Regional Clean Air Incentives Market (RECLAIM). However, we focus on restrictions that impact the use of capital inputs, divisibility of a permit, corporate ownership, and consolidation and therefore have the potential to impact profitability through mechanisms including limiting size and returns to scale, access to credit and interest rates, and limiting technology and constraining variable cost structures. Similar mechanisms in contexts including the lead phase out program and wetland credit trading have been shown to reduce program efficiency (see e.g. Kerr and Maré (1998) and Shabman (2004)). Furthermore, restrictions based on similar mechanisms exist or are proposed for other TPPs, most notably in contexts with multiple user groups. For example, geographical sectors can arise through the division of markets by political entity, such as the European Union, Californian, and Chinese carbon markets (see e.g. Munnings

[2] Of course, there are other means besides trading restrictions to address these goals. For example, when Peru implemented a TPP to manage the Anchoveta stock, the program included a social fund called FONCOPES to provide crew financial incentives for early retirement, retraining opportunities, and assistance in small business development (Young and Lankester, 2013). In the carbon abatement context rebates can be used to offset increases in the costs of energy associated with permit costs and therefore prevent low-income households from experiencing an increase in energy costs (see e.g. Kunkel and Kammen (2011)). An assessment of the most cost-effective means to address non-efficiency goals is beyond the scope of the paper.

[3] See, for example, OECD (2004) and Tietenberg (2006) for summaries of multiple programs, and for specific examples see Fowlie and Perloff (2012), Ellerman and Buchner (2007), Montero (1999), Schmalensee et al. (1998) and Stavins (1998).

et al. (2014) and Pizer et al. (2006)). User groups may also be separated within a program, such as mobile and stationary emission sources, non-point and point sources, and commercial and recreational fisheries sectors (see e.g. Call and Lew (2014)).

To estimate the impact of the restrictions we exploit a real-world policy experiment where the designers of the Alaska federal halibut and sablefish Individual Transferrable Quota (ITQ) program created both restricted (to varying degrees) and unrestricted markets. This variation allows us to identify the costs of trading restrictions without imposing structural assumptions necessary to estimate a counterfactual. Specifically, we consider the question of whether the restrictions in the ITQ program resulted in lower resource rent than hypothetically would have existed if the program had been implemented without the restrictions in place. We conduct our analysis using a reduced form model of quota prices, with dummy variables capturing the impact of restrictions. Similar identification strategies have been used to measure the underlying costs and benefits of programs in a variety of settings. For example, Chattopadhyay and Duflo (2004) exploit randomization across village councils of a mandate that a leadership role be filled by a woman to study public good provision and gender in India, while Bai, Li and Ouyang (2014) use geographic variation in property tax implementation to consider property taxation effects in China.

In the fisheries context, our work contributes to the growing body of research utilizing policy experiments to identify the impacts of policies. For example, Newell, Sanchirico and Kerr (2005) use information on fish stocks that had the greatest reduction in catches pre and post the ITQ program to identify the rate of return in an ITQ program, Smith, Zhang and Coleman (2006) use data from before and after the creation of closed areas to measure the impact the of the closure on the fishery, Abbott and Wilen (2010) use variation in the choice to participate in a cooperative management structure to identify the gains from information sharing, and more recently, Scheld, Anderson and Uchida (2012) exploit that only a share of the fishermen fishing multiple fish stocks were operating under a quota program to measure the economic effects of the program.

We use a unique (confidential) dataset from the Alaska federal halibut and sablefish ITQ program. The program was implemented in 1995 (58 FR 215: 59375-59413) to limit access to each of the fisheries, reduce overcapacity, and address “conservation and management problems that are endemic to open access fisheries” (69 FR 84: 23681). At the same time, concern about the potential impacts of the program on the social and cultural characteristics of the fisheries and fishing communities in Alaska led to restrictions on quota trading.

The number and diversity of restrictions on the transfer of quota in the halibut and sablefish markets makes the program a unique and well-suited laboratory to measure the efficiency costs of achieving non-efficiency objectives. Furthermore, relative to other TPPs, the halibut and sablefish ITQ program has been in place for a long time, has an active and well-documented trading market, and has a large number of participants.

Using both parametric and non-parametric methods, we find that restrictions in the fisheries have decreased the present value of resource rent (as measured by quota asset prices) over the lifetime of the program by approximately $121 million for halibut and $46 million for sablefish (in $2012 USD). To put these numbers in context, the gross revenues for the halibut and sablefish fisheries in 2011 was $205.2 million and $128.9 million, respectively (Fissel et al. 2012).

Our findings suggest that restrictions in TPPs can have significant efficiency implications. This is a particularly important finding given that imposing restrictions in these programs is becoming more commonplace. For example, recently proposed air pollution legislation in California (see e.g. EPRI (2013)) and newly implemented programs for managing West Coast and New England fisheries impose restrictions on permit markets. In the fisheries management context, the use of restrictions is likely to grow as the National Oceanic and Atmospheric Administration's (NOAA) Catch Share Policy (NOAA 2010) discusses the key role trading rules can play in addressing multiple objectives.

The remainder of the paper is organized as follows. First, we describe the Alaska halibut and sablefish ITQ program, the restrictions we focus on in the paper, and the data used in our analysis. We then provide a brief overview of how the costs of the restrictions were measured. This is followed by estimates of the costs of the restrictions, including a set of parametric and non-parametric robustness checks. We conclude with a summary of our results and future research questions.

The Alaska Halibut and Sablefish Transferable Quota Program

Prior to ITQ implementation, both the halibut and sablefish fisheries were managed using season length restrictions as a means of restricting catch. However, both fisheries went through periods where significant numbers of vessels entered the fishery, causing the season lengths to be progressively shortened in an effort to avoid exceeding the annual catch limits. When ITQs were implemented in 1995, openings as short as 24 hours had occurred in the halibut fishery and seasons were as short as 20 days in the sablefish fishery.[4] The Alaska halibut and sablefish program was implemented in 1995 by the North Pacific Fishery Management Council (NPFMC), the regulatory body overseeing the management of the fishery. The NPFMC determines how much sablefish can be caught each year, while the annual amounts of Pacific halibut that can be harvested in the United States (and Canada as well) are determined by the International Pacific Halibut Commission (IPHC).

To sustain healthy fish populations, the yearly total allowable catch (TAC) of the halibut stock and the sablefish stock are capped. TACs are assigned to specific geographic areas, of which there are eight in the halibut fishery and six in the sablefish fishery (see Figure 1A in the Appendix). Area-specific TACs are intended to prevent local stock depletion (Pautzke and Oliver 1997).

At the inception of the program, the NPFMC granted revocable permits, which are denoted quota share (QS), to past participants in the fisheries. The QS were allocated for a species-area combination and based on the fishing history of each participant. Prior to program implementation it was common for fishermen to fish both halibut and sablefish and fish in multiple areas, and therefore some fishermen were allocated quota for multiple species-area combinations. Ownership of QS for a species grants the owner the privilege to fish a percentage of the species' TAC in an area each year and into perpetuity. The yearly allowances in pounds of fish are determined by multiplying the percentage of the TAC an individual is entitled to, which is based on their QS holdings, with the TAC. The annual allocations of pounds are called IFQ pounds and are allocated to individuals who hold QS via an IFQ permit.

Transfer of QS and IFQ is allowed in the fishery but subject to a number of restrictions. Rather than provide an exhaustive coverage of them, we describe in detail the rules most relevant for our analysis. Specifically, we discuss the vessel class and blocking rules.[5]

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[4] See, e.g., Homans and Wilen (1997) and NRC (1999) for more detail on the history of the halibut and sablefish fisheries and their management.

[5] The program also includes accumulation caps limiting how much quota an individual or entity can hold. We do not focus on this restriction because there is evidence that fishermen find ways to circumvent these restrictions (see e.g. Carothers (2013)). Additionally, there are also criteria fishermen must meet in order to purchase quota and enter the fishery (see Pautzke and Oliver (1997) and also fishery management reports available at http://www.fakr.noaa.gov/ram/ifq.htm).

Vessel Class Restriction

Limiting the use of specific quota to certain vessel classes impacts production flexibility and use of capital inputs. The restriction dictates who can own the QS and IFQ pounds and where and how they can be fished and transferred, as well as the size and type of vessel permitted to fish the IFQ pounds. Class A QS and IFQ pounds are the least restrictive, as they can be owned by a corporation or an individual, sold,[6] and fished on a vessel with or without the owner on board. All other classes of quota may be fished only when the owner of the IFQ pounds, who must be an individual, is on board.[7]

The class also dictates the type and length of the vessel on which the IFQ can be fished. In both fisheries, Class A IFQ is the only IFQ that can be fished on any length vessel, including catcher-processor vessels (large vessels that both catch fish and process it at sea). All other IFQ must be fished on catcher-vessels, which are vessels that deliver their catch to shore-side processors. Classes B and C in the sablefish fishery[8] and Classes B, C, and D in the halibut fishery,[9] designate a variety of sizes of catcher-vessels on which the IFQ can be fished. Class B vessels are larger than Class C vessels, which are larger than Class D.

Blocking Restriction

The blocking restriction makes some QS only transferable as an indivisible block and places limits on the number of blocks one can hold. Blocked QS was established at the beginning of the program for the purpose of ensuring a minimum fleet size (Pautzke and Oliver 1997); in other words, there were concerns that the total number of vessels fishing would drastically decrease. In conjunction with other restrictions the intention was to prevent over-consolidation and ensure that the fishery would not end up dominated by only a few firms (Pautzke and Oliver 1997). Whether the initial issuance of QS was blocked depended on the amount of QS a

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[6] IFQ transactions are akin to leases. These leases are restricted to emergency circumstances only (such as a death or military deployment) for quota associated with all classes of vessels, except Class A quota.

[7] Companies grandfathered in at the beginning of the program are exempt from this restriction. Additionally, participants who were initially allocated QS at the beginning of the program are permitted to hire skippers.

[8] In the sablefish ITQ program the vessel lengths associated with the classes are as follows: Class A IFQ pounds can be fished by any length and by either type of vessel, Class B must be fished by catcher vessels and the vessels can be greater than 60 feet in length, and Class C must be fished by catcher vessels 60 feet or less.

[9] The vessel classes in the halibut fishery are the same except Class C must be fished by vessels between 35 and 60 feet in length, and there is also a Class D designation, for which the IFQ pounds must be fished on catcher vessels 35 feet in length or less.

participant received;[10] participants receiving a relatively small amount of QS received quota in an indivisible "block."[11]

Blocked quota also results in a restriction on the total amount of quota a participant can hold. Specifically, the number of blocks a participant can hold is limited, and the size of each block is capped, restricting total QS units and associated yearly IFQ pounds that can be owned. Furthermore, owning blocked quota can limit the ability to own unblocked quota. Specifically, holding more than one block of QS disqualifies a participant from holding unblocked QS.

Data

We acquired primary confidential data on quota transactions from the National Marine Fisheries Service, Alaska Regional Office. The dataset covers all market transactions since the program's inception in January 1995 through the end of the 2011 fishing year (the final year for which we have complete data).[12] Information describing the transactions includes: the transaction date, names and identification numbers for the buyer and the seller, addresses of the buyer and the seller, information on the price paid/received, the amount of IFQ pounds and QS in the transfer, the reason for the transfer, information on how the buyer and seller found one another, details on the relationship (if any) between the buyer and seller, and details of the quota transacted (e.g., species, area, vessel class, blocked or unblocked, and "fishdownable").[13]

Because of limitations on IFQ pound trading (i.e., leases) and the resulting small number of leases, we use the QS (asset) price data that consists of 4,870 transactions for halibut and 2,160 for sablefish. Specifically, we use data from transactions that include both QS and IFQ pounds, and where the number of pounds is equal to the yearly issuance of IFQ pounds

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[10] See Pautzke and Oliver (1997) for details on how the initial allocation of quota was determined.

[11] Other examples of blocking restrictions include the West Coast sablefish limited entry endorsed sector permit stacking scheme (Kroetz and Sanchirico 2009) and 'locking' of quota in the British Columbia trawl program (Grafton, Nelson and Turris, 2005).

[12] Our primary results use transaction data from the 2000-2011 fishing seasons due to different reporting requirements than the earlier data. As a robustness check, we did the analysis using the period from 1995 to 2011. Overall, the results are consistent with the shorter time period. The full set of results is available upon request.

[13] As Newell, Sanchirico and Kerr (2005) found in the New Zealand ITQ fisheries, individual level market data can include transactions that are not arm's length (transactions where both parties act strictly in their own best interest). Given the detailed nature of our transaction data, specifically the fields in the dataset describing the reason for the transfer, information on how the buyer and seller found one another, and details on the relationship (if any) between the buyer and seller, we are able to eliminate non-arm's length transactions (8% of priced observations were removed for halibut and 14% for sablefish).

associated with the quantity of QS in the transaction.[14] These transactions represent 78% of the transactions in each fishery, and the prices are less likely to be confounded by other factors, such as adjustments to the price for IFQ pounds not included in the transaction.

The observed transactions in the final set are relatively evenly distributed across the years, although the transactions are more heavily concentrated in the spring relative to the rest of the fishing year (the open season runs from late February/March through November). See Table 1 for a summary of the breakdown of the total quota by restriction type and see Table 2 for a summary of the transaction data. Also see the appendix for more details.

Identifying the Costs of Restrictions

In a well-functioning quota market, the QS price (asset price) is equal to the discounted present expected value from fishing the yearly allocation of pounds into the future. The annual return (dividend) to holding a share is the resource rent and represents "the surplus value, i.e., the difference between the price at which fish can be sold and the respective production costs which include a normal return" (NOAA 2010). The asset price, therefore, is a function of the future expectations of profitability in the fishery, discount rates, and expected TAC allocations in the future (for more detailed discussion of quota prices and examples see Clark (1980, 1985, 2005) and Newell, Papps and Sanchirico (2007)).

We set out to answer the question of whether or not restrictions led to lower resource rent than would have existed in the hypothetical case where the ITQ program was implemented without restrictions in place. Our focus is on estimating the differential in the QS price between restricted quota and unrestricted quota. The basis of our identification strategy is that potentially binding trading restrictions distort the price signals in the permit market. That is, a market where rules restrict production processes is likely to lead to the TAC being fished at higher costs and/or at lower per-unit revenue than when the trading market is unrestricted. We exploit the policy

[14] We observe three types of transactions in the data. The first is QS-only transactions. These transactions do not include any IFQ pounds. In the halibut fishery these transactions made up approximately 14% of the transactions, and in the sablefish fishery the percentage is approximately 15%. The second type of transaction includes both QS and IFQ pounds, and the amount of pounds is equal to the yearly issuance of IFQ pounds, which varies by year, associated with the quantity of QS in the transaction. These "Full-IFQ" transactions are the majority of the transactions we observe: 78% of halibut transactions and 78% of sablefish transactions are this type. Finally, there are also transactions that include both QS and IFQ pounds, but the number of IFQ pounds is fewer than the yearly issuance associated with the quantity of QS in the transaction. These transactions make up 7% of halibut transactions and 8% of sablefish transactions.

experiment that restrictions only apply to segments of each fishery, and we observe the quota prices associated with both the unrestricted and restricted segments of the fisheries. [15]

Our estimates represent the long-run marginal value of moving one unit of quota from a restricted operation to an unrestricted one. For example, we consider the situation where one unit of Class C blocked quota was instead unblocked or where one unit of Class C quota is fished on vessels with lengths in the Class B category. We do not attempt to model the transitional dynamics that would occur if a restriction is relaxed at a point in time and the fishermen and markets readjust.[16]

The success of our identification strategy rests on the assumption of a competitive market for quota where no one fisherman can influence the quota price. This assumption is supported by work in other fisheries quota markets showing the markets are well-functioning (see Newell, Sanchirico and Kerr (2005)), as well as by characteristics of the specific fisheries and quota markets we analyze. Specifically, there are a large number of individuals owning quota in the fisheries we examine (over 2,600 individuals in the halibut fishery and over 800 individuals in the sablefish fishery are allocated pounds of quota each year (RAM 2012)), and brokers have been active in the markets facilitating trades since the inception of the program.

While we estimate the marginal value of moving one unit of quota across restrictions, from a policy perspective primary interest is likely to be on the difference in *total* resource rent in the restricted versus the unrestricted scenario. For this, we compare the total resource rent in the restricted scenario to that in the counterfactual scenario where one or more restrictions did not exist. In the case where the equilibrium without restrictions would consist of vessels similar to the vessels in the unrestricted segment of the fishery, we measure the total resource rent as the product of the observed unrestricted quota price and the total TAC in the counterfactual.

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[15] Note that because we estimate a difference between restricted and unrestricted quota prices we do not view our estimates as either an upper or lower bound. In other words, there is no reason to expect the difference to be higher or lower over time as it is possible the timeframes and impacts of transitions of capital would differ between restricted and unrestricted markets.

[16] There is evidence, for example, that capital in fisheries may be slow to turn over after a policy change (see e.g. Weninger and Just (1997)). The path of adjustment to a new management regime (with or without restrictions) is interesting to consider, and a structural econometric model that incorporates capital dynamics is one method to measure the full dynamic costs of the restrictions, but is beyond the scope of this paper.

Similarly, the total restricted scenario resource rent is the sum of the products of the restricted prices and the corresponding restricted TACs.[17]

Econometric Analysis

Before developing our reduced form model to measure the long-run impact on resource rent of the blocking and vessel class restrictions, we present summary statistics that show how prices across the restricted categories have varied over time. Specifically, Figure 1 illustrates average quota prices by vessel class; the percentages of priced transactions we observe in each vessel class are 1% A, 23% B, 45% C, and 31% D in the halibut fishery. For sablefish, the observed percentages of priced transactions are 6% A, 37% B, and 56% C. The shortest halibut vessel class (Class D) tends to have prices below the other classes, but the other class prices are close to one another and the ranking changes year-to-year in some cases. There are several possible reasons for why quota prices may differ by vessel class. For example, Haynie and Layton (2010) provide empirical evidence that profitability varies by length of vessel in the Bering Sea pollock fishery (e.g., due to different technologies and variable cost structures, and ability to travel further distances).

Figure 2 illustrates the average real quota prices over time based on the blocking status, where blocked quota comprises 80% of the halibut transactions and 57% for sablefish. The average blocked quota prices are lower than the unblocked prices in both the halibut and sablefish markets. Blocking has the potential to impact quota prices through similar mechanisms as other restrictions that limit production flexibility including: impacts on size of the operation, variables costs, and access to credit and interest rates.

These summary statistics are limiting, however. For example, the price of quota may depend on the area designation of the quota[18] and the class *and* blocking restrictions jointly. Therefore we investigate potential price differences using a regression analysis to control for other potential factors influencing quota prices. Ideally, we would observe restricted and unrestricted quota prices for species *k* and quota attributes *j* at the same point in time *t*, and could

[17] Using the average difference in quota prices we can estimate what the quota price and total resource rent in the fisheries would have been without one of the restrictions (rent equals unrestricted quota price x TAC) and with the restriction (rent equals unrestricted quota price x unrestricted TAC + restricted quota price x restricted TAC). Differences between these estimates are the costs due to the restrictions.

[18] See Table A1 in the Appendix for a breakdown of transactions by area.

calculate the difference, which can be written as:

$$D(k,j|t) = P(k,j|R,t) - P(k,j|U,t) \qquad (1)$$

where *U* and *R* are used to distinguish between unrestricted and restricted quota prices, respectively. The estimate is a reduced form estimate in the sense that we cannot ascribe the difference to particular factors that may influence profitability including differences in ex-vessel price received, inputs used, or input prices.

Estimation of $D(k,j|t)$ is complicated by the fact that we only observe restricted and unrestricted quota prices when a quota trade occurs and transactions often do not occur in the same window of time or at regular intervals throughout the season. Furthermore, because factors influencing quota prices change over time, we cannot condition on *t* (measured in days), and we do not use this simple framework to directly compare quota prices observed at two different points in time.

Instead, we rely on the fact that factors influencing prices tend to be correlated through time (for example, current fish stock size is a function of fish stock size in the previous period; similarly prices such as ex-vessel prices and fuel prices tend to be correlated through time). Therefore, we expect the difference between restricted and unrestricted prices that are observed close to the same day to be a good approximation of the difference $D(k,j|\,t)$. This allows us to use a reduced form regression model, with controls for factors other than the restrictions that influence QS prices, to estimate the difference in prices.

For our analysis we construct a separate model for each species using observed quota prices as our dependent variable. Specifically, we estimate:

$$f(Quota\ price)_{i,s,y} = \alpha + \mathbf{R}'\boldsymbol{\beta} + \boldsymbol{D}'_{\boldsymbol{y*area}}\ \boldsymbol{\gamma}_{\boldsymbol{y*area}} + \boldsymbol{D}'_{\boldsymbol{s}}\boldsymbol{\gamma}_{\boldsymbol{s}} + \mathrm{D}_{pol}\gamma_{pol} + \varepsilon_{i,s,y} \qquad (2)$$

The *i* subscripts index the observed market transactions, *s* indexes season, and *y* indexes year. Because there are multiple restrictions, a fully-interacted set of vessel class and blocking dummy variables (***R*** vector) are used to measure the impact of restrictions. We use the coefficients on these variables, $\boldsymbol{\beta}$, to estimate the reduction in quota price due to each of the restrictions.

We also include multiple control variables in the analysis, represented by $\boldsymbol{D}$. A policy dummy variable is included to capture the change to the regulations that occurred in the halibut fishery, where the limit on the number of blocks held increased from two to three. Seasonal dummy variables are also included to capture seasonality in processing and/or potential costs associated with the weather that varies throughout the season.[19] Other variables include controls for year to capture changes in the fishery at a yearly time scale, which are interacted with area dummy variables specifying where the quota can be fished.[20]

The area of fishing can impact the profitability of fishing and quota prices, and therefore we control for area differences in our model. Specifically, ex-vessel prices vary by port in the Alaska halibut and sablefish fisheries (NMFS 2010a, NMFS 2010b). Costs may also be region-specific due to differences in distance to the fishing grounds, fuel prices, the prices of other supplies, and fish abundance levels. We expect fishing costs to be lower where stocks are higher, ceteris paribus.

We estimated a number of different specifications including unweighted and weighted models using both a logged dependent variable (hereafter the “LLM” Model) and an untransformed dependent variable (hereafter the “LM” Model). Because we have no economic rationale for preferring one dependent variable formulation over the other, we use comparable R^2 statistics to identify the preferred specification, and find that the LM is preferred (Wooldridge 2012).[21] Therefore, in the remainder of the paper, we present the results of the LM model, but include a parallel set of results in the Appendix for the LLM model.

In terms of weighting, we focus our discussion on the estimates that put greater weight on the larger transactions in the larger markets.[22] Smaller markets are less important for the fishery both from an economic and ecological point of view and often have few transactions. To put more weight on the transactions from the larger markets, we weight the quota prices by the size

[19] For our analysis, the year is divided into five periods, a pre-fishing season, three approximately three-month fishing seasons (Spring, Summer, and Fall), and a post-fishing season. Alternative seasonal time period specifications were tried, such as monthly dummies, but none impacted the restrictions coefficients of interest.

[20] We take the area TAC (cap) as given and control for it in our analysis, as the area-specific TACs “reflect the biological distribution of the stocks of fish… retaining these separations was intended to prevent local stock depletion” (Pautzke and Oliver 1997). Whether the combination or further splitting of TACs could increase economic efficiency is beyond the scope of this analysis.

[21] Parameter estimates for both models are provided in the Appendix.

[22] Specifically, the total weight assigned to an observation is the product of a within submarket weight and a between submarket weight. To arrive at the within submarket weight, we begin by calculating the total pounds transferred via all the transactions in each class/blocking/area submarket. This is just the sum of the pounds in each of the transfers in the submarket. Within the submarket, we give each transaction a within submarket weight that is proportional to the pounds in the transaction. The between submarket weight is proportional to the class/blocking/area share of the TAC.

of the potential market (IFQ pounds in an area/class/blocking combination). Because there are reasons to think that the price signals from larger (relative) trades within a market might be more reliable in any given year, we also weight by size of the transaction relative to the size of all transactions in that submarket in a year.[23] The weighting approach provides a good approximation of the value/pound reduction due to restrictions to each pound in the fishery.

For comparison purposes, we also illustrate the unweighted regression results (specification II). The coefficients of the unweighted regression can be interpreted as the average observed difference in transacted quota prices, after controlling for interacted year and area fixed effects, policy changes, and seasonal effects.

By multiplying the per-pound-equivalent reductions with the size of the market (i.e., amount of restricted TAC pounds in each category in 2011), we obtain estimates of the total efficiency loss. In the remainder of the paper, we focus on describing the costs of the restrictions based on the regression results for the restrictions individually and in aggregate.

Costs of Vessel Class Restriction

In Table 3 and Figure 3, we break down the effect of the vessel class restriction by blocking status. In the halibut market, the results suggest the Class A unblocked quota trades for higher prices than Class B, C, and D unblocked quota by \$2.63, \$3.04, and \$5.24, respectively. Recall that Class A quota is the least restrictive quota across a number of dimensions, including that it can be fished on any size of vessel, can be leased and can be owned by a company or individual. In fact, during our timeframe, we find that all Class A quota was landed by the same length and type of vessels as Class B quota. Therefore, the large and significant difference that we estimate between Class A and Class B unblocked QS prices in the halibut fishery is a measure of the economic efficiency gains associated with having an essentially unrestricted use of the quota.

Within each vessel class, there is also blocked quota. In the halibut blocked market, we find that the difference between the value of A blocked quota and D blocked is \$4.48 and the difference between A blocked quota and C blocked quota prices is \$1.92. The difference between halibut Class A blocked quota and halibut Class B blocked quota is not statistically

[23] For example, with one restriction the weight a restricted transaction would receive would be: $\frac{Restricted\ TAC}{Restricted+Unrestricted\ TAC} * \frac{Pounds\ in\ transaction}{Total\ restricted\ pounds\ transferred}$.

significant. This result could stem from a number of factors, but most likely is due to the limited Class A blocked halibut quota allocated and even fewer trades.

In the sablefish market, we find that unblocked Class B and C quota trades approximately $1.39 and $1.61 lower per pound than Class A unblocked quota, respectively. Blocked B and C quota trade $2.52 and $3.07 below A blocked quota. Within both the halibut and sablefish unblocked and blocked categories there is overlap in the confidence intervals between the Class B and Class C coefficients (Figure 3). It could be that there is not a large difference in profitability between the two sizes of vessel.

Costs of Blocking Restriction

Table 3 and Figure 3 also include statistics summarizing the effect of the blocking restriction broken down by vessel class. We find for the halibut market that Class A blocked quota trades at approximately $3.31 less than Class A unblocked quota, B blocked is lower than B unblocked by $1.55, C blocked lower than C unblocked by $2.19, and D blocked lower than D unblocked by $2.54. In the sablefish market, we find that B blocked quota is $1.90 lower than B unblocked, and C blocked trades $2.23 lower than C unblocked.

Generally, our regression results suggest blocked quota trades at lower prices relative to unblocked quota. The one exception is in the sablefish Class A market. This result is not surprising given that there is so little blocked quota allocated, and similarly, so few transactions. Furthermore, because every participant may hold up to one block of quota and still hold unblocked quota, it is possible the blocking restriction on Class A quota has little impact.

Total Cost of Restrictions

In addition to calculating the cost of the blocking and vessel class restriction for each possible combination, we can aggregate these costs based on the size of the market to arrive at estimates of the total efficiency loss due to the set of restrictions (see Table 4). We do this by calculating a linear combination of the coefficients on the restriction dummy variables and the associated restricted TAC.

We estimate that including restrictions in the ITQ program design decreased the present value of resource rent over the lifetime of the program by approximately $117 million for halibut and $39 million for sablefish (in $2012 USD), relative to a hypothesized case where the restrictions were not included in the program design. To aid in the understanding of these numbers we also present the total costs of restrictions as a percentage of total resource rent.[24] We find that including the restrictions resulted in a reduction in resource rent of 25% (36%) and 9% (10%) in the halibut and sablefish fisheries respectively, when calculated for year 2011 (2000).

Additionally, we provide separate estimates for the total impact of the class restriction and for the total impact of the blocking restrictions (Table 4). In the halibut fishery we estimate a reduction in resource rent due to the class restriction equal to $73 million USD. We estimate the impact of the blocking restriction on resource rent to be a reduction of approximately $28 million, or about 40% as large as the impact of the class restriction.[25] In the sablefish fishery the impact on resource rent due to restrictions is dominated by the class restriction, with a total reduction in resource rent associated with these restrictions of $36 million relative to an $8 million reduction in resource rent attributable to the blocking restriction.

Robustness Checks

In this section, we explore the robustness of our results to different weighting schemes under similar parametric assumptions[26] and in a non-parametric analysis (local linear regression). Our intent is to present results that follow directly from several sets of valid justifications and explore the robustness of our results. We find the preferred model results are robust to a number of specifications and approaches.

Parametric Robustness Checks

We explore weighting schemes based on two different criteria: the first is market size and the second is the size of the transaction. Additionally, for each weighting scheme, we test the assumption that there is a statistically significant change in the difference throughout the program.[27]

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[24] We estimate the total resource rent using the mean values of variables such as the area and season where appropriate. We then calculate the percentage reduction in resource rent as the estimated resource rent with restrictions in place divided by the total estimated unrestricted rent.

[25] Note that the total impact does not equal the sum of the class and the blocking impacts due to the presence of significant class×blocking interaction terms.

[26] An alternative model is to formulate a regression without the year and area interacted dummy variables and instead include variables related to the underlying factors that change through time that may influence quota prices. We present the results with year and area interacted dummy variables as our primary results because they are more parsimonious and the fit is similar.

[27] Specifically, we rerun the analysis using subsets of the data corresponding to early and later periods in the program. We find that the signs and magnitudes of the coefficients are generally similar and the overall estimates of the costs of the restrictions do not differ significantly.

Market Size Only

We explore the impact of assigning each transaction within a submarket equal weight; the between submarket weight is proportional to the class/blocking/area share of the TAC, and is the same as in the preferred specification. There are differences in some cases in the magnitude and statistical significance of the parameter coefficients and point estimates of the costs of the blocking and vessel class restrictions (see Table A3 in the Appendix). However, we find that the confidence intervals for this and our preferred specification of the *total* impacts are overlapping (see Table A4 in the Appendix).

Transaction Size

To account for the volume transacted (including exploring the impact of block size) on our estimates of the costs of restrictions, we estimate a model weighting each observation according to the number of pounds in the transaction (with no between submarket weights). The rationale for pound-weighted models is that if the quota price differs according to transaction or block size, then changing the weight given to the transactions will change the coefficient estimates on the blocking dummy variables. The result is that the coefficients on the restriction dummy variables represent the average difference in the price per pound per pound transacted. As with the submarket size weighting scheme, we do find differences in the estimated impacts for the blocking and vessel class restrictions but they are all the same sign and similar magnitude as our preferred model (Table 3), and confidence intervals for the total costs of restrictions overlap with those of the preferred model (Table 4).

Nonparametric Analysis

Our assumption that average differences in restricted and unrestricted quota prices are sufficient to characterize efficiency losses would fail if there is a clear trend in the difference over time (for example the difference systematically increases or decreases over time). To explore this assumption we concentrate on the densest submarkets in order to generate nonparametric estimates of the restricted and unrestricted quota prices over time using a local linear regression with epanechnikov weights and a fixed bandwidth (window) of 12 months.[28]

[28] When estimating the non-parametric fitted curve at a particular point, this choice of kernel and bandwidth gives higher weight to observations that occur closer in time within the window and zero weight outside the window. Using a window of 12 months provides a nice balance between the comparability of the prices and having a large enough window to ensure adequate market activity.

We present the restricted and unrestricted quota prices along with 95% confidence intervals in Figure 4 for two example markets: 3A Class C blocked versus unblocked and SE Class C blocked versus unblocked.[29] The nonparametric curves were fit at 100 equally-spaced points during the 2000-2011 time period. The confidence intervals were constructed by re-estimating the nonparametric curve after removing a random subset of observations. For the results we present, we randomly chose 10% of observations to remove and replicated the procedure where we remove 10% of the observations randomly 5,000 times.[30] The confidence bands are calculated for each point of the function-evaluation, and are calculated as the observation in the lowest 2.5th percentile of the fitted values of the replicate curves and the 97.5th percentile observation. Figure 4 also includes the original quota prices that are used to estimate the two (restricted and unrestricted) curves.

The nonparametric results suggest there are not significant changes to the differences in restricted and unrestricted prices over time. Figures 4a and 4b corroborate our regression results; the 95% confidence interval of the difference in prices attributable to the blocking restriction implied by the fitted curves contains the point estimates from the parametric models.[31] Furthermore, our non-parametric modeling (Figure A2c in the Appendix) is also suggestive of the fact that there may not be a significant difference between Class B and Class C prices.

Conclusions and Discussion

TPPs are policy instruments that have the potential to achieve economic efficiency. However, theoretical efficiency gains may not be realized in practical applications, which necessitates evaluation of the actual performance of TPPs (Hahn 1984).

On their own, TPPs can create additional economic value; however, as we have shown, the design can influence returns. Across all of our models and the time period 2000-2011, the estimated total cost of including restrictions in the ITQ program design is on the order of 10-35%

[29] We also include estimates for the 2C Class C blocked versus unblocked, 2C blocked Class C versus Class D, and 3A unblocked Class B versus Class C markets in Figure A2 in the Appendix.

[30] Our result that the difference between restricted and unrestricted quota prices does not show a significant trend over time is robust to the choice of the percentage of observations to omit, although obviously we cannot omit relatively large percentages and still estimate the curve. Our result is also robust to the number of points of evaluation.

[31] We calculate the difference between the two fitted curves and bootstrap, with replacement, to estimate an average difference and a 95% confidence interval. We find that halibut 3A Class C blocked quota trades for approximately $4.22 USD lower than unblocked (95% CI -$6.41, -$1.69). Sablefish SE Class C blocked quota trades for approximately $2.90 USD lower than unblocked (95% CI -$5.13, -$0.92).

of the total resource rent. Better informed decisions can be made if estimates of the costs of various types of restrictions are available and can be weighed against the potential benefits.

Several important areas of research remain that could help refine estimates of the costs of restrictions in the halibut and sablefish TPP. First, we estimated the equilibrium cost but the total costs of the restrictions needs to consider the costs in each year, which is dependent on how the restrictions impact the adjustment path of capital in the fishery. Developing the necessary counterfactual (what the adjustment path would have looked like without the restrictions) will entail estimation of a dynamic discrete choice model of entry/exit decisions of quota owners. Such a model will also allow for the quantification of potential benefits such as the change in number of vessels and crew fishing, and crew income. Second, in this paper we examine several types of restrictions, but do not go into detail about how the restrictions may interact with one another and how these interactions may also impact economic efficiency. Third, while we focused on direct impacts of restrictions, restrictions may also impact economic efficiency indirectly through increased transaction costs (Hahn 1984, Stavins 1995, Fowlie and Perloff 2013). How transaction costs affect participation in and subsequently the efficiency of these markets seems like an important area for further study.

Furthermore, we control for the area in our analysis, but we do not attempt to estimate its impact on current and future fishery profit. Other contexts where spatial heterogeneity in location (of extraction or pollution) is important include groundwater use, water quality, and air pollution (see e.g. Seskin, Anderson Jr and Reid (1983), Farrow et al. (2005), Lankoski et al. (2008), and Muller and Mendelsohn (2009)). In the fisheries context, a spatially differentiated management structure may outperform a homogenous management structure (one area) in terms of efficiency, if the population is indeed spatially differentiated and depending on the degree to which the area designations account for the underlying population structure. We leave for further analysis a quantitative assessment of optimal management area choice, optimal setting of TACs, and the impact of these choices on profitability.

Our results are relevant for the design and assessment of TPPs attempting to achieve multiple objectives through the imposition of trading restrictions. One common type of restriction is the creation of sectors (akin to vessel classes in our analysis) within a broader trading scheme for the same resource or pollutant, between which there are barriers to trade (or between which trading is completely restricted). Sectors can include industrial sectors; for example, in recently implemented Chinese carbon programs sectors including transportation, water, hotels, restaurants, and public institutions are included in some but not all of the programs (see e.g. Munnings et al. (2014)).

Additionally, new potential applications of TPPs are being proposed, including the management of habitat (Wissel and Watzold 2010), biodiversity (Gunningham and Young 1997), and agrobiodiversity losses associated with land cover changes (Pascual and Perrings 2007). With more TPPs being proposed and implemented worldwide, it is likely the implementation of restrictions within TPPs will continue in the future.

This work is also relevant in light of the emphasis in fishery management programs on non-efficiency objectives, including vibrant coastal communities, maintaining the culture of fishing communities, and healthy ocean ecosystems. Non-efficiency goals often relate to the distribution of the benefits and costs of management changes (see e.g. Wilen (2013) for a discussion of the political economy of small-scale artisanal fishery management reforms). Recent policies such as a mandate under the Magnuson Stevens Act National Standard 8 have begun to require that the design and evaluation of management policies take into account the impact of management changes on fishing jobs and communities. In turn, researchers have begun to evaluate non-efficiency goals. For example, community-level changes are being evaluated by creating indices of vulnerability, resilience, and participation (see e.g. Himes-Cornell and Kasperski (2015) and Sethi, Reimer and Knapp (2014)).

When multiple management goals exist, using a single policy instrument to accomplish all of the goals simultaneously poses challenges for policy design and can reduce the economic efficiency of the policy (see e.g. Péreau, Little and Thébaud (2012) for a general discussion and analysis of the challenge of designing ITQs to meet multiple objectives). Empirical analyses, such as the analysis in this paper, are necessary to provide decision-makers with quantitative estimates of tradeoffs between economic efficiency and non-efficiency goals.

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Figures and Tables

Figure 1. Average Quota Price by Vessel Category ($2012) (unweighted averages by year)

(a) Halibut **(b) Sablefish**

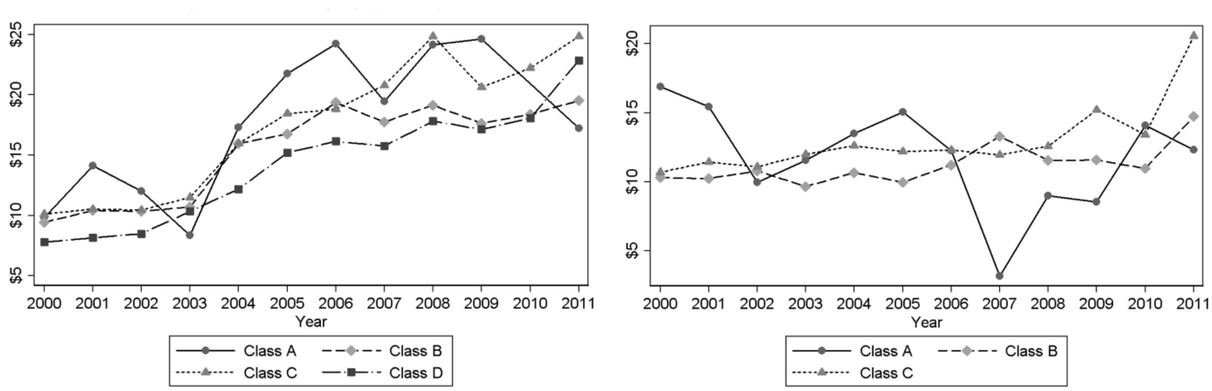


Figure 2. Average Quota Price by Blocking Status ($2012) (unweighted averages by year)

(a) Halibut **(b) Sablefish**

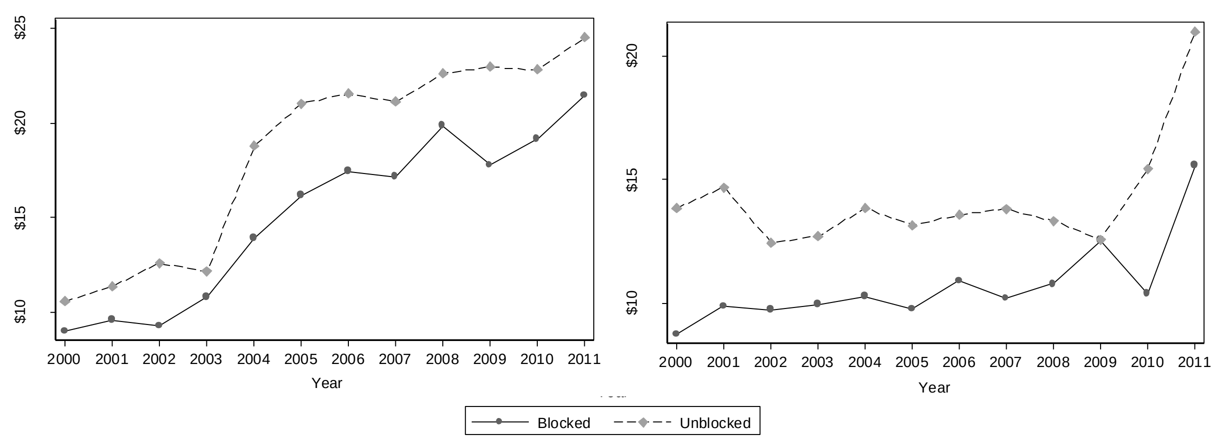


Figure 3. Difference between Restricted and Unrestricted Quota Prices ($2012) (impact of the class and blocking restrictions)

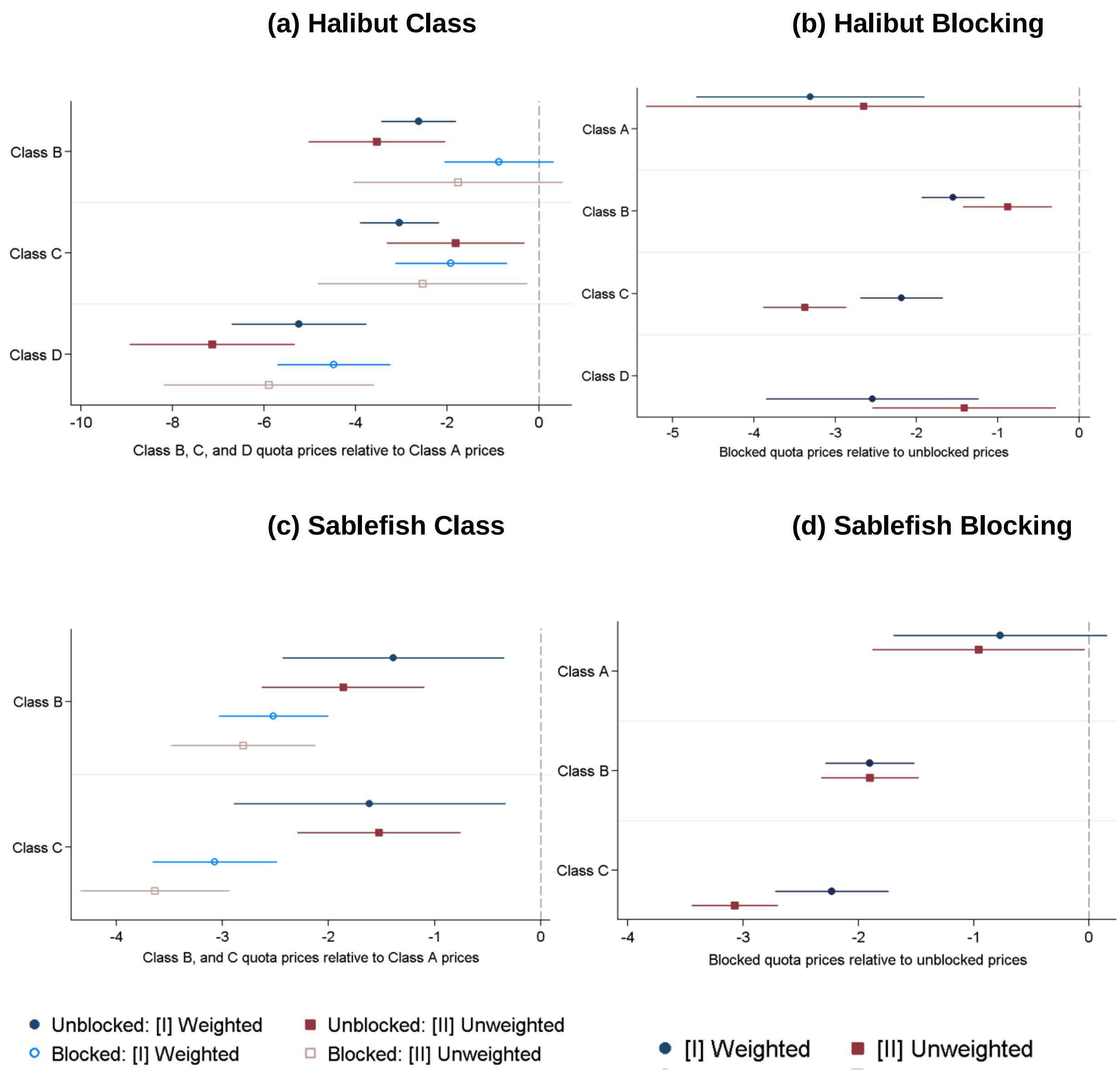
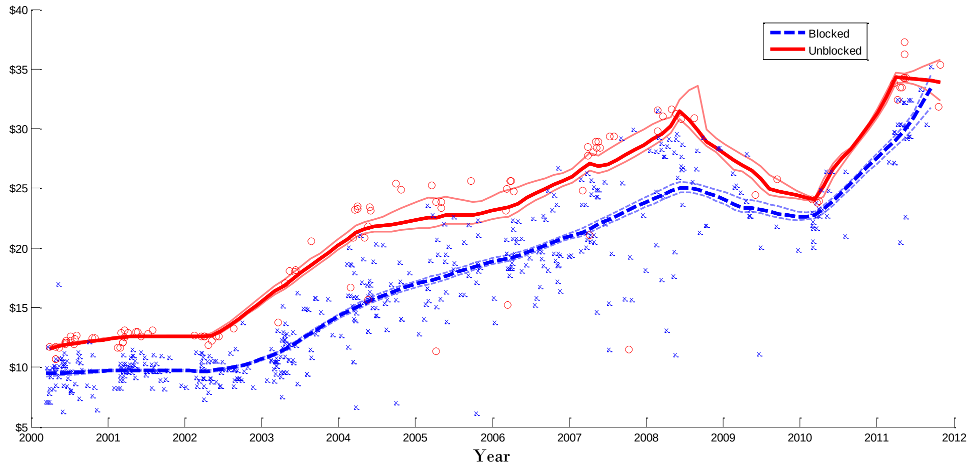


Figure 4. Nonparametric Estimation of Restricted (Blocked) and Unrestricted (Unblocked) Quota Prices ($2012)

(a) Halibut Area 3A Class C



(b) Sablefish Area SE Class C

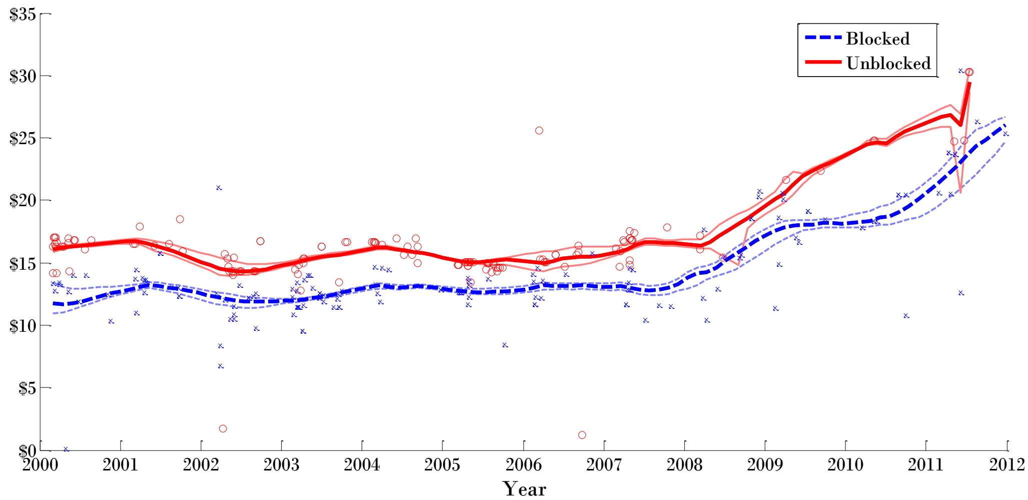


Table 1. 2011 TAC by Vessel Class and Blocking Combination

	Halibut			*Sablefish*		
Vessel Class	**Unblocked**	**Blocked**	**Total**	**Unblocked**	**Blocked**	**Total**
A	2%	1%	***3%***	20%	2%	***22%***
B	32%	10%	***42%***	35%	6%	***41%***
C	21%	27%	***48%***	29%	8%	***37%***
D	1%	6%	***7%***	**--**	**--**	**--**
Total	***55%***	***45%***	***100%***	***84%***	***16%***	***100%***

Note: The vessels sizes that correspond to the classes differ between the fisheries, where in Halibut A is unrestricted, B is length >60ft, C is length 35-60 feet, and D is length <35ft. In the Sablefish fishery there are only three classes: A is unrestricted, B is >60 feet, and C is <60 feet.

Table 2. Summary of Transactions

		Halibut	**Sablefish**
Buyers	*Unique*	1,269	491
	Yearly ave.	165	65
	Min.	82 (2009)	43 (2009)
	Max.	225 (2001)	104 (2003)
Sellers	*Unique*	1,921	584
	Yearly ave.	197	69
	Min.	92 (2009)	50 (2009)
	Max.	258 (2001)	104 (2003)
Transactions	*Ave. size (lbs)*	6,678	9,997
	Median size (lbs)	4,975	3,545

Table 3. Change in Quota Prices due to Blocking and Vessel Class Restrictions (in $2012): LM Model[a]

	[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]		[II] Unweighted	
	Halibut	**Sablefish**	**Halibut**	**Sablefish**
IMPACT OF CLASS RESTRICTION ON UNBLOCKED QUOTA PRICES				
B Unblocked	-2.627***	-1.389***	-3.537***	-1.862***
	(0.412)	(0.530)	(0.757)	(0.389)
C Unblocked	-3.042***	-1.613**	-1.814**	-1.523***
	(0.435)	(0.650)	(0.762)	(0.390)
D Unblocked	-5.239***	NA	-7.13***	NA
	(0.746)		(0.914)	
IMPACT OF CLASS RESTRICTION ON BLOCKED QUOTA PRICES				
B Blocked	-0.869	-2.518***	-1.768	-2.804***
	(0.603)	(0.261)	(1.160)	(0.344)
C Blocked	-1.92***	-3.071***	-2.539**	-3.637***
	(0.617)	(0.296)	(1.160)	(0.356)
D Blocked	-4.475***	NA	-5.897***	NA
	(0.624)		(1.166)	
IMPACT OF BLOCKING RESTRICTION				
Class A	-3.308***	-.771	-2.65*	-.959**
	(0.713)	(0.470)	(1.365)	(0.467)
Class B	-1.55***	-1.899***	-.882***	-1.901***
	(0.195)	(0.195)	(0.277)	(0.213)
Class C	-2.185***	-2.229***	-3.376***	-3.072***
	(0.257)	(0.249)	(0.258)	(0.189)
Class D	-2.543***	NA	-1.417**	NA
	(0.665)		(0.574)	

a. The coefficients should be interpreted as absolute changes in real quota price. A negative coefficient implies the restricted quota price is below that of the unrestricted quota price. The unblocked (blocked) class restriction coefficients represent the difference between unblocked (blocked) Class B, C, and D unblocked (blocked) quota relative to Class A unblocked (blocked) quota. The blocking restriction coefficients represent the difference between blocked and unblocked quota in each vessel class. The standard errors of the coefficients are below the coefficients.
b. The combination is weighted by the average yearly percentage of the TAC.

Table 4. Aggregate Change in Resource Rent due to Restrictions (in $million)[a]

	Halibut	Sablefish
	Point Estimate (95% Conf. Interval)	
TOTAL (CLASS AND BLOCKING)		
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-117.3 (-139.7, -94.9)	-39.5 (-62.7, -16.3)
[II] Unweighted	-120.5 (-162.8, -78.2)	-45.7 (-60.9, -30.5)
CLASS ONLY		
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-73.1 (-93.2, -53.0)	-36.2 (-56.1, -16.3)
[II] Unweighted	-85.1 (-122.8, -47.4)	-41.6 (-54.4, -28.8)
BLOCKING ONLY		
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-28.3 (-33.4, -23.1)	-8.2 (-9.4, -7.1)
[II] Equal Weight Per Transaction	-33.8 (-38.7, -28.8)	-10.2 (-11.3, -9.0)

a. Negative numbers imply lower resource rent
b. The combination is weighted by the average yearly percentage of the TAC

Appendix.

Extended Data Description

Quota Transaction Data

Under a confidentiality agreement with the National Marine Fisheries Service, Alaska Region Restricted Access Management (RAM) Division, we acquired primary data on quota transactions. The dataset covers all of the transactions that occurred since the program's inception in January 1995 through the end of the 2011 fishing year.

There are a large number of holders of both blocked and unblocked quota. In the halibut fishery in 2011 there were 2,455 registered owners of blocked quota and 640 of unblocked. In 2011 in the sablefish fishery there where 663 registered owners of blocked quota and 449 of unblocked.

Information describing the transactions includes: the transaction date, the NMFS ID for both the buyer and the seller, addresses of the buyer and the seller, information on the price paid/received,[32] the amount of IFQ pounds and QS units in the transfer, the reason for the transfer, information on how the buyer and seller found one another, details on the relationship (if any) between the buyer and seller, and details of the quota transacted (e.g., species, area, vessel class, blocked or unblocked, and fishdownable). We are also able to identify lease transactions. Lease transactions include only IFQ pounds and include no QS. Given the restrictive conditions under which lease transaction may occur, very few leases do occur, and therefore we do not use the lease data in our analysis.

We use data from the 2000-2011 fishing years. During this period 7,584 halibut quota transactions and 3,085 sablefish quota transactions took place. Eliminating records with no price listed left 4,869 halibut transactions and 2,158 sablefish transactions. Using the information provided about each transaction we were able to eliminate administrative transfers, transactions between family members, gifts, trades, transactions where payment was based on a percentage of vessel profits, and lease of IFQ pounds. This left 4,256 halibut and 1,775 sablefish transactions. Finally, we observed the price distribution to detect any potential entry errors. We eliminated

[32] We adjust the prices to account for inflation using the producer price index (PPI). All the summary statistics and analysis we do use these real prices.

one sablefish record with a price over $100/pound-equivalent. Finally, we eliminate 215 halibut transactions and 101 sablefish transactions due to inconsistency across fields. Specifically, we eliminate transactions where the total transaction price differs depending on the method we use to calculate it.

The standard in the fishery is to report a “pound-equivalent” quota price (hereafter quota price), which is equal to the total transaction price (the value of the IFQ pounds plus the value of the QS units) divided by the IFQ pounds in the transaction. By dividing the reported quota value by the number of IFQ pounds, the quota price is comparable across areas, which have different TAC levels.[33]

The class and/or blocking restrictions impact a substantial portion of the quota. In the halibut fishery, the four vessel classes and two blocking statuses together create eight different vessel class and blocking combinations. In the sablefish fishery, there are three vessel classes and two blocking statuses resulting in six vessel class and blocking combinations. The allocation of quota across these combinations has varied to some extent over the years. Using the 2011 TAC allocation as an example, Table 1 in the main text illustrates that the distribution of halibut quota in 2011 is non-uniform with the B and C vessel classes receiving 42% and 48%, respectively. On the other hand, the vessel class allocations in sablefish are more uniformly distributed than halibut, but the amount of blocked (84%) versus unblocked (16%) quota is skewed, while it is more evenly distributed in halibut.

CFEC Ex-vessel Price Data

Ex-vessel prices are difficult to estimate because fishermen often have relationships with processors and negotiate contracts to receive compensation in different ways. For example, often compensation is received at dates later than the landings date - sometimes when the processor actually sells the fish. The variability in compensation results in self-reported raw fish ticket price data being problematic. Therefore, we rely on the Alaskan Commercial Fisheries Entry Commission’s (CFEC) estimated ex-vessel prices. These CFEC estimates are available in a confidential landings database and address some of the issues with the reporting of prices.

[33] Using the IFQ pounds in this calculation is potentially problematic if fishermen have expectations that future TACs, and therefore the later allocation of IFQ pounds associated with each QS unit, will differ substantially from the current one.

Other Data

We use data on fuel oil prices from the Pacific States Marine Fisheries Commission (http://www.psmfc.org/efin/data/fuel.html#REPORTS). We also obtained confidential data on the amount fished in each year, area, and vessel class combination from RAM. Together with the yearly issuance data, we can approximate the percent of the TAC remaining to be fished for each area and vessel class combination throughout the year. The within-season variation in the supply of IFQ pounds available for purchase can help control for within-season changes in the quota price that otherwise might be attributed to the particular restrictions.

Extended Program Description

In this section we highlight 3 key types of changes that have occurred over the course of the program:

1. Since 1995, the QS restrictions on vessel length were relaxed several times due to safety concerns and problems with fully harvesting the quota in certain area/vessel class categories. For instance, in 1996, a fish-down provision was implemented in both fisheries (RAM 2009b, RAM 2009a) that allows an owner holding QS designated for a particular vessel length to fish the associated IFQ pounds on shorter vessels (e.g., B vessel IFQ could be fished on C vessels).[34]
2. Up to 2007, the number of halibut and sablefish blocks that could be held was limited to two in each fishery (RAM 2009d). In 2007, the limit on the maximum number of halibut QS blocks that an individual or entity may hold was increased to three (50 CFR 679.42). The objective for the increase was to provide additional flexibility to owners of blocked quota (72 FR 44795).
3. In 2005, the managers relaxed the area-specific quota for halibut Area 4C by letting 4C quota be harvested in either Area 4C or 4D (Restricted Access Management

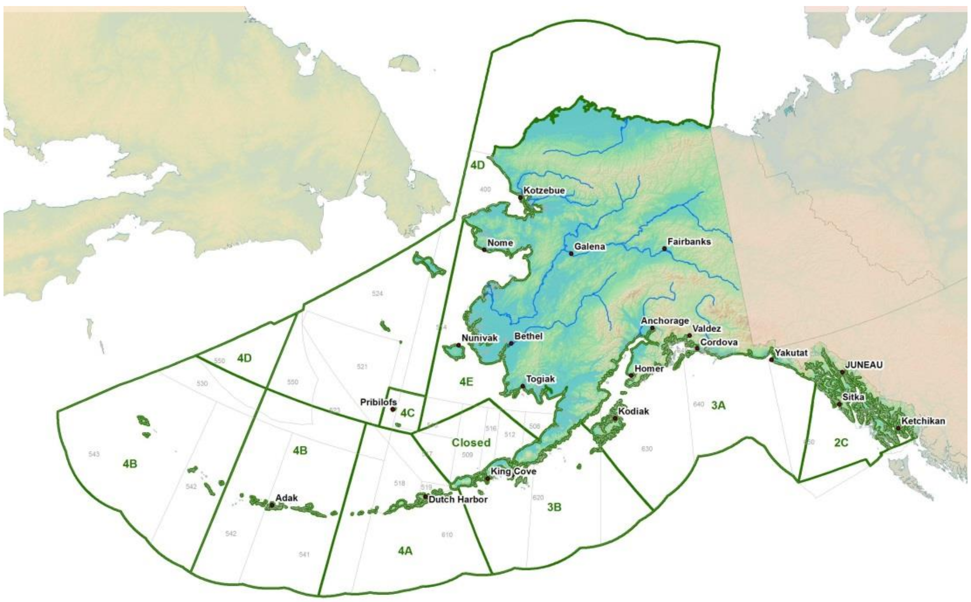
[34] Initially, the fish-down provisions were not instituted in area 2C and the Southeast (SE) area for the halibut and sablefish fishery, respectively. In Area 2C, fish-down was restricted to only those who held relatively small blocks of quota (Restricted Access Management (RAM) Division, 2009a). In the SE fish-down of IFQ pounds was also only allowed for smaller-sized blocks (Restricted Access Management (RAM) Division, 2009b). The rules in area 2C and SE were relaxed in 2007 to be consistent with the rules in the other areas (RAM 2009c). In 2007, a “fishing up” provision in halibut areas 3B and 4C was instituted, where Class D IFQ pounds could now be used on Class C vessels (RAM 2009c).

(RAM) Division, 2007a). This change was implemented because of localized stock depletion in Area 4C (70 FR 43328).

Supplementary Figures

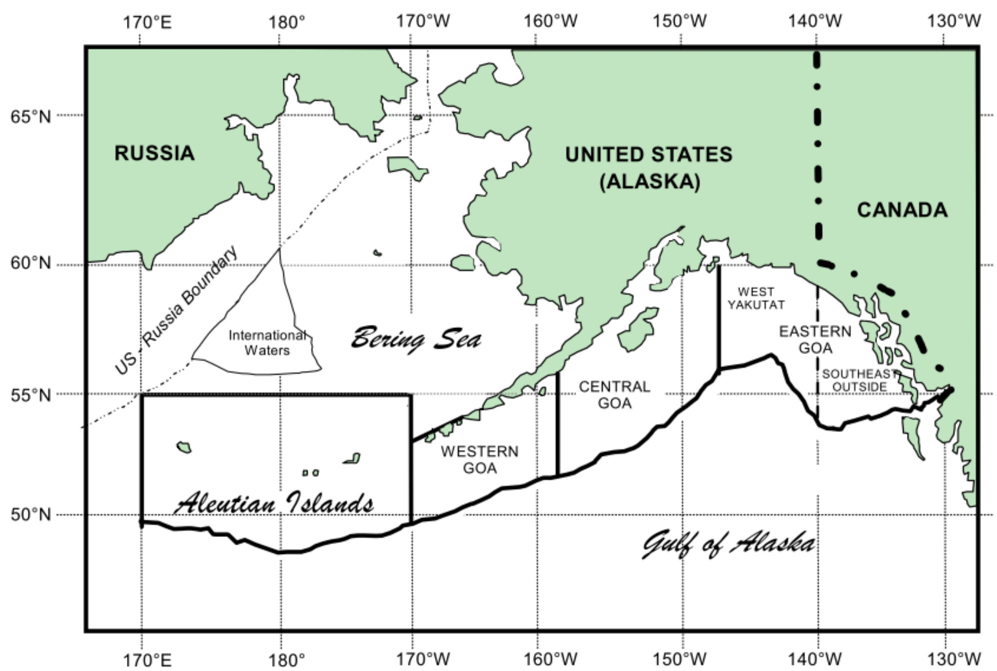
Figure A1. Regulatory Areas

Figure A1a. International Pacific Halibut Commission Regulatory Areas



Note: Reprinted from the National Marine Fisheries, Alaska Regional Office webpage. Available: http://alaskafisheries.noaa.gov/maps/sport/iphc_nmfs_areas.jpg

Figure A1b. Sablefish Regulatory Areas



Note: Reprinted from the National Marine Fisheries, Alaska Regional Office webpage. Available: http://alaskafisheries.noaa.gov/rr/figures/fig14.pdf

Figure A2. Nonparametric Estimation of Restricted and Unrestricted Quota Prices

Figure A2a. Nonparametric Estimation of Halibut Area 2C Class C Blocked and Unblocked Quota Prices ($2012)

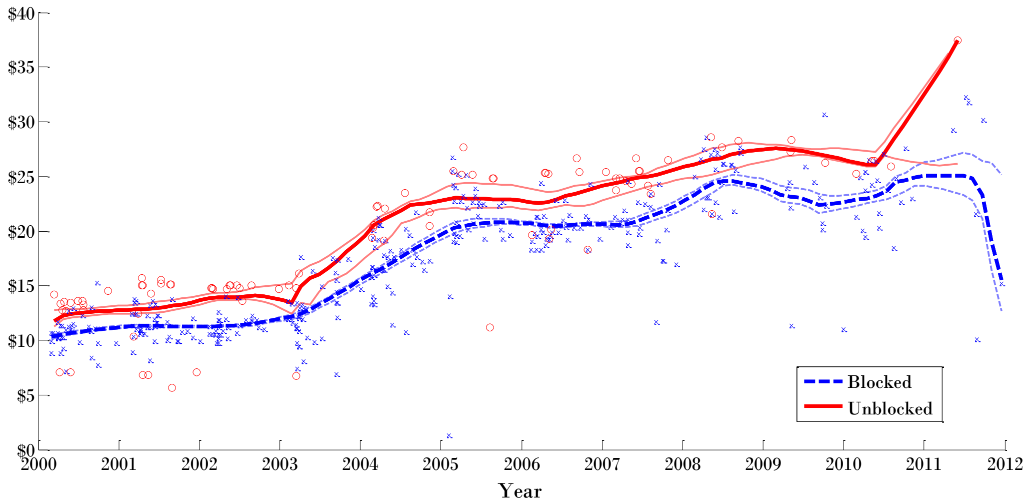


Figure A2b. Nonparametric Estimation of Halibut Area 2C Blocked Class C and Class D Quota Prices ($2012)

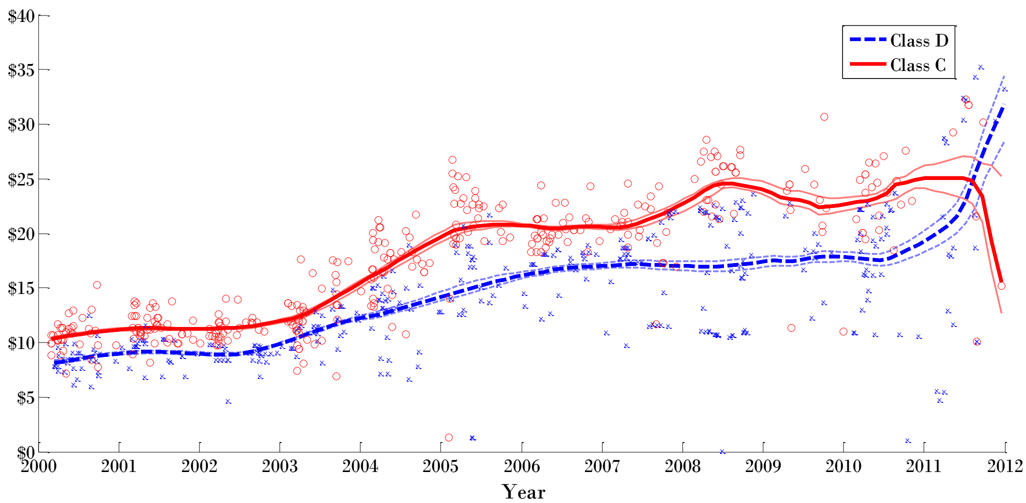
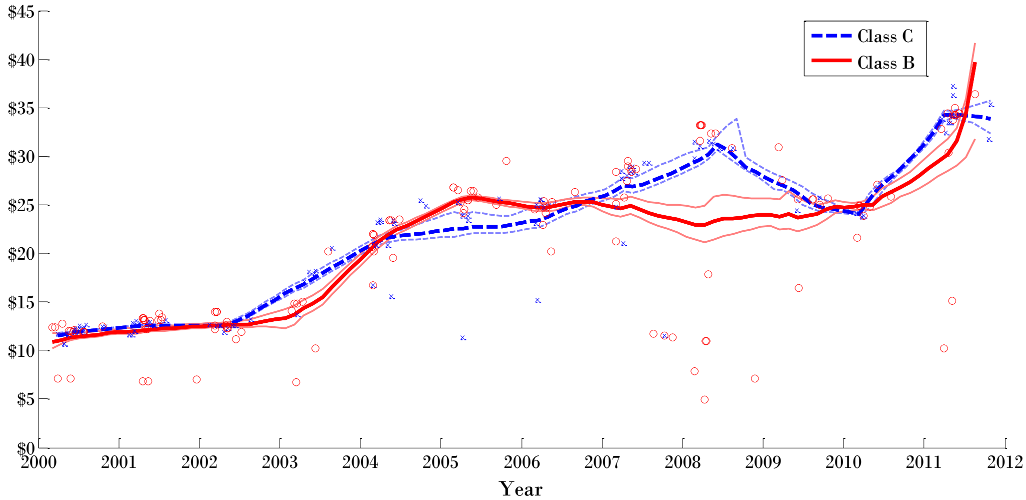


Figure A2c. Nonparametric Estimation of Halibut Area 3A Unblocked Class B and Class C Quota Prices ($2012)



Supplementary Tables

Table A1. Percentage of Transactions by Area

Area	2C	3A	3B	4A	4B	4C	4D
Halibut %	28%	42%	13%	10%	4%	2%	2%
Area	**AI**	**BS**	**CG**	**SE**	**WG**	**WY**	**--**
Sablefish %	6%	10%	26%	29%	14%	15%	--

Note: The percentages may not add to 100% due to rounding.

Table A2. Reduced-Form Model Output: Dependent Variable Quota Price (LM Model)

	Halibut				*Sablefish*			
Variables	**[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination[a]**	**[II] Equal Weight Per Transaction**	**[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination[a]**	**[IV] Equal Weight for each Pound Transacted**	**[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination[a]**	**[II] Equal Weight Per Transaction**	**[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination[a]**	**[IV] Equal Weight for each Pound Transacted**
Blocked (Unblocked Omitted)	-3.307***	-2.650*	-5.377***	-2.091***	-0.770	-0.958**	-0.630	-0.565
	(0.713)	(1.365)	(1.428)	(0.641)	(0.470)	(0.467)	(0.406)	(0.411)
Class B (Class A Omitted)	-2.626***	-3.536***	-5.373***	-2.417***	-1.389***	-1.862***	-1.755***	-1.548***
	(0.412)	(0.757)	(1.376)	(0.293)	(0.530)	(0.389)	(0.490)	(0.364)
Class C	-3.042***	-1.813**	-3.814***	-2.609***	-1.612**	-1.523***	-1.427***	-1.661***
	(0.435)	(0.762)	(1.361)	(0.351)	(0.650)	(0.390)	(0.548)	(0.483)
Class D	-5.239***	-7.130***	-8.917***	-4.346***	NA	NA	NA	NA
	(0.746)	(0.914)	(1.526)	(0.697)				
Blocked & Class B	1.757**	1.768	4.359***	0.702	-1.128**	-0.942*	-1.248**	-0.994**
	(0.738)	(1.399)	(1.495)	(0.671)	(0.567)	(0.512)	(0.504)	(0.469)
Blocked & Class C	1.122	-0.725	1.920	-0.047	-1.458**	-2.113***	-2.377***	-1.498***
	(0.741)	(1.392)	(1.455)	(0.679)	(0.618)	(0.506)	(0.510)	(0.512)
Blocked & Class D	0.764	1.233	3.629**	-0.852	NA	NA	NA	NA
	(0.966)	(1.489)	(1.605)	(0.916)				
Post-Season (Fall Omitted)	-0.607	-1.433***	-1.690*	-0.555	-0.782*	-0.335	-0.879*	-0.522

	(0.890)	(0.421)	(1.008)	(0.621)	(0.407)	(0.516)	(0.498)	(0.379)
Pre-Season	-1.250***	-0.442	0.142	-0.897***	-0.314	0.639**	0.617	-0.233
	(0.326)	(0.293)	(0.491)	(0.254)	(0.445)	(0.285)	(0.455)	(0.379)
Spring	-0.55193**	-0.06577	0.36067	-0.48800***	-0.37447	0.43179*	-0.00963	-0.26102
	(0.220)	(0.212)	(0.379)	(0.180)	(0.250)	(0.253)	(0.351)	(0.304)
Summer	-0.05941	0.31163	0.91124**	-0.00488	0.05536	0.60482**	0.21237	-0.03722
	(0.216)	(0.222)	(0.373)	(0.179)	(0.272)	(0.266)	(0.409)	(0.304)
Dummy for 2008 and on blocked quota[b]	-0.23052	0.25643	0.38252	-0.45228*	NA	NA	NA	NA
	(0.263)	(0.519)	(0.561)	(0.257)				
Constant	16.63853***	15.85403***	16.89247***	15.96104***	17.55090***	16.55741***	17.09755***	17.42781***
	(0.468)	(0.767)	(1.377)	(0.387)	(0.664)	(0.568)	(0.625)	(0.523)
Observations	3,138	3,138	3,138	3,138	1,263	1,263	1,263	1,263
R-squared	0.925	0.739	0.774	0.918	0.911	0.847	0.833	0.926

White hetereoskedasticity consistent standard errors in parentheses (yearxarea fixed effects omitted here to save space)

*** p<0.01, ** p<0.05, * p<0.1

a. The combination is weighted by the average yearly percentage of the TAC

b. Change from 2-3 block maximum

Table A3. Blocking and Vessel Class Restriction: Change in Quota Prices due to Restrictions: Dependent Variable Quota Price (LM Model) [a]

	Halibut				*Sablefish*			
	[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination [b]	**[II] Equal Weight Per Transaction**	**[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination [b]**	**[IV] Equal Weight for each Pound Transacted**	**[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination [b]**	**[II] Equal Weight Per Transaction**	**[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination [b]**	**[IV] Equal Weight for each Pound Transacted**
IMPACT OF CLASS RESTRICTION ON UNBLOCKED QUOTA PRICES								
B Unblocked	-2.627***	-3.537***	-5.373***	-2.417***	-1.389***	-1.862***	-1.755***	-1.548***
	(0.412)	(0.757)	(1.376)	(0.293)	(0.530)	(0.389)	(0.490)	(0.364)
C Unblocked	-3.042***	-1.814**	-3.814***	-2.609***	-1.613**	-1.523***	-1.428***	-1.661***
	(0.435)	(0.762)	(1.361)	(0.351)	(0.650)	(0.390)	(0.548)	(0.483)
D Unblocked	-5.239***	-7.13***	-8.917***	-4.347***	NA	NA	NA	NA
	(0.746)	(0.914)	(1.526)	(0.697)				
IMPACT OF CLASS RESTRICTION ON BLOCKED QUOTA PRICES								
B Blocked	-0.869	-1.768	-1.013**	-1.715***	-2.518***	-2.804***	-3.004***	-2.543***
	(0.603)	(1.160)	(0.514)	(0.597)	(0.261)	(0.344)	(0.277)	(0.293)
C Blocked	-1.92***	-2.539**	-1.894***	-2.656***	-3.071***	-3.637***	-3.805***	-3.16***
	(0.617)	(1.160)	(0.494)	(0.599)	(0.296)	(0.356)	(0.313)	(0.296)
D Blocked	-4.475***	-5.897***	-5.287***	-5.199***	NA	NA	NA	NA
	(0.624)	(1.166)	(0.523)	(0.609)				
IMPACT OF BLOCKING RESTRICTION								
Class A	-3.308***	-2.65*	-5.378***	-2.091***	-.771	-.959**	-.631	-.565
	(0.713)	(1.365)	(1.428)	(0.641)	(0.470)	(0.467)	(0.406)	(0.411)
Class B	-1.55***	-.882***	-1.018***	-1.389***	-1.899***	-1.901***	-1.879***	-1.56***

	(0.195)	(0.277)	(0.279)	(0.204)	(0.195)	(0.213)	(0.222)	(0.198)
Class C	-2.185***	-3.376***	-3.457***	-2.138***	-2.229***	-3.072***	-3.008***	-2.064***
	(0.257)	(0.258)	(0.284)	(0.252)	(0.249)	(0.189)	(0.226)	(0.214)
Class D	-2.543***	-1.417**	-1.748**	-2.944***	NA	NA	NA	NA
	(0.665)	(0.574)	(0.703)	(0.664)				
	*** p<0.01, ** p<0.05, * p<0.1							

a. The coefficients should be interpreted as absolute changes in real quota price. A negative coefficient implies the restricted quota price is below that of the unrestricted quota price. The unblocked (blocked) class restriction coefficients represent the difference between unblocked (blocked) Class B, C, and D unblocked (blocked) quota relative to Class A unblocked (blocked) quota. The blocking restriction coefficients represent the difference between blocked and unblocked quota in each vessel class. The standard errors of the coefficients are below the coefficients.
b. The combination is weighted by the average yearly percentage of the TAC.

Table A4. Aggregate Impact of Restrictions on Resource Rent

Table A4a. Aggregate Impact of Restrictions on Resource Rent in the Halibut Fishery ($ million) [a]

	Aggregate Change in Resource Rent		
	Point Estimate	*95 Percent CI*	
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-117.3	-139.7	-94.9
[II] Equal Weight Per Transaction	-120.5	-162.8	-78.2
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-179.4	-257.7	-101.1
[IV] Equal Weight for each Pound Transacted	-105.9	-121.5	-90.3

a. Negative numbers imply lower resource rent
b. The combination is weighted by the average yearly percentage of the TAC

Table A4b. Aggregate Impact of Restrictions on Efficiency in the Sablefish Fishery[a]

	Aggregate Change in Resource Rent ($2012)		
	Point Estimate	*95 Percent CI*	
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-39.5	-62.7	-16.3
[II] Equal Weight Per Transaction	-45.7	-60.9	-30.5
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-43.2	-63.3	-23.2
[IV] Equal Weight for each Pound Transacted	-40.7	-57.3	-24.1

a. Negative numbers imply lower resource rent
b. The combination is weighted by the average yearly percentage of the TAC

Robustness Check, LLM

Table A5. Reduced-Form Model Output: Dependent Variable Logged Quota Price (LLM Model)

	Halibut				*Sablefish*			
Variables	[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination[a]	[II] Equal Weight Per Transaction	[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination[a]	[IV] Equal Weight for each Pound Transacted	[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination[a]	[II] Equal Weight Per Transaction	[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination[a]	[IV] Equal Weight for each Pound Transacted
Blocked (Unblocked Omitted)	-0.251***	-0.284***	-0.331***	-0.182***	-0.005	0.063	0.059	-0.030
	(0.036)	(0.093)	(0.049)	(0.036)	(0.052)	(0.070)	(0.055)	(0.059)
Class B (Class A Omitted)	-0.196***	-0.279***	-0.311***	-0.192***	-0.165***	-0.240***	-0.193***	-0.296***
	(0.014)	(0.034)	(0.031)	(0.018)	(0.039)	(0.038)	(0.035)	(0.043)
Class C	-0.219***	-0.190***	-0.223***	-0.216***	-0.177***	-0.239***	-0.171***	-0.313***
	(0.016)	(0.035)	(0.030)	(0.020)	(0.045)	(0.039)	(0.040)	(0.047)
Class D	-0.345***	-0.556***	-0.514***	-0.311***	NA	NA	NA	NA
	(0.040)	(0.053)	(0.055)	(0.039)				
Blocked & Class B	0.136***	0.212**	0.249***	0.070*	-0.193***	-0.238***	-0.279***	-0.135**
	(0.039)	(0.096)	(0.055)	(0.042)	(0.058)	(0.071)	(0.059)	(0.066)
Blocked & Class C	0.091**	0.072	0.111**	0.021	-0.179***	-0.318***	-0.335***	-0.152**
	(0.038)	(0.094)	(0.049)	(0.039)	(0.060)	(0.074)	(0.063)	(0.065)
Blocked & Class D	0.040	0.199*	0.166**	-0.072	NA	NA	NA	NA
	(0.054)	(0.103)	(0.069)	(0.053)				
Post-Season	-0.114**	-0.096***	-0.131**	-0.093**	-0.170**	-0.080	-0.149*	-0.152**

(Fall Omitted)								
	(0.051)	(0.030)	(0.065)	(0.043)	(0.071)	(0.069)	(0.080)	(0.072)
Pre-Season	-0.079***	-0.040	0.002	-0.067***	-0.032	0.038	0.049	-0.043
	(0.021)	(0.029)	(0.036)	(0.022)	(0.031)	(0.034)	(0.043)	(0.049)
Spring	-0.040***	-0.002	0.026	-0.044**	-0.033	0.027	0.009	-0.039
	(0.014)	(0.021)	(0.028)	(0.018)	(0.021)	(0.031)	(0.042)	(0.042)
Summer	-0.001	0.022	0.067**	-0.003	-0.006	0.044	0.035	-0.028
	(0.013)	(0.023)	(0.028)	(0.016)	(0.022)	(0.031)	(0.044)	(0.044)
Dummy for 2008 and on blocked quota[b]	0.051***	0.080**	0.082**	0.027	NA	NA	NA	NA
	(0.015)	(0.032)	(0.036)	(0.019)				
Constant	2.796***	2.727***	2.729***	2.777***	2.957***	2.858***	2.883***	3.099***
	(0.026)	(0.045)	(0.050)	(0.034)	(0.049)	(0.125)	(0.063)	(0.057)
Observations	3,138	3,138	3,138	3,138	1,263	1,263	1,263	1,263
R-squared[c]	0.567	0.583	0.583	0.565	0.710	0.698	0.699	0.686
	White hetereoskedasticity consistent standard errors in parentheses (yearxarea fixed effects omitted here to save space)							
	*** p<0.01, ** p<0.05, * p<0.1							

a. The combination is weighted by the average yearly percentage of the TAC

b. Change from 2-3 block maximum

c. The R^2 values are calculated based on the procedure outlined in Wooldridge (2012) in Chapter 6. These R^2 values can be compared to those in Table A3 to determine the relative fit of the LM and LLM.

Table A6. Blocking and Vessel Class Restriction: Change in Quota Prices due to Restrictions: Dependent Variable Logged Quota Price (LLM Model) [a]

	Halibut				*Sablefish*			
	[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination [b]	[II] Equal Weight Per Transactio n	[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination[b]	[IV] Equal Weight for each Pound Transacted	[I] Equal Weight for each Pound Transacted within an Area/Class/ Blocking Combination [b]	[II] Equal Weight Per Transaction	[III] Equal Weight for each Transaction within an Area/Class/ Blocking Combination [b]	[IV] Equal Weight for each Pound Transacted
IMPACT OF CLASS RESTRICTION ON UNBLOCKED QUOTA PRICES								
B Unblocked	-.196***	-.279***	-.311***	-.192***	-.165***	-.24***	-.194***	-.296***
	(0.014)	(0.034)	(0.031)	(0.018)	(0.039)	(0.038)	(0.035)	(0.043)
C Unblocked	-.219***	-.19***	-.224***	-.216***	-.177***	-.239***	-.172***	-.313***
	(0.016)	(0.035)	(0.030)	(0.020)	(0.045)	(0.039)	(0.040)	(0.047)
D Unblocked	-.345***	-.556***	-.514***	-.311***	NA	NA	NA	NA
	(0.040)	(0.053)	(0.055)	(0.039)				
IMPACT OF CLASS RESTRICTION ON BLOCKED QUOTA PRICES								
B Blocked	-.06*	-0.066	-0.063	-.122***	-.358***	-.477***	-.472***	-.431***
	(0.036)	(0.089)	(0.044)	(0.036)	(0.043)	(0.062)	(0.050)	(0.053)
C Blocked	-.128***	-0.117	-.113***	-.195***	-.356***	-.556***	-.507***	-.465***
	(0.036)	(0.088)	(0.041)	(0.035)	(0.045)	(0.064)	(0.055)	(0.053)
D Blocked	-.305***	-.357***	-.349***	-.384***	NA	NA	NA	NA
	(0.037)	(0.089)	(0.045)	(0.038)				
IMPACT OF BLOCKING RESTRICTION								
Class A	-.252***	-.285***	-.332***	-.183***	-.005	.063	.059	-.03
	(0.036)	(0.093)	(0.049)	(0.036)	(0.052)	(0.070)	(0.055)	(0.059)
Class B	-.116***	-.072***	-.084***	-.113***	-.198***	-.174***	-.219***	-.165***

	(0.017)	(0.026)	(0.022)	(0.023)	(0.023)	(0.025)	(0.028)	(0.029)
Class C	-.161***	-.212***	-.221***	-.161***	-.184***	-.254***	-.276***	-.182***
	(0.015)	(0.017)	(0.017)	(0.015)	(0.023)	(0.027)	(0.027)	(0.024)
Class D	-.212***	-.085*	-.166***	-.256***	NA	NA	NA	NA
	(0.040)	(0.044)	(0.049)	(0.039)				
	*** p<0.01, ** p<0.05, * p<0.1							

a. The coefficients should be interpreted as the percentage change in real quota price. A negative coefficient implies the restricted quota price is below that of the unrestricted quota price. The unblocked (blocked) class restriction coefficients represent the percentage difference between unblocked (blocked) Class B, C, and D unblocked (blocked) quota relative to Class A unblocked (blocked) quota. The blocking restriction coefficients represent the percentage difference between blocked and unblocked quota in each vessel class. The standard errors of the coefficients are below the coefficients.
b. The combination is weighted by the average yearly percentage of the TAC.

Table A7. Aggregate Impact of Restrictions on Resource Rent

Table A7a. Aggregate Impact of Restrictions on Resource Rent in the Halibut Fishery[a]

	Percentage Change in Resource Rent[c]			Aggregate Change in Resource Rent[d]		
	Point Estimate	*95 Percent CI*		*Point Estimate*	*95 Percent CI*	
TOTAL (CLASS AND BLOCKING)						
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-28.17%	-30.44%	-25.89%	-117.3	-139.7	-94.9
[II] Equal Weight Per Transaction	-31.96%	-38.06%	-25.86%	-120.5	-162.8	-78.2
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-35.54%	-40.95%	-30.14%	-179.4	-257.7	-101.1
[IV] Equal Weight for each Pound Transacted	-27.81%	-30.86%	-24.75%	-105.9	-121.5	-90.3
CLASS ONLY						
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-17.0%	-20.37%	-13.81%	-73.1	-93.2	-53.0
[II] Equal Weight Per Transaction	-19.43%	-27.59%	-11.27%	-85.1	-122.8	-47.4
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-20.94%	-25.57%	-16.32%	-107.5	-152.4	-62.6
[IV] Equal Weight for each Pound Transacted	-19.77%	-23.27%	-16.28%	-77.9	-95.9	-60.0
BLOCKING ONLY						
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-7.02%	-8.03%	-6.00%	-28.3	-33.4	-23.1
[II] Equal Weight Per Transaction	-7.24%	-8.38%	-6.10%	-33.8	-38.7	-28.8
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-8.13%	-9.30%	-6.96%	-36.3	-41.8	-30.7
[IV] Equal Weight for each Pound Transacted	-7.19%	-8.29%	-6.09%	-27.8	-32.9	-22.6

a. Negative numbers imply lower resource rent
b. The combination is weighted by the average yearly percentage of the TAC
c. Based on the log specification
d. Based on the linear specification

Table A7b. Aggregate Impact of Restrictions on Resource Rent in the Sablefish Fishery[a]

	Percentage Change in Resource Rent[c]			Aggregate Change in Resource Rent ($2012)[d]		
	Point Estimate	*95 Percent CI*		*Point Estimate*	*95 Percent CI*	
TOTAL (CLASS AND BLOCKING)						
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-15.97%	-22.14%	-9.81%	-39.5	-62.7	-16.3
[II] Equal Weight Per Transaction	-21.62%	-27.19%	-16.06%	-45.7	-60.9	-30.5
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-17.69%	-23.02%	-12.35%	-43.2	-63.3	-23.2
[IV] Equal Weight for each Pound Transacted	-26.22%	-32.91%	-19.54%	-39.5	-62.7	-16.3
CLASS ONLY						
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-15.89%	-21.22%	-10.56%	-36.2	-56.1	-16.3
[II] Equal Weight Per Transaction	-22.63%	-27.57%	-17.70%	-41.6	-54.4	-28.8
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-18.64%	-23.44%	-13.83%	-40.5	-58.2	-22.9
[IV] Equal Weight for each Pound Transacted	-25.74%	-31.53%	-19.96%	-38.3	-52.4	-24.2
BLOCKING ONLY						
[I] Equal Weight for each Pound Transacted within an Area/Class/Blocking Combination[b]	-2.67%	-3.16%	-2.18%	-82.5	-94.2	-70.7
[II] Equal Weight Per Transaction	-2.95%	-3.54%	-2.36%	-101.5	-113.0	-90.1
[III] Equal Weight for each Transaction within an Area/Class/Blocking Combination[b]	-3.40%	-4.00%	-2.81%	-98.1	-110.1	-86.0
[IV] Equal Weight for each Pound Transacted	-2.51%	-3.07%	-1.94%	-72.4	-83.9	-60.8

a. Negative numbers imply lower resource rent
b. The combination is weighted by the average yearly percentage of the TAC
c. Based on the log specification
d. Based on the linear specification

Additional Robustness Regression

Following Newell et. al (2005), we rerun our regressions using data on ex-vessel price, area-specific stock, fuel price, and labor indices. Additionally, we include measures of the prior year's percent of the TAC caught as well as the year-to-date percent of the TAC caught the prior year. Finally, we include the change in GDP as a general measure of the economy, the 30-day T-bill rate representing the risk-free portion of the quota discount rate. Our general result that restrictions significantly impact efficiency is robust to this change in specification. Furthermore, the coefficients of interest are of similar magnitudes. We present the results with year and area interacted dummy variables as our primary results because they are more parsimonious and the fit is similar.