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Market Share, Capacity Utilization, Resource Conservation, and Tradable Quotas

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Abstract *This paper examines the impact of the introduction of Individual Transferable Quotas (ITQs) on catch, market share, and capacity utilization of firms in the Mid Atlantic Surf Clam and Ocean Quahog (SCOQ) Fishery. Via the production function framework, catch and market share regression models are utilized in examining the effects of operator size, vessel age, and alternative product catch variables on industrial structure and how such effects changed after ITQs were introduced. Results indicate that in both fisheries, the ITQ system enhanced the value of each vessel by allowing vessel owners to apply greater effort to fewer boats, thus reducing excess capacity in the fishery. Results also indicate an overall resource conservation effect of ITQ introduction in the surf clam fishery. These results suggest that in the presence of ITQs, overall efficiency was enhanced in the SCOQ fishery.*

Key words Fisheries, individual transferable quotas, industrial organization, market share, ocean quahog, surf clam.

Introduction

Individual Transferable Quotas (ITQs) constitute a form of rights-based allocation in natural resource management (Neher, Arnason, and Mollet 1989). Under an ITQ system, shares of a quota are allocated among individuals or firms which are free to trade them. The objective is to allow the market mechanism to influence decisions about the allocation of labor, capital, and other resources, in contrast to the incentives for overcapacity created by open-access or competitive-quota resource management systems (Anderson 1986, 1989; Squires, Kirkley, and Tisdell 1995; Young and McCay 1995).

Under an ITQ system, an annual quota or the total allowable catch (TAC) is broken into shares which, in the Mid Atlantic Surf Clam and Ocean Quahog (SCOQ) fishery, were initially distributed to all vessel owners with permits for the fishery. The amount of the share was based on performance history and investment in the

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fishery. It is important to note that the shareholders do not own rights to the clams themselves, but they do own a share or percentage of the TAC. The TAC is determined by the Mid Atlantic Fisheries Management Council (MAFMC) upon advice from scientists and industry representatives, taking into account biological and other variables. The quota was similarly determined before the ITQ system was introduced.

An ITQ owner may sell or lease his or her quota share. Hence, high-cost vessel owners holding quota shares are likely to sell or lease out their quota shares, while low-cost owners will buy or lease shares from others. Consequently, ITQs can reduce over-capitalization by providing incentives for greater efficiency on the part of all operators, which for some may mean selling out and for others may mean buying in. Thus, ITQs are expected to aid the retention of and enhance fishing by the most efficient operators, result in fewer vessel owners, and lead to greater incomes for remaining vessel owners.

The first comprehensive ITQ system in marine fisheries was enacted in New Zealand in 1986 (Sissenwine and Mace 1992). Others have followed in Australia, Canada, Iceland, and other countries. The subject of this article is the first ITQ system for U.S. marine fisheries: the U.S. Exclusive Economic Zone (EEZ) fishery for Mid Atlantic surf clams and ocean quahogs. Both surf clams (*Spisula solidissima*) and ocean quahogs (*Arctica islandica*) are species of clams processed into consumer food products. The ITQ system was implemented in October 1990. Since the introduction of ITQs, the SCOQ fishery has been of great interest to fisheries economists and managers.

Appraisals of the Mid Atlantic SCOQ fishery have shown that since the introduction of ITQs, economic efficiency in clam harvesting has increased, excess harvesting capacity has declined (Wang 1995), employment has declined, and thus the bargaining power of crew and captains has declined (McCay, Gatewood, and Creed 1990; McCay and Creed 1994; McCay 1994). However, specific empirical, econometric evidence of the role of ITQs in these and other changes is lacking. Specifically, evidence is lacking about the impact of ITQs on individual catch and market share, on the concentration of operators, on capitalization in the industry and on resource conservation. Uncovering such important evidence is the focus of this paper.

Individual Transferable Quotas are controversial largely because of concerns about the social consequences of bringing market forces to bear upon rights to participate in a fishery where such rights have either been free (as in open access) or determined by governmental processes (McCay 1994). For example, some long-time operators exit the fishery as the benefits of selling their quota share become greater than the benefits of using the quota share to harvest clams. There is related concern that the ITQ system can disadvantage small-scale fishermen and the coastal communities dependent on them (Moore 1993; Gifford 1997). Because of these and other possible social consequences, it is important to accurately document the structural impacts, benefits, and adverse consequences associated with ITQ introduction. Specific empirical evidence showing causality between ITQs and various industrial organizational changes that have occurred in the fishery will be helpful in understanding the advantages as well as the disadvantages of ITQs.

In this paper we address these questions by looking at how regulatory changes may have affected the structure of the industry, the absolute and relative level of production of firms, and resource conservation in the industry. In other articles, we examine changing structures of ownership and the extent of market power (Adelaja, Menzo, and McCay 1998). The specific goal of this paper is to isolate the effects of the ITQ system by estimating the extent to which it has led to increases in a vessel owner's production (catch) as well as share of surf clam/ocean quahog landings, and the mechanism by which these changes have happened. Also examined is its net impact on catch and, therefore, fishing mortality, which may be associated with resource conservation. The analysis is based on simple linear production function regressions which allow estimation of the magnitudes of the impacts of factors of production on operator catch (landings) and shares of total landings. Among the explanatory factors are indicators of fixed inputs or the nature of the physical plant (*e.g.*, fleet size, vessel size, vessel age, and alternative product catch), industry output regulation (*i.e.*, total allowable catch) and ITQ related variables to capture the independent effects of ITQ introduction. Given the importance of determining if ITQs have worked to offer greater advantages to vessel owners of certain fleets (certain size, age, and product mix), cross-terms between ITQs (a dummy variable for the presence of ITQs) and other explanatory variables were included in the regression. As it will be shown later, by comparing the impacts of ITQ introduction on operator's catch and share, effects on total industry catch is further determined. This has implications for the resource conservation effects of ITQs.

The background section provides a brief history of the Mid Atlantic SCOQ fishery. The conceptual framework section conceptualizes the effects of ITQs on an owner's catch and share of landed clams via a production function framework. The empirical model, data and estimation section presents the modeling techniques. The empirical results and conclusion, respectively, provide the results of the regressions and a summary and conclusion.

Background of the Mid Atlantic SCOQ Fishery

Vessel owners in the SCOQ fishery may use their boats and crews to harvest both surf clams and ocean quahogs. Surf clams are found both close to shore and at greater depths, whereas ocean quahogs are found only well beyond the surf. Until the early 1970s, surf clams were harvested mainly off the coasts of New York and New Jersey. As stocks declined, vessel owners moved their operations further south to the North Carolina and Virginia coasts. In 1976, the surf clam stock collapsed due to over-harvesting and to anoxic conditions. This collapse led fishermen to look for alternative sources of income and for alternative uses for their vessels. A substitute resource for the surf clam was found in the ocean quahog (Lipton and Strand 1992). Although ocean quahogs had been harvested commercially since the mid 1940s in the Rhode Island and Block Island Sound fisheries, it was not until the 1976 collapse of the surf clam stock that ocean quahog production began to develop in the Mid Atlantic region (Kennish and Lutz 1995).

The Magnuson Fishery and Conservation Act was passed in 1976, during the same period the surf clam resource was in serious trouble. The Magnuson Act extended national jurisdiction over fisheries to 200 nautical miles (the Exclusive Economic Zone or EEZ) and created a system for managing both foreign and domestic fisheries. Eight regional councils were established across the U.S. for this purpose. The Mid Atlantic Fisheries Management Council (MAFMC) quickly took up the challenge of managing the EEZ surf clam and ocean quahog fishery. In 1977 the first fishery management plan was approved for the SCOQ fishery. Between 1979 and 1988, the SCOQ fishery management plan was amended seven times. In 1988, Amendment #8 was passed to create the ITQ system; the amendment went into effect in 1990.

Until the implementation of the ITQ system, the surf clam fishery and the ocean quahog fishery were managed differently. Between 1979 and 1988, the surf clam fishery was managed using various combinations of regulations including quarterly and annual quotas, time limits set on hours that a vessel could fish, a moratorium on entry of new vessels, minimum clam size requirements, the use of catch logbooks, and vessel permits. After ten years of this type of regulation, the fishery was very inefficient (Wang 1995). Table 1 details the regulatory history of the SCOQ fishery

Table 1
History of the Mid Atlantic Surf Clam and Ocean Quahog Fishery, 1970–90

Date	Event
1970–72	Sharp increase in VA Exclusive Economic Zone (EEZ) surf clam (SC) landings and decline in NJ EEZ SC landings.
1974	VA EEZ SC landings exceed NJ EEZ SC landings.
1975–76	Collapse of NJ SC fishery, due to low levels of oxygen in the spring and summer.
1976–79	Continued drop in landings.
1976	First MAFMC meeting.
1977	First Fishery Management Plan (FMP) approved for SCOQ fishery. Quarterly quota for SCs, annual quota for ocean quahogs (OQs). Effort limitation, permit, logbook provisions, and vessel moratorium included for SC fishery, OQ fishery is open access.
1978	Amendment #1 implemented. Extends SCOQ FMP through December 1979. Moratorium in SC fishery is continued.
1980	Amendment #2 implemented. Extends SCOQ FMP through December 1981. SC fishery is divided into New England and Mid Atlantic area. The moratorium is continued in the Mid Atlantic region. Beginning of recovery in SC landings.
1981	Amendment #3 approved November 1981. The FMP is extended indefinitely. The moratorium is extended in the Mid Atlantic region.
1984	Amendment #4 implemented on emergency basis. Never approved, but later incorporated into Amendment #6.
1984	Amendment #5 implemented. Revised the SC minimum size limit provisions and extended the size limit through the entire fishery. Instituted a cage tag provision.
1986	Amendment #6 implemented. Implemented provisions of proposed Amendment #4. Quota adjustments made. Weekly landing limits for the Nantucket Shoals Area are eliminated. Presented additional justification for the one landing per trip provision.
1987	Amendment #7 approved. The amendment was developed to change the quota distribution on the Georges Bank.
1990	Amendment #8 approved by NOAA. Institution of Individual Transferable Quota system.

Source: *Amendment #8 Fishery Management Plan for the Atlantic Surf Clam and Ocean Quahog Fishery*. Mid Atlantic Fishery Management Council in cooperation with the National Marine Fisheries Service and the New England Fishery Management Council. June 1990.

from 1970 through 1990. Under the rules of the moratorium, participation required ownership of one of the original vessels (vessels that were active in the fishery before the moratorium was implemented), but catch rates increased while the overall total allowable catch (TAC) did not fluctuate to a great degree. Although the TAC and the number of vessels did not change much, new technologies were added to vessels which gave them greater harvesting capacity. Overcapacity resulted to the point that by 1985 a surf clam vessel was allowed to fish for only six hours every other week. In addition, the task of dealing with several regulations under the effort limitation scheme proved unreasonably time consuming and complicated for administrators.

The ocean quahog fishery was not regulated nearly to the degree that the surf clam fishery was. Although the fishery management plan called for regulation of both surf clams and ocean quahogs, many provisions directed toward ocean quahogs were never put in place (Brandt 1994–95). No entry or effort restrictions were imposed between 1979 and 1988, with the exception of an annual landings quota. Finally, it was agreed to simplify the SCOQ fishery management plan by implementing ITQs. On 1 October 1990, the ITQ system was implemented (McCay and Creed 1994).

Although several observable changes have taken place since the introduction of the ITQ system to this fishery, it is not known to what extent the ITQ system has influenced some of these changes. The first change to be noted is that of a shift northward in the landings of surf clams. Just as the industry shifted south in the 1970s, the Mid Atlantic states, especially New Jersey, have shown increasingly larger shares of catch during the 1988–94 period. In 1988, New Jersey operators landed 57% of all landed surf clams, while Virginia operators landed 20%. By 1994, New Jersey operators harvested 86% of landed surf clams while Virginia operators landed none. This shift northward developed as catch per unit effort began to decline in more southern states.

The second set of changes suggests that overcapacity declined. Our review of National Marine Fisheries Service (NMFS) data, combined with the data set we developed for a study of ownership,[1] shows that the number of active vessels in the fishery declined markedly between 1988–94 (the decision to create an ITQ regime was made in 1990). In 1988 there were 133 boats fishing for surf clams in the EEZ; by 1994, there were only 48. This is not surprising, given the fact that the original moratorium created an artificial incentive to own more vessels than needed to harvest the surf clams;[2] ITQs enabled rapid adjustment of capacity. In the 1988 ocean quahog fishery, 62 vessels participated, but only 35 vessels were active in 1994. Almost as dramatic was the decline in the number of firms that owned active surf clam vessels, from 56 in 1988 to 28 in 1994. In the ocean quahog fishery, the number of participating firms declined from 24 in 1988 to 17 in 1994. This result is also remarkable, suggesting the high degree of consolidation of ownership predicted by many opponents of ITQs.

Other changes included a steady increase in hours fishing per vessel (table 2) and in the average surf clam catch per trip (figure 1). Average surf clam trips per vessel (figure 2) and average surf clam catch per vessel rose as well over the period. This would ordinarily reflect the greater utilization of vessels that results from the displacement of less productive vessels under an ITQ system. Changes in these measures in the ocean quahog fishery are slightly more ambiguous (figures 3 and 4 and table 2), although it is clear that the number of trips taken per vessel rose between 1988 and 1994. While these changes suggest that capacity has been more fully utilized and vessels less often idled (the intended effect of the ITQ), empirical evidence is lacking in the economic literature to support such a hypothesis. Other more salient changes may also have occurred, such as an independent effect of ITQ introduction on actual industry catch. The investigation conducted in this study will provide some explanation for these changes.

Conceptual Framework

Perhaps the appropriate starting point for evaluating the impact of ITQs on production is to conceptualize the effect on fisheries production structure. The catch of an operator (C_i) is synonymous with the physical quantity of output or production.

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[1] Our data on ownership of vessels is based on the "true owner" data set created by C.F. Creed (McCay and Creed 1994), updated with the help of representatives of the fishing industry. NMFS files are inadequate to the task of identifying changes in ownership patterns because many firms create separate corporations for each of their vessels. The "true owner" is based on industry recognition of ownership of vessels, verified where possible through the NMFS license data.

[2] Although initial quota share allocation was based on historical participation in the fishery, and therefore may also have created an artificial incentive to own vessels, the number of vessels participating was artificially high even prior to the advent of the ITQ system.

Table 2
Fishing Hours Per Vessel in the
Mid Atlantic SCOQ Fishery, 1988–94

	Hours Fishing Per Vessel	
Year	Surf Clam	Ocean Quahog
1988	401.7	537.2
1989	434.5	576.2
1990	473.1	740.9
1991	866.1	936.1
1992	944.8	808.8
1993	1,246.7	1,186.8
1994	1,400.5	1,249.1

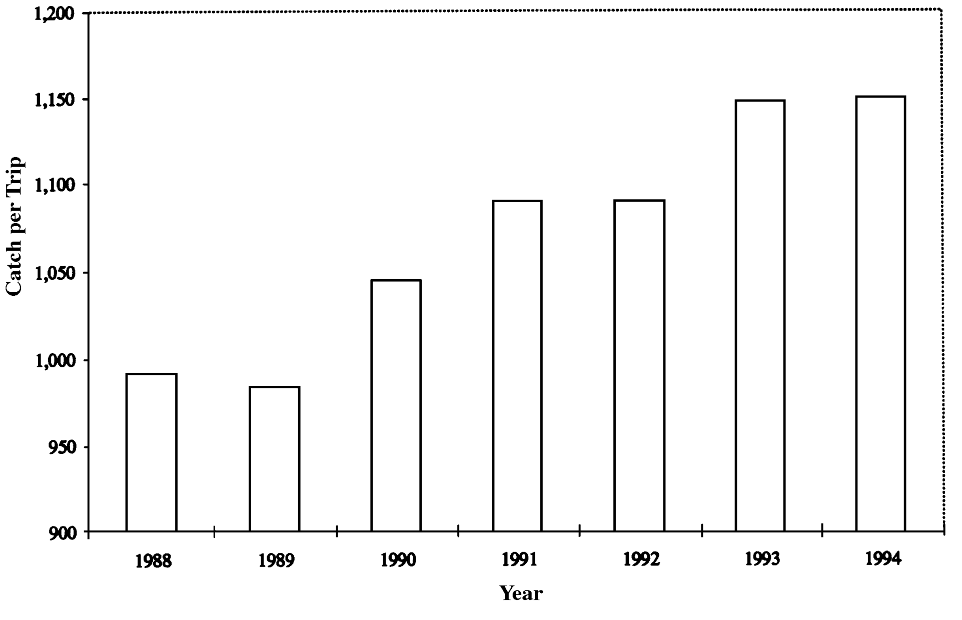

Figure 1. Surf Clam Catch per Trip (in bushels), 1988–94

Hence, one can specify and estimate a production function for surf clams or ocean quahogs. Denote the catch of the ith operator of the rth product (surf clam or ocean quahog) as C_i^r where $i = 1, 2, \ldots, n$; $r = s$ or q (surf clam or ocean quahog); and n is the total number of operators in the fishery. The production function for the rth product by the ith operator can be specified as:

$$C_i^r = C_i^r\,(X, ITQ, TAC, Z) \tag{1}$$

where $X = X_v = X_1, X_2, \ldots, X_w$ is a vector of conventional inputs or factors of production, ITQ is a binary choice variable specified to capture the introduction of ITQ

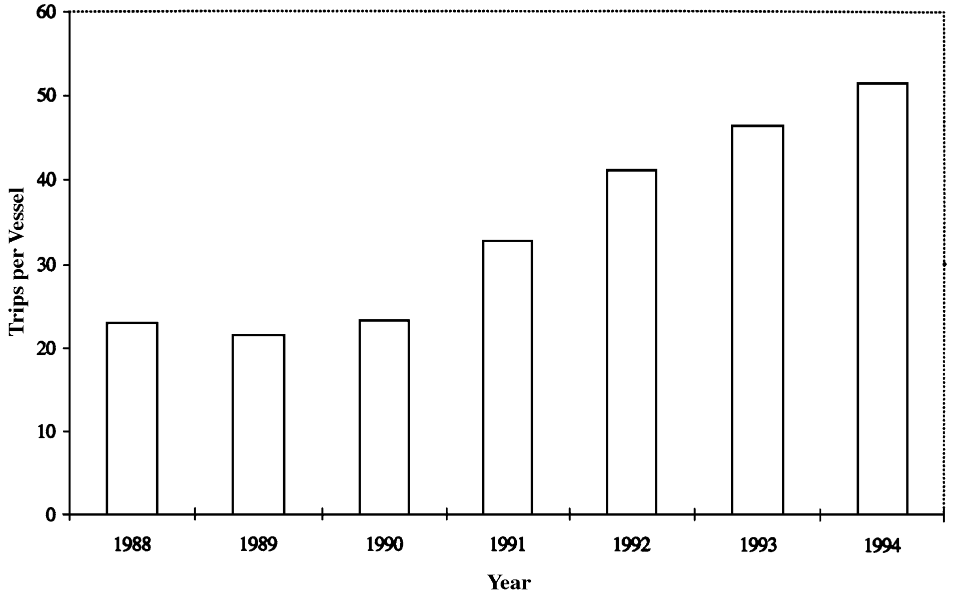

Figure 2. Surf Clam Trips per Vessel, 1988–94

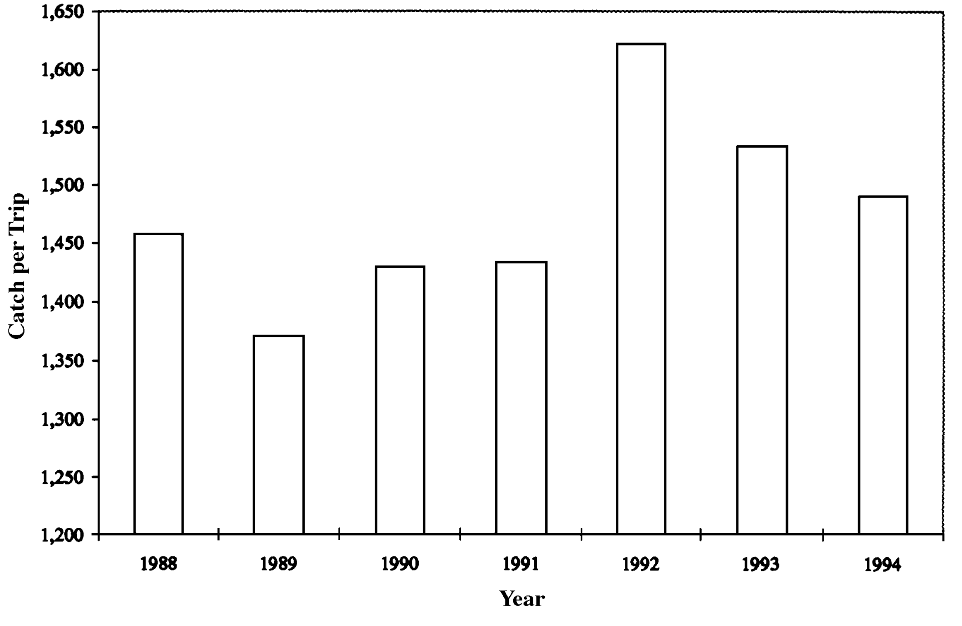

Figure 3. Ocean Quahog Catch per Trip (in bushels), 1988–94

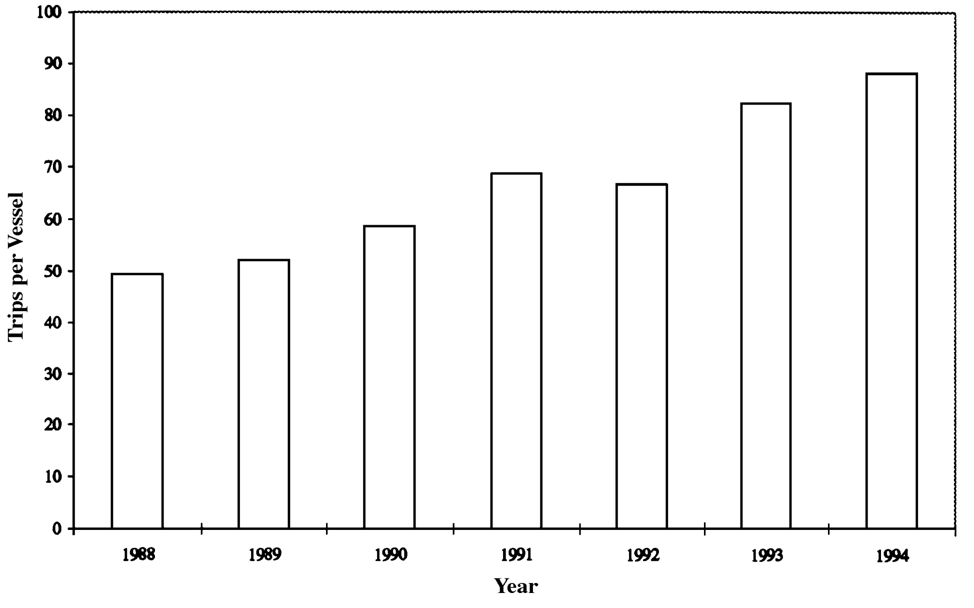

Figure 4. Ocean Quahog Trips per Vessel, 1988–94

(ITQ = 1 from 1991–94 and ITQ = 0 otherwise); TAC is Total Allowable Catch which is a measure of industry output regulation; and $Z = Z_k = Z_1, Z_2, \ldots, Z_y$ is a vector of other exogenous variables. Relevant factors of production to include in the X vector include measures of the size of the physical plant (*e.g.*, fleet size and vessel size), measures of the size of variable inputs (*e.g.*, crew size and fuel use), and measures of constraints on production (*e.g.*, vessel appropriateness and vessel age). A factor in the production of a product will be the level of output of the alternative product. Hence, the variables to be included in the Z vector would include ocean quahog catch in the case of surf clam production and surf clam catch in the case of ocean quahog production. The production function in equation (1) satisfies the usual neoclassical properties such that $C^r_{ix} > 0$ and $C^r_{ixx} < 0$.

Totally differentiating equation (1), one obtains the following:

$$dC^s_i = \sum_{v=1}^{w} F^s_v dX_v + F^s_{ITQ} dITQ + F^s_{TAC} dTAC + \sum_{k=1}^{y} F^s_k dZ_k \qquad (2)$$

and

$$dC^q_i = \sum_{v=1}^{w} F^q_v dX_v + F^q_{ITQ} dITQ + F^q_{TAC} dTAC + \sum_{k=1}^{y} F^q_k dZ_k \qquad (3)$$

where F^s_v and F^q_v are the marginal products of the vth conventional input in the production of surf clams and ocean quahogs, respectively; F^s_{ITQ} and F^q_{ITQ} are the marginal impact of ITQ introduction (shift in catch as a result of ITQ introduction), F^s_{TAC} and F^q_{TAC} are the marginal impacts of TAC adjustment on catch, and F^s_k and F^q_k are measures of the effects of other exogenous variables. Note that the inclusion of TAC as an independent variable allows one to isolate the impact of ITQ introduction on catch through the use of the ITQ dummy.

Therefore,

$$dC_i^s/C_i^s = \sum_{v=1}^{w} F_v^s(dX_v/C_i^s) + F_{ITQ}^s(dITQ/C_i^s) + F_{TAC}^s(dTAC/C_i^s) + \sum_{k=1}^{y} F_k^s(dZ_k/C_i^s) \tag{4}$$

and,

$$dC_i^q/C_i^q = \sum_{v=1}^{w} F_v^q(dX_v/C_i^q) + F_{ITQ}^q(dITQ/C_i^q) + F_{TAC}^q(dTAC/C_i^q) + \sum_{k=1}^{y} F_k^q(dZ_k/C_i^q). \tag{5}$$

From equations (4) and (5) it is seen that

$$\delta C_i^s/C_i^s\delta ITQ = \sum_{v=1}^{w} F_v^s(\delta X_v/C_i^s\delta ITQ) + F_{ITQ}^s(\delta ITQ/C_i^s\delta ITQ) + F_{TAC}^s(\delta TAC/C_i^s\delta ITQ) + \sum_{k=1}^{y} F_k^s(\delta Z_k/C_i^s\delta ITQ). \tag{6}$$

and,

$$\delta C_i^q/C_i^q\delta ITQ = \sum_{v=1}^{w} F_v^q(\delta X_v/C_i^q\delta ITQ) + F_{ITQ}^q(\delta ITQ/C_i^q\delta ITQ) + F_{TAC}^q(\delta TAC/C_i^q\delta ITQ) + \sum_{k=1}^{y} F_k^q(\delta Z_k/C_i^q\delta ITQ). \tag{7}$$

The effect of the introduction of ITQs on the fishery depends on F_{ITQ}^s and F_{ITQ}^q which reflect the marginal effect (product) of ITQ introduction. If ITQs are output restrictive, then F_{ITQ}^s and $F_{ITQ}^q < 0$. As mentioned above, the framework utilized in this paper is the production function approach. The empirical implementation of the framework would require the regression of catch against levels of conventional and nonconventional inputs, including factors such as ITQ introduction and total allowable catch.

Adelaja (1991) has shown the relationship between production (catch) and producer share of total industry output. This framework, which involves decomposing effects of exogenous variables on firm-level catch into effects on yield per unit of fixed input and fixed input endowment per operator, allows the evaluation of the structure of production and of industrial organization. It can thus be used to link the effects of explanatory factors on operator catch to effects on operator's share of total industry output. This framework can be used to explain the effects of ITQ introduction on catch as well as industry structure.

To illustrate the approach, consider the following decomposition of an operator's catch during a given period. Denote the total number of vessels owned by the *i*th owner by V_i, and the total number of trips made by the operator as T_i. The following identity holds true:

$$C_i^r = (C_i^r/T_i^r)(T_i^r/V_i^r)(V_i^r). \tag{8}$$

Where C_i^r/T_i^r is catch per trip which is an effort variable denoting how much catch is realized on the average trip. Henceforth, this variable will be denoted by the variable E_i^r ("effort" per trip) since it reflects, to some degree, the extent to which resources are applied on each trip. T_i^r/V_i^r is the frequency of trips variable which will be denoted by the variable F_i^r. Therefore, equation (8) can be re-specified as:

$$C_i^r = (E_i^r)(F_i^r)(V_i^r). \tag{9}$$

An owner's share of total fishery catch (S_i^r) can be denoted by

$$S_i^r = C_i^r / C_T^r \tag{10}$$

where C_T^r is $\sum_{i=1}^{n} C_i^r$ or total industry catch and n is the number of vessel owners. C_T^r, which is the choice level of total industry catch, is not necessarily equal to TAC which is the regulated maximum catch. In fact, under an ITQ system, it is conceivable that profit maximizing C_T^r falls below TAC. From equation (9), it is apparent that:

$$\delta \ln C_i^r / \delta ITQ = \delta \ln E_i^r / \delta ITQ + \delta \ln F_i^r / \delta ITQ + \delta \ln V_i^r / \delta ITQ. \tag{11}$$

Equation (11) suggests that because the impact of ITQ introduction on catch is the sum of the impacts on effort, frequency of trips and total vessels, the production function estimates of impacts of ITQs can be evaluated in the context of effort, frequency, and number of vessels. By combining equations (9) and (10), S_i becomes:

$$S_i^r = C_i^r / C_T^r = (E_i^r)(F_i^r)(V_i^r)/C_T^r. \tag{12}$$

Therefore,

$$\delta \ln S_i^r / \delta ITQ = \delta \ln C_i^r / \delta ITQ - \delta \ln C_T^r / \delta ITQ \tag{13}$$
$$= \delta \ln E_i^r / \delta ITQ + \delta \ln F_i^r / \delta ITQ + \delta \ln V_i^r / \delta ITQ - \delta \ln C_T^r / \delta ITQ.$$

Equation (13) shows that the impact of ITQ introduction on owner's share of landings can also be decomposed into the impacts on effort, frequency of trips, vessels, and overall fisheries catch. It is useful in understanding how ITQ introduction affects catch and market share. It is noteworthy that the inclusion of *TAC* as a causal factor improves the ability of the *ITQ* dummy variable to isolate the effect of ITQ on total actual industry catch.

Now, consider the case where $\delta \ln C_T^r / \delta ITQ = 0$. Equation (13) reduces to:

$$\delta \ln S_i^r / \delta ITQ = \delta \ln E_i^r / \delta ITQ + \delta \ln F_i^r / \delta ITQ \tag{14}$$
$$+ \delta \ln V_i^r / \delta ITQ = \delta \ln C_i^r / \delta ITQ.$$

Under this scenario, the impact of *ITQ*, or indeed any other explanatory factor, on market share is exactly equal to the impact on firm-level catch. This would be the case if C_T^r is always equal to TAC or when ITQ introduction does not affect C_T^r.

Consider an alternative case where $\delta \ln C_T^r / \delta ITQ$ is not equal to 0. This implies that

$$\delta \ln C_T^r / \delta ITQ = \delta \ln C_i^r / \delta ITQ - \delta \ln S_i^r / \delta ITQ. \tag{15}$$

From equation (15), the effect of ITQ introduction on total actual industry catch (C_T^r) is the difference between the impacts on individual firm catch and share. Hence, to the extent that C_T^r differs from TAC, the effects of ITQ on C_T^r can be isolated. This effect is essentially the independent resource conservation effect of ITQ introduction. That is, the resource conservation effects of ITQ introduction can be observed by estimating catch as well as share functions and comparing the estimates.

The analysis above basically demonstrates that the production function framework can be used to estimate the impact of ITQs on catch, share, and resource conservation while simultaneously observing the effects through effort, frequency, and vessels.

Empirical Model, Data, and Estimation

To operationalize the production function model, simple linear production functions with selected cross-terms were specified for surf clams and ocean quahogs. The dependent variables are the natural logarithms of owner's catch (*LNCATCH*) for each product. Given the interest in the share equations, another set of dependent variables is the logarithms of vessel owner's share (*LNSHARE*). Independent variables should include proxies for factors of production (inputs) as well as nonconventional input variables capturing the effects of policy, production restrictions, and market constraints. For this study nonconventional variables include changes in TAC, a dummy variable depicting ITQ introduction, and variables depicting the catch of the alternative resource.

Data on variable inputs are limited, and the database did not include information on production costs. On the other hand, data were abundant on the level of fixed inputs, and there was a large choice of fixed inputs to choose from. The fixed factors upon which data were available included horsepower, dredge size, fleet size, year built (age), and gross tonnage. The variable factors upon which information was available included crew size.[3] Due to the large number of fixed factors and the possibility of multi-collinearity, correlation analysis was conducted to determine which ones were correlated. The use of correlated independent variables could lead to multicollinearity and inefficient parameter estimates.

The correlation coefficients between crew size and most fixed factors were high. For example, the correlation coefficient between horsepower and crew size was (0.61), and it was statistically significant at the 5% level. The high correlation between crew size and other variables, and the fact that crew size is essentially used in fixed proportions with horsepower suggested a high probability of multicollinearity if this variable was included in the production function. Most other fixed factors were highly correlated. A low and statistically insignificant (at the 5% level) correlation coefficient was found between horsepower and year built (0.07), between fleet size and year built (–0.01), and between fleet size and horsepower (–0.06). Based on the correlation coefficients, the primary fixed factors of production included as exogenous variables in the catch and share functions were horsepower, fleet size, and year built. In addition to these and the *ITQ* dummy variable, *TAC*, bushels of the alternate clam resource harvested, and cross-terms between the *ITQ* variable and other factors were included. The appropriate estimation technique is a simultaneous equation estimation method. Hence, the Two-Stage Least Squares (2SLS) estimation technique was used to estimate the set of catch equations and the set of share equations, with each set estimated. Preliminary regressions involving all possible exogenous variables and all possible cross-terms yielded many insignificant parameter estimates and exhibited significant multicollinearity. Chow F-tests were used to identify the appropriate structures of the models. The tests suggested not only that horsepower, year built, and fleet size were the appropriate fixed factors of production to include, but also that the cross-terms between horsepower and *ITQ* could be

[3] However, even this can be seen as a fixed factor of production since crew size on a vessel is fixed over time and in the data set.

excluded. The coefficient of the cross-term was not statistically significant in the preliminary specifications of the model. Intuitively and based on observation, the lack of interaction between horsepower and *ITQ* makes a lot of sense—why bother to invest in bigger, more powerful vessels when you no longer have to race to get as many clams as you can in a short period of time?

The final specification of the production functions and the share functions are the following simple linear models with cross-terms between *ITQ* and conventional inputs:

$$LNCATCH = a_0 + a_1HP2 + a_2NUMBER + a_3YB2 + a_4SUBST + a_5ITQ + a_6TAC + a_7NUMITQ + a_8YBITQ + a_9SUBSTITQ \quad (16)$$

$$LNSHARE = b_0 + b_1HP2 + b_2NUMBER + b_3YB2 + b_4SUBST + b_5ITQ + b_6TAC + b_7NUMITQ + b_8YBITQ + b_9SUBSTITQ \quad (17)$$

where *LNCATCH* is the natural log of catch for an operator, *LNSHARE* is the natural log of each operator's share of total landings, *HP*2 is a measure of horsepower of the vessels utilized by the operator, *NUMBER* is a measure of vessel operator's fleet size, *YB*2 is a measure of the age of an operator's vessels and it proxies fishing technology, *SUBST* is a measure for the alternate product harvested, *ITQ* is a dummy variable to capture the introduction of *ITQs*, *TAC* is the total allowable catch level set for the fishery, and *NUMITQ*, *YBITQ*, and *SUBSTITQ* are interaction terms between *ITQ* and the other independent variables.

A positive relationship is hypothesized between horsepower and catch, and horsepower and owner's share. Operators with larger and more powerful vessels should catch more and have greater owner's shares due to economies of scale, greater capacity, greater crew size, greater access to capital, and greater flexibility in applying more effort to capital. That is, the marginal product of a bigger boat is expected to be positive in the relevant stage of production.

The hypothesized relationship between vessel age and catch is negative, as is the anticipated relationship between vessel age and owner's share. Older boats are less versatile, cannot readily accommodate greater effort, are less appropriate as collateral for capital and involve greater maintenance, repair, and down time. Newer boats can be taken out to sea more frequently and are more conducive to the use of new technologies.

The hypothesized relationship between both catch and share, and number of vessels is positive. Typically, the more vessels an operator has, holding effort constant, the greater the catch. Although initial quota share distribution was based on vessel ownership prior to ITQ introduction, after the initial distribution, quota share was not tied to vessel ownership. Nevertheless, economies of scale and management advantages may accrue to large fleet operators.

The hypothesized relationship between catch and effort devoted to alternative products is expected to be negative. The more effort devoted to harvesting ocean quahogs for example, the less the effort and trips devoted to surf clams, and the less the surf clam catch and share.

The hypothesized relationship between TAC and catch is positive. However, the expected relationship to owner's share is difficult to determine *a priori*. The extent to which firm level catch declines can vary with type of operation.

In the presence of ITQs, it is hypothesized that the typical operator's landings would increase as benefits accrue to operators from the utilization of fewer, newer, or larger boats. That is, ITQs should discourage the use of small, old, and inefficient vessels, thereby reducing the total number of vessels and operators (*V*), increasing the average catch of remaining operators (*E*) and increasing trips per vessel (*F*). The physical plant is therefore expected to be used at greater efficiency and capacity so that the shares of remaining operators increase. Based on the above, one expects the impact of ITQs on the marginal products of horsepower and of fleet size to be positive, and the impact on the marginal product of age to be negative. Finally, for a vessel operator whose effort toward alternative products remains constant, ITQs can be expected to raise catch by raising vessel operating efficiency. Consequently, for remaining operators, owner’s share and catch should rise with the introduction of ITQs.

All the data used in this study were made available by the National Marine Fisheries Service (NMFS), Northeast Fisheries Center. Logbook data were collected for every trip made by each vessel. These logbook data provide the date of the fishing trip, the vessel name and permit number, species of clam landed, number of bushels landed, and vessel owner. Vessel characteristic data and information about the annual TAC levels were provided by the NMFS upon request.

Each observation in the data represents a particular owner during a particular year (see footnote 1). Data on all participants in the fishery are included in the analysis from 1988 through 1994. Therefore the same owner may appear as an observation once for each of the seven years of data.

Horsepower is represented by the variable *HP*2 which is the percentage of vessels owned by this particular owner that are 400 to 1,640 horsepower. The median horsepower of vessels in the fishery was approximately 400. The data set includes vessels that range from 115 to 1,640 horsepower. The expected coefficient of *HP*2 is positive. *NUMBER* is measured simply as the total number of vessels owned in a particular year by a particular vessel operator, and therefore is also a measure of size of the operation. It is expected that the coefficient of *NUMBER* is positive.

Age of the vessel is proxied by *YB*2 which represents the percentage of “newer” vessels owned by a particular fisherman in a particular year that were built in 1980 or later. Vessels in the data set were built anywhere from 1866 to 1991. By 1980, the vessel moratorium on surf clam vessels had been in effect for three years. The only way new vessels could be brought into the fishery during the moratorium was as a replacement for a vessel that was no longer operable. Although new gear was allowed to be incorporated on vessels in the fishery, the new vessels allowed into the fishery were one of the few means by which vessel owners could introduce new technologies to their operations. The expected coefficient of *YB*2 is positive.

The number of bushels of the alternate resource landed by the owner (*SUBST*) is a proxy for effort devoted to alternative products. An increase in ocean quahogs landed by the operator should reduce surf clam catch and owner’s share of total industry surf clam catch.

The dummy variable for *ITQ* equals 1 if the ITQ was in place for the entire year; therefore, *ITQ* equals 1 for 1991 through 1994. *ITQ* equals 0 if the ITQ was not in place for all or part of the year, and *ITQ* equals 0 for 1988 through 1990. The cross-terms between the *ITQ* variable and other factors show how the introduction of ITQs alter the marginal product of other inputs. These cross-terms are created by multiplying the value of the *ITQ* dummy variable by the value of the independent variables *NUMBER*, *YB*2, and *SUBST* to create the variables *NUMITQ*, *YBITQ*, and *SUBSTITQ*. Finally, TAC was measured as the maximum bushels of each species allowed to be harvested by the entire fishery.

Empirical Results

Parameter estimates of the production functions appear in table 3, and the estimates of the share equations appear in table 4. In the tables, both Ordinary Least Squares (OLS) and 2SLS results are presented. The 2SLS results generally exhibited similar

Table 3

Estimated Impacts of Explanatory Variables on the Natural Log of Catch in the Mid Atlantic Surf Clam and Ocean Quahog Fishery Using OLS and 2SLS, 1988–94

	Surf Clam		Ocean Quahog	
Variable Name	OLS Parameter Estimate (Standard Error)	2SLS Parameter Estimate (Standard Error)	OLS Parameter Estimate (Standard Error)	2SLS Parameter Estimate (Standard Error)
Intercept	10.58*	6.75*	9.86*	–2.80
	(1.06)	(3.71)	(0.77)	(5.20)
*HP*2	0.002128	0.022867*	0.003328	0.125705*
	(0.0013)	(0.0044)	(0.0043)	(0.0064)
NUMBER	0.198162*	0.339072*	0.570696	1.991212*
	(0.03)	(0.11)	(0.41)	(0.27)
*YB*2	0.001971	0.00747807	0.020340*	0.047023*
	(0.0030)	(0.011)	(0.0082)	(0.013)
SUBST	0.000000728	–2.57617 E–6	–0.000000336	–0.00002408*
	(0.00000051)	(2.2 E–6)	(0.0000022)	(6.0 E–6)
ITQ	–0.285177	–2.638576*	0.405956	0.362150
	(0.20)	(0.66)	(0.71)	(0.67)
NUMITQ	0.482861*	2.083156*	–0.109941	0.649699*
	(0.077)	(0.27)	(0.42)	(0.37)
YBITQ	–0.000236	0.00935525	–0.017680*	–0.035061*
	(0.0040)	(0.01)	(0.0092)	(0.017)
SUBSTITQ	–0.000002097*	–0.00001012*	–0.000002176	0.000010208
	(0.00000067)	(2.8 E–6)	(0.0000027)	(7.9 E–6)
TAC	–0.000337	0.00042613	–1.019634	–0.00032009
	(0.00033)	(0.0012)	(0.63)	(0.00095)
	R^2: 0.44	R^2: 0.30	R^2: 0.33	R^2: 0.79

* Statistically significant at the 0.10 level.

signs as the OLS results, although far more coefficients were significant in the 2SLS models. For example, for both the catch and share equations, the coefficient of the independent *ITQ* variable became significant in the 2SLS regression for surf clam while the coefficients of *HP*2, *NUMBER*, *SUBST*, and *NUMITQ* became significant in the 2SLS regression for ocean quahogs. In the rest of the analysis, we will focus on the 2SLS results since the coefficients are more efficient than the OLS results.

The results for the two fisheries are similar, but there are a few important differences. There were 302 observations. The R-square for the surf clam catch and share regressions were 0.29 and 0.48, respectively. The R-square values for the ocean quahog catch and share equations were 0.79 and 0.67, respectively. Considering the short length of the time series, the limited information on costs, and the cross-section nature of the data, the R-square values can be considered high. It is important to note that because the parameter estimates represent changes in the natural log of catch (or share) given a one unit change in the independent variable, the coefficients are percentage changes in catch (or share).

The estimates of the share equations and their levels of significance differed from those of the catch equations. Hence, $\delta \ln C_T^r / \delta ITQ$ and the impact of explanatory factors on total actual industry catch can be observed as the difference between impacts on catch and share. In the surf clam fishery, six out of ten coefficients were statistically significant at the 10% level for both the catch and share equations. In

Table 4
Estimated Impacts of Explanatory Variables on the Natural Log of Owner's Share in the Mid Atlantic Surf Clam and Ocean Quahog Fishery Using OLS and 2SLS, 1988–94.

	Surf Clam		Ocean Quahog	
Variable Name	OLS Parameter Estimate (Standard Error)	2SLS Parameter Estimate (Standard Error)	OLS Parameter Estimate (Standard Error)	2SLS Parameter Estimate (Standard Error)
Intercept	–4.66*	–5.05*	–5.55*	–7.57*
	(1.05)	(1.07)	(0.77)	(1.4)
*HP*2	0.002324*	0.00405771*	0.003705	0.015517*
	(0.0013)	(0.0013)	(0.0043)	(0.0017)
NUMBER	0.197205*	0.214356*	0.574019	0.510649*
	(0.030)	(0.033)	(0.41)	(0.071)
*YB*2	0.001859	0.00320419	0.019888*	0.00997655*
	(0.0030)	(0.0032)	(0.0081)	(0.0036)
SUBST	0.000000723	3.071146 E–7	–0.000000345	–3.00554 E–6*
	(0.00000051)	(6.3 E–7)	(0.0000022)	(1.6 E–6)
ITQ	–0.172576	–0.323123*	0.413965	0.329494*
	(0.20)	(0.19)	(0.71)	(0.18)
NUMITQ	0.472164*	0.615002*	–0.112717	0.270865*
	(0.077)	(0.077)	(0.42)	(0.099)
YBITQ	–0.000572	–0.00050678	–0.017250*	–0.00689300
	(0.0040)	(0.0042)	(0.0092)	(0.0047)
SUBSTITQ	–0.000002077*	–2.91602 E–6*	–0.000002153	1.082874 E–7
	(0.00000066)	8.1 E–7	(0.0000027)	(2.1 E–6)
TAC	–0.000233	–0.00015115	–0.966268	0.00013632
	(0.00033)	(0.00033)	(0.63)	(0.00025)
	R^2: 0.44	R^2: 0.48	R^2: 0.33	R^2: 0.67

* Statistically significant at the 0.10 level.

the ocean quahog fishery, six out of ten were significant at the 10% level for the catch equation, while seven out of ten were significant for the share equation. The intercept, *HP*2, *NUMBER*, *ITQ*, *NUMITQ*, and *SUBSTITQ* were significant in the share and catch equations for the surf clam fishery. The *HP*2, *NUMBER*, *YB*2, *SUBST*, *NUMITQ*, and *YBITQ* were significant in the ocean quahog fishery for catch. In contrast to the catch equation, for the ocean quahog share equations the intercept and the *ITQ* variable became significant, while the *YBITQ* variable became insignificant. As will be seen later, these similarities and differences reflect not only the differences in the fisheries before ITQ, but also suggest differences in the ways ITQ introduction impacted production, productivity, and industrial organization.

Production and Industry Structures in the Pre-ITQ Regulatory Era

We first examine the coefficients of the production and share functions prior to the ITQ regulatory regime. In the surf clam fishery, the hypotheses that the age of the vessel is important to catch and owner's share are rejected since the coefficients of *YB*2 are not statistically significant in both equations. However, in the ocean quahog fishery, the *YB*2 coefficient is statistically significant and positive for both the share and catch equations, suggesting a positive marginal product of vessel newness and greater market share for owners of newer vessels. That is, the younger the vessels, the greater the catch and market share. The explanation for this is as follows. Despite the greater productivity of younger vessels in the ocean quahog fishery prior to ITQ introduction, many old vessels remained in the fishery. On the other hand, in the case of the surf clam fishery, where time restrictions on vessels existed, the benefits of vessel newness were negligible.

The positive statistical significance of the *HP*2 coefficient in the catch and share equations for both fisheries suggests that, consistent with expectations, using a more powerful boat increases catch and market share. The larger impacts of *HP*2 on catch and market share in the ocean quahog fishery compared to the surf clam fishery suggest greater benefit of vessel power in the ocean quahog fishery. Similarly, the coefficients of the *NUMBER* variable, which represent the marginal product of an additional vessel, are also statistically significant and positive for both fisheries. Results suggest that by adding a vessel to one's fleet, the vessel owner's catch/share of landings increase with greater percentage increases in catch and share in the ocean quahog fishery than in the surf clam fishery. This is not surprising because there were many more vessels in the surf clam fishery than in the ocean quahog fishery (133 in the surf clam fishery and 62 in the ocean quahog fishery in 1988), and, therefore, the addition of one more vessel in the ocean quahog fishery should have a greater impact.

Substitutability between ocean quahogs and surf clams was hypothesized. The hypothesis is rejected in the surf clam fishery in the pre-ITQ period, but not rejected in the ocean quahog fishery for the pre-ITQ period. Both catch and market share are adversely affected in the ocean quahog fishery when the catch of surf clam increases. Hence, while increased resource commitment to ocean quahog fishing did not affect surf clam fishing prior to ITQ introduction, increased resource commitment to surf claming reduced ocean quahog fishing. Fishing time restrictions were imposed on the surf clam fishery before ITQs were implemented. Hence, excess capacity existed to the point where ocean quahog catch could be increased without an impact on surf clam catch. An operator was only allowed to fish for surf clams at certain periods of time. Therefore, ocean quahog harvesting could be done when the operator was not allowed to fish for surf clams. The finding of nonsubstitutability in the surf clam fishery is evidence of inefficiency in the fishery prior to the introduction of ITQs. As will be seen below, the substitutability of ocean quahogs for surf clams changes after the introduction of ITQs. Finally, the coefficients of the *TAC* variable are not statistically significant in the catch and share equations for both surf clam and ocean quahog, suggesting that marginal changes in TAC do not affect industry equilibrium.

Production and Industry Structure After the Introduction of ITQs

Before examining the ways by which ITQ introduction shifted the marginal products and shares of conventional inputs, it is useful to examine first the independent noninput-augmenting effects of ITQs. In the ocean quahog fishery catch equation, the *ITQ* variable in and of itself is not statistically significant, suggesting that the ITQ system did not independently affect catch and industrial organization in the industry. However, it appears that ITQ introduction did affect industrial organization in that fishery by accentuating the effects of other explanatory variables. This hypothesis is supported by the fact that some of the interaction terms (between *ITQ* and other explanatory variables) are statistically significant. The implication of this is that the way the ITQ system worked in the ocean quahog fishery is by encouraging organizational changes that allow more efficient use of fisheries resources.

In the surf clam fishery, the *ITQ* variable is statistically significant and negative, suggesting that there is an independent negative ITQ effect. Note that the effect of ITQ introduction on surf clam production exceeds the effect in ocean quahog production. A possible reason for this is that many of the changes to the SCOQ fishery in 1990 really were changes to the surf clam fishery. The surf clam fishery was more restricted than the ocean quahog fishery prior to ITQ introduction; hence, ITQ introduction brought about more significant changes to the surf clam fishery. The fact that cross-terms were also significant in the surf clam fishery suggests the enhancement of marginal products for conventional inputs.

We now examine the cross-terms between *ITQ* and the other independent variables. The positive estimated coefficients of the (*NUMITQ*) variable in the catch and share equations for the surf clam fishery suggest that the marginal impact of an additional vessel increased significantly after the introduction of ITQs. The marginal percentage change in catch as a result of adding one boat was 0.34 prior to ITQ introduction, but increased to 2.42 after ITQ introduction. The only ways that the marginal benefit of adding a boat can be greater after the introduction of ITQs than previously are if greater effort is applied per vessel and per trip and/or if more trips are made per vessel after the introduction of ITQs. This is consistent with the fact that much of the overcapacity that existed before ITQ implementation developed as a result of restrictions on fishing time and number of trips per vessel (Wang 1995). In the ocean quahog fishery, the *NUMITQ* coefficient is also statistically significant and positive, suggesting that ITQs also shifted the marginal product of *NUMBER*.

One way to explain the results, above, is the following. Before the ITQ system was implemented, an additional vessel would allow a firm to increase surf clam landings only to a certain point due to the fact that the vessel could not necessarily be used at its full capacity due to the time and effort restrictions. These restrictions encouraged operators to keep a large number of boats in the fishery. Although the vessels were probably operating at full capacity while fishing, they were only allowed to fish at certain times, and the fishery could catch no more than the allotted quota. Because of the time restrictions, another way for a firm to obtain a greater share of the annual industry quota was to replace incapacitated vessels with larger vessels. After the implementation of the ITQ system, the number of vessels in the fishery began to shrink rapidly due to the fact that time and effort restrictions were removed. The results here suggest that greater effort and/or more frequent trips were a major impact of ITQs.

In the surf clam fishery, increases are observable in hours fishing per vessel, catch per trip, and number of trips per vessel (see table 2 and figures 1 and 2). These increases were consistent with the decomposition depicted in equations (13) and (14). The hours fished per vessel rose from 402 in 1988 to 1,400 in 1994. The surf clam catch per trip rose from 992 in 1988 to 1,149 in 1994. The number of surf clam trips per vessel rose from 23 in 1988 to 52 in 1994.

In the surf clam fishery, the interaction term between *ITQ* and the number of ocean quahogs caught (*SUBSTITQ*) is statistically significant and negative in the share and catch equations, suggesting that ocean quahogs were a substitute for surf clams after the introduction of ITQs, while they were not before ITQ introduction. For increased ocean quahog catch not to affect market share of surf clam prior to ITQ introduction, but for it to decrease surf clam catch after ITQs were introduced, it must be the case that capacity utilization was lower prior to the introduction of ITQs. The results suggest that after the ITQ system was introduced, surf clam operators had to make output decisions as to which resource to harvest because ocean quahogs started to become substitutes for surf clams. In the catch and share equations for the ocean quahog fishery, however, the *SUBSTITQ* parameter estimates are not statistically significant. Hence ITQ introduction did not impact on the effect of surf clam catch on ocean quahog catch.

The interaction of the age of vessel variable with the *ITQ* variable was not statistically significant in the surf clam fishery, suggesting that the efficiency level of older vessels did not change after ITQ implementation. However, the *YBITQ* parameter estimate in the ocean quahog fishery is statistically significant and negative.

Implied Effects of ITQs on Resource Conservation

Recall that the C_T^r (total actual industry catch) is not necessarily equal to TAC (total allowable catch) as it is conceivable that under a tradable quota situation, TAC is not optimal. Hence, to the extent that ITQ introduction could expand the difference between C_T^r and TAC, ITQs could contribute to or detract from resource conservation to the extent that conservation is enhanced by lowering catch levels below TAC.[4] Given the differences in the coefficients of the share and catch equations, it is apparent that $\delta \ln C_T^r / \delta ITQ$ is not zero and that ITQ introduction affected resource conservation. The possibility that the allowance of share tradability resulted in further resource conservation beyond that achieved via the setting of TAC below the unregulated equilibrium level has been ignored in previous studies on ITQs.

To evaluate the resource conservation implications of ITQ introduction, obtain the following from equation (15): $\delta \ln C_T^r / \delta ITQ = \delta \ln C_i^r / \delta ITQ - \delta \ln S_i^r / \delta ITQ$. The partial derivatives obtained from equations (16) and (17) suggest that

$$\delta \ln C_i^r / \delta ITQ = a_5 + a_7(NUMBER) + a_8(YB2) + a_9(SUBST) \tag{18}$$

and

$$\delta \ln S_i^r / \delta ITQ = b_5 + b_7(NUMBER) + b_8(YB2) + b_9(SUBST). \tag{19}$$

Hence, by substituting equations (18) and (19) into equation (15) one obtains

$$\delta \ln C_T^r / \delta ITQ = (a_5 - b_5) + (a_7 - b_7)(NUMBER) + (a_8 - b_8)(YB2) + (a_9 - b_9)(SUBST). \tag{20}$$

By incorporating the statistically significant parameter estimates from the regressions in equations (16) and (17), equation (20) becomes –2.32 + 1.47(*NUMBER*) – 0.000007(*SUBST*) for the surf clam fishery and 0.33 + 0.38(*NUMBER*) – 0.035(*YB*2) for the ocean quahog fishery. Hence, the elasticities of total actual industry catch with respect to *ITQ* are –5.97 (statistically significant at the 0.10 level) for the surf clam fishery and 0.294 (not statistically significant at the 0.10 level) for the ocean quahog fishery.[5] These results suggest that the introduction of tradable

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[4] Our use of the term “resource conservation” is two-fold. One follows the popular idea that lowering catch, as measured by landings, lowers fishing mortality, and hence, increases the size of the spawning stock. This presumes determinant relationships between spawning stock and future recruitment, a relationship not yet demonstrated for surf clams and ocean quahogs. In fact, TACs for these species have been predicted on the idea that there is no such observable relationship, and thus TACs are based on a mining strategy concerning rates of harvest of a nonrenewable resource. Accordingly, the second meaning of resource conservation pertains to reducing the rate of extraction in order to make a limited and possibly nonrenewable resource last longer. However, the most recent Stock Assessment Review Committee report of the Northeast Fisheries Science Center of NMFS suggests that signs of good recruitment warrant moving toward a “sustainable yield” strategy (as excerpted in Mid Atlantic Fisheries Management Council 1998; attachment 8).

[5] Standard errors were calculated for $\delta \ln C_T^r / \delta ITQ$ based on the component coefficients, and the means and variances of relevant variables.

quotas contributed, albeit marginally, to resource conservation in the surf clam fishery, but not in the ocean quahog fishery.

Conclusion

This paper contributes to the literature on ITQs by simultaneously investigating the catch, capacity utilization, resource conservation and industrial organizational changes, and the associated private and social efficiency gains that occurred in the Mid Atlantic SCOQ fishery since the 1990 introduction of the ITQ system. The approach provides an unusual mechanism for simultaneously measuring changes in capacity utilization, changes in industrial organization, and changes in resource conservation. Results show that the ITQ system was factor augmenting in both the surf clam and ocean quahog fisheries. In particular, the positive impacts of fleet size became more pronounced since the introduction of ITQs. Thus, operational efficiency is enhanced with ITQ introduction. Operational efficiency increases accrued because vessels became more fully utilized and down time was reduced. Results also suggest greater competition for resources between the ocean quahog and surf clam fisheries after ITQ introduction. Overall, ITQ introduction also increased social efficiency by resulting in further resource conservation over and beyond what was achieved by the imposition of TAC.

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