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The Effects of ITQ Management on Fishermen's Welfare When the Processing Sector is Imperfectly Competitive

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Abstract

In this paper we use a general model of imperfect competition to predict welfare changes within an open-access fishery after it transitions to individual transferable quota (¡TQ) management. Although related research has explored the effects of market power in the harvesting sector on ÍTQ performance, none has considered the implications of an imperfectly competitive processing sector. Addressing this question, we find that although fishermen should expect to gain from ITQs under perfect competition, they may suffer welfare losses if the processing sector is imperfectly competitive.

I. Introduction

Tradable property rights systems are increasingly considered by fisheries regulators as the most promising solution to the problems that often accompany open-access resource use. The potential efficiency gains from tradable property rights over the more traditional command-and-control style regulations, given that all the strict assumptions are satisfied, are well documented in both the theoretical and empirical literature (Moloney and Pearse 1979; Weninger 1998; Grafton, Squires,, and Fox 2000; Weninger et al. 2003). By introducing individual transferable quotas (ITQs) into a perfectly competitive fishery in which (1) fishermen have complete information, (2) they can interact in the permit market with zero transactions costs, and (3) the initial distribution of quotas does not affect the marginal valuation of the resource, the fishery is expected to realize an efficient distribution of fishing effort.

In tandem with the predicted efficiency gains, recent research has emphasized that fishermen, in aggregate, may achieve welfare increases as a result of ITQ management (Terrebonne 1995; Matulichatid Sever 1999; Heaps 2003; Boyce 2004). However, these potential welfare gains depend critically on the assumption that all sectors of the fishing industry are perfectly competitive and that consumers' demand is elastic. Case studies of fisheries in which these assumptions do not accurately describe the industry are ubiquitous (for a review see National Research Council 1999).

In contrast, the economics literature lacks research examining the impact of imperfect competition in the fishing industry. Love (1995) uses data from the Pacific halibut industry to test for the existence of market power in the processing sector and finds that the degree of monopsony power varies inversely with the length of the fishing season. Clark and Munro (1980) model the welfare impacts of a monopsonistic processor in a fishery, but they do not consider varying degrees of market power or the effect of ITQ management on welfare measures. A couple of studies analyze how monopoly power in the harvesting sector (fishermen amassing large percentages of quotas) may alter the environmental and economic performance of ITQs (Anderson 1991; Adclaja, Menzo, and McCay 1998). Matulich, Mittelhammer, and Reberte (1996) explore the welfare losses to processors with nonmalleable capital investments under an ITQ regime. However, no study specifically addresses the problem of introducing a property rights system in a fishery with a less than competitive processing sector.

This paper fills this gap in the literature by developing a flexible model of imperfect competition for analyzing the long-run effects of ITQ management on fishermen's welfare in the presence of an imperfectly competitive processing sector. The analysis is developed in the context of the Atlantic herring fishery but may be generalized lo any fishery exhibiting similar industry structure.

Predicting how policy-induced welfare measures change when relaxing the assumption of a perfectly competitive industry is critical for analyzing many fisheries as well as multitiered agricultural product markets in general (Sexton 2000; McCorriston 2002). Related agricultural market studies show that the existence of oligopsonyoligopoly power in the processing of foods can affect the size and distribution of welfare changes from technological innovation (Chen and Lent 1992; Dryburgh and Doyle 1995; Huang and Sexton 1996; Alston. Sexton, and Zhang 1997, 1999; Hamilton and Sunding 1997). In general, if regulators falsely assume that an industry is behaving perfectly competitively, the predicted consequences of prescribed policies are likely to be misleading.

II. Background on Atlantic Herring *Existing Regulation and the Need for Further Action*

The Atlantic herring fishery is on the verge of implementing property-rights-

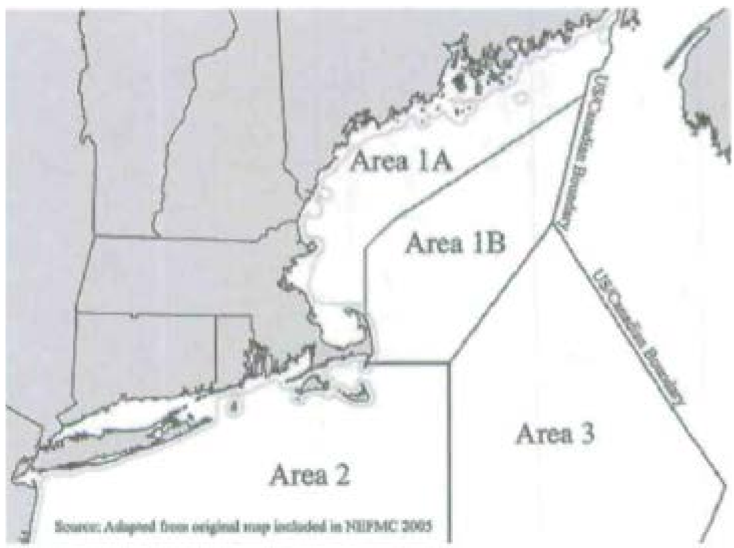

FIGURE 1
Management Area in the Atlantic Herring Fishery

based management. Since January 2000, the Atlantic herring fishery has been managed under a federal fisheries management plan developed jointly by the New England Fisheries Management Council (NEFMC) and the Atlantic States Marine Fisheries Commission (ASMFC).' The fishery is divided into four management areas (Figure 1), and the primary management tool is a cap on aggregate harvest and harvests within each area (the total allowable catch [TAC]) (NEFMC 1999).

The fishery essentially remains open access because existing regulations do not limit the number of participants. Like other fisheries that restrict aggregate harvest levels without restricting effort levels, an unbounded number of fishermen race for an unspecified portion of the herring TAC. This type of derby fishing promotes inefficiencies and potentially limits the length of the fishing season, which can disrupt herring supplies and jeopardize the overall stability of the industry (Gordon 1954; NEFMC 2005).

In response to these concerns, NEFMC and ASMFC have developed the first

TABLE I

Percentage of Total Allowable Catch (TAC) by Management Area for 2000-2004

PERCENTAGE OF TOTAL ALLOWABLE CATCH (TAC) BY MANAGEMENT AREA FOR 2000–2004

Year	Area 1A TAC = 60,000 mt % of TAC	Area 1B TAC = 10,000 mt % of TAC	Area 2 TAC = 50,000 mt % of TAC	Area 3 TAC = 60,000 mt[a] % of TAC	Total (mt) 180,000
2000	101%	75%	54%	26%	108,658
2001	89%	167%[b]	32%	70%	121,332
2002	100%	73%	22%	28%	92,594
2003	100%	50%	33%	36%	103,187
2004	100%	136%	23%	15%	94,152

Sources: Vessel trip reports from NEFMC 2001, 2005, 2006.

[a] The TAC in Area 3 was increased from 50,000 mt to 60,000 mt in 2003.

[b] The few cases in which harvest levels exceeded the quotas can be explained by inconsistencies in the two types of reports fishermen submit regarding their harvests. Fishermen continuously submit voice reports regarding their harvest amounts in each fishing area, called interactive voice reports (IVRs). The IVRs are estimated harvests, made in real time. Herring management closes areas when the reported estimated harvests reach the TACs. Actual harvests are recorded in the vessel trip report at the conclusion of a trip. In cases where the IVRs underestimate actual harvests, the TAC may be exceeded.

amendment to the 2000 management plan to "prevent excess capacity in the harvesting sector" and to "minimize, to the extent practicable, the race to fish for Atlantic herring in all management areas" (NEFMC 2005, 11-12). To address these broad goals, there is a provision within the amendment to allow an ITQ system to be implemented in the future through a streamlined public review process.

In aggregate, the statistics available on the status of the commercial herring fishery suggest little cause for immediate management action. Total harvests during 2000 to 2004 have averaged roughly only 55'^ of the fishery-wide TAC, and the herring biomass as a whole has been increasing over recent years.'' However, a different picture develops when describing the individual fishery management areas. Effort is not dispersed evenly throughout the four management areas, with the inshore area 1A having exhausted 100% of its quota in four of the five years between 2000 and 2004 (Table 1). Inshore area IB has also witnessed high harvest levels relative to the two offshore management areas, exhausting its allotted annual quota twice between 2000 and 2004. As is common in open-access fisheries with a constraint on aggregate harvest, the herring fishery has significant levels of excess capacity (Brandt and McEvoy 2006). Thus, fishermen and management continue to voice concern about the existing race to fish and the resulting inefficiencies.

Another source of concern is the increase in harvesting pressures in response to changes in the American lobster industry. As the primary source of bait for American lobstermen, the herring fishery allocates roughly 60% of its annual harvest to lobster bait. Lobsters have long remained the most lucrative commercial fishery on the eastern coast of the United States, earning annual revenues averaging over S300 million in the past five years. Although lobster harvest rates have remained relatively stable since 2000, in 2004 the fishery witnessed a *ITA* increase in the annual catch (roughly 40.000 metric tons) (NOAA 2006). The 2004 harvest, the largest since 1999, was partially driven by developments in information and shipping technologies that have enabled the fishery to meet demands outside of New England. New shipping products such as the

"Habitat Packing Solution" allow live lobsters to be shipped virtually anywhere in the world at reasonable costs (Hast Coast Seafood Company 2006).

A future swift increase in the demand for herring as lobster bait could exacerbate the already inefficient race to the fish in areas lA and IB, where the majority of herring sold as bait is harvested. Although a portion of the predicted increase in effort could take place in the offshore areas, the added costs of transport and refrigeration tied to harvesting bait in these areas would likely limit such a movement. Consequently, incentives would be created for additional capital to enter the industry, fueling the existing problem of excess capacity. Regulatory action to alleviate the problems associated with derby-style fishing is thus seen as imperative.

ITQ Management in the Atlantic Herring Fishery and the Concern for Market Power

Although an individual property rights system has been submitted under Amendment 1, not all stakeholders are supportive of this type of regulation. Processors voice concern about a drastic change in the flow of herring supply due to a change in the fishing season and its effect on their processing capacity." Herring fishermen disagree on how and to whom ITQs should be allocated, and many fear manipulation of the ITQ market by those with large holdings. Fishermen may have yet another reason for remaining skeptical concerning ITQ management-processors, market power--and it is this concern that motivates our analysis.

As mentioned previously, well over half of the total herring harvest is sold as bait to American lobster fishermen. In Maine, the state that consistently accounts for roughly 75% of annual lobster harvests, herring has long remained the bait preferred by lobstermen (NOAA 2006). The majority of herring processed as bait is channeled

TABLE 2
Volume and Percentage of Herring Sold to Bait Dealers for the Largest Four Bait Dealers in 2003

Volume of Largest Four Bait Dealers	Cumulative Percentage of Total Bait Harvest
11,793 mt	20%
8,332 mt	34%
7,451 mt	47%
5,443 mt	56%

Source: Computed using 2003 dealer data and NEFMC 2006.

through a handful of large wholesalers who then sell to smaller dealers and lobster wharfs (NEFMC 2006). The four largest wholesalers market at least 56% of the total herring harvested, each accounting for roughly 20%, 14%, 13%, and 9%, respectively (Table 2). Bait wholesalers have vertically integrated their operations in a number of ways, including producing their own ice, generating their own power, owning trucks, and performing maintenance and repairs onsite. Within the largest wholesaler operations, very few components of bait processing are outsourced (NEFMC 2005). With such a concentrated and vertically integrated bait industry, the potential for wholesalers to exercise market power in the buying of raw herring and the selling of finished bait may potentially alter the predicted benefits of ITQ management. Although only aggregate data were available, average industry input and output prices suggest imperfect competition at the processor's level. Based on NEFMC reports, in 2003 the average price paid for raw herring was $.08 per pound (calculated as a weighted average using average monthly prices and monthly quantities), the lowest price being $.05 per pound for the month of July and the highest being $.16 per pound for the month of October (NEFMC 2004). The average price per pound of barreled bait in the same period (accounting for the weight in salt) is calculated at $.27 per pound (NEFMC 2005). It is reasonable to believe the processing costs associated with rinsing, salting, barreling, and shipping would likely not explain the 330% markup.

Additionally, there is evidence of barriers preventing additional bait processors from entering the industry. First, as with many fisheries, Atlantic herring fishermen have long-lasting, close-knit relationships with their buyers (Wilson 1980: Acheson 1981. 1985). Many vessels sell their entire annual harvests exclusively to a single dealer. This relationship instigated the development of the "days-out" agreement specified in the ASMFC's management plan, which limits the number of days fishing to five per week. The regulation was first implemented and enforced cooperatively by both fishermen and buyers to extend the fishing season to ensure stability of both the lobster and herring fishery. Over time the regulation has been codified into the state's management plan but is still monitored and enforced informally by both sectors of the industry. This strong and long-term relationship can prevent outsiders from seamlessly entering and establishing clientele in the bait processing sector. An additional hindrance to entry is the physical constraint of having only a limited number of fishing ports and associated space to build a processing plant. From 2000 to 2004, an average of 56% of total herring harvests has been landed at the same three ports (NEFMC 2006). These barriers, along with the evidence of a concentrated processing sector earning significant price markups, are suggestive of the existence of imperfect competition among bait dealers.

In the next section we present a model of a fishery consisting of bait buyers, bait processors, and fishermen selling fish to be processed as bait. The model will then be used in Section IV to examine the welfare effects of implementing an ITQ system when bait processors have market power.

III. The Model

Consider a fishing industry comprised of three distinct sectors: herring fishermen, bait processors who act as middlemen in the purchase of raw herring and sale of herring bait, and lobstermen who are the final bait consumers. The single existing regulation in the herring fishery is a cap on aggregate harvest.

There are F heterogeneous herring fishermen $y = (1,2, \dots F)$ in the industry, each harvesting a homogeneous fish product. Fishermen are assumed to behave perfectly competitively, taking input prices and output prices as given. Fishermen choose their level of fishing effort to maximize

(1) $$\pi_f = f(b_j(e_j), W, c_f(e_j)),$$

where π_j is individual profit. $b_j(e_j)$ is the harvesting production function determining the quantity of raw fish supplied to the bait dealers as a function of effort, *ej* is individual effort level (e.g., days fishing), *W* is the unit price paid to fishermen for their harvest, and *cj* is the variable cost of fishing as a function of an individual's effort. We assume concavity of the production function and convexity of the cost function, which requires $b'_j(e_j) > 0,$, $b''_j(e_j) < 0, \quad c'_f(e_j) > 0, \quad \text{and} \quad c''_f(e_j) > 0.$. Solving the first-order condition for the optimal level of effort *eji W)* and substituting this term into the harvesting production function yields a fisherman/s supply curve $b_j(e^*_j(W))$.

The market supply schedule for raw fish (denoted by *B)* is the aggregation of the individual supply functions of the fishermen

(2) $$\sum_{j=1}^{F} b_j(e^*_j(W)) = B(W)$$

and is subject to the constraint that market supply must not surpass the TAC that is. B(W) <= *TAC.* In other words, the supply function becomes vertical at the TAC. On the other side of the market, *L* perfectly competitive lobster fishermen *(I* = 1.2. ... L) purchase bait as an input into their production of lobster. Each is assumed to maximize

(3) $$\pi_l = f(k_l(q_l), P, R, \mathbf{V}),$$

where ni is individual profit, $k_i(f_i)$ is the quantity of lobster harvested and sold as a function of the quantity of bait purchased as an input. *P* is the unit price of bait, *R* is the output price of lobster, and V is a vector representing the cost of other inputs. Solving the first-order condition for the optimal quantity of bait yields an individual lobsterman's demand function for bait, which, when aggregated, forms the market demand function for bait

(4) $$\sum_{l=1}^{L} q_l(P|R, \mathbf{V}) = Q(P|R, \mathbf{V}).$$

The middlemen sector consists of *M* processors *(m* = 1,2, ... M) transforming a single input—raw herring (b)—into a homogeneous output—herring bait (q). The production function for bait output is characterized by a fixed proportion technology, namely, $q_m = \min[\alpha b_m, h(\mathbf{g})]$*,* where alpha is the conversion factor between b, and q, g is a vector of other processing inputs, and h(•) may exhibit variable proportions. We include h(•) to indicate that the other inputs, in contrast to raw herring, are not restricted to being used in fixed proportions. More specifically, we assume that raw herring is transformed into bait in a one-to-one relationship, that is, $\alpha = 1$ and $q_m = b_m$. With fixed proportions, the cost function of the processor is separable into input costs and processing costs. The firm-level cost function is $W(B)b_m + C(q_m, \mathbf{Y})$, where C is the processing cost of bait and Y is the price vector of other inputs. Assuming further that there are constant returns to scale in processing, then $C(q_m, \mathbf{Y}) = c(\mathbf{Y})q_m$, where c(.) is the marginal processing cost. Thus, the profit function of a representative bait processor *m* is expressed as

(5)
$$\pi_m = P(Q)q_m - W(B)b_m - cq_m,$$

where the notation for *R,* V, and Y is henceforth suppressed. The first-order condition of the profit-maximization problem with respect to b_m is

(6)
$$\begin{aligned} &P(Q) + P'(Q)\frac{\partial Q}{\partial q_m}q_m - c \\ &= W(B) + W'(B)\frac{\partial B}{\partial b_m}b_m. \end{aligned}$$

This expression states that profit is maximized at the quantity where the representative processor equates the marginal revenue from selling an additional unit of output, less the marginal processing cost, to the marginal outlay from purchasing an additional unit of input. The expression can be rewritten as

(7)
$$P(Q)\left(1 - \frac{\theta_m}{\varepsilon}\right) - c = W(B)\left(1 + \frac{\lambda_m}{\eta}\right),$$

where $\varepsilon = (\partial Q/\partial P)(P/Q)$ is the market price elasticity of demand for bait (in absolute value) and $\eta = (\partial B/\partial W)(W/B)$ is the market price elasticity of supply for raw herring. The terms $\theta_m = (\partial Q/\partial q_m)(q_m/Q)$ and $\lambda_m = (\partial B/\partial b_m)(b_m/B)$ are the processors' conjectural variations in elasticity form for the final product and the raw input, respectively. The terms *0,,,* and /.„„ vary between zero (perfect competition) and one. When *0„,* = 1. there is monopoly power or perfect collusion in the selling of bait, and when h,„ = 1, there is monopsony power or perfect collusion in the purchase of herring. We assume identical bait processors with identical production technologies producing homogeneous products. Thus, each firm's conjectural variation is identical in equilibrium, in other words, $\theta_1 = \theta_2 = \ldots = \theta$ and $\lambda_1 = \lambda_2 = \ldots = \lambda$ (Schroeter 1988: Bresnahan 1989; Wann and Sexton 1992; Corts 1999). In this context, the industry equilibrium condition is

(8)
$$P(Q)\left(1 - \frac{\theta}{\varepsilon}\right) - c = W(B)\left(1 + \frac{\lambda}{\eta}\right).$$

which in conjunction with the market supply equation [2] and the market demand equation [4] yields equilibrium values for *P, W,* and *Q* - *B* any set of parameters and values of the exogenous variables.

IV. Welfare Analysis

In this section we compare predicted changes in fishermen's surplus when in transition from open-access to individual property rights management. This comparison is performed for perfectly and imperfectly competitive processors. The one regulation in common between open-access and ITQ management is the existence of an exogenously determined TAC. Under ITQs fishermen are guaranteed a portion of the established TAC through their transferable quotas, and fishermen will buy or sell quota until each equates its marginal benefit from fishing to the market price for the ITQ (National Research Council 1999: Grafton et al. 2000; Grafton, Squires, and Fox 2000; Weninger 2002). Thus, in contrast to the overinvestment in capital, production inefficiencies, and overcrowding externalities resulting from open-access management, the long-run equilibrium under ITQs satisfies the condition for an efficient allocation of the resource (Matulich, Mittelhammer, and Reberte 1996). Furthermore, the literature on ITQs predicts a reduction in capital and marginal fishing costs as the less-efficient vessels exit the fishery (Weninger 2002; Squires 2003). We use these results from the literature to characterize the market effects of ITQ management. Therefore, the welfare analysis pertains to harvesters active in the long run after all welfare-improving trades have been made and does not consider welfare changes during the transition to ITQs.

The ITQ-induced reduction in marginal fishing cost is captured in our model by a shift in the market supply curve for raw fish. The shift in market supply captures two fundamental effects of IT'Q management. It captures the reduction in production externalities realized when there is no longer a race to the fish, as well as the increase in fishing effort by the most-efficient vessels relative to the least-efficient vessels due to an exchange of quotas. Although it is well accepted that market supply will shift with efficiency gains in harvesting (e.g., Johnson and Libecap 1982),, there is continuous debate as to the nature of that supply shift, that is, whether the shift will take a pivotal or parallel form. A pivotal supply shift is represented by a reduction in the slope of market supply (clockwise rotation), while a parallel supply shift implies a lower supply intercept. Recognizing that the particular form of supply shift may have significant implications on welfare analyses, we follow Alston. Sexton, and Zhang (1999) and model the effect of both forms on fishermen's welfare.

To proceed with the welfare analysis, we characterize the fishery by adopting the flexible functional forms for market supply and demand applied by Alston, Sexton, and Zhang (1999). Specifically, we denote

(2a) $$B = \left[\frac{1}{\beta}(W - v)\right]^{\rho}$$

and

(4a)

$$Q = \left[\frac{1}{\delta}(a - P)\right]^{\sigma}$$

as the market supply (equation [2]) and the processor derived demand (equation [4]) lor herring, respectively. In these expressions, *B* is the quantity of raw fish supplied, W is the input price of raw fish. *Q* is the quantity of biiit demanded. /*is the output price of bait, and $a,\ v,\ \beta,\ \delta,\ \rho,$ and σ are all positive parameters. These particular functional forms are useful because simple restrictions on parameter choices allow for investigation of a few special cases. Specifically, the market supply and demand functions take on linear forms when $\rho = \sigma = 1$, square root forms when $\rho = \sigma = 2$, and quadratic forms when $\rho = \sigma = 0.5$.

Although the Atlantic herring fishery is divided into four distinct management areas, we consider the impact from ITQ management only in the areas in which the TAC is presently binding, that is, area lA and area IB. Focusing our attention on these areas in which the TAC is binding is appropriate because a binding aggregate quota is a necessary condition for an ITQ system to induce efficiency gains through trade. We assume that fishermen do not move between areas because the ITQ system proposed by herring management under Amendment 1 allocates ITQs by specific fishing areas, Trade between herring management areas must be restricted because each area has different characteristics (e.g.. stock assessments and number of participants) that require different management strategies. Restricting trade between areas is common in other fisheries, as well, and is often motivated by sociopolitical concerns as in Iceland's extensive system of ITQs.

Perfect Competition

Under open-access management, the TAC is assumed to be set somewhere between zero and the equilibrium quantity that would be realized in the absence of a quantity restriction, that is. *BTAC* ^ [Ü. *B,,,i]*- where the subscript *oa* indicates open-access

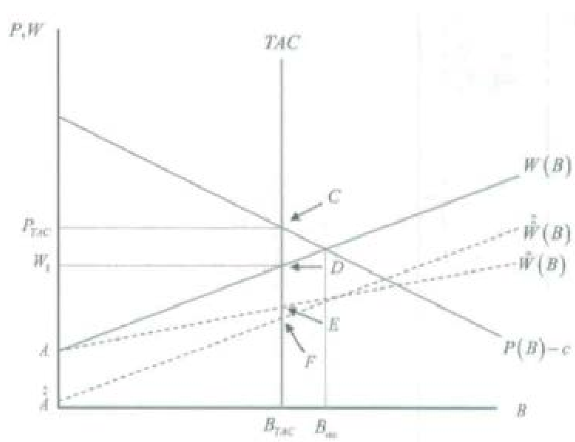

FIGURE 2

Changes in Producer Surplus after the Transition from Open-Access to ITQ Management under Perfect Competition $(\rho = \sigma = 1)$

management. Under the assumption that the TAC is binding, along with $\theta, \lambda = 0$. The equilibrium prices are determined by substituting *BTAC* into [2a] and [4a]. In other words, the price of herring is determined at the intersection of the derived demand and supply of herring, where the supply becomes vertical at the TAC. The derived demand for herring corresponds to the demand for bait shifted down by the constant marginal processing cost, *c.* The special case of linear supply and demand in which $\rho = \sigma = 1$ is illustrated in Figure 2, which depicts the market for raw herring.

In Figure 2, the solid lines represent market supply and derived demand under open-access management (i.e.. before predicted efficiency gains are realized). The vertical quota line, TAC, indicates that total harvest is binding under open-access management at *BTAC.* With a perfectly competitive fishery, fishermen harvest *BTAC* at a marginal cost of *Wi* while selling their catch at a price of *PTAC->* which is the bait price net of processing costs. Therefore, in Figure 2, producer surplus is represented by $ADCP_{TAC}$, which includes the full quota rent (i.e., area $P_{TAC}CDW_1$*).* Next we consider the ITQ-induced pivotal and parallel shifts in turn.

Pivotal supply shift. With the imposition of ITQs we model a pivotal shift in the market supply curve after ITQs as

(2b)
$$B = \left[\frac{1}{t\beta}(W - v)\right]^{\rho},$$

where 0 < t < 1. In Figure 2 the pivotal shift in market supply is represented by the dashed line *W(B).* With a binding quota, the aggregate harvest level remains fixed at ^r.-ic after the shift in market supply. Thus, fishermen will sell the same quantity of herring for the same net price *PJAC-* but producer surplus has increased due to the increase in efficiency associated with ITQs. Producer surplus under ITQ management in this case is represented by area $AECP_{TAC}$.

In Figure *2,* area *AED* represents the gain in producer surplus from an ITQ-driven outward pivot in market supply. The change in producer surplus can be expressed formally as

(9)
$$\begin{aligned}\Delta PS^{v} &= PS^{v}_{ITQ} - PS_{oa} \\ &= \beta\left(\frac{\rho}{1 + \rho}\right)B_{TAC}^{1 + \frac{1}{\rho}}(1 - t) > 0,\end{aligned}$$

where the subscripts *ITQ* and *oa* indicate individual transferable quota and open-access management, respectively. The superscript V indicates a pivotal shift in market supply. Recall that 0 < í < 1, and therefore the change in producer surplus must be positive for any specification of *p.* Thus fishermen will strictly gain from the imposition of ITQs when the industry is perfectly competitive and the TAC is binding. Equation [9] shows that larger efficiency gains for herring fishermen (i.e.. lower *t)* result in larger gains in producer surplus from ITQ management.

Parallel supply shift. Under this scenario, the effect of ITQ management is modeled as a reduction in the intercept of the market supply function for herring and is denoted as

(2c) $$B = \left[\frac{1}{\beta}(W - v + z)\right]^{\rho},$$

where z > 0. For the special linear case *{p =* σ = I), [2c] is illustrated as *W(B)* in Figure 2. As with the pivotal supply shift, because the TAC is binding before efficiency gains are realized, aggregate harvest again remains fixed at *BTAC* with the parallel shift in market supply. Thus, fishermen will sell the same quantity of herring for the same net price *Ptac* but producer surplus is now measured as *AFCptac.* The change in producer surplus is expressed formally as

(10) $$\Delta PS^{l} = PS^{l}_{ITQ} - PS_{oa} = zB_{TAC} > 0,$$

where the superscript l indicates a parallel shift in supply. Note that because r > 0, the change in producer surplus is strictly positive. Equation [10] shows that increases in efficiency (larger -) result in greater gains in producer surplus. In summary, under perfect competition fishermen are expected to strictly gain from ITQ management when efficiency gains trigger either pivotal or parallel shifts in supply. Further, the absolute size of the gain in producer surplus is a positive function of the level of efficiency (z or t).

Imperfect Competition

In this section we relax the assumption that the bait processing sector is perfectly competitive. In the absence of a binding quota, the market quantity of herring under imperfect competition would be determined where the processor's marginal revenue curve net of marginal processing costs *{MR* in Figure 3) intersects its marginal outlay curve *{MO* in Figure 3). However, because the TAC is binding in the fishery, the market quantity of herring, *B¡IAC-* falls somewhere between zero and the open-access level of harvest, *B/,,,,,* where throughout, the subscript *i* indicates values under imperfect competition. As Sexton and Zhang (1996) point out, with a perfectly inelastic supply curve the traditional industrial organization models to determine equilibrium prices under imperfect competition are not valid. That is, with a binding quota on harvest and an imperfectly competitive processing sector,

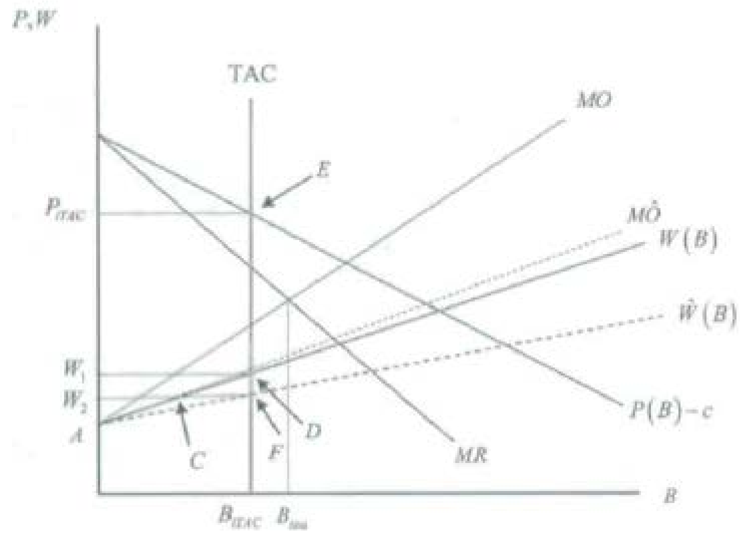

FIGURE 3
Changes in Producer Surplus after the Transition from Open-Access to ITQ Management under Imperfect Competition, Pivotal Supply Shift $(\rho = \sigma = 1)$

the division of fixed surplus between the processors and competitive herring fishermen remains undetermined. However, the herring price will be set somewhere between the perfectly competitive price (the price determined by the intersection of the derived demand and the vertical quota line) and the monopsony or perfectly collusive price (the price determined by the intersection of the supply and the vertical quota line). Where exactly in this range the price is set depends on the relative strength of processors and fishermen in determining the price (Oczkowski 1988, 1991, 1999; Gervais and Devadoss 2006).

We specify the herring price as a linear combination of the perfectly competitive price, $P(B_{iTAC}) - c$, and the monopsony price, $W(B_{iTAC})$, the quota level according to ϕ, which denotes the level of processors' strength in determining the price. Thus, the open-access equilibrium net input price is denoted as $W_{iTAC} = \phi W(B_{iTAC}) + (1 - \phi)[P(B_{iTAC}) - c]$. Note that, ϕ can also be interpreted as the share of the quota rent captured by the processors, requiring that $0 \leq \phi \leq 1$.

We expect that the lower the level of market power held by the processors (such as with a large number of processors), the further away the price of herring will be from $W(B_{iTAC})$. However, processors' strength in determining the price could also depend on other factors such as the level of information of processors relative to fishermen, the ability of processors to maintain tacit collusion, the availability of substitutes, and the exit costs of fishermen (Coff 1999).

The special case of ϕ = 1, illustrated in Figure 3, implies that processors capture the total quota rent in the fishery, that is, area W_1DEP_{iTAC} *.* In this case, the price paid to fishermen for raw herring is *W.* For all other cases in which $0 \leq \phi < 1$ the quota rent will be divided between fishermen and processors. Note that for the example illustrated in

Figure 3, producer surplus under open-access management is represented by area *ADW.*

Pivotal supply shift. An ITQ-induced pivotal shift in the supply curve, in the absence of a quantity restraint, would result in an increase in the amount of herring sold and purchased on the market. However, because the TAC is assumed binding, the rotation in the supply curve caused by the implementation of ITQs simply causes a decrease in the minimum price fishermen are willing to accept for the same quantity of herring. In Figure 3, the new market supply is denoted as *W(B),* and the corresponding marginal outlay is denoted as *MO.* Assuming $\phi = 1$ still holds, the new herring producer surplus is represented by area *AFW* in the example illustrated in Figure 3.

The corresponding change in producer surplus from the change in management is expressed formally as

$$\Delta PS_i^v = PS_{iITQ}^v - PS_{ioa}$$
$$= \beta\left(\frac{\rho}{1+\rho} - \phi\right)\left(B_{iTAC}^{1+\frac{1}{\rho}}\right)(1-t). \quad \textbf{(11)}$$

Because (1 - t) > 0 and $\beta\left(B_{iTAC}^{1+\frac{1}{\rho}}\right)$ *> 0,* whether fishermen gain from ITQs will depend on the sign of the first term in brackets in equation [11]. Note that this term will be positive, indicating a gain in fishermen's welfare, whenever $\phi < \rho/(1+\rho)$ *.* In other words, fishermen gain when the strength of processors in determining price is relatively small. It is easy to verify that if ϕ = 0, fishermen will strictly gain from the management change, whereas if $\phi = 1$ fishermen will strictly lose. The change in welfare in Figure 3 (when $\rho = \sigma = 1$ and $\phi = 1$) is the difference between the gain in producer surplus *ACF,* minus the corresponding loss W_2CDW_1*.*

Therefore, when the TAC is binding under open-access management, fishermen gain from ITQ management if processors' strength in determining price is such that they capture no share of the quota rent and lose if processors capture the quota rent in its entirety. For any situation in between, whether fishermen gain depends on both the functional form of market supply and the share of the quota rent captured by the processors. For the three special cases of linear, square-root, and quadratic functional forms of supply, the levels of processors' bargaining strength that will allow fishermen to gain from ITQ management are $\phi < 1/2,\ \phi < 2/3,\ \text{and}\ \phi < 1/3$, respectively. Therefore, the conditions necessary for fishermen to gain from ITQ management are least restrictive if market supply takes the square-root form and most restrictive under the quadratic form.

Thus we find that when the processing sector is imperfectly competitive, it is possible for fishermen to suffer welfare losses from the imposition of transferable property rights management. Considering that previous welfare analyses, as well as this one, find that fishermen gain from ITQ management under perfect competition.

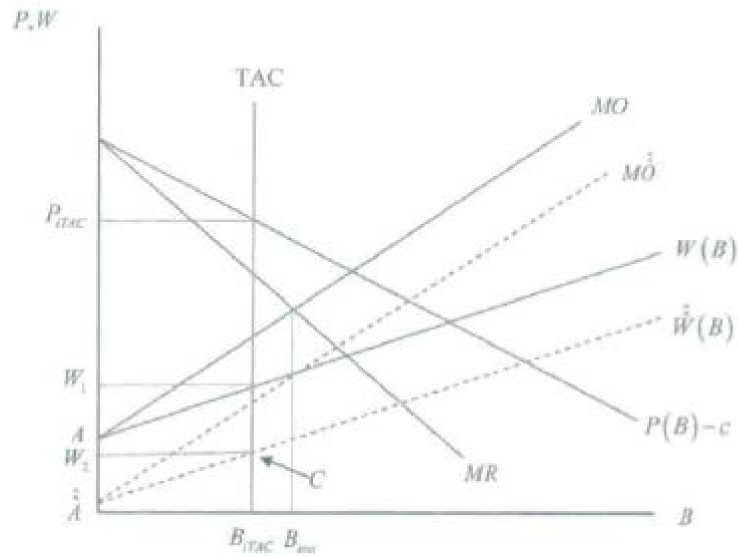

FIGURE 4
Changes in Producer Surplus after the Transition from Open-Access to ITQ Management under Imperfect Conditions, Parallel Supply Shift $(\rho = \sigma = 1)$

this is an important result. If efficiency gains from ITQs manifest themselves as a pivotal shift in supply, as is characterized in Johnson and Libecap (1982), fishermen may actually lose from the change in management, provided that processors have sufficient influence over the price of raw fish. Comparing equations [9] and [11] provides insight into evaluating ITQs in fisheries. Although in both perfect and imperfect competition larger efficiency gains (decreases in t) result in larger gains in fishermen's surplus, those gains are mitigated and potentially offset entirely by the degree of processors' strength in determining the price. Therefore, careful consideration of the market structure of the fishery, including the processing sector, is critical for prescribing good fisheries management policies.

Parallel supply shift. To complete this section, we model the long-run effect of ITQ management as a parallel shift in market supply. Again, the harvest quantity remains fixed at *BiTAC-* and the share *oï* the quota rent captured by the processors is denoted by ϕ. To be consistent with our previous illustrations, Figure 4 illustrates the special case in which $\rho = \sigma = 1 \text{ and } \phi = 1$. The new market supply and marginal outlay curves after ITQs are denoted by *W(B)* and *MÔ,* respectively. In Figure 4 the new measure of producer surplus is represented by *ACW^.* The change in producer surplus in this scenario is expressed formally as

$$\begin{aligned}\Delta PS_i^l &= PS_{iITQ}^l - PS_{ioa} \\ &= (1-\phi) z B_{iTAC} \geq 0.\end{aligned} \tag{12}$$

When efficiency gains are modeled as a parallel shift in supply, fishermen will gain (at least weakly) from ITQ management. A comparison of equation [12] with equation [10] shows that although fishermen gain from ITQ management under a parallel supply shift regardless of the bargaining strength of processors with market power, the size of their gain under perfect competition will be strictly greater. Therefore, efficiency gains alone do not determine the gain to fishermen from ITQ management because these potential gains may be largely captured by the processors.

To summarize, fishermen may actually suffer welfare losses from a pivotal supply shift when the processing sector is less than perfectly competitive. In the other three scenarios discussed, fishermen increase their welfare (at least weakly). However, in terms of absolute gains, imperfect competition within the bait processing sector plays a significant role even with a parallel shift in supply. Equation [12] demonstrates that the size of the gain in producer surplus from ITQs decreases with the processors' control over price. Therefore, the existence of market power in the processing sector is not innocuous, regardless of the nature of the supply shift. This result implies that it is important to consider the market structure of the processing sector and firms' conduct when comparing various fisheries management policies using traditional cost-benefit analyses.

V. Discussion and Concluding Remarks

Individual property rights management is often portrayed as the "silver bullet" to solving fisheries management problems. The literature on ITQs suggests two reasons for efficiency gains. First, fishermen with relatively high fishing costs will opt to sell their quotas and exit the fishery, while the remaining participants are able to fish the entire TAC at a lower total cost. Second, individual fishermen can shift to a lower cost of harvesting. Under open access with a TAC, fishermen race to catch a share of the fish, whereas under ITQs fishermen can catch their share of the TAC at their cost-minimizing rate.

While much of the economic literature on ITQs focuses on gains in the aggregate, the fundamental policy debate revolves around the distribution of these gains among industry participants. Stylized models of ITQ management predict that fishermen, as a whole, will witness an increa.sc in welfare resulting from the management change (Terrebonne 1995). However, these efficiency and welfare gains have been derived relying on the assumption of a perfectly competitive industry. In many fisheries, and in particular the Atlantic herring fishery, certain sectors of the industry show evidence of imperfectly competitive behavior. Therefore an important question remains concerning the impact of middlemen's market power on fishermen's welfare. This paper specifically addressed how fishermen's welfare changes in the long run after it converts from open-access to ITQ management in the presence of an imperfectly competitive processing sector. While the circumstances in the Atlantic herring fishery motivated this analysis, its implications are relevant to all fisheries with similar market characteristics.

Although the Atlantic herring fishery is divided into four management areas, we focused our analysis on the popular inshore areas lA and IB in which the TAC is generally binding. We explore the welfare gains to fishermen under both a perfectly and imperfectly competitive processing sector, and allow for efficiency gains to take either the form of a pivotal or parallel shift. The principal result of our study is that although efficiency increases from ITQs can generate welfare gains for fisher men under perfect competition, these gains are reduced and potentially completely offset by an imperfectly processing sector. With both parallel and pivotal shifts in supply, the magnitude of the welfare loss relative to open-access management increases with respect to the processor's strength in setting the price of bait. Moreover, in the case of a pivotal supply shift, fishermen may suffer an absolute loss in welfare relative to open-access management. The predicted increases in efficiency attainable through tradable property rights management are therefore incomplete measures of regulatory impacts because the imperfect competition in the processing sector can appropriate welfare gains.

A touchstone in the policy debate over individual tradable quotas in fisheries is the distribution of the gains and losses over participants from a rationalization of the fishery. This analysis demonstrates that while there may be efficiency gains from tradable property rights management, those gains are incomplete measures of regulatory impacts if the processing sector is imperfectly competitive. Under imperfect competition some of the efficiency gains are appropriated away from the harvesting sector. Thus, careful consideration of the market structure of the fishery is important regardless of the nature *of* the supply shift when comparing management options using traditional cost-benefit analyses.

There are three critical implications for renewable resource management that stem from this research. First, evaluations of ITQs need to incorporate the processing sector and explicitly consider market imperfections. Second, aggregate changes in efficiency or capacity utilization are not a sufficient measure of the distribution of gains from ITQ management. Third, if achieving welfare gains for fishermen is a fundamental management objective, relying on a policy of individual property rights is unlikely to generate the desired outcome under the presence of powerful market intermediaries. Thus, policy makers concerned with these imperfections should explore mechanisms to improve fishermen's bargaining position relative to processors by leveraging legislation such as the Fishermen's Collective Marketing Act of 1934.

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