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Derby Fisheries, Individual Quotas, and Transition in the Fish Processing Industry

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Abstract *Processors adapt to the pulse of landings in derby fisheries by investing in large-scale facilities capable of preserving and storing fish products. In fisheries where the pulse of landings suppresses the ability of processors to meet consumer demand for fresh product, the imposition of individual quota (IQ) systems transforms the associated fish processing industry. The cost of fresh fish processing is generally lower and more malleable than that for preserved fish, and consumers may pay a price premium for fresh product, which creates an opportunity for entry by fresh-fish processors and results in higher equilibrium ex-vessel prices. Incumbent firms are likely to experience an economic dislocation due to a diminished value of nonmalleable capital used to preserve and store fish products. Our paper generalizes and provides a modeling framework for the observed changes in the British Columbian halibut harvester/processor industry complex following the introduction of an IQ system.*

Key words Derby fishery, individual quotas, pulse of landings, fish processing, fresh fish, preserved fish, product forms, ex-vessel price, wholesale fish price, processing capital, malleability.

JEL Classification Codes Q13, Q22.

Introduction

Derby conditions in a commercial fishery can occur due to naturally occurring periods of market-ready abundance, or when harvesters lack individual quota (IQ)

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shares to a given common-pool stock of harvestable fish. In order to protect stocks, management of derby fisheries often includes season openings when commercial fishing can occur. Economic conditions in the derby fishery are best at the start of a season when those stocks are most abundant, and steadily deteriorate as harvesting depletes the available stocks. These conditions induce a race for fish, which, in turn, results in overcapitalization and a temporal compression ("pulse") of landings.[1] Fish processing firms respond to the pulse of landings with fixed capital investment in processing capacity such as freezer storage, workspace, and docks, a portion of which is likely to be nonmalleable.[2] Due to the temporal compression of landings, most of this processing capacity is used to produce preserved fish products that can be stored and sold over the remainder of the year.[3]

Analysis of the production technologies required to process different types of fish products from a given quantity of round fish inputs of a certain species or species group indicates that both fixed and variable processing costs are, in many cases, higher for preserved fish than for comparable fresh fish.[4] This is not surprising, since the processing steps for producing fresh fish products are generally common to the processing of similar fish products that undergo additional preservation steps prior to human consumption. Moreover, there is evidence that consumers value fresh fish as much as (or more than) similar preserved fish products. In this case, the necessity of preserving the pulse of landings from derby fisheries appears to suppress the market for fresh fish. If derby conditions could be eliminated, then it may be profitable for firms to transition to the processing of fresh fish products.

In recent years, many derby fisheries have been transformed through the use of IQ systems (National Research Council 1999). The question is how this change in fishery management affects the structure and performance of fish processing. Matulich, Mittelhammer, and Reberte (1996) address this issue in a model where a total allowable catch (TAC) determines the fixed annual quantity of fish that is landed and processed, and a group of homogeneous processors have each made fixed investment in capacity based on the annual pulse of landings from the derby fishery. Imposition of an IQ system with quota shares allocated to harvesters extends the time period over which the TAC is landed relative to initial derby conditions, thus changing the flow of product to the processors. Because the IQ system spreads out landings, each incumbent firm now has the capacity to process a larger share of the TAC over a given fishing season. Consequently, the total quantity of fish demanded by processors exceeds quantity supplied by harvesters at any given time in the fishing season, creating an excess demand situation that results in higher ex-ves-

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[1] The National Research Council defines a derby as a "[f]ishery in which the total allowable catch (TAC) is fixed and participants in the fishery do not have individual quotas" (1999, p. 270). It is interesting to note, however, that derby conditions occur in the California/Oregon/Washington Dungeness crab fishery even though this fishery does not have a TAC. In this case, "sex-size-season" management and biological constraints limit the annual catch.

[2] While some processing capacity may be malleable to the extent that it can be used to process or store other products, at least some capital is likely to be nonmalleable and tied to a particular species of fish in a particular regional or local fishery.

[3] Preserved fish, as the term is used here, refers to product forms that have undergone primary processing that enables them to be stored over a period of time prior to consumption. The processing of preserved fish products may involve freezing, canning, or curing (drying, salting or smoking). Rendering is another preservation method, but rendered products (oil and meal) are primarily for non-human consumption and thus are not the focus of this paper. Secondary processing results in convenience products, such as breaded fillets, that are usually sold frozen. Products from secondary processing are not directly comparable to fresh fish products, and consequently are not addressed in this analysis.

[4] As used here, "fresh" refers to fish products that have not been frozen, canned, cured, or rendered. While in some cases these may be live (*e.g.*, lobster or crab), our primary focus is on fish that have been killed and processed into products ready for human consumption.

sel prices. These higher ex-vessel prices raise processor costs and result in some processors exiting the industry. Therefore, a key implication of Matulich, Mittelhammer, and Reberte's analysis is that transforming a derby fishery by way of IQs will result in further concentration in the fish-processing sector. Considerable policy debate exists around the issue of equity concerns raised by differing effects on harvesting and processing sectors with the implementation of an IQ system.

Our model builds on the foundation provided by Matulich, Mittelhammer, and Reberte (1996) with the crucial distinction that we provide for a heterogeneous fish-processing sector made up of firms that process preserved products and firms that process fresh products. Of the various forms of preserved fish, frozen products that have not undergone secondary processing provide perhaps the clearest and most relevant comparison with similar fresh fish products for the purpose of this analysis. By temporally spreading out landings, the imposition of an IQ system reduces the extent to which the fresh fish market is suppressed, thereby allowing firms to process and sell a larger percentage of annual landings as fresh fish.

The transformation to fresh fish processing that occurs when derby fisheries are displaced by an IQ system may include incumbent processors (and the stranding of some nonmalleable capital dedicated to preserving fish), or may be driven by new entrant firms. The processing of fresh fish involves less nonmalleable processing capital than is required for the processing of preserved fish products, which eases the conditions of entry. Under competitive conditions, lower processor costs will result in higher ex-vessel prices. Unlike Matulich, Mittelhammer, and Reberte (1996) however, our model does not imply that transforming a derby fishery with an IQ system will result in increased processing industry concentration. In fact, the presence of a significant fresh-fish processing segment that can operate with lower fixed costs suggests that economically efficient production can occur at smaller output levels than for the processing of similar preserved fish products. As a result, there is the potential for *decreased* processing industry concentration if incumbent firms convert to processing fresh fish products.

Processing Sectors in a Derby Fishery

The effects of fishing derbies on harvesters and processors are well documented (*e.g.*, National Research Council 1999; Casey *et al.* 1995). As the temporal distribution of landings concentrates, processors are faced with landings in excess of the demand for fresh product. The highly perishable nature of fish products encourages fixed capital investment for preserving fish, such as freezer capacity or canning equipment.

Processing preserved fish products, especially frozen fish, involves higher fixed costs relative to fresh fish. Moreover, Montaner *et al.* (1995) find evidence of economies of scale in the production of preserved fish products, as well as evidence that less capital is required for the processing of fresh fish. In particular, they find that fish processing plants that produce preserved fish products have a cost-capacity factor that ranges between 0.50 and 0.89. Their cost-capacity factor is the exponent "x" for the function $I_1 = I(Q_1/Q)^x$, where Q is a basic plant capacity size, I is the level of fixed investment for Q, Q_1 is a larger plant capacity size, and I_1 is the level of fixed investment for Q_1. While Montaner *et al.* did not estimate cost-capacity factors for the processing of fresh fish, they found that the capital investment required to process a given quantity of fresh fish tended to be considerably less than for equivalent quantities of frozen and canned fish, fish meal, and fish protein concentrate. This is not too surprising, since fresh-fish processors need not invest in large freezers or canning or curing equipment.

There is evidence that processing preserved fish products also involves higher variable costs. The industrial sector guide to fish processing published by the United Nations Environment Program's Division of Technology, Industry and Economics and the Danish Environmental Protection Agency sheds light on variable energy inputs required to process several different fish product forms (UNEP DTIE 2001). In particular, this industrial guide indicates that substantially more energy is required to process preserved fish products. The preparation of fresh, frozen, canned, and cured products from large species of finfish all include cleaning, filleting, skinning, and trimming steps.[5] Additional processing steps are required to prepare preserved fish products, which, in turn, implies additional variable inputs. For example, of the energy inputs required for all the steps in processing frozen fish products, UNEP DTIE reports that an average of 79% is attributable to the freezing step.[6] Similarly, of the energy inputs required for all the steps in processing canned fish products, UNEP DTIE reports that an average of 69.5% is attributable to the canning step when the fillets are previously frozen, and 92.5% when canning from fresh fillets.[7] UNEP DTIE did not provide information on the energy inputs required for cured fish products, or other non-energy variable inputs. Nevertheless, the overall evidence suggests that processing fresh fish requires fewer variable inputs than similar preserved fish products destined for human consumption.

Following Matulich, Mittelhammer, and Reberte (1996), we assume that the wholesale "ex-processor" market for fish products is competitive. This might occur, for example, if processors serving a particular regional fishery compete in national or worldwide markets for processed fish products. In the case of Icelandic cod, for example, the National Research Council (1999) notes that nearly all these fish products are exported, and the wholesalers that buy this cod "have a wide range of alternative suppliers" (pp. 335–36).

Following, Matulich, Mittelhammer, and Reberte (1996), we assume that the variable cost of fish purchased from harvesters is separable from the ("non-fish") variable cost of processing this fish. Matulich, Mittelhammer, and Reberte (1996) also define net price (*NP*) to be the difference between the ex-processor wholesale price for fish products (P_{wh}), and the yield adjusted ex-vessel price for the round fish (P_{exv}). Therefore, $NP = P_{wh} - \alpha P_{exv}$.[8] The non-fish average total cost (NFAC) for processing preserved fish products is assumed to be a typical "U" shaped curve.[9]

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[5] There are exceptions. For example, some smaller species of fish, such as sardines and pilchards, may be processed whole. Some live finfish and crustaceans (*e.g.*, lobster and crab) are sold as a fresh product, the processing of which involves holding tanks and transportation to markets. Moreover, some fresh crab is sold as a whole cooked and chilled product.

[6] UNEP DTIE (2001, pp. 15–17) provides production input information for processing various types of oily fish and whitefish into frozen product. This report provides a range of high and low energy figures, in kilowatt-hours, for icing, filleting, and freezing or canning whitefish and oil fish, based on average technology deployed in Denmark, the U.S., and Africa. According to their analysis, kilowatts of electricity for freezing preserved fillets from whitefish represents between 77% and 80% of total energy, with a midpoint of 79%. For oily fish (herring), the midpoint figure is 81%.

[7] Canning is an even more energy-intensive step than freezing. If the product being canned was previously filleted and frozen (such as from imported product), the canning step represents between 68.6% and 70.7% of total electricity usage. If the product being canned was fresh fillets, the canning step represents between 92% and 93% of total energy usage.

[8] Our notation is slightly different from that of Matulich, Mittelhammer, and Reberte (1996). Note that α equals the inverse of the yield rate from the round fish to the processed fish product. For example, fish fillets may represent only 50% of the weight of the round fish, and so in this case $\alpha = 1/0.5 = 2$, implying that one must purchase two pounds of the round fish to yield one pound of the fish fillet product. Our analysis is based on comparisons of similar fresh and preserved fish products, and consequently yield rate α is the same for both fresh and preserved fish products.

[9] Neoclassical short-run average (total) cost curves first decline with quantity produced due to declining average fixed costs and possible increasing marginal returns. They then rise with quantity produced due to decreasing marginal returns.

Matulich, Mittelhammer, and Reberte (1996) assume the usual optimization result that profit-maximizing processing firms set output where the equilibrium net price (NP^*) equals non-fish marginal cost (NFMC). Moreover, they assume that competitive ("open-access") conditions result in a zero-profit equilibrium, where net price equals non-fish marginal cost where it intersects with the minimum point of the non-fish average cost curve, as shown at point "c" in figure 1.

We note, however, that due to the existence of nonmalleable processing capital, there is the potential for an entry-deterrence equilibrium at a higher net price. Nonmalleability of certain elements of processing and storage capital, such as canning equipment and frozen storage facilities may occur, for example, when fish processing plants are remote from farm and ranch lands that might provide alternative agricultural products for processing and storage.[10] The sunk costs associated with investment in nonmalleable capital can serve as an entry deterrent in the sense described by Dixit (1980). In particular, if sunk-cost investment is necessary for entry, and if incumbent firms have preexisting capacity to process the entire TAC, then the presence of positive economic profits may not be sufficient to induce entry due to the risk of losing the value of sunk-cost investment.

To see this, suppose that each incumbent firm is producing output "*Q* (pre-entry)" and receiving net price NP_{max} as shown at point "a" in figure 1. Since total processed fish output is set by the TAC, entry by a new (but otherwise identical) processor will reduce each firm's share of the TAC, but will not reduce net price NP_{max}.[11] Assume that entry by a new processing firm with identical production technology will reduce each firm's output to "*Q* (post-entry)" as indicated at point "b" in figure 1. If non-fish average variable cost ($NFAVC$) $< NP_{max} < NFAC$ at point "b", then incumbent processors, which have already made sunk-cost investment in nonmalleable processing capital, can credibly commit to continuing operations in the short run and ignore fixed cost. Knowing that entry will result in $NFAVC < NP_{max} < NFAC$, a potential entrant will have no incentive to enter because economic profits are negative and exit involves the loss of nonmalleable processing capital. Under these circumstances, an entry-deterrence equilibrium exists at point "a" in figure 1 in which incumbent processors enjoy positive economic profits. Thus, positive economic profits may persist in the long-run equilibrium configuration of a processing industry serving a derby fishery, a circumstance not addressed by Matulich, Mittelhammer, and Reberte (1996).

Transition in the Processing Sector as Harvesting Moves from Derby Conditions to IQ Management

In this section, we will consider how the transition from a derby fishery to an IQ management system affects the processing industry for this fishery. We assume that quota shares are allocated to harvesters. As before, and following Matulich, Mittelhammer, and Reberte (1996), we assume that the total quantity of landed fish is set by a fixed TAC that serves as a binding constraint on total product flow.

We make the crucial assumption that consumer preferences for fresh fish are equivalent to that for similar preserved fish products, and that there are no temporal

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[10] Moreover, malleability is reduced if the value of the capital is low relative to the cost of disassembling and moving it to locations where it can be productively employed.

[11] Recall our assumption that processors sell into a competitive processed fish market. Since entry redistributes total quantity supplied rather than increases it, there is no decrease in net price following entry.

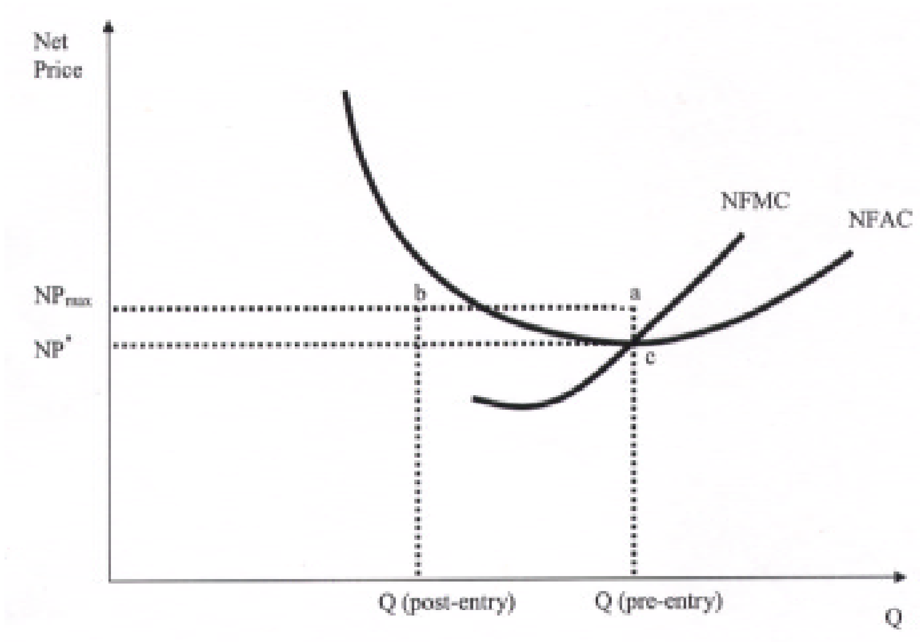

Figure 1. Equilibrium Processor Net Price and Output in a Derby Fishery

constraints that limit the supply or the demand for fresh fish.[12] There is evidence of strong consumer preference for fresh fish. According to the Food and Agriculture Organization (FAO) of the United Nations, in recent years the demand for fresh fish products has grown much faster than for preserved fish products (FAO 2000). In particular, between 1988 and 1998 the world volume of processed fresh fish products increased by 68%, which the FAO attributed to growing demand for fresh fish products. In contrast, the volume of preserved fish products increased by only 11%. Of the fish destined for direct human consumption in 1998, fresh fish was the most important product, with a share of 45.3%, followed by frozen fish (28.8%), canned fish (13.9%), and cured fish (12%).

There has been relatively limited research focused on the question of consumer perceptions of fresh fish quality relative to similar preserved fish products. According to consumer preference research conducted by Nielsen and Listov-Såbye (2003), consumers consider frozen fish to be associated with lesser eating quality than fresh fish.[13] While technological improvements, such as flash freezing on board catcher

[12] The fundamental thrust of our analysis also holds in circumstances where consumers consider fresh fish to be superior to that of similar preserved products. In other circumstances, however, we acknowledge that consumers may value the storage convenience of preserved fish products. Supply or demand constraints may restrict the fresh fish market. Supply constraints may occur, for example, when fisheries are remote from markets, and catcher vessels must utilize on-board freezing of fish to prevent spoilage in transit to markets. Demand constraints may occur when regional fresh fish markets are small relative to overall landings.

[13] Consumers in their study indicated that they only consider fish fresh within a couple of days after catch.

vessels, have improved the quality of frozen fish products; nevertheless, Nielsen and Listov-Såbye found that many consumers appear to *perceive* the quality of fresh fish to be superior, especially if the fish has only been stored a few days.

Along these same lines, in their empirical analysis of Norwegian cod product forms, Asche and Hannesson (2002) found that fresh cod was not a close substitute to other cod product forms, and argue that this "may be explained by the fact that the quality of fresh fish is often higher, especially with respect to freshness, than for input to other kinds of products" (p. 230). Moreover, an FAO report on aquaculture in East Asia indicated that consumers in the region generally prefer fresh fish products relative to preserved fish products (FAO 1989).[14]

The effect of IQ systems in extending the time period over which a given TAC is landed has several impacts on incumbent processing firms. Matulich, Mittelhammer, and Reberte (1996) noted that spreading out landings over a longer period of time allows better capacity utilization at existing processing facilities. As a result, incumbent firms can process a larger quantity of fish over the entire season, resulting in an outward shift in the non-fish average cost curve.[15] This shift in incumbent firm processing costs is shown in figure 2. As a consequence of this shift in the non-fish average cost curve, the minimum point of this cost curve occurs at a larger output level. Since all incumbent firms can now efficiently process a larger

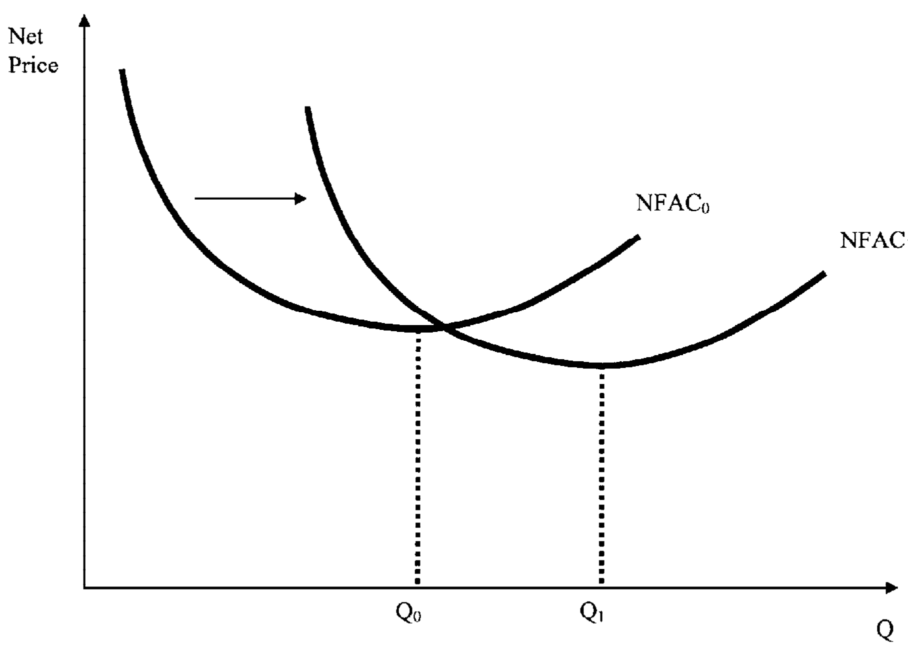

Figure 2. Implementation of Individual Quotas Temporally Spreads Landings, Allowing Better Capacity Utilization at Existing Processing Facilities

[14] In their survey of consumer preferences for fresh fish in the northeastern US, Nauman *et al.* (1995) found that ethnic and racial minorities, people over age 60, and people who live in coastal communities were the most likely to make frequent fresh fish purchases.

[15] Non-fish average costs also shift downward as well as outward due to lower average fixed costs at the higher output level.

quantity of fish, but the total quantity of fish is fixed by the TAC, Matulich, Mittelhammer, and Reberte (1996) argue that quantity of landed fish demanded by processors will exceed the quantity of fish available for processing. This increase in demand results in an increase in ex-vessel price, P_{exv}, and consequently a decrease in NP. As Matulich, Mittelhammer, and Reberte (1996) point out, the decline in NP reduces processor profits and induces exit by some incumbent processors. Thus, they note that the value of the nonmalleable processing capital of firms that exit the industry is lost, which represents an uncompensated economic cost to processors when IQ systems are implemented in derby fisheries.[16]

An implicit assumption by Matulich, Mittelhammer, and Reberte (1996), which underlies this result, is that the extended period of landings caused by the IQ system does not interfere with the processing of fish from other fisheries. In fact, Hackett *et al.* (2003) found that large, incumbent firms that process Dungeness crab in California (a derby fishery) also process shrimp, salmon, and groundfish.[17] These processors were found to have species-specific processing capital (*e.g.*, for shrimp, crab, salmon, and groundfish) that could be moved into or out of the workspace at different times of the year when other fisheries were active. The timing of this multi-species processing system may be significantly disrupted by an IQ system that extends landings into the season of other fisheries.[18] These incumbent processors may lose the "goodwill" of valuable wholesale accounts and market channels that are lost if their participation in receiving and processing fish from other fisheries is limited by an IQ system that extends landings into the season of other fisheries. The point is that these multi-species processors may not be able to process a larger percentage of the TAC if an IQ system temporally spreads out landings. As a result, there may be less of the excess demand from incumbent processors in the ex-vessel market that results in reduced processor profit, exit, and increased processing industry concentration, as argued by Matulich, Mittelhammer, and Reberte (1996).

Of more central concern to our analysis, Matulich, Mittelhammer, and Reberte (1996) do not consider the possibility that fresh fish market channels may have been suppressed due to the need to freeze or otherwise preserve the large pulse of landings from a derby fishery. In fact, as landings are spread out over time by IQ management, market channels for fresh fish are no longer suppressed, and incumbents or new entrant firms can begin processing fresh fish products. There are several possible new industry configurations in the post-derby fishery environment.

One of these industry configurations, shown in figure 3, features entry by small-scale fresh fish processing firms that require little in the way of processing capital. As shown in figure 3, the threat of entry by fresh fish processors with cost structure $NFAC_F$ that can operate efficiently at output level Q_F is not as easily deterred as under the prior derby conditions, since these new entrant processors need not invest in nonmalleable capital for preserving fish. With sufficiently low $NFAC_F$, such as that shown in figure 3, entry by fresh fish processing firms will occur. Since non-fish average costs are lower for fresh fish processing, under competitive conditions fresh fish processors will bid up P_{exv}, lowering NP_F and making it unprofitable for incumbent firms to continue processing preserved fish.

If fresh fish processing capital is largely malleable in nature, an entry-deter-

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[16] Matulich, Mittelhammer, and Reberte (1996) use this result to argue in favor of allocating quota shares to processors in IQ systems, or implementing a tax on landed fish that can be used to compensate processors that have suffered economic dislocation in the transition to an IQ system.
[17] Likewise Casey *et al.* (1995) found evidence that large, incumbent processors of British Columbian halibut also processed large quantities of salmon.
[18] Overlapping seasons induced by implementation of an IQ system can also impact harvesters that participate in multiple fisheries.

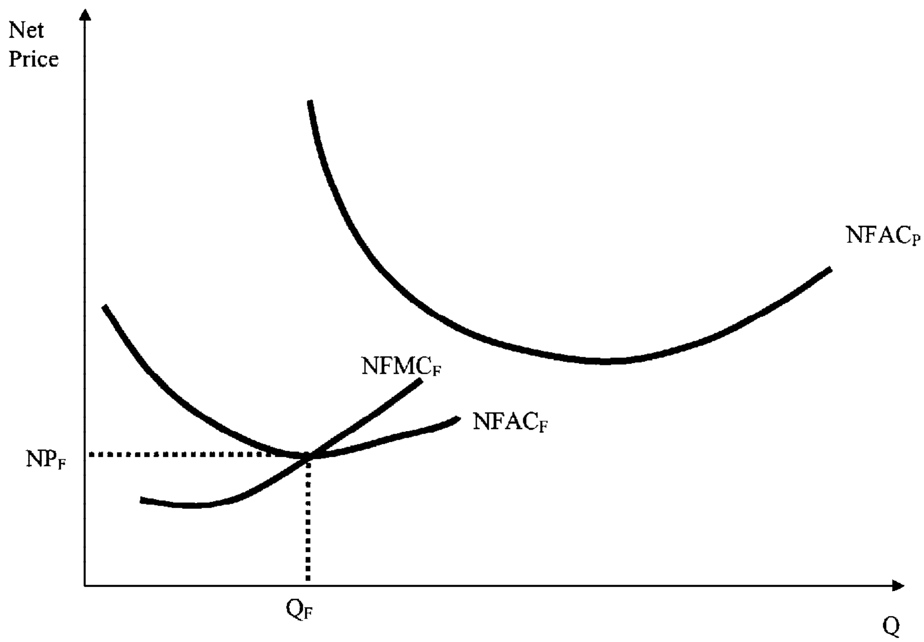

Figure 3. Implementation of Individual Quotas Temporally Spreads Landings, Expands Markets for Fresh Fish, and Results in Entry by Small-Scale Fresh Fish Processors

rence equilibrium is not possible at $NP_F > NFMC$. In this case, a new zero-profit fresh fish processing equilibrium will arise where each firm produces Q_F units of fresh fish where net price $NP_F = \min(NFAC_F)$. Moreover, this equilibrium features a larger number of smaller processing firms relative to prior derby conditions. If fresh and similar preserved fish products have equivalent consumer value, ex-processor wholesale prices will not be affected by the transition to fresh fish processing. Alternatively, if fresh fish products are perceived as having superior quality by consumers, it is likely that ex-processor prices will rise. In either case, NP_F will be lower than what would otherwise exist for preserved fish products. Net price falls in the transition to fresh fish processing due to competitive pressures in the processing industry and lower fresh-fish processing costs. Positive economic profits in the processing sector would be dissipated as fresh fish processors compete for landed fish, driving up ex-vessel prices and thereby lowering NP_F.[19]

Another possible industry configuration occurs when incumbent firms abandon any nonmalleable capital for processing preserved fish (*e.g.*, freezers, canning equipment), but are able to adapt their existing malleable large-scale workspace to the processing of fresh fish. In this case, illustrated in figure 4, incumbent firms are not displaced, and a relatively high industry concentration may persist despite fresh fish processing. An IQ system that assigns quota shares to incumbent processors

[19] Likewise the analysis by Weninger (1999) indicates that an increased number of processing firms, or an increase in total processing capacity, will result in a higher ex-vessel price in a fishery with a binding TAC. The profits created by higher wholesale prices for fresh fish will largely be passed along to harvesters in the form of higher ex-vessel prices.

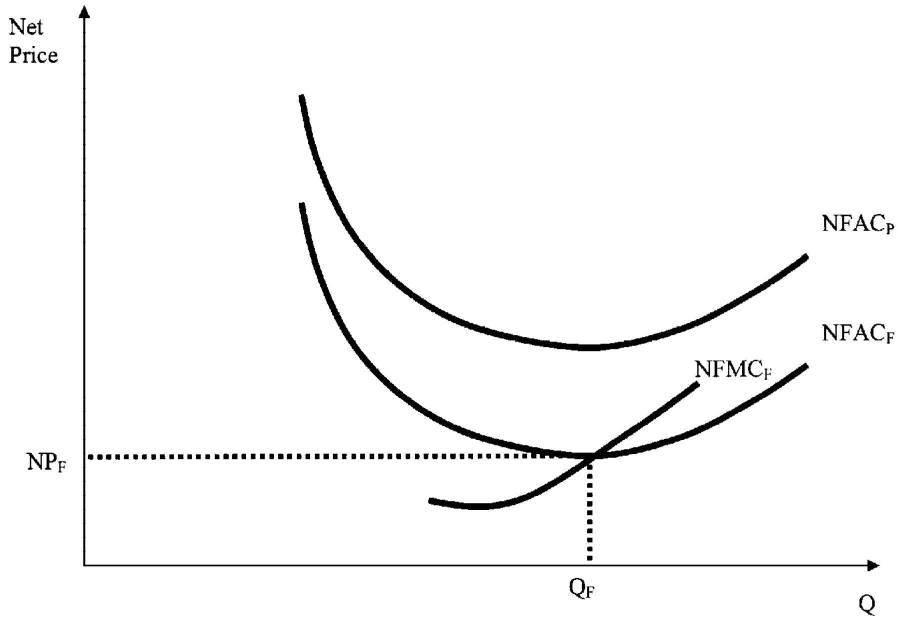

Figure 4. Implementation of Individual Quotas Temporally Spreads Landings, Expands Markets for Fresh Fish, and Results in Incumbents Redeploying Malleable Processing Capital to Process Fresh Fish at Large Scale

might contribute to this industry configuration if incumbents choose not to accommodate entry by selling quota shares to new entrants. Nevertheless lower non-fish average costs and the threat of entry will drive down net price, implying higher ex-vessel prices.

Thus in the context of our model, as with the model of Matulich, Mittelhammer, and Reberte (1996), incumbent processors experience a diminished economic value for their nonmalleable capital that is specific to processing preserved fish products, such as canning and freezing capital. This occurs because the processing of fresh fish can occur at lower *NFAC*, and under competitive conditions net price will fall below $NFAC_P$. Therefore, actual or threatened entry and lower fresh fish processing costs act in a manner similar to increased incumbent processor capacity in the Matulich, Mittelhammer, and Reberte (1996) model by increasing the ex-vessel price and consequently reducing NP_F.

The transition to fresh fish processing described in this paper relies on a number of assumptions that may not always hold. For example, we assume that consumer preferences for similar preserved and fresh fish products are equivalent. Consequently, the analysis does not apply to market niches where consumers strongly prefer preserved fish products, perhaps due to traditional product identity and greater storage convenience. Canned tuna in the U.S. illustrates this point. According to INFOFISH (2004), until very recently fresh tuna was hardly an important item in U.S. imports of fishery products. According to this report, consumption of fishery products in the U.S. was 15.6 pounds of edible meat per person in 2002, and canned tuna was the favorite seafood among U.S. consumers for a long period with a quantity that fluctuated from 3–3.5 pounds per person per year. With sufficiently strong preference for canned tuna over fresh tuna among some consumers, more expensive canning can persist.[20]

The analysis in this paper is also based on the assumption that there are no temporal constraints that limit the supply or demand for fresh fish. For example, if catcher vessels are deployed in remote areas for extended periods of time, on-board preservation (*e.g.*, curing or freezing) may be the only way to bring these products to market.

Evidence from Existing Fisheries

A number of harvesting/processing industry complexes have experienced important elements of the transformation we model, and those that have been documented are summarized in table 1. Perhaps the best-documented example is the British Columbian halibut fishery, where derby conditions were transformed by the imposition of an IQ system in 1991. In the first year under the IQ system Macgillivray (1997) notes that the halibut season was 214 days, compared to 6 days in the 1990 derby year. Macgillivray also notes that ex-vessel halibut prices increased. Herrmann (1996) reports that discussions with industry representatives indicate that a sizeable portion of that ex-vessel price increase "was due to lengthening of the fishing season, which allowed the fish to be sold fresh instead of frozen" (p. 152). In their analysis of the consequences of this transformation, Casey *et al.* (1995) found that the percentage of halibut processed into fresh product increased to 94% of annual landings in the two years immediately following imposition of the IQ system. Only 42% of total annual landings had been processed into fresh product forms in the two derby years immediately prior to imposition of the IQ system.

In terms of documenting the transformation of a processing sector following the imposition of an IQ system, Casey *et al.* provide important insights from the field

Table 1
Summary of Worldwide Research on the Effects of
Derby Reduction on the Seafood Processing Industry

Location	Fishery	Source	Ex-Vessel Price	Number of Processors	Proportion Product Fresh
British Columbia	Halibut and Sablefish	Casey *et al.* (1995)	+	+	+
Alaska	Halibut and Sablefish	NRC (1999)	+	+	+
Iceland	Cod	NRC (1999), Eythorsson (2000, 2003)	+	-	+
New Zealand, Australia	Rock Lobster	Donohue and Barker (2000)	+	+	Increased Live
Scotia-Fundy, Canada	Groundfish	NRC (1999)	+	-	+

[20] Nevertheless, cost pressures have pushed most tuna canning offshore. See Hackett (2002) for detailed information on the loss of tuna processing in California to tropical sites such as American Samoa.

that support the fundamental arguments in this paper. In particular, they note that under prior derby conditions, "substantial capital" in the form of "large freezing and handling capacity," combined with a multi-species processing strategy, led to concentration in the British Columbian halibut processing industry (p. 220). They found that following the imposition of the IQ system, "a substantial number of smaller, less capitalized firms" entered this halibut processing industry, and that the new entry "appears to be the result of a shift from a predominantly frozen [product] market to a predominantly fresh [product] market" (p. 220). They document an average increase of 21% in the number of processing firms, and argue that "[i]n a fresh [product] market, halibut buyers no longer need a large freezing/storage facility" (p. 220).

An IQ system was put into place for Icelandic cod in 1983 in response to overexploitation that had occurred due to excessive fishing effort and capacity of the fishing fleet (National Research Council 1999).[21] Commenting on the impacts of Iceland's IQ management on processing, Eythorsson (2000) states that "land based frozen fish production is in decline, while processing at sea and export of fresh products have increased during the 1990's. Consequently, the local freezing plants, mostly constructed in the 1960's and 1970's, are no longer a guarantee for employment and prosperity in the fishing communities" (p. 489). Eythorsson (2003) also notes that fresh Icelandic cod sold at a higher price per kilogram than frozen cod.

The effect of IQ systems in slowing the race for fish can also result in a growing role for the processing of live fish. For example, IQ management was introduced in New Zealand for a variety of species of finfish and crustaceans starting in 1986, and Dewees (1989) and Boyd and Dewees (1992) provide evidence of the impacts of IQs on fish handling and processing in New Zealand. By easing the race for fish, the New Zealand IQ system allowed harvesters to adopt innovative fish handling methods that improved ex-vessel value, including an increase in the quantity of live fish exported to Japan. These changes have been more recently documented by Donohue and Barker (2000).

Summary and Conclusions

Analysis of derby fisheries indicates that processors adapt to the pulse of landings in derby fisheries by investing in large-scale facilities capable of preserving and storing fish products. In fisheries where the pulse of landings suppresses the ability of processors to meet consumer demand for fresh product, the imposition of IQ systems transforms the associated fish processing industry. The cost of fresh fish processing is generally lower and more malleable than that of preserved fish, and consumers may pay a price premium for fresh product, which creates an opportunity for entry by fresh-fish processors and results in higher equilibrium ex-vessel prices.

While Matulich, Mittelhammer, and Reberte (1996) did not provide for a heterogeneous fish processing sector, in both our model and theirs the transition to IQ fishery management results in higher ex-vessel prices and economic dislocations to incumbent processing firms due to a diminished value of nonmalleable capital used to preserve and store fish products. Nevertheless, by allowing for a heterogeneous fish processing sector that includes fresh fish products, the results of our analysis indicate that the transition to IQ fishery management may lead to industry configu-

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[21] This IQ system was seen as a partial measure in response to emergency conditions in the fishery. The Fisheries Law of 1990 made the IQ system permanent, eliminated exemptions for smaller vessels, allowed the IQs to be fully divisible and transferable, and extended IQs to most all Icelandic fisheries.

rations that soften the economic dislocations to processors suggested by Matulich, Mittelhammer, and Reberte (1996). In particular, incumbent processors can redeploy their malleable capital to the production of fresh fish products. Moreover, unlike Matulich, Mittelhammer, and Reberte (1996) we find that the transition to IQ management does not necessarily lead to increased processing sector concentration. Both of these points are potentially important to policy makers sensitive to equity concerns surrounding implementation of IQ fishery management.

Large incumbent processors may be an important source of jobs and income for coastal communities. Moreover, these large, incumbent processors frequently process multiple species of fish, and thus completely displacing them with single-species fresh fish processors could also eliminate local or regional markets for other species of fish that are not normally marketed as a fresh product.

It may not always be the case that consumer demand for fresh product will be equivalent to, or superior to, that of preserved product. Convenient and storable products such as frozen breaded fillets, canned tuna, and picked meat from crab, for example, are likely to retain important shares of the overall demand for fish products.

A potential area for future research may be to investigate the impact of substantial inter-annual variation in TACs on the structure and performance of firms in an IQ fishery. Inter-annual variation in a TAC may occur due to stock fluctuations or changes in the portion of a TAC allocated to noncommercial harvest (*e.g.*, recreational harvesters, subsistence, or natural predators). The present analysis, as well as that of Matulich, Mittelhammer, and Reberte (1996) and Weninger (1999), assumes that a fixed equilibrium TAC persists indefinitely. Highly variable fish stocks (squid, salmon, wetfish) may provide an additional incentive for preserved fish processing under IQ systems because fresh fish market channels may be unable to absorb large volumes of fish in abundant years, and valuable wholesale market accounts may be lost in poor years.

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