

Market Rent Dissipation in Regulated Open Access Fisheries

By

Frances R. Homans

Department of Applied Economics
University of Minnesota
1994 Buford Ave., 217F ClaOff
St. Paul, MN 55108-6040
(612) 625-6220, fhomans@dept.agecon.umn.edu

James E. Wilen

Department of Agricultural and Resource Economics
University of California at Davis
Davis, CA 95616
(530) 752-6093, wilen@primal.ucdavis.edu

Paper presented at the American Agricultural Economics Association Meetings
Tampa Florida, August 2000

Copyright 2000 by Frances R. Homans and James E. Wilen. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

Abstract

Using a new model of markets in regulated open access resources, we illustrate the evolution of a fishery as demand for the product grows. We show that increased demand for fish in its fresh form shortens the fishing season and leads to the development of a market for processed fish. The model allows us to calculate the rent gains from rationalizing the fishery, and we show that much of the rent gains come on the market side as the season lengthens and more fish can be delivered to the higher-valued fresh market.

1. INTRODUCTION

It is probably not an exaggeration to state that resource economists have been mostly preoccupied with the production and cost structure of resource industries, to the relative exclusion of the market structure. In renewable resource economics, this “bias” may actually reflect the long intellectual influence of H.S. Gordon's [10] foundational paper on open access exploitation published in 1954. That paper laid out the theory of open access exploitation, but within a structure that purposefully ignored many of the complexities of real world fisheries. One of the assumptions made by Gordon was that prices were fixed, implying no feedback into or from the market as a fishery evolved from under-exploited to over-exploited conditions.

Over the nearly fifty years since Gordon's paper appeared, fisheries economists have focused primarily on the normative issues he raised, the most significant of which is that open access is socially wasteful, since resource rents will be dissipated by over-capacity and excessive application of inputs. This focus on the production or input side of the system led fisheries economists to propose an extensive array of policies such as limited entry programs and individual transferable quota (ITQ) programs, intended to tackle this problem of “too many inputs chasing too few fish.” The most dramatic changes in fisheries have occurred under ITQ programs, the first of which began to appear in the early 1980s. To date there are over sixty of these programs in existence (OECD, [11]), and important empirical evidence is beginning to accumulate on how significant rent dissipation is, and what kinds of efficiency-improving methods are adopted once stakeholders have a property right to the resource.

Perhaps the biggest surprise emerging in the empirical evidence from rationalizing fisheries is that the first kinds of changes adopted more often reflect alterations in the attributes of the **product** rather than reductions in **costs** or inputs *per se*.¹ While some capacity reduction generally takes place, and some inputs are reconfigured eventually, it is more often the case that revenues rise immediately in response to changes in fishing practices that deliver higher valued raw products to new market niches previously under-served under open access conditions. This market-side reservoir of potential rent gains was not generally expected

by economists, perhaps because our view of the rent dissipation process was so closely colored by Gordon's exclusive focus on excessive (production) inputs.

To better understand the role of markets in the rent dissipation process, this paper develops a relatively simple model of markets under regulated open access conditions. As has been argued elsewhere, H. S. Gordon's depiction of pure open access fisheries popularized in his 1954 paper (and subsequently by Garrett Hardin's work) has become largely obsolete since the extension of jurisdiction in 1976. Since then, most fisheries have come under the auspices of some national or multi-lateral regulatory body and hence are no longer subject to pure open access conditions. The manner in which a fishery evolves is thus no longer determined mainly by the interaction of unrestrained effort and biological capacity. Instead, what unfolds in modern fisheries is largely influenced by the nature of the goals of the regulatory agency, the regulatory instruments used, and the responsiveness of fishermen to those regulations. As has been argued recently, a different paradigm is needed to depict modern fisheries, one that gives proper recognition to the role of the regulatory sector as a determinant of the outcome under new regulated open access institutional regimes.²

In this paper, we further develop this theme, by adding a market to a model of joint industry/regulator interaction. This enables us to accomplish two tasks. The first is that we are able to characterize how changes in the market affect the regulated equilibrium. For example, we can depict how income- and population-induced growth of markets has influenced the level of over-capacity and the stringency of regulatory instruments in regulated fisheries. Second, we can also characterize how the institutional structure of regulated open access fisheries has, itself, affected the development and emergence of particular market niches. Hence we can show, for example, mechanisms by which most of the raw product in a regulated open access fishery will be diverted into lower valued product markets rather than higher valued markets. This gives us some new insights into exactly how the market-side rents that are currently being unlocked by ITQs were originally dissipated.

In the next section, we develop a model of exvessel price determination in a regulated open access fishery. The market equilibrium in this setting is complicated for several reasons. First, the harvesting season length (and conversely the length of the processed (frozen) product marketing period) is determined

endogenously. Regulators set season lengths to ensure stock safety, but based on expected capacity committed by the industry. The capacity chosen by industry, in turn, is based partly on expected exvessel prices, which are determined by the manner in which the whole marketing year is divided up between a fresh market and a frozen market period. Exvessel prices also must reflect relative demand conditions during the fresh market period and derived demand for additions to inventories. The derived demand for inventories must also reflect expectations of the market for processed product to be supplied out of storage for the remainder of the marketing year. Hence in the final analysis, total capacity, the harvesting season length, the period over which fresh fish are sold, the period over which frozen fish are sold, exvessel price paths, and inventory market price paths are all determined endogenously.

2. A MODEL OF MARKETS IN A REGULATED OPEN ACCESS FISHERY

In this model, the fishing industry is assumed to commit a fixed level of harvesting capacity, E , for the upcoming season. The regulatory authority sets the fishing season length, τ , in order to ensure that the total harvest over the season does not exceed a predetermined total allowable catch (TAC). Whole fish are landed throughout the fishing season and fishermen are paid an exvessel price P_t^{EV} . As the raw product is landed, it is allocated into either the fresh wholesale market or into the frozen wholesale market or both. Inventory accumulation for the frozen market may start at the outset of the harvest season (time 0), or may be delayed until later in the season. Once the harvest season is over (at time τ), the inventory can be sold as frozen fish until the end of the inventory dissipation period, T . The beginning and ending dates of the marketing year (0 and T) are assumed to be exogenous, but the length of the inventory accumulation period and the length of the harvest season are endogenously determined. Fishing capacity (E) and the wholesale price that prevails in the frozen market at the end of the marketing period (P_T^Z) are also determined within the model.

2.1 Industry Behavior

Firms are assumed to commit to a certain level of capacity, E , for the season. Harvest, H , is modeled as a standard density-dependent Schaefer production function of capacity and biomass, X :

$H_t = qEX_t$. Since harvest depletes the biomass by the amount of harvest, the equation governing biomass depletion during the season is³: $\dot{X} = -qEX_t$. Integrating this equation, noting that biomass at the beginning of the season is X_0 , we get: $X_t = X_0 e^{-qEt}$. Now, harvest in any period t will be:

$$H_t = qEX_0 e^{-qEt}. \quad (1)$$

Note that harvest declines as the season progresses due to the reduction in biomass resulting from fishing.

In an open access setting, the capacity level is determined by the assumption that the entry proceeds until total harvest rents anticipated over the whole season are dissipated. We write the expression for discounted seasonal rents as:

$$\pi = \int_0^{\tau} e^{-rt} [P_t^{EV} H_t - vE] dt - fE,$$

where P_t^{EV} is the exvessel price at time t , v is the daily variable cost of employing capacity and f is the fixed seasonal cost of participation per unit of capacity. Substituting in the expression for harvest and setting profits equal to zero, we get:

$$\int_0^{\tau} e^{-rt} [P_t^{EV} qEX_0 e^{-qEt} - vE] dt - fE = 0. \quad (2)$$

This equation determines (implicitly) the rent dissipating level of capacity, given other parameters and endogenous variables including the season length τ .

2.2 Regulator Behavior

We assume that regulators establish a total allowable catch (TAC) for the season, based upon a stock sustainability criterion. They then set the season length to achieve that goal in the face of capacity expectations.⁴ The season length will thus depend upon the amount of capacity in the fishery; with less

capacity, a longer season may be allowed than with more capacity. Since regulators know the production function of the fishery, or that total harvest over the season will be

$$\int_0^{\tau} H_t dt = X_0(1 - e^{-qE\tau}), \quad (3)$$

they can solve (3) for the season length that will allow total harvest to equal the *TAC*, namely:

$$\tau = \frac{1}{qE} \ln \left[\frac{X_0}{X_0 - TAC} \right]. \quad (4)$$

The above is the basic regulated open access model as discussed in Homans and Wilen [16], with the simple addition of a time varying path for exvessel prices. In the sections below, we close the model by discussing various ways to solve the equilibrium exvessel price path under a variety of assumptions about the market.

2.3 *The Market-Fresh Only*

Assume, for the time being, that the **only** market outlet for raw fish is to sell them into a fresh wholesale market. In this case, fishermen deliver raw fish to a daily market, where they are paid an exvessel price P_t^{EV} . The raw fish are then immediately resold, after a moderate amount of conversion, into a fresh wholesale market. Before proceeding, we need to reconcile the units of measurement in both the exvessel and wholesale markets. Generally, exvessel prices are paid for fish at the dock and are paid per pound of dressed (headed and gutted) fish. In contrast, wholesale prices are usually for partially processed fish (trimmed and partially butchered). We thus need to introduce a conversion or product loss factor to account for differences in the units of the product at the two levels of the market chain. For simplicity, we assume that an exvessel-to-wholesale conversion factor of k applies, so that each pound of landed weight converts into k pounds of wholesale quantity, Q^F (fresh). For example, if the conversion factor is .65, each pound of dressed weight will be converted into .65 pounds of wholesale weight. Alternatively, to obtain one pound of wholesale product, we need $(1/.65)=1.54$ pounds of landed weight.⁵

How will the market clear under these simplified circumstances? Since only fresh fish are marketed during the open harvest season, we can use the conversion factor and the expression for harvest

(equation (1)), to determine the quantity of dressed fish entering the fresh wholesale market in each period, namely:

$$Q_t^F = kH_t = kqEX_0 e^{-qEt} . \quad (5)$$

For tractability we specify an isoelastic instantaneous wholesale demand function for fresh fish:

$$Q_t^F = B(P_t^F)^{-\beta} . \quad (6)$$

Then, we can insert the periodic exvessel supply equation (5) into the demand function (equation (6)) and, expressing in inverse form, we get:

$$P_t^F = \left[\frac{kqEX_0 e^{-qEt}}{B} \right]^{-1/\beta} .$$

This is the within-season equilibrium wholesale price path. It is upward sloping since the quantity of fish landed falls as the biomass is depleted during the season. Note that the rate of increase of prices is qE/β , so that a fishery with more effort and a higher catchability coefficient will experience more steeply rising prices within the season than a fishery with low effort and/or catchability. Note also that the effort level itself is an endogenous variable that depends upon exvessel prices rather than wholesale prices. In this simplified model, exvessel prices can be found by multiplying the wholesale price by the conversion factor: $P^{EV} = kP^F$, so that the exvessel price path during this phase can be written as:

$$P_t^{EV} = kP_t^F = k \left[\frac{qEX_0 e^{-qEt}}{B} \right]^{-1/\beta} . \quad (7)$$

These exvessel prices can be inserted into the rent dissipation equation (2) and, in combination with the regulatory decision rule in (4), we have two equations [(2) and (4)] to determine two unknowns [E and τ]. In a regulated open access fishery in which the entire harvest is allocated into the fresh market, total exvessel demand over the season will equal the TAC, and the equilibrium price path that emerges will be just high enough to induce the correspondingly correct amount of capacity to harvest exactly the targeted amount over the allowed season length τ , all with zero rents.

2.4 *The Market--Fresh and Frozen*

The above scenario is straightforward and only a modest extension of the basic regulated open access model. But the implications of including a more realistic depiction of the market are more profound than in this simple model. In particular, when we close the open access model with a market sector, it becomes clear that the market is an important engine for the rent dissipation process.⁶ As the market grows, for example, more effort will be attracted to the fishery. This implies, in turn, that regulators will have to constrict seasons (or tighten other efficiency stifling regulations) in order to ensure that the TAC is not exceeded. Thus over the long run, a fishery like the one depicted here is likely to find itself backed into a shorter and shorter season. This is, in fact, what we see in many regulated open access fisheries. The classic example is the North Pacific Halibut fishery that was reduced to five-day seasons by the end of the 1980s. This case is not isolated; other examples with artificially short seasons include sablefish, salmon, and roe herring on the West Coast, and Chesapeake Bay oysters, and clams and quahogs on the East Coast. The phenomenon of increasingly compressed seasons was not predicted by the Gordon model since he ignored both market complexities and regulations in his simple open access model.

A second important implication of this depiction of regulated open access with markets is that we would expect alternative processed markets to develop in response to shortening seasons. Thus in a paradoxical way, as the fresh market grows with income and population growth, prices will rise, effort will be attracted, and the season will shrink, opening up enhanced opportunities for markets that ultimately **substitute** for the fresh market. This is also what we see in many regulated open access fisheries; namely a gradual conversion of the fishery from one serving exclusively a fresh market to one serving (almost exclusively) a frozen or otherwise processed market. In the Halibut fishery for example, virtually all fish was sold fresh over a season that lasted close to a full calendar year in the early part of the century. After a regulatory structure was introduced in 1930, seasons began to steadily shorten. By the 1950s over 80% of the product was sold into the frozen wholesale market, and by the 1980s virtually all halibut were frozen.

Modeling the possibility of a frozen or otherwise processed product adds considerable complexity to the regulated open access model. This is because, unlike the case with fresh fish, the daily market for frozen

fish must clear according to stock and flow demands for an **inventory** market. With inventories of a stored product, we can divide a typical year into a harvest season and an inventory dissipation period. In order to accumulate inventories of frozen fish to sell after the season closes, inventory holders must begin buying fish to store during the harvesting period. This implies that the exvessel market will be influenced by the joint willingness to pay of both fresh and frozen fish wholesalers. Figure 1 shows one possible configuration of harvesting and marketing activities during a typical season. As the figure is drawn, there is an initial **fresh phase** during which all of the harvested fish are sold into a fresh market. This occurs until period s , at which time some of the harvest is added to inventory in an **accumulation phase** for later sales after the season is closed. During the period between s and τ , raw fish are bid for by wholesalers serving both the fresh market and the market for additions to inventory. At the end of the harvest season at time τ , there is a third **dissipation phase** in which the frozen market is served out of accumulated inventories, a period which lasts until the end of the inventory dissipation period, T .

In the following sections, we characterize the price and quantity paths that emerge in each of the three possible marketing phases. In particular, we need to find the exvessel price path in the fresh and accumulation phases in order to express the zero rent equation (equation (2)) in terms of the four endogenous variables. We do this by deriving equilibrium exvessel prices that reflect the seasonal wholesale demands for fish, in both the fresh market and the market for inventory. These prices reflect the elimination of arbitrage opportunities between wholesalers buying for fresh and frozen markets during the fishing season, and also among wholesalers selling inventoried fish after the season is completed.

2.4.1 The Fresh Phase

As discussed above, in the phase in which all harvest flows into the fresh fish market, the wholesale and exvessel price paths increase since harvest is declining as the season progresses. Since the entire harvest flows into the fresh market in this phase, we know that total exvessel demand for fresh fish must equal total supply, or the integral of the equation for harvest (equation (1)), between 0 and s :

$$D_1^F = X_0(1 - e^{-qEs}). \quad (8)$$

2.4.2 The Accumulation Phase

We define the accumulation phase as one in which harvest is allocated simultaneously to the fresh wholesale market for immediate sale and to the frozen wholesale market for storage and subsequent sales.⁷ The exvessel price path is then determined by competition between fresh market wholesalers and frozen market wholesalers. In equilibrium, the exvessel price path in the accumulation phase will partially reflect the same markdown of wholesale fresh prices as in (7) above. Importantly, however, the exvessel price path will reflect the shadow value path of additions to inventory, which depends on the plans of inventory holders in the competitive frozen wholesale market. In an inventory equilibrium, inventory holders must be indifferent between selling their stored product at any time during the post-season marketing period. In addition, their willingness to pay during the accumulation phase buying period should reflect their expected sales prices during the post-season marketing period and costs of storage. For simplicity, we ignore holding costs other than the opportunity cost of inventories.⁸ Under these assumptions, in order for buyers to be willing to buy and hold stocks of inventory, they must anticipate that the net wholesale price will rise at a rate to cover their opportunity costs. This implies that the wholesale frozen price P^Z must rise exponentially, or

$$\dot{P}^Z = rP^Z,$$

where r is the discount rate. Integrating this equation from t to T yields the price path that must emerge in the wholesale market for frozen fish:

$$P_t^Z = P_T^Z e^{-r(T-t)}. \quad (9)$$

where P_T^Z is the choke price, or price in the last period in the marketing period. Prices must follow this path from the start of the inventory accumulation period (s in Figure 1) to the end of the inventory dissipation period, T , in order for wholesalers to be willing to hold some raw product in inventory for later sales.

Between s and τ , the shadow prices for additions to inventory must follow the same path whereas after τ , inventory holders will receive these actual prices in the wholesale market for frozen fish. The exvessel price path, then, will be a markdown of the net wholesale shadow price path⁹:

$$P_t^{EV} = kP_t^Z = kP_T^Z e^{-r(T-t)}. \quad (10)$$

During the accumulation phase, wholesalers in the fresh market must also offer a competitive price in order to obtain raw fish to serve the fresh market. If they offer an exvessel price below that offered by wholesalers purchasing for inventory, they will be unable to operate in the market. If wholesalers in the fresh market can offer an exvessel price above that determined by the inventory shadow price, then they will be able to purchase the entire harvest for the fresh market. In an arbitrage equilibrium in the accumulation phase in which both fresh and frozen wholesalers are participating, the exvessel price paid by fresh market wholesalers must equal the exvessel price paid by accumulators of inventory, and the net wholesale price for fresh fish will equal the net wholesale price for frozen fish:

$$P_t^F = P_t^{EV} / k = P_t^Z = P_T^Z e^{-r(T-t)}. \quad (11)$$

Given this price path, we can calculate the total wholesale demand for fresh fish between s and τ :

$$\int_s^\tau B [P_T^Z e^{-r(T-t)}]^\beta dt = \frac{B e^{r\beta T}}{(P_T^Z)^\beta r\beta} (e^{-r\beta s} - e^{-r\beta \tau}).$$

This is the cumulative fresh wholesale demand, given that fresh wholesalers must pay the same price that inventory holders are paying during the accumulation phase $[s, \tau]$. Converting this into landed weight by dividing by k , we get the total exvessel demand for fish destined for the fresh market in accumulation phase, namely:

$$D_2^F = \frac{B e^{r\beta T}}{k (P_T^Z)^\beta r\beta} (e^{-r\beta s} - e^{-r\beta \tau}). \quad (12)$$

The remainder of the harvest in this phase is sold into inventory and becomes inventory supply, destined for the frozen wholesale market.

2.4.3 The Dissipation Phase

During the final phase, from τ to T , there is no harvesting since the season is closed and the inventory is sold until it is fully depleted.¹⁰ Periodic wholesale demand for frozen fish is also assumed to be isoelastic:

$$Q^Z = A(P^Z)^{-\alpha}.$$

Since prices follow equation (9), the frozen sales path is given by:

$$Q_t^Z = A[P_T^Z e^{-r(T-t)}]^{-\alpha}$$

Total wholesale demand for frozen inventory is calculated by integrating this quantity between τ and T :

$$\int_{\tau}^T A[P_T^Z e^{-r(T-t)}]^{-\alpha} dt = \frac{A}{(P_T^Z)^{\alpha} r\alpha} (e^{r\alpha(T-\tau)} - 1).$$

We can get the total demand for frozen inventory in landed weight by dividing by the conversion factor:

$$D_3^Z = \frac{A}{k(P_T^Z)^{\alpha} r\alpha} (e^{r\alpha(T-\tau)} - 1). \quad (13)$$

2.3.4 Inventory Supply and Demand

The total supply of raw fish placed in inventory in the accumulation phase must equal the demand for inventory over the subsequent marketing or dissipation period. The supply of fish added to inventory is equal to the total supply of fish over the harvesting season (equation (3)) less total fresh demand in both the fresh and accumulation phases (equations (8) and (12)):

$$S^Z = X_0(1 - e^{-qE\tau}) - D_1^F - D_2^F.$$

Demand for inventory is D_3^Z , given in equation (13). Therefore, the inventory-clearing equation that must be satisfied is that $S^Z = D_3^Z$, or

$$(14) \quad X_0(e^{-qEs} - e^{-qE\tau}) - \frac{Be^{r\beta T}}{k(P_T^Z)^{\beta} r\beta} (e^{-r\beta s} - e^{-r\beta\tau}) - \frac{A}{k(P_T^Z)^{\alpha} r\alpha} (e^{r\alpha(T-\tau)} - 1) = 0.$$

2.4 Equilibrium

Now that expressions for the exvessel price paths in both phases have been developed, we can rewrite the zero rent condition (equation (2)) to include these prices:

$$\int_0^s e^{-rt} k^{\frac{\beta-1}{\beta}} \left[\frac{qEX_0 e^{-qEt}}{B} \right]^{-1/\beta} qEX_0 e^{-qEt} dt + \int_s^\tau e^{-rt} k P_T^Z e^{-r(T-t)} qEX_0 e^{-qEt} dt - \int_0^\tau e^{-rt} vEdt - fE = 0,$$

which, when integrated out gives us:

$$\frac{B^{1/\beta} (kqEX_0)^{(\beta-1)/\beta} \beta}{qE(1-\beta) - r\beta} \left(e^{(qE((1-\beta)/\beta) - r)s} - 1 \right) + k P_T^Z X_0 e^{-rT} \left[e^{-qEs} - e^{-qE\tau} \right] - \frac{vE}{r} (1 - e^{-r\tau}) - fE = 0. \quad (15)$$

This zero rent equation, together with the inventory clearing equation (14), and the regulator equilibrium equation (4) gives us three equations, expressed in terms of four unknowns: E , s , τ , and P_T^Z . The remaining equation is determined by relating the choke price to an arbitrage condition that must hold at either the beginning or the end of the inventory accumulation period.

There are two qualitatively different scenarios possible, depending upon whether the equilibrium price path for fresh fish rises faster or slower than the discount rate. Recall that the fresh fish price path rises at a rate qE/β . If this rate (with the equilibrium effort level) is smaller than r , then the shadow price path of inventory will cross the fresh fish wholesale price from below. Under these conditions, the market will be characterized by an exclusively fresh phase, an accumulation phase with both fresh and frozen inventory buyers, and then a dissipation phase, in that order. This pattern is the case that is developed above in equations (8)-(16) and it is illustrated in Figure 2. As Figure 2 shows, fresh wholesaler buyers can outbid frozen wholesalers during the first phase. In the second (accumulation) phase, inventory buyers pay the shadow price of additions to inventory and some raw product goes into each of the fresh and frozen markets.¹¹ To the equilibrium equations (4), (14), and (15), we add:

$$k^{\frac{\beta-1}{\beta}} \left[\frac{qEX_0 e^{-qEs}}{B} \right]^{-1/\beta} = k P_T^Z e^{-r(T-s)}, \quad (16)$$

which enables us to find s , or the date at which inventory accumulation begins. This equation requires that the exvessel price paid by fresh market wholesalers for the last unit purchased in the exclusively fresh phase is just equal to the price paid for the first unit of raw product purchased for inventory.

The other pattern of market sequences arises when the fresh fish market price rises faster than the discount rate, in which case the shadow price path for inventory will cross the fresh fish price from above as in Figure 3. In this scenario, the market will be characterized by a pattern involving an accumulation phase in which raw fish are allocated to both wholesale markets, an exclusively fresh phase, and a dissipation phase, in that order. In this case, frozen wholesalers establish the price in the first (accumulation) phase and some raw product is allocated to both fresh and frozen wholesale markets. Buyers for the fresh market must pay the inventory shadow price; again the dotted line shows what they could pay if all landings were devoted to the fresh market (at the equilibrium effort level). In the second phase, fresh wholesale buyers can pay more than the shadow price of inventory and hence they receive all the raw product. The lighter black line indicates the amount frozen wholesalers could pay, but they are outbid in the second phase.¹² The analytics of this scenario require straightforward modifications in (14) and (15), and then (16) gives the date s at which the accumulation period ends¹³. *A priori*, it is difficult to tell which sequence of markets should prevail in any situation. Different combinations of parameters will lead to different qualitative scenarios.¹⁴ Thus we turn in the next section to a calibration to conditions in the North Pacific Halibut fishery based on explicit parameters drawn from various sources.

3. AN APPLICATION: THE NORTH PACIFIC HALIBUT FISHERY

The system developed above to describe the workings of the exvessel and wholesale markets in a regulated open access fishery is complicated and difficult to examine using simple analytical methods such as comparative statics. In particular, there are several kinds of qualitative equilibria possible, with a range of interior (and corner) solution outcomes depending upon parameters in the harvesting, regulator, and marketing components. Moreover, the regime and the order of the marketing, accumulation and dissipation phases depends upon which of two regimes one is in, and the equilibrium regime is itself endogenous.

In order to explore some of the model's predictions, we calibrate it using parameters drawn from data and analysis of the North Pacific Halibut Fishery. This fishery has been described and analyzed elsewhere, but the important point for our purposes is that it fits the structure outlined in the model presented here almost exactly. First, it has been managed from 1930 until very recently primarily with season length controls. Second, regulators set TACs on a year-to-year basis in accordance with implicit and explicit goals designed to ensure that the biomass is kept at a safe level. Third, the market consists primarily of a fresh and a frozen market. In the frozen market, raw fish are inventoried and removed during the marketing season and sold into higher levels of the marketing chain.

The halibut fishery has exhibited a long history of interesting and hitherto relatively unexplored interactions between the market and the fishery.¹⁵ During the early periods of the fishery's development (1890-1920), the fishery was conducted year long under completely open access conditions and most fish were sold into local fresh and moderately processed markets. In the 1920s, rail completions and refrigerated shipping opened up eastern markets and resultant high prices continued to draw in effort and deplete stocks. After a decade of negotiation, the U.S. and Canada agreed in 1930 to jointly manage the fishery, using scientifically determined TACs designed to rebuild the stocks to healthy levels. The success of the rebuilding program attracted entry throughout the 1930-1960 period, and this was met with steadily reduced season lengths, falling to less than two months in the 1950s. During the 1960s and 1970s, world demand for fish boomed, fueling price increases and pressures on most stocks, regulated or not. In the halibut fishery, frozen markets continued to expand, fueling further effort increases and further shortening of the seasons. By the 1970s, markets had strengthened and capacity has risen so dramatically that harvesting seasons had been reduced to a week or less.

Using data described in the Appendix, we calibrated our conceptual model to illuminate some of the history of the halibut fishery. The simulations reported simulate the role of the evolution of market forces that served as prime drivers of the steady and self-reinforcing progression of the fishery into the final stages of the 1970s. Table I shows a regulated open access fishery in its very early stages, characterized by a reasonably long season, modest amounts of effort, and an exclusively fresh market. In the first row, the

fresh market is of modest size and the rent dissipating capacity is just enough to catch the TAC in a twelve-month period. As the fishery matures, markets are developed and there is growth of the fresh market, driven by income and population growth and transportation/handling innovations. These changes are depicted by a shift in the wholesale demand curve, the implications of which can be seen in subsequent rows.¹⁶ The result of this evolution of the market is predicted by the simulations, so that as fresh demand rises, exvessel prices also rise, attracting more effort to dissipate the potential rents that grow as the market expands. Unlike the pure open access Gordon model (which would predict a lower open access biomass level with higher prices), the regulated open access model predicts that biomass remains fixed by regulatory actions while the primary effects are displayed in growing capacity and a season length that progressively falls over time.

At some point in this pattern of effort growth and shorter seasons, it becomes profitable for a wholesale processed market to emerge. In particular, with a larger and larger fraction of the year left with no fish as the fresh market is compressed, it eventually pays to buy fish for storage and sales during the post-season period. Table II depicts this scenario by a gradual shift of wholesale frozen demand. We assume that frozen demand is more elastic than fresh demand, and that the market is initially dominated by the existing strong fresh market.¹⁷ But as marketers focus attention on building the frozen market, the demand for frozen increases. As can be seen in Table II, this opens up an inventory market in which some raw product is stored for later sale. The parameters of the halibut case generate a sequence of markets in which there is an accumulation phase in which both fresh and inventory wholesalers buy raw product as soon as the season opens. For example, in the second row, inventory accumulation takes place until period 1.79, at which time inventory wholesalers can no longer compete against fresh buyers. The exclusively fresh market then lasts from period 1.79 until the end of the season at 3.46, at which time the frozen product is dissipated out of inventory. With such a small frozen market initially, most of the important market activity is still in the fresh market; 98.48% of the harvest is sold fresh, split roughly evenly between the accumulation phase and the exclusive fresh phase. As the frozen market begins to grow, exvessel prices rise, effort is attracted, and the season length is reduced.¹⁸ At some point (here when the scale parameter for the frozen market reaches

0.5) the whole season is characterized by an accumulation phase in which both fresh and frozen buyers are buying in an arbitrage equilibrium.

Over the long run, the frozen market continues to grow, fueled by population and income growth and market development. This market growth leads to a continuation of the process exhibited during the all-fresh market phase, namely a situation in which the season length is progressively shortened as the new market grows. Hence we see, for example, the season dropping from three to two and finally to one month as more and more effort is attracted. By the time the frozen market has reached the stage depicted in the final row, the bulk (74.09%) of the raw product is frozen, stored, and dissipated out over a marketing period that lasts nearly a year (10.27 months). This mechanism thus reveals another mostly ignored source of rent dissipation associated with open access. In particular, even when fresh markets yield higher wholesale prices, *ceteris paribus*, the evolutionary forces associated with market growth sow the seeds of their own destruction in a regulated open access fishery. In the early phases, as fresh markets grow, they induce regulatory counter-reactions (shorter seasons) that open up preconditions for markets for processed commodities that may be inherently inferior uses of the raw product. The process is self-reinforcing, since shorter seasons cause more marketing resources to be shifted into processed market development, hastening the constriction of the season. Eventually, with very short seasons, most of the product must be allocated to the frozen market, even if it would yield more revenues when spread over a longer period in the fresh markets.

In summary, the analytical model and the simulations developed here depict both the qualitative and the quantitative forces at work in the halibut fishery over the last 70 years to a reasonable level of accuracy. More generally, the model shows mechanisms by which the market both drives and reacts to changes in a regulated open access fishery. As we have demonstrated, market growth drives the rent dissipation process by raising prices and bidding up raw product values. But when effort enters a regulated open access fishery, it will be met by regulatory reactions, and these may influence the impact of market growth and set the process off in new path-dependent directions. For example, as fresh markets grow, they will attract entry and force regulators to restrict the season. But as the season is reduced, the window opens for the evolution

and development of processed markets. Processed markets may then take over as drivers of the system in a self-reinforcing spiral towards the ultimate absurdity witnessed in many modern fisheries, namely an intense artificially short season in which all the product must of necessity be devoted to lower end value processed uses. This product conversion to low valued end uses is thus another source of rent dissipation associated with open access. Since market losses have been largely ignored by most fisheries economists, it is not clear how the magnitude of these kinds of losses compare with the excessive production input losses that Gordon focused on in his influential 1954 article. It is likely, however, that we are underestimating the potential waste from open access by focusing exclusively on production efficiency losses.

4. CONCLUDING REMARKS

Among natural resource economists generally, and among those who study renewable resources specifically, there has not been much attention paid to resource output markets.¹⁹ This is in contrast to what we see in agricultural economics, where there is a long-standing tradition of more evenly balanced interest in production and marketing topics related to food production. We have suggested a reason for this in the case of fisheries economics; namely an intellectual tradition heavily influenced by H. S. Gordon's early paper on open access exploitation, which downplayed the market in order to focus on distortions in production inputs and output supplies

Whatever the reasons for the lack of formal attention, the relative neglect of the output market in studies of renewable resource systems has led to some important misreading of market failures, some incomplete or even faulty policy advice, and probably some misapplication of intellectual energy. As we have pointed out, by missing the importance of the output market to the rent dissipation problem in fisheries, we have failed to appreciate exactly what has been happening in the important test cases of fisheries rationalization with individual transferable quotas (ITQs). Much of the initial rent generation in these cases has emerged from reconfigured product markets rather than reconfigured input combinations. Whether this will generalize across many fisheries is an interesting question, as is the question of whether, in the long run,

input cost saving rents will catch up to output market rents. But what is needed, and what we take a first cut at in this paper, is a clearer depiction of how markets operate in regulated open access settings.

The model presented here is very stylized, in the sense that the fishing technology, regulatory structure, and market are all depicted under simplified assumptions. The only regulatory instrument assumed in play is the choice of season length, and the only two markets are a fresh and frozen market. At the same time, these assumptions are mostly adequate to cover a large fraction of the world's fisheries. They also illustrate the manner in which regulations, technology, industry behavior, and market structure simultaneously affect the structure and evolution of fisheries.

Our results show why we observe many of the most important and valuable fisheries backed into a situation of extreme excess capacity, short seasons, and inferior products, even in the face of worldwide growth in protein demand. In particular, the growth in output markets provides the engine for rent dissipation, which ultimately manifests itself in both wasted inputs and inferior output product mix. The model predicts that, over time, an increasing fraction of raw product will be devoted to processed products. The mechanism for this is subtle, because it is partly driven by regulatory reactions to increased fishing capacity. As exvessel prices rise, capacity enters, and this capacity must be stifled by shortening the season. Shorter seasons, in turn, reduce the opportunity to sell into the fresh market and increase the need to hold raw product in inventory to sell into inferior markets later in the year. This is a positive prediction, of course, with normative implications related to the social welfare losses due to the waste. But it also suggests some hypotheses about where we might expect to find large market losses *vis a vis* excess capacity costs.

In addition, the model can be used to show what can happen once a regulated open access resource is rationalized with an instrument like ITQs. It is possible to run the model "backward" from the end point of the scenarios in Tables I and II depicting regulated open access equilibria with short seasons. Suppose that property rights are created by dividing the TAC into ITQs and distributing them to original participants. In this case, the harvesting season length would almost immediately stretch to the full year, and quota holders would plan the timing of harvests over the year to achieve the highest possible exvessel prices. If this can be achieved by allocating a more even and smaller average monthly flow to the fresh market, then

raw product would be diverted from frozen to fresh markets. This, in fact, happened almost immediately in British Columbia when their portion of the halibut fishery came under ITQs in 1993.²⁰ For the parameters we use in the simulations here, Table III shows what is predicted to happen. We begin with the regulated open access conditions depicted in the final row of Table II, in which the fishery has attracted 85 thousand units of gear, operating over a season of less than 2 months, selling 74% of the product out of inventory as a frozen commodity. As can be seen, there are two important consequences of rationalization. The first is as predicted by Gordon, namely a reduction in the need for the excessive inputs attracted under open access. We see, for example, total discounted yearly input costs falling from 93 million dollars to 20 million dollars, mainly through a reduction in redundant fixed costs associated with excessive vessels. Variable costs fall slightly, but the total variable costs represent costs associated with fewer units being used over a longer period. The other important consequence of rationalization is the gain in revenues, as the raw product is diverted back into the more valuable fresh market. With the parameters used here, the estimated market gains are associated with revenues rising from 93 million to 174 million dollars annually. Importantly, the gains in market rents are equal or even slightly larger in size relative to the cost savings induced by input reduction.

The initial “impact effect” of rationalization no doubt understates the longer term effect because we would likely see new development of fresh marketing niches, essentially re-creating opportunities in the fresh market that would have been dormant under short seasons. This occurred when British Columbia adopted ITQs in their halibut fishery in 1993. Prior to ITQs, the BC halibut fishery was conducted over a five-day season, with most fish sold into frozen inventory and parceled out over the subsequent marketing season. Interviews with marketers after ITQs were adopted revealed that the fresh market network grew as wholesalers opened up new sales opportunities for fresh fish that had never been served before. As one wholesaler put it: “when ITQs were first adopted, fresh fish prices would drop dramatically as soon as 100,000 pounds per week were landed. After two years, however, the fresh fish market could absorb 800,000 pounds per week before prices began to drop.”

This kind of innovation in the product market in response to rationalization makes it even more difficult for analysts to forecast what might happen under discrete changes in property rights. The task is more difficult because fishing technology choice and the market are inextricably intertwined. For example, when New Zealand converted its mixed inshore trawl fisheries to species-specific ITQs in the 1980s, some fishermen completely switched gear types and fishing practices in order to access new market opportunities made possible by the slower-paced fishery. The snapper fishery is an oft-cited example in which fishermen holding rights switched away from trawl toward long line gear. This was done in order to target certain sizes to sell into the lucrative Japanese live fish trade and fishermen reportedly were able to triple their revenues. Interestingly, however, it is generally **more** costly to harvest with long line gear. This kind of change in response to rationalization would be completely missed if one were expecting, a la H.S.Gordon, a simple decrease in inputs in response to rationalization.

If there is any central lesson to be learned from these kinds of empirical cases it is that naïve extrapolations based on, for example, econometric estimation of technology in use before rationalization may be inappropriate for forecasting the kinds of changes we might expect under discrete changes in property rights. When one considers that market rent dissipation may be just as important as input inefficiencies in conditioning technology and behavior, it becomes clear that the unraveling of a system bound up by controls and distortions can take unanticipated turns. An analyst trying to forecast the impacts of implementation of ITQs in New Zealand, for example, might wade in armed with data and flexible functional forms and sophisticated duality models that fit mixed trawl fisheries in hindsight just fine, only to discover that there are no trawl fisheries remaining after ITQs. These kinds of discrete process shifts are difficult to forecast under any circumstances, of course. What this paper suggests is that analysts ought to be aware of the possibility as regulated open access fisheries are rationalized, because rent dissipation and distortions on the marketing side of the ledger may be as important as distortions on the production or cost side of the ledger.

Table I: Market Exclusively Fresh

Fresh Market	Season Length	Capacity	Exvessel Price at 0	Exvessel Price at τ
--------------	---------------	----------	---------------------	--------------------------

Scale Parameter					
B	τ	E	P_0^{EV}	P_τ^{EV}	
1.66	12.00	12.21	0.34	0.39	
2	10.71	13.69	0.36	0.41	
3	8.41	17.42	0.42	0.48	
4	7.13	20.58	0.47	0.54	
5	6.28	23.35	0.51	0.59	
10	4.29	34.16	0.68	0.78	
15	3.46	42.38	0.81	0.93	

Table II: Growth of Frozen Market

Fresh Market Scale Parameter	Frozen Market Scale Parameter	Inventory Accumulation End Period	Season Length	Capacity	Exvessel Price at 0	Exvessel Price at τ	Percent Frozen	Percent Fresh between s and τ	Wholesale Price at T
B	A	s	τ	E	P_0^{EV}	P_τ^{EV}			P_T^Z
15	0	0.00	3.46	42.38	0.81	0.926	0.00%	100.00%	1.05
15	0.1	1.79	3.43	42.72	0.85	0.919	1.52%	46.72%	1.10
15	0.2	2.51	3.40	43.06	0.86	0.912	2.99%	25.68%	1.11
15	0.3	3.05	3.38	43.41	0.87	0.906	4.44%	9.53%	1.12
15	0.5	3.32	3.32	44.10	0.88	0.909	7.30%	0%	1.14
15	5	2.35	2.35	62.28	1.18	1.211	52.38%	0%	1.53
15	10	1.73	1.73	84.81	1.56	1.586	74.09%	0%	2.02

Table III: Rents Under Rationalization

	Optimal	Regulated Open Access
Fixed Costs	12.22	84.81
Variable Costs	8.29	8.72
Total Costs	20.51	93.53
Revenues	173.95	93.53
Profits	153.44	0.00

APPENDIX

Parameter	Value	Source
Biomass	440	Implied equilibrium biomass from the quota rule target, combining Areas 2 and 3. Homans and Wilen [16]
Quota	60	Implied equilibrium quota from the quota rule target, combining Areas 2 and 3. Homans and Wilen [16]
Fixed Cost (F)	1	Estimated fixed cost for Area 2 Homans and Wilen [16]
Variable Cost (V)	0.06	Estimated variable cost for Area 2. Homans and Wilen [16]
Frozen Elasticity (α)	1.5	Herrmann [14] has an import own-price elasticity of 1.68. Homans and Wilen [16] estimate 1.16 at the means
Fresh Elasticity (β)	1.1	
Catchability Coefficient (q)	0.001	Estimated catchability coefficient for Area 2. Homans and Wilen [16]
Discount Rate (r)	0.01	Implied monthly discount rate, from a 12% annual discount rate
Conversion Factor (k)	0.87	Reported conversion factor from dressed weight (headed and gutted) to blocks, fillets, and steaks (Dept. of Commerce [23])

REFERENCES

1. R. Arnason, The Icelandic individual transferable quota system: A descriptive account, *Mar. Resour. Econom.*, **8**(3): 210-218 (1993).
2. K. E. Casey, C. M. Dewees, B. R. Turriss, and J. E. Wilen, The effects of individual vessel quotas in the British Columbia halibut fishery, *Mar. Resour. Econom.* **10**(3), 211-30 (1995).
3. C. Clark and G. Munro, Fisheries and the processing sector: Some implications for management policy, *Bell J. Econom.* **11**(2): 603-616 (1980).
4. J. Crutchfield and A. Zellner, *Economic Aspects of the Pacific Halibut Fishery*, U. S. Dept. of Interior, Bureau of Commercial Fisheries, U.S.GPO (1962).
5. J. Eales, C. Durham, and C. Wessells, Generalized models of Japanese demand for fish, *Amer. J. Agr. Econom.* **79**(4): 1153-1163 (1997).
6. J. R. Gauvin, J. R. Ward, J. M. Burgess, and E. Richardson, Description and evaluation of the Wreckfish (*Polyprion Americanus*) Fishery under individual transferable quotas, *Mar. Resour. Econom.* **9**(2): 99-118 (1994).
7. G. Geen and M. Nayar. Individual transferable quotas in the Southern Bluefin Tuna fishery: An economic appraisal, *Mar. Resour. Econom.* **5**(4), 365-87 (1988).
8. D. V. Gordon and R. Hannesson. On Prices of fresh and frozen Cod fish in European and U. S. markets, *Mar. Resour. Econom.* **11**(4): 223-238 (1996).
9. D. V. Gordon, K. Salvannes, F. Atkins. A Fish is a Fish is a Fish? Testing for market linkages in the Paris Fish Market, *Mar. Resour. Econom.* **8**(4): 331-343 (1993).
10. H. S. Gordon, The economic theory of a common property resource: The fishery. *J. Polit. Econom.* **63**:116-124 (1954).
11. Kathryn Graddy, Testing for imperfect competition at the Fulton Fish Market, *Rand J. Econom.* **26**(1): 75-92 (1995).
12. G. Hardin, The tragedy of the commons, *Science*, **162**:1243-1248 (1968).
13. W. Hardle and A. Kirman, Nonclassical demand: A model-free examination of price-quantity relationships in the Marseille fish market, *J. Econometrics* **67**(1): 227-257 (1995).
14. M. Herrmann, Estimating the induced price increase for Canadian Pacific Halibut with the introduction of the individual vessel quota program, *Canad. J. Agr. Econom.* **44**(2): 151-164 (1996)

15. F. R. Homans, "Modeling Regulated Open Access Resource Use," Ph.D. dissertation, University of California at Davis (1993).
16. F. R. Homans and J. E. Wilen. A model of regulated open access resource use. *J. Environ. Econom. Management*. **32**:1-21 (1997).
17. S. Larkin and G. Sylvia, Intrinsic fish characteristics and intraseasonal production efficiency: a management-level bioeconomic analysis of a commercial fishery, *Amer. J. Agri. Econom.* **81**(1): 29-43 (1999).
18. B. H. Lin, H. S. Richards, and J. M. Terry, An analysis of the exvessel demand for Pacific Halibut, *Mar. Resour. Econom.* **4**(4): 305-314 (1987).
19. S. Matulich, R. Mittelhammer, and C. Reberte, Toward a more complete model of individual transferable fishing quotas: Implications of incorporating the processing sector, *J. Environ. Econom. Management* **31**(1): 112-128 (1996).
20. Organisation for Economic Co-operation and Development, "The use of individual quotas in fisheries management," OECD Publications and Information Centre, Paris (1993).
21. K. Salvanes and D. DeVoretz, Household demand for fish and meat products: Separability and demographic effects, *Mar. Resour. Econom.* **12**(1): 37-55 (1997).
22. W. Schworm, Monopsonistic control of a common property renewable resource, *Canad. J. Econom.* **16**(2): 275-287 (1983).
23. United States Department of Commerce, "Environmental impact statement, regulatory impact review, initial regulatory flexibility analysis for proposed individual fishing quota management alternatives for the halibut fisheries in the Gulf of Alaska and Bering Sea/Aleutian islands" July (1991).
24. J. E. Wilen and F. R. Homans, Marketing losses regulated open access fisheries, in "Fisheries Economics and Trade: Proceedings of the Sixth Conference" (J. Catanzano, Ed.) IFREMER-SEM (1994).
25. J. E. Wilen and F. R. Homans, Unraveling rent losses in modern fisheries: Production, market, or regulatory inefficiencies? in "Fisheries Management--Global Trends" (D. Huppert, E. Pikitch, and M. Sissenwine, Eds.) University of Washington Press, Seattle (1997).
26. Q. Weninger, Equilibrium prices in a vertically coordinated fishery, *J. Environ. Econom. Management* **37**(3): 290-305 (1999).

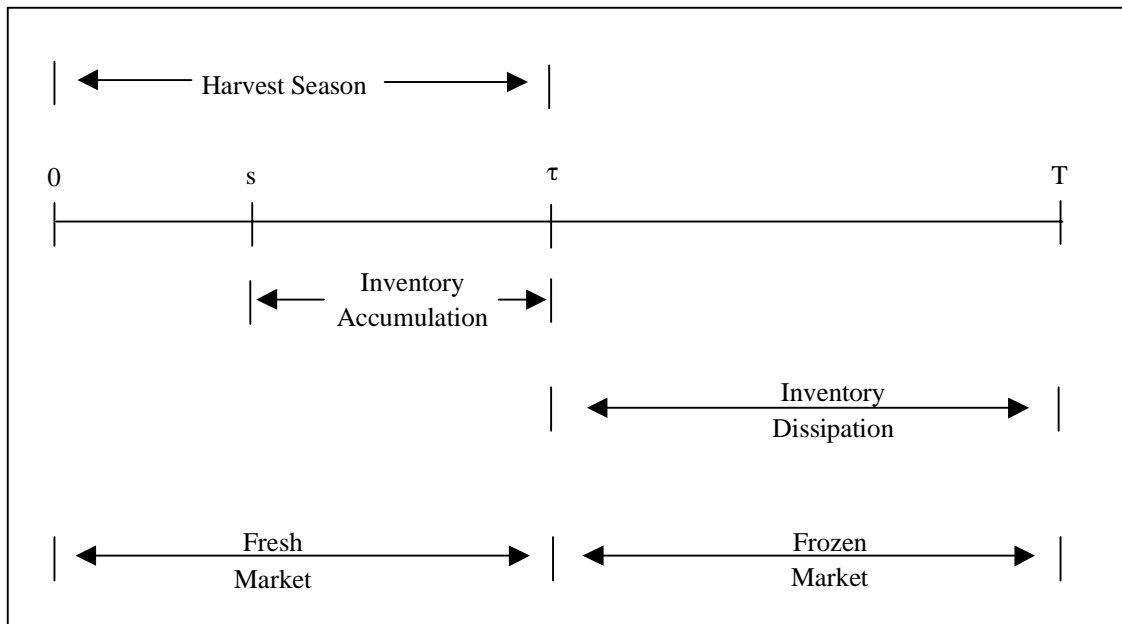


Figure 1: Phases of the Harvest/Marketing Year

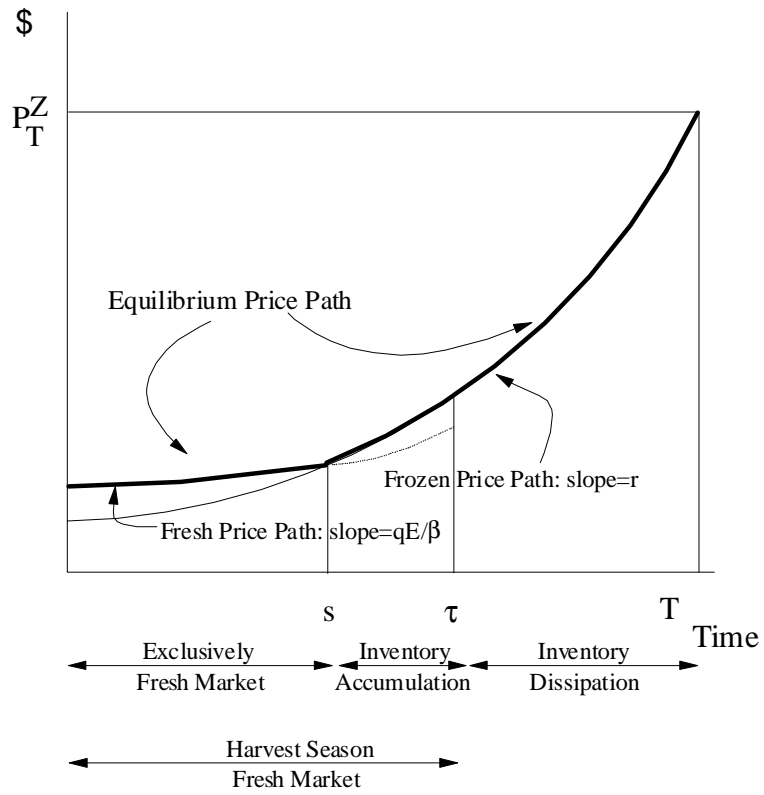


Figure 2: Equilibrium Wholesale Price Path: Early Fresh Scenario

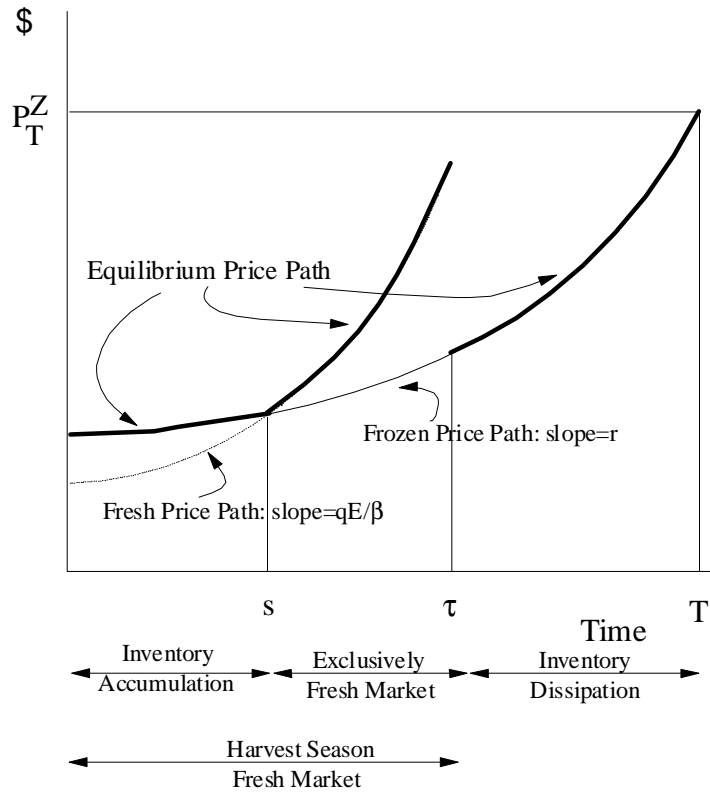


Figure 3: Equilibrium Wholesale Price Path: Late Fresh Scenario

ENDNOTES

¹ For example, Casey *et. al.* [2] report that in the British Columbia halibut fishery, the season lengthened from 5 days to 8 months after ITQs. As a result, wholesalers were able to sell 94% fresh after ITQs compared with 42% before, and exvessel prices rose over 50% in the first couple of years. Geen and Nayar [7], reporting on the Australian Southern Bluefin Tuna, conclude that prices doubled from about AUS\$988 to AUS\$2000 per metric ton within three years of the ITQ program's inception. This occurred as fishermen switched from targeting small tuna in nearshore regions to larger more mature tuna off the continental shelf. Before ITQs only 13% of tuna were greater than 15kg.; 2 years after ITQs the percentage had risen above 35%. In Iceland, Arnason [1] reports that a 1985 study conducted soon after ITQs were adopted showed benefits from reduced effort worth US\$14 million from effort reduction and US\$6 from improved product quality. Gauvin *et. al.* [6] reported two years after the wreckfish fishery converted to ITQs that prices had risen to about \$1.85 per pound with considerably more stability from pre-ITQ levels fluctuating between \$0.90-1.55. Their interviews with processors confirmed that this was due to the elimination of supply gluts and the practice of dumping raw product into less valuable frozen and discount supermarket outlets.

² Homans and Wilen [16].

³ For analytical simplicity, we ignore natural mortality, although the qualitative conclusions would not be affected by including it. In addition, this model is a within-season model and hence we ignore between-season dynamics. Homans and Wilen [16] discuss the approach path in a fully dynamic regulated open access model.

⁴ For simplicity, we ignore the determination of the TAC in this paper. Homans and Wilen [16] discuss how regulatory agencies typically choose a TAC in order to maintain biomass at some "safe" level. We also ignore the complications that would be introduced by making the model stochastic. In the model presented here, we assume a deterministic world in which the equilibrium is reached by some tatonnement process. Alternatively, we could assume that the equilibrium is reached with each player operating in a Nash setting, forming expectations of the other's actions, etc. Again, the qualitative conclusions are not changed appreciably by alternative and more complicated equilibrium mechanisms.

⁵ Conversion losses explain part of the often contentious differences between prices received by harvesters (or farmers) and prices received by first wholesalers and others in the marketing chain. Even if there were no costs of conversion, wholesalers would need (in the above example) to get \$1.54 per pound of wholesale product for every \$1.00 they paid fishermen for dressed raw product, simply to cover conversion losses. If there are conversion and other marketing costs between links in the chain the differences would be even larger.

⁶ The other primary engine in the rent dissipation process is technological change. There are always pressures to adopt fishing-power increasing technology, which only exacerbates the rent dissipation process. There are reasons to believe that fishermen might even over-adopt in a situation in which they are scrambling for shares of an uncertain pie.

⁷ We assume that frozen fish are only consumed after the season closes. This assumption seems reasonable, particularly for short seasons.

⁸ This is an assumption we make for analytical convenience since it allows us to solve for a relatively simpler closed form solution than would be the case with, for example, fixed holding costs. Empirically, it may not be too inaccurate to assume that the most important holding costs are interest costs and deterioration costs, both of which can be depicted with a simple geometric rate.

⁹ We assume that the landed to wholesale conversion factor for frozen is k , or the same as for landed to fresh wholesale. This assumption is not important--but it simplifies the notation.

¹⁰ There are several ways to close this model. One is to assume that there is an exogenously given choke price. Then the length of the marketing period T will need to be determined endogenously. A second way to close the model is to assume T is given and then allow the final price at that date to be endogenous and determined. We close the model in this second manner in this paper since it seems to fit most of the cases we are familiar with better. Most markets with a semi-perishable product form (such as frozen) operate on a year to year basis, with the end of the marketing period coinciding with the new season opening. In this way inventory holders attempt to sell all of their accumulated inventories by the start of the new season. For processed products that are more durable (such as canned) inventories are carried over. Carryover complicates the story considerably by linking optimal inventory decisions within the current marketing period to expectations of all future harvests, etc. (see Homans [15]).

¹¹ The dotted price path below the actual bold joint wholesale price represents the price that wholesalers would be paying for raw fish destined for the fresh market, if they were buying all of it, at the equilibrium effort level. Since they must pay the price frozen wholesalers are paying, the quantity actually destined for the fresh market is less, by the

amount entering frozen storage inventories.

¹² Note the drop in wholesale prices at the end of the harvest season. This does not indicate a disequilibrium because the prices are for different wholesale products. In the last period of the second phase, wholesalers are paying a high price for raw fish to sell into the fresh market, but in the next period there is no fresh market and the wholesale prices clear the frozen market.

¹³ The interpretation of the modified arbitrage equation in (16) would then be that it represents the switchover date at which the shadow value of the last unit added to inventory equals the value of the first unit allocated to the exclusively fresh market.

¹⁴ It should also be noted that corner solutions are possible. For example, it would be possible for accumulation to take place over the entire season. It would also be possible for parameters to be such as to allow only the fresh market to be viable. It is also possible, in principle, to have circumstances in which the shadow price of inventories is always greater than that for fresh fish, although this would invite some odd arbitrage opportunities whereby fresh fish are bought and immediately converted to frozen. For the models we present in this paper, with isoelastic demand curves, the solution is always interior in the sense that it never pays to devote all the raw product to only one market because the price in the other market would then approach infinity.

¹⁵ The exception to this relative neglect of market analysis is the remarkable study by Crutchfield and Zellner [4] published in 1962. Crutchfield and Zellner devoted several chapters to the workings of the halibut market at the wholesale and exvessel levels. They note that, by the 1950s, regional markets like the Seattle market were serving both a fresh wholesale as well as an inventory market for frozen fish, and that exvessel prices were determined by the simultaneous operation of both forces. Other work on the halibut fishery includes Lin *et.al.* [18] and the recent analysis by Herrmann[14] which examines the impact of ITQs on the Canadian halibut market.

¹⁶ For simplicity, we simulate market growth by increasing the scale constant in the wholesale demand curves. We might expect elasticities to change also, although mixing shifts and elasticity changes muddles the overall results.

¹⁷ Table 2 has the frozen market growing from a trace level to higher levels, all assuming that the fresh market is still characterized by the scale given in the last row of Table 1 (namely $B=15$).

¹⁸ Note the interesting phenomenon with exvessel prices. As the frozen market grows, exvessel prices in the initial period are always bid up. But exvessel prices in the terminal period fall over some ranges. This occurs because the season must be shortened, reducing the period during which the exclusively fresh market can operate.

¹⁹ Note that we are focusing explicitly on the lack of attention to the mechanisms linking rent dissipation, regulations, and markets. There has been a considerable amount of work, particularly in the last decade or so, estimating retail and wholesale demand for fish. Examples include Saalvanes and DeVoretz [21], Eales *et.al.* [5], Hardle and Kirman [13], Gordon *et.al.* [9], and Graddy [11]. In addition, there has been some work describing the role of the processing sector in fisheries. For example, early work by Clark and Munro [3] and Schworm [22] looked at the manner in which processor market power might mitigate pure open access rent dissipation. Matulich *et.al.* [19] and Weninger [26] have recently modeled wholesale/exvessel linkages in a vertical market chain for fisheries products. A nice example of an empirical analysis of marketing losses associated with sub-optimal regulations in the Whiting fishery is in Larkin and Sylvia [17].

²⁰ See Casey *et. al.* [2].