Effects of Rights-Based Management on Processors' Supply: An Application to the Alaska Pollock Fishery

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ABSTRACT

Economists have generated numerous studies analyzing how a move to rights-based fishery management from open-access management affects fish harvesters' behavior. Conversely, the impacts that such a change in management can have on fish processors has received relatively little attention. This paper presents a simple two-product processor supply model to show that switching to a rights-based managed fishery can be a source of rent generation for the processors by making their supply more responsive to output prices. Using data from the Alaska pollock fishery, a cointegration with structural break analysis is used to provide evidence of a change in the long-run relationship between processors output, product prices, and whole fish deliveries. The empirical application finds that the endogenously determined structural breaks happened near the time this fishery implemented an individual fishing quota. Furthermore, the estimation of the cointegrating vector indicates that the processors of this fishery are significantly more price responsive after the change in management

Keywords: Rights-based management, fishery rationalization, cointegration, structural breaks.

Introduction

Since the seminal work of [1] on the inefficiencies of open access fisheries, many economists have been proponents of rights-based fishery management. To this end, an extensive body of literature, both theoretical and empirical, has developed, explaining in more detail the numerous consequences of implementing rights-based management. Most of the research to date has focused on the various ways fishery rationalization leads to rent generating behavior in the harvesting sector.[1] Most likely due to Gordon's specification of the problem, economists initially pointed to consolidation as major source of rent generation brought about by rationalization. A greater understanding of the harvesting sector under open-access management has led economist to find more subtle sources of rent generation via rationalized fisheries, such as fish targeting [2], improved fish quality [3], and improved capital efficiency [4].

Several studies have examined how this change in harvesters' behavior will impact the associated processors in the ex-vessel market [5,6,7]. It is also logical to think that such changes in harvesters' behavior may impact the output decision of the associated processors. Put succinctly by [8], "the alternatives presented in the market are not exogenous, but instead reflect the fishing process itself." Despite this link few studies have looked at the fishery management system's effect on processors output.

A notable exception to this is the work of [9]. They model a fishery with a fresh and frozen product output and show that with increasingly shorter fishing seasons in a regulated open-access managed fishery, rents in the fishery will dissipate as processors move more of their output to the lower valued frozen product. The authors note that if their model was run in reverse (i.e. seasons are elongated by a move from regulated open-access to some form of rights-based management) processors would increase their production of high-valued fresh product. This was obviously the case in the North Pacific halibut fishery.

In the model presented in [9], the fresh product is clearly the more profitable product and season elongation allows for an increase in its production. For many fisheries this high valued fresh fish product alternative does not exist. In this case, processors in a multi-product fishery presumably make an optimal product mix based on the market conditions for the respective products. Several studies, though relatively few, have looked at the output price responsiveness of processors in fisheries where processors choose an output mix among several competing product forms [10,11,12]. However, this research fails to account for potential changes in price responsiveness due to changes in fishery management or any other possible supply shocks. The purpose of this study is to develop a scenario under which the change in fishery management does invoke a change in output price responsiveness and to find empirical evidence of such behavior using data from the Alaska pollock fishery.

The organization of this paper is as follows. First a simple model in which a single species is processed into one of two products, as in [9], is presented to build intuition about how rationalization could potentially alter processors' price responsiveness. The products in this model are not differentiated strictly by value and perishability, but rather by speed of processing. The model predicts that season elongation and/or secured rights to the fish, will increase both own-price and cross-price output elasticities for the processors. The subsequent sections attempt to find evidence of this increased supply responsiveness using data from the Alaska pollock fishery. The empirical test is done via a non-structural cointegration model with structural breaks in the cointegrating relationship. The examination is actually a three-fold testing procedure. First, I seek evidence of a cointegrating relationship between processors output, product prices, and whole fish processed, accounting for potential instability in the cointegrating vector. Second, given that the cointegration vectors for the various processing sectors investigated do show signs of instability, I provide evidence that such breaks occur around the time the fishery management moved from a regulated open-access fishery to a rights-based fishery. Finally, using the endogenously determined break dates, I estimate the cointegrating relationship, determining that under rationalized fishery management processors output does appear to be much more sensitive to output prices.

Basic Model

Consider an individual processor with fixed non-fish inputs (i.e. capital and labor), processing a single species of fish that is harvested from a regulated, open-access fishery. The processor has the option of converting the fish into two distinct products. The problem for the processor is then to find the profit maximizing output mix for a given fishing season subject to a production possibility set constraint and an implied throughput constraint.[2] Given that the two products have the same frozen storage life, same product recovery rates, and it takes equal time to process the fish into either of the two product forms; the processors problem, whether in regulated open-access or rights-based management, can be represented as:

$$\max_{y_1, y_2} p_1 y_1 + p_2 y_2 - c(y_1, y_2)$$
$$\text{subject to} \qquad \text{(Eq. 1)}$$
$$f(y_1, y_2) = \alpha H$$

In this representation y_1 and y_2 are the processor's outputs with respective market prices p_1 and p_2. The cost of producing a set of outputs is represented by $c(y_1, y_2)$. The profit is maximized subject to a production possibility frontier constraint, with $f(y_1, y_2)$ as the production possibility function, *ppf*, α as the product recovery rate and H as the amount of whole fish delivered to the processor over the course of the season.

Now consider the instance where the processing time for each product is not the same. For the purpose of this example it is assumed that the time it takes to process whole fish into final product y_1 exceeds that of final product y_2. This disparity in processing time changes the processor's problem when the fish is being harvested from the regulated open-access fishery. The amount of fish delivered to the processor now becomes a function of the output mix. The new problem can be represented as:

$$\max_{y_1, y_2} p_1 y_1 + p_2 y_2 - c(y_1, y_2)$$
$$\text{subject to}$$
$$f(y_1, y_2) = \alpha H(y_1, y_2) \qquad \text{(Eq. 2)}$$
$$\text{with}$$
$$\partial H / \partial y_1 < 0 \text{ and } \partial H / \partial y_1 \geq 0$$

The property $\partial H / \partial y_1 < 0$ follows from the implied throughput constraint. The intuition behind this property is a follows. In a regulated open-access fishery, fishers are harvesting, and hence delivering fish to processors, at a more rapid pace than under rationalized fishery management.[3] Assuming the throughput constraint is binding and assuming that harvesters have the option of taking their catch to multiple processors (i.e. the processing sector is not a monopsony), if the processor chooses to produce more of y_1 the total amount of fish delivered to that processor over the length of the season will decline taking the production of the competing processors as given.[4]

Clearly, as the penalty for producing y_1 in terms of lost fish increases is large relative to the respective marginal profits of y_1 and y_2, then the product mix will not appear to be as responsive to changes in market prices or reduction in production costs in empirical studies. Therefore, both own-price and cross-price elasticities of supply decrease.

Assuming there is no biological feature of the fish population that prohibits season elongation, if the fish is being harvested in a rationalized fishery the pace of harvesting is expected to decline. In a fishery where the harvesting sector and processing sector is not vertically integrated, if the decline in harvesting pace is sufficient to relax the throughput constraint the processors would face no penalty by producing the slower to make product. If the harvesting sector and processing sector are vertically integrated, such as in fisheries dominated by catcher-processor vessels, then obviously there will be no penalty in terms of lost harvest by producing the slower to make product because harvest rights are secure. In both of these situations, the processor's problem becomes that given in (1). The result of the diminished penalty for producing y_1 is increased own price and cross price supply elasticity.

All other variables held constant, relaxing the production constraint necessarily generates rents for the fishery by the Le Chatelier principle. However, the relaxed constraint comes at the cost of season elongation. Obviously, the processors will have certain seasonal operating costs that will increase with season elongation. If the processing sector and harvesting sector are not vertically integrated, the processors will not be able to control the season length and season elongation will occur assuming fishers are not already harvesting at a pace that minimizes average costs.[5] In this case it cannot be determined if the increased price responsiveness is generating rents because gains may be offset by increased operating costs. If the processing sector and harvesting sector is vertically integrated, processors will only move to the "optimal" product mix neglecting the season elongation costs if the benefits from this mix outweigh the additional operating costs. If season elongation and increased price responsiveness in a vertically integrated fishery are observed, it can be seen as evidence that this increased price responsiveness is generating rents in the fishery.

The above discussion highlights the difference between the model presented in this paper and that of [9]. The model of [9] credits season elongation, brought about by fishery rationalization, for allowing processors to switch to producing the higher valued fresh product for a greater period of the year. This model credits season elongation and/or secured property rights associated with rights-based fishery management as the factors that allow processors to be more responsive to output markets. Thus in multi-product fisheries, it is possible for rights-based management to induce additional rent generation on the output side even if fishery does not service a fresh fish market.

Alaska Pollock Fishery

The Bering Sea Aleutian Islands (BSAI) Alaska pollock fishery is a multi-product fishery that, with the passing of the 1998 American Fisheries Act (AFA), has moved from a regulated open-access fishery to a quota-based management. Therefore, this fishery provides the applied researcher with an arena to potentially to find empirical evidence in support of the processors behavior described above.

There are two principal flesh products derived from pollock, surimi and fillets. Surimi is a fish paste product sold predominantly in Japan, but small markets do exist in Europe and North America. Fillets, on the other hand, are to a large extent sold in domestic markets. In terms of processing speed, surimi can be made more quickly from whole pollock than fillets.

From 1992 through 1998 the fishery was managed as a regulated open access fishery. The total allowable catch (TAC) not allocated as a community development quota (CDQ) was divided among two separate sectors, the inshore sector and the offshore sector.[6] The inshore sector consists of catcher vessels that deliver to one of eight shore-based processing facilities. From 1992-1998, this sector was allocated roughly thirty-five percent of the non-CDQ TAC. The majority of the fish caught in the inshore sector is processed by a group of three processing entities, two of which are large, Japanese seafood firms that control a sizeable percentage of the Japanese surimi market. The importance of this is that it has been argued, notably in [13], that the processing facilities owned by these Japanese firms are mostly pure surimi suppliers to wholesalers within these firms vertically integrated supply chains (i.e. their product mix is not responsive to market prices). The offshore sector consists primarily of catcher-processor (CP) vessels and a small number of smaller catcher vessels which deliver their harvest to large motherships (MS). The remaining sixty-five percent of the non-CDQ TAC was allocated to the offshore sector. The CP vessels harvested and processed the bulk of the TAC allocated to the offshore sector under open-access management.

The AFA changed the management of the fisheries in several important ways. First, the TAC was reallocated starting in 1999 such that the inshore sector received 45 percent of the TAC, catcher-processors received 35 percent of the TAC, and the motherships received 10 percent of the TAC. Second, in order to reduce effort level in the CP sector and to further Americanize the fishery, nine CP vessels, owned by Norwegian companies, were retired. Finally, the AFA introduced rights-based management by allowing for the creation of fishing cooperatives in the CP, MS, and inshore sectors which could further allocate the TAC on a per vessel level. The CP and MS cooperative took effect in 1999, while the inshore cooperatives formed in 2000. Additionally, the seven inshore cooperatives are each associated with a corresponding processor, creating a more vertically integrated harvesting and processing sector atmosphere.

Econometric Methodology

The purpose of this empirical investigation is to determine if processors' output price responsiveness has changed over time and if that change coincides with a change in fishery management. There are several econometric methods that could determine if this has happened. A potential technique is to estimate structural supply curves for the processors. However, limited data from the BSAI pollock fishery, and in fisheries in general, makes theoretically consistent structural supply modeling techniques difficult to impossible to implement. A relationship between processors' output, product prices and whole fish deliveries can still be determined using more non-structural time series techniques, specifically cointegration analysis. The technique is also useful because it allows for the potential of nonstationary data in the various time series employed in this study. In addition, with the use of time series econometric techniques, it is possible to endogenously test for breaks in the relationship between output and prices rather than simply imposing a possible break location.

For the reasons given above, the econometric methodology used in this study is a cointegration analysis, describing a long-run relationship between processors' output, product prices, and whole fish deliveries. Normalizing on output, the model can be written in the single equation form of:

$$y_{i,t} = \alpha_0 + \gamma_s D_{s,t} + \beta_{sur} p_{sur,t} + \beta_{fill} p_{fill,t} + \beta_H p_{H,t} + \varepsilon_t \qquad \text{(Eq. 3)}$$

$$i = \text{surimi, fillet}$$

where $y_{i,t}$ is the surimi or fillet output for the fishery, or aggregate output from a sub-grouping of processors, $D_{s,t}$ is a seasonal dummy variable, p_{sur} and p_{fill} are the respective surimi and fillet prices, and H_t represents the amount of whole fish delivered to or caught by the processors. As shown in [14], if the series do have a stable long run relationship, i.e. the system is cointegrated, the error term, ε_t, will be a stationary process.

It should be noted that this specification is formulated to find the long-run relationship between current output, current prices and metric tones of current fish deliveries. One might expect for frozen fishery products that current production is also a function of future prices, especially during shorter seasons under open-access management. Therefore, implied in this long-run relationship is the assumption that current prices provide the best expectation of future market conditions. This formulation also assumes that processors are price takers. While this fishery is a very large fishery in terms of landings, evidence of a global whitefish market shown in [15], the availability of other protein food substitutes, and the fact that the TAC is fully utilized each season all lend support to the notion that the processors are price takers. In addition, the cointegrating vector estimation technique employed does allow for endogeneity in the regressors [16].

The relationship presented in (3) also assumes parameter stability, that is it assumes the cointegrating relationship has remained unchanged over the sample viewed. For many cointegration analyses such an assumption may be inappropriate. In this context, if the model described in above is correct then it is expected that the marginal response of output with respect to prices changed after the fishery rationalized. A more suitable model representation may be given as:

$$y_{i,t} = \alpha_0 + \gamma_s D_{s,t} + \beta_{sur} p_{sur,t} + \beta_{fill} p_{fill,t} + \beta_H H_t + D(1 > \tau)\delta^{'}\mathbf{X}_t + \varepsilon_t \qquad \text{(Eq. 4)}$$

$D(1>\tau)$ is an indicator function equal to one when $t > \tau$ and $0 \le \tau \le T$, where T is the final date of the sample. $\mathbf{X}_t$ is a vector containing some or all of the right hand side variables in (3).

The empirical section of this paper essentially amounts to determining if (3) is a more appropriate specification than (4), and if so determining if the marginal response of output with respect to prices has increased in magnitude. Before this is done, several preliminary tests must be run. A description of the series being used is given in the next section along with a brief description of the nonstationarity tests employed. Next, to see if a long run relationship between outputs, prices, and whole fish deliveries exist, residual-based cointegration tests are ran with and without a structural break included. To determine which specification is correct, test of parameter stability are then ran. Finally, given the appropriate model specification, the cointegrating vector is estimated.

Data

This empirical study uses monthly output, price, and whole fish delivery (harvest) data over the period 1994-2004. Surimi and fillet output series are obtained from the National Marine Fisheries Service (NMFS) weekly processors reports. Because of the timing of the AFA provisions and market structure features described above, output measures were used for several groupings of processors to see if any intra-fishery heterogeneity exists. A surimi output series and a fillet output series are constructed for each of the following groups: the fishery as a whole, the inshore sector, the offshore sector, inshore sector excluding Japanese owned processor (NJ inshore), and the CP sector.[7] All output series are given in metric tones. A domestic wholesale pollock fillet block price series was used for the fillet price and a surimi export price was used for the surimi price.[8] Both price series are converted to dollars per metric ton and put into real terms using a producer price index for the fresh and frozen seafood processing industry. The whole fish deliveries to individual processors, or landings by individual CPs, were obtained from NMFS "blend" database and aggregated into the same groups as given above for the output data.

Prior to conducting any cointegration analysis, it must be confirmed that the series used are in fact I(1) series. Various tests exist to verify that a series is nonstationary. For the purpose of this study, the standard augmented Dickey-Fuller (ADF) test and the more efficient ADF-GLS test of [17] were employed. The results of this test provide evidence that each series is best modeled as an I(1) series. Furthermore, because it is hypothesized that the change in fishery management may have altered the relationship between these series, it is logical to think that the individual series may have also been impacted by the series. Such an impact could lower the power of the more standard stationarity tests. Therefore, the test developed in [18], which allows for an endogenously determined level shift and trend shift in the auxiliary regression, was run. Results from this test confirm that the series are best represented as I(1) processes.

Cointegration and Parameter Stability Tests

I(1) series are said to be cointegrated if there is a linear combination of the variables that results in a stationary process. In this context, the aim is to determine if there exists a linear combination of output, prices and whole fish deliveries that results in a stationary process. The linear combination is often referred to as the long-run relationship between the I(1) series, so testing for cointegration is tantamount to determining if the variables in question "move" together in some predictable fashion.

The cointegration test of [14], henceforth the Engle and Granger test, essentially calls for estimating the linear relationship between the I(1) series by an OLS estimation, then testing the residual of that regression for stationarity. If the residuals are found to be stationary the system is cointegrated and the OLS parameter estimates are consistent estimators of the true parameters. If the residuals are not found to be stationary then the system is *not* cointegrated and the results of the OLS estimation are spurious regression results.

In this study, the Engle and Granger tests are conducted by first estimating (3), with and without monthly dummy variables, by OLS for the various processor groupings, then testing the respective residuals for stationarity using ADF type tests. The results of theses tests indicate that all of the different groupings of processors have a long-run relationship between their respective outputs, prices, and whole fish deliveries, except for the case where CP surimi is used as the dependent variable and monthly dummy variables are included. However, [19] found that the ADF type tests for cointegration has its power considerably reduced in the presence of structural break in the long-run relationship. Consequently, the inference based on the results of the Engle and Granger test could be incorrect if a break is present. Building on the work of [18], this issue was addressed in [20], henceforth Gregory and Hansen, in which they developed a residual based test for the null of no cointegration with an alternative allowing for a single structural break in the cointegrating vector at an unspecified time. The Gregory and Hansen tests simply augment the standard auxiliary regression used in residual based cointegration test by including a structural break dummy. In this instance, their augmentation would result in (4) being used as the auxiliary regression. This auxiliary regression is run over all possible break dates for the sample, excluding some predetermined upper and lower bound on the break. The residuals from each iteration of the auxiliary regression are then tested for stationarity using an ADF type test, deemed the ADF* test. The minimum test statistic (most negative) over the potential break dates used is then reported as the test statistic.

When a break is allowed for the parameters on both price series and for the whole fish deliveries and monthly dummy variables are included in the auxiliary regression (4), the results of the ADF* indicate that each of the different processor groupings tested rejected the null of no cointegration. Combined with the results of the more standard Engle and Granger test, there is strong evidence that a stationary long-run relationship between processors' outputs, product prices, and whole fish deliveries does exist. The correct model specification, however, is not as apparent.

The regression using CP surimi as the output measure was the only model to fail to reject the null of no cointegration based on the conventional ADF test of cointegration when monthly dummy variables were included. However, based on the results of the ADF* test, the null of no cointegration is rejected at the five percent significance level when the CP surimi series is the output. This gives evidence that this cointegrating relationship is best specified with a structural break. Because the ADF* test also has power against the alternative of cointegration with no structural break, when both the Engle and Granger test and ADF* test reject the null of no cointegration at a reasonable level of statistical significance the correct model specification is unclear. Therefore, the correct model specification is not clear for the other processor groupings tested in this application. When this specification ambiguity is present, Gregory and Hansen suggest using the parameter stability tests for I(1) regressions developed in [21], henceforth Hansen, to determine model specification.

Hansen provided the first, and still often used, tests of parameter stability with I(1) variables. Utilizing the fully modified OLS (FM-OLS) cointegration vector estimation technique of [22], Hansen developed Lagrange Multiplier (LM) structural change tests under the null of parameter stability with two separate alternative hypotheses. The first alternative hypothesis explored is that of a single break in the coefficients. He gives two tests for this alternative, both employing LM formulations of the classic *F*-test for structural change. The first of these tests uses a known break date, while the other assumes the break to be unknown and the resulting test statistic is a supremum test (sup-*F*) taken over a trimmed sample of possible breaks. In the other alternative, he models the parameter vector as a martingale process. Again, two tests are given for this hypothesis. The first is an average *F*-test over the trimmed sample (mean-*F*). The second test, labeled L_c by Hansen, is similar to the mean-*F*, but requires no sample trimming. Furthermore, Hansen suggests using the L_c statistic as testing the null of cointegration against the alternative no cointegration since rejecting the null in favor of the hypothesis indicates that estimated cointegrating vector is unstable, thus there exists no stable long-run relationship between the variables. However, in practice, as pointed out by Hansen, one should cautiously interpret the results given that all of the tests have power against each of the alternatives. That is, rejection of the null in the L_c test does not necessarily imply no cointegration and likewise rejection of the null in the sup-*F* test does not necessarily imply the cointegrating relationship has two regimes. [23] claims that the rejection of the null for any of these tests is best used simply as evidence against the traditional cointegration specification.

While the Hansen tests are used extensively in applied work, they are often not well suited for models with a larger number of regressors in the single equation specification because they are tests of pure structural change, meaning they assume a change in all regressors used. The work of [24], henceforth Kuo, extended the Hansen tests to allow for tests of partial instability. The results from this test can help give a more accurate portrayal of the correct cointegration specification.

Table I gives the results of the Hansen L_c, mean-*F* and sup-*F* tests and also presents the results of the Kuo sup-*F* test results, with breaks allowed for the parameters associated with those variables given in the column heading. The parameters on the prices are allowed to change for each of the subset sup-*F* tests run since it is hypothesized that the output response to prices should change over this sample. Both the Hansen and Kuo tests are constructed given the results from an FM-OLS estimation procedure.[9] Monthly dummy variables were used in the regressions of all the reported test statistics in Table I. For the sup-*F* and mean-*F* tests the top and bottom fifteen percent of the sample were trimmed from the potential break dates.

The Hansen tests provide at least some evidence of model misspecification for all regressions run, except for the case where offshore surimi output was used as the dependent variable. In most cases, evidence for model misspecification is supported by the partial structural change tests of Kuo. Combining these results with results of the Gregory and Hansen tests, the model of cointegration with a structural break appears to be the more appropriate specification for each instance tested here, except for the case of offshore surimi as the dependent variable.

Table I – Parameter Stability Tests

Dependent Variable	**Hansen (1992) Tests**			**Kuo (1998) sup-*F* Tests**			
	L_c	mean-F	sup-F	P_{sur}, P_{fill}	P_{sur}, P_{fill}, H	P_{sur}, P_{fill}, α	P_{sur}, P_{fill}, H, α
$Fillet_{total}$	4.16**	41.32**	114.90**	18.40**	43.95**	26.45**	44.08**
$Surimi_{total}$	1.85	26.89**	48.32**	12.56**	12.70	14.84*	14.45
$Fillet_{inshore}$	3.47**	51.09**	384.52**	23.73**	31.67**	24.15**	32.09**
$Surimi_{inshore}$	3.72**	45.87**	289.63**	22.18**	31.08**	23.69**	32.59**
$Fillet_{offshore}$	3.87**	30.30**	77.57**	12.77**	38.51**	17.87**	38.58**
$Surimi_{offshore}$	1.76	19.74	31.69	8.45	10.68	8.84	11.62
$Fillet_{NJ\ inshore}$	2.72	33.76**	117.50**	26.45**	34.55**	29.51**	35.11**
$Surimi_{NJ\ inshore}$	2.25	21.54**	41.08**	20.71**	26.52**	21.76**	27.73**
$Fillet_{CP}$	4.26**	34.20**	82.48**	13.13**	41.21**	19.18**	41.66**
$Surimi_{CP}$	1.42	21.00*	30.87	8.97	8.99	11.57	11.57

*-significant at 10% level

**-significant at 5% level

There are several potential explanations for why there does not appear to be a structural break in the equation with offshore surimi as the dependent variable discussed above. One possible explanation is that because the offshore sector has a vertically integrated in processing and harvesting, the processors of this sector must determine if the benefit from moving to the more "optimal" product mix outweighs the cost of season elongation. If the benefits do not, then price responsiveness will not change and no structural break should be detected. Support for this explanation is somewhat diminished given that the structural breaks are detected for the specifications using the output variables of CP surimi, CP fillet, and offshore fillet. A more likely explanation is that the traditionally surimi intensive MS processors have chosen not to make the capital adjustments necessary to produce both surimi and fillet. This committment to surimi production by MS processors may prevent the detection of a structural break when the offshore sector aggregate surimi production is used as the dependent variable.

Estimation and Discussion

Two commonly used single equation efficient estimators in the applied cointegration literature are the FM-OLS estimator of [22] and the dynamic OLS (DOLS) estimator of [16]. Both of these estimation procedures correct for serial correlation between the regressors and the error of the estimating regression and both are asymptotically efficient (equivalent to maximum likelihood). However, [16] showed that in finite sample tests the DOLS estimator generally outperformed the FM-OLS estimator. For this reason and due to its ease in implementation when a structural break is included, the DOLS estimator was used for this application.

Using the DOLS specification with a structural break suggested by [25], the specification of the model estimated for this application is of the form:

$$y_{i,t} = \alpha_0 + \gamma_s D_{s,t} + \beta_{sur} p_{sur,t} + \beta_{fill} p_{fill,t} + \beta_H H_t + D(1 > \tau)(\delta_{sur} p_{sur,t} + \delta_{fill} p_{fill,t} + \delta_H H_t) + \sum_{j=-p}^{p} \phi^{'} \Delta \mathbf{X}_{t-j} + \varepsilon_t \quad \text{(Eq. 5)}$$

where $D_{s,\,t}$ is a monthly dummy variable vector and $\Delta\mathbf{X}_{t\text{-}j}$ is the leading and lagging first differenced vector of I(1) variables. This specification was chosen because the ADF* test results rejected the null of no cointegration for each of the processor grouping when a break was included for the parameters on all the I(1) variables and the Kuo sup-F results provided evidence that most of the processor groupings tested have parameter instability for the parameters on the I(1) variables.[10]

The next issue of specification is to decide where the break should be placed (i.e. where τ is located). Because the ADF* test and the sup-F tests are supremum test statistics over a range of potential break dates, both types of tests can also be used to determine the timing of the break. Table II gives the break location according to these statistics when a break is allowed for the parameters on the I(1) variables.

For most dependent variable designation, the ADF* determined break date is reasonably close to the sup-F determined break. There are however a few exceptions. It must then be determined which set of endogenously determined breaks should be used in estimating (5) for each processor grouping. In several simple Monte Carlo experiments, Gregory and Hansen show that the minimum t-statistic break date estimator performs well in moderately sized samples (T = 100) when the true break is present in the latter half of the sample. [26] also found that the Gregory and Hansen tests are more precise in the estimation of the break point than Hansen style sup-*F* tests. Given the results of these Monte Carlo experiments and the fact that many of the estimated breaks across tests are separated by only a few months, the estimated break dates from the ADF* test are used in the DOLS estimation.

Table II – Endogenous Break Dates

Dependent Variable	**Break Date** ADF*	sup-*F*
Fillet_{total}	Jan-00	May-00
Surimi_{total}	Apr-00	Jun-00
$\text{Fillet}_{inshore}$	Feb-00	May-00
$\text{Surimi}_{inshore}$	Feb-00	Jun-00
$\text{Fillet}_{offshore}$	Dec-99	May-00
$\text{Surimi}_{offshore}$	Feb-00	Jul-00
$\text{Fillet}_{NJ\ inshore}$	Feb-00	May-00
$\text{Surimi}_{NJ\ inshore}$	Sep-99	May-00
Fillet_{CP}	Dec-99	May-00
Surimi_{CP}	Apr-00	Jul-00

*-significant at 10% level

**-significant at 5% level

Using these estimated break dates, the next obvious question is, are these estimates in line with the *a priori* expectations that the provisions in the AFA fundamentally changed the long-run supply relationship? Looking at the aggregate measures for the fishery as a whole, the break dates for both surimi and fillet supply occur in late 1999 and early 2000. Since the movement to rights-based management took place over the 1999 and 2000 fishing seasons, these estimates do seem in line with the expectations. Similarly, the aggregate measures for the inshore processors, both the inshore total and the non-Japanese controlled subsets, show breaks in early 2000 and late 1999 which is as expected. Surprisingly, the estimated breaks for the offshore sector and for the CPs only also fall in late 1999 and early 2000. Given that this sector moved to rights-based management in the 1999 season, it was expected that the break should be in late 1998 or early 1999. However, the nine CP vessels that were retired under the AFA accounted for the majority of the fillet production for the offshore sector. Many of the remaining CPs did not have the capital to produce both surimi and fillets. Consequently, the delay in the break could be the result of a capital adjustment period. It should also be noted that while it seems likely that the provisions of the AFA were a major contributor to the structural change in the long-run supply relationship for many of these processor groups examined, other possible causes may have also contributed to the change. The emergence of new fillet markets and the decreased reliance on Japanese surimi markets are two probable reasons for structural breaks. In reality, the change in supply behavior is most likely a complex mixture of several factors including, but not limited to, the change in fishery mangament.

Given that the break date appear to coincide with *a priori* expectations, the next step is to determine if the price responsiveness of the processors has increased post-break. The estimated parameters of interest from the specification in (5) are given in Table III. Standard errors, reported in parentheses below parameter estimates, are corrected for serial correlation using a VARHAC type correction (see [25] for details) and the lead/lag length of the first differenced I(1) variables is chosen by BIC minimization. In order to get a better understanding of how the price responsiveness of the processors changed post-break, Table IV presents the pre-break and post-break price elasticities, evaluated at the pre-break and post-break means, respectively.

The results presented in Table III show relatively low and often statistically insignificant price parameter estimates before the endogenously determined break date. However, after the break all of the regressions display dramatic magnitude increases in the long-run marginal response of processors' output with respect to prices. Furthermore, all of the post break parameter estimates are statistically significant. The coefficients on whole fish delivery by contrast did not show comparable post-break changes. The results of this estimation are as predicted in the basic model given above. Table IV displays a similar story. Excluding the fillet own price elasticity for the offshore sector as a whole, both own-price and cross-price elasticities increased in magnitude for each of the processor groupings, providing further evidence to the hypothesis that processors are more price responsive in a rationalized fishery.

Table III – Parameter Estimates

Dependent Variable	β_{sur}	$\delta_{sur}+\beta_{sur}$	β_{fill}	$\delta_{fill}+\beta_{fill}$	β_H	$\delta_H+\beta_H$
$Fillet_{total}$	-1.34	-11.67**	4.08**	11.74**	0.09**	0.13**
	(1.016)	(1.762)	(0.589)	(1.455)	(0.006)	(0.006)
$Surimi_{total}$	0.86	10.76**	-1.00	-8.41**	0.10**	0.11**
	(1.589)	(2.960)	(0.935)	(2.374)	(0.010)	(0.009)
$Fillet_{inshore}$	0.03	-6.58**	0.71	5.81**	0.10**	0.13**
	(0.791)	(1.462)	(0.480)	(1.206)	(0.014)	(0.012)
$Surimi_{inshore}$	0.63	5.47**	-0.84**	-4.11**	0.13**	0.11**
	(0.702)	(1.299)	(0.427)	(1.071)	(0.012)	(0.010)
$Fillet_{offshore}$	-0.72	-4.91**	2.90**	5.99**	0.07**	0.12**
	(0.573)	(1.008)	(0.347)	(0.813)	(0.005)	(0.005)
$Surimi_{offshore}$	0.98	4.39**	-0.66	-3.28**	0.08**	0.10**
	(0.964)	(1.683)	(0.564)	(1.352)	(0.008)	(0.008)
$Fillet_{NJ\ inshore}$	0.21	-4.60**	0.41	4.25**	0.14**	0.18**
	(0.466)	(0.868)	(0.291)	(0.701)	(0.016)	(0.014)
$Surimi_{NJ\ inshore}$	0.08	3.37**	-0.41*	-2.85**	0.08**	0.06**
	(0.382)	(0.644)	(0.248)	(0.590)	(0.015)	(0.013)
$Fillet_{CP}$	-0.83	-5.40**	2.81**	6.12**	0.08**	0.14**
	(0.561)	(0.981)	(0.337)	(0.792)	(0.006)	(0.006)
$Surimi_{CP}$	0.54	4.95**	-0.81*	-4.22**	0.07**	0.08**
	(0.753)	(1.364)	(0.442)	(1.086)	(0.008)	(0.007)

*-significant at 10% level
**-significant at 5% level

Table IV – Price Elasticities

Processor Grouping	Pre-break		Post-break	
Total	*i = fillet*	*i = surimi*	*i = fillet*	*i = surimi*
$e_{i, fill}$	1.27	-0.11	1.56	-0.74
$e_{i, sur}$	-0.41	0.09	-1.22	0.74
Inshore				
$e_{i, fill}$	0.56	-0.18	1.76	-0.70
$e_{i, sur}$	0.02	0.13	-1.57	0.73
Offshore				
$e_{i, fill}$	1.44	-0.14	1.44	-0.59
$e_{i, sur}$	-0.35	0.21	-0.93	0.62
NJ Inshore				
$e_{i, fill}$	0.36	-0.27	1.73	-1.55
$e_{i, sur}$	0.18	0.05	-1.47	1.46
CP				
$e_{i, fill}$	1.39	-0.28	1.56	-1.06
$e_{i, sur}$	-0.39	0.27	-1.08	1.04

Comparing results across the different groupings of processors tested also gives some insights into the nature of this fishery. First, the CP sector, which is a vertically integrated harvesting and processing sector by the construction of the CP vessels, shows an increase in price responsiveness post-rationalization. Assuming that this increased price responsiveness generally leads to a greater production of fillets, which by visual inspection of the data appears to be the case, the results suggest that benefits of moving to the optimal product mix in terms of market prices outweigh the additional operating costs incurred by the season elongation. If this was not the case, one would expect to see the CP sector's price responsiveness unchanged after the implementation of harvesting quota program.

Second, prior to the passing of the AFA, the offshore sector appeared to be more price responsive in both the production of surimi and fillets. This supports the notion presented in Wilen (1998) that the inshore sector processors were primarily surimi specific producers, while the offshore sector processors were more responsive to the market conditions. However, after the implementation of the rights-based management, the inshore sector processors now appear to be more price responsive in both the production of surimi and fillets than the offshore sector as a whole and the CP sector by itself. Therefore, while [13] may have been correct in his categorization of this fishery at the time of his testimony, the results presented here do not support the idea that the inshore sector is still a dedicated surimi supplier.

Finally, to highlight the importance of accounting for the possibility of structural break, estimates based on equation (3), the specification with no structural breaks, are given in Table V. Comparing the estimation results, particularly for the price parameter estimates, of Table V with those of Tables 3, one can see that specifying a structural break in the model vastly changes one's interpretation of how the processors respond to market prices. With no structural break specified the price parameter estimates are generally not statistically significant and several estimates have signs that do not adhere to economic theory.

Table V – Parameter Estimates without Breaks

Dependent Variable	β_{sur}	*stnd error*	β_{fill}	*stnd error*	β_{H}	*stnd error*
Fillet_{total}	-8.42**	0.98	4.45**	0.91	0.14**	0.01
Surimi_{total}	-1.00	1.40	-1.61	1.30	0.11**	0.01
$\text{Fillet}_{inshore}$	-1.37*	0.83	0.59	0.69	0.15**	0.01
$\text{Surimi}_{inshore}$	0.76	0.79	-0.89	0.64	0.11**	0.01
$\text{Fillet}_{offshore}$	-6.38**	1.20	3.21**	1.12	0.11**	0.01
$\text{Surimi}_{offshore}$	-1.59*	0.94	-0.88	0.87	0.10**	0.01
$\text{Fillet}_{NJ\ inshore}$	-1.14	0.74	0.18	0.60	0.20**	0.03
$\text{Surimi}_{NJ\ inshore}$	0.46	0.51	-0.37	0.42	0.06**	0.02
Fillet_{CP}	-5.73**	0.92	3.26**	0.86	0.13**	0.01
Surimi_{CP}	-0.34	0.58	-1.05*	0.54	0.08**	0.01

*-significant at 10% level
**-significant at 5% level

Conclusion

The link between harvesting sectors and processing sectors in commercial fisheries leads one to logically reason that changing behavior in the harvesting sector could lead to changes in the processing sector. Economists have studied in depth how rights-based management induces rent seeking behavior in harvesters, but have largely ignored any corollary changes in processors' behavior. This study attempts to address this gap in the literature by displaying how the move from a regulated open-access management system to a rights-based management system can increase price responsiveness of processors where multiple products are derived from a single species.

The simple two product model developed in this paper highlights the trade-off that non-monopsonistic processors face in a regulated open-access fishery between making a product mix that is optimal in the sense of output market conditions and making a product mix that allows them to process a greater portion of the TAC. When harvesting rights are imposed, the resulting slower paced harvesting, or the secured portion of the TAC in the case of vertically integrated harvesters and processors, allows processors to make a product mix that is more responsive to output prices.

To find evidence of this change in price responsiveness, a cointegration analysis with structural break is conducted using data from the BSAI Alaska pollock fishery. The results from this analysis confirm that for all of the different groupings of processors considered there is a cointegrating relationship between processors' outputs, product prices, and whole fish deliveries. Furthermore, with the exception of one of the processor grouping, there is evidence that the parameters of the various cointegrating vectors exhibit some instability. Modeling the cointegrating relationships with a single structural break, it is found that endogenously determined break location for each processor grouping happens near the time this fishery implemented rights-based management. The estimation of the cointegrating vector with a structural break included reveals that the processors' marginal output response with respect to product prices increases in magnitude for both the products own price and the price of the alternative product form. These results therefore lend supporting evidence to the hypothesis that rights-based management can induce rent seeking behavior in the processing sector through greater price responsiveness.

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ENDNOTES

[1] The author realizes that using the term rationalized fishery encompasses management regimes broader in scope than just rights-based management. However, for the purpose of this paper, fishery rationalization will be synonymous with some form of rights-based management.

[2] The throughput constraint in this context states that at any given time the processor has a fixed capacity of fish it can hold, whether that fish is being held in whole fish form or is in some stage of processing.

[3] For a discussion on why the pace of harvesting is expected to be slower in rationalized fishery see [5].

[4] This model assumes that a processor calculates the amount of whole fish lost by producing y_1 as a given function of that processor's production of y_1. The model could be analyzed using a strategic framework, where the processors whole fish delivery is a function of their production and the production of other processors.

[5] This statement assumes that processors are unable to make some type of side payments to harvesters in order to increase harvesting pace. If such side payments are possible and economically advantageous to both the processing and harvesting sectors we would not expect to see season elongation to the same extent as when such payments are not possible.

[6] The community development quota program is a fishery management plan that allocates a portion of the total allowable catch for federally-managed BSAI fishery species to eligible communities in Western Alaska, deemed dependent upon fishing. The CDQs are transferable and have been leased and/or sold to both inshore and offshore harvesters.

[7] Output series for the inshore processors controlled by Japan based firms and output series for the MS sector could not be constructed due to confidentiality agreement restrictions.

[8] The surimi export price is a derived price, calculated by taking the value of monthly exports divided by the metric tones of exported surimi.

[9] The Hansen and Kuo tests can be run using any efficient cointegration vector estimation technique. The FM-OLS technique was chosen to conduct these tests because that is the estimation technique employed in both [21] and [24], making the implementation of these tests easier in the FM-OLS framework.

[10] Even though the regressions using offshore surimi output, total surimi output, and CP surimi output as the dependent variables do not show signs of parameter instability when a break is included for only the I(1) regressors, the regressions using these independent variables do show sign of instability based on other specifications. Therefore, the common specification of (5) was chosen to conserve degrees of freedom and for comparison basis.