FIRM-LEVEL HEDONIC ANALYSES OF U.S. PRODUCED SURIMI: IMPLICATIONS FOR PROCESSORS AND RESOURCE MANAGERS

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Abstract

Surimi is an intermediate, processed seafood product of which the U.S. is the world's largest supplier. Using firm-level data, we show that surimi quality characteristics are affected by factors controlled by public and private managers (such as the processing speed and season opening date, respectively). A subsequent had the largest affect on price. The grade, production location (shore or sea), and processing date were also significant. Given the effect of public management strategies on surimi quality and on surimi price directly, fisheries management policies are a critical factor in the ability of private managers to maximize the value of the resource.

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Seafood quality is difficult to measure and convey, consequently, there are few quality-graded products as compared to terrestrial-based industries (Anderson and Anderson). One such seafood product is surimi; a protein paste made from minced fish that is used in the fabrication of final food products. The quality evaluation and marketing of surimi is complicated since the product appears homogeneous and grade standards are firm specific (Park and Morrissey). Like all products derived from "wild" natural resources, the condition of the stock at the time of harvest can affect final product quality, quantity, and value. This additional uncertainty emphasizes the importance of resource management plans that control fishing seasons and, ultimately, the value of the resource.

There is an overwhelming amount of literature on the biochemical production process of surimi (Hall and Ahmad). In comparison, the economic studies have concentrated only on the market(s) for the final goods (Sproul and Queirolo). The lack of economic studies is surprising given that the majority of Alaska pollock (the most abundantly harvested specie in the U.S.) and Pacific whiting (the largest U.S. groundfish resource south of Alaska) goes into surimi production (Sproul and Queirolo; Freese, Glock, and Squires). Consequently, the U.S. is the world's largest supplier of surimi, producing nearly 155,000 tonnes in 1995 (National Marine Fisheries Service, NMFS). In terms of edible fish exports from the U.S., surimi is second only to salmon: in 1995, exports were valued at over $350 million (NMFS).

Fish surimi is a unique seafood product because the production process is highly technical, it is graded and sold based on a set of quality attributes, and it is used to produce hundreds of final products (Sonu). Each type of product requires a specific combination of surimi quality characteristics, consequently, a wide range of quality is demanded (Sonu). Recently, processors of surimi-based foods have begun to blend various surimi grades to achieve the desired quality required for new products (Park and Morrissey). This production change has increased the substitutability of raw surimi and placed greater emphasis on the individual characteristics (Marris).

Surimi quality is usually characterized by a grade, which is based on the quantitative measurement of several product attributes such as color, texture, water content, gelling ability, pH level, and impurities. Since surimi grade schedules are firm specific, each firm decides which characteristics to include, how they are measured, and the levels and nomenclature that define each (Park and Morrissey; Marris). However, many companies have adopted the nomenclature and relative rankings of the highest grades (i.e., SA and FA) developed by the National Surimi Association in Japan (Park and Morrissey). Hence, an identically graded product produced by two different companies may not be perfect substitutes. Given that some U.S. companies have chosen not to use the Japanese grades, and the characteristics and levels defining each grade are unknown, reported wholesale prices cannot be linked to a pre-defined level of quality.

The lack of available market data has limited previous quantitative analysis of seafood product quality to conjoint techniques. An alternative approach is to use transaction data to estimate the implicit price of each quality attribute. This hedonic price method has been successfully applied to agricultural goods (Davis; Ethridge and Neeper; Jordan et al.), but not seafood products.

The primary objectives of the study are to test quality-related hypotheses regarding U.S. produced Alaska pollock and Pacific whiting surimi and generate empirical information needed to determine optimal firm-level processing and resource-management strategies. Since all surimi producers and processors of surimi-based foods test the quality of each lot of surimi (Park and Morrissey), cross-section time-series data can be used to estimate: (1) the effect of production and management-controlled factors on surimi quality characteristics and (2) the implicit price of each characteristic.

This study employs data from a catcher-processor that produced both pollock and whiting surimi during the 1994 season (*n*=651) and data from a processor of traditional surimi-based foods in Japan who purchased multiple grades of land and sea produced pollock surimi during a two-week period in early 1995 (*n*=36). Aside from general production information such as processing date, the time between harvest and processing, and whether the product was processed at-sea or onshore, each firm quantifies six to eight quality characteristics (Park and Morrissey). Each characteristic is measured twice, once on the raw surimi and after the surimi has been heated or cooled (temperature changes allow for an assessment of final product quality). Consequently, there are at least 20 variables in each data set.

Surimi Quality

In practice, the quality of a given lot of surimi is assessed from basic information such as specie, production date and location, and grade (Marris). Surimi grades are commonly based on, at least, the following characteristics: color, gel strength (a measure of overall texture), water content, and impurities (Park and Morrissey). Each company produces between three and six distinct grades. Multiple grades result from the production process. During this process, minced fish is washed repeatedly with water to remove water-soluble proteins, various enzymes, blood, and fat; as washings continue, lower-quality product is separated (Hall and Ahmad).

Several factors have been hypothesized to impact surimi quality. Sproul and Queirolo claim that quality is determined by the production conditions. They argue that the longer the time between harvest and processing, the lower the quality (hence the perception that catcher-processors produce higher quality surimi). Specifically, increasing the time between harvest and processing causes the flesh to denature and affect surimi color and impurities (Hall and Ahmad). Sonu believes that other characteristics of the fish, such as average size, are also important. And, Hall and Ahmad describe how spawning cycles affect flesh composition (i.e., protein, moisture, and fat content) which, in turn, influences the water content and gel strength of the resulting surimi. All authors agree that specie is an important factor; in particular, gel strength and whiteness are usually higher for pollock.

Using the 1994 data from the catcher-processor vessel, the following equation was specified to test these hypotheses:

$$X_i = \alpha_i^o + \sum_{j=1}^{3} \alpha_{ij}^z Z_j + \alpha_i^d D + \sum_{j=1}^{3} \alpha_{ij}^{zd} Z_j D$$

where *i* represents the characteristics that this company used to define its grades:

i = 1: WATER (water content; percent by weight),

2: IMPURITY (points per 40 gram sample; 1 point if piece> 2mm, else 0.5 point),

3: WHITE (whiteness; blue region of spectrum, Z value in CIE X,Y,Z),

4: GEL (gel strength; overall texture, measure of force (grams) times depth (cm)),

5: GEL2 (gel strength of heated or cooled surimi; g*cm), The characteristics (X_i) were assumed a linear function of the Z_j continuous factors, where:

j = 1: HOURS (number of hours the fish were held before processing),

2: WEIGHT (average fish weight in grams),

3: JULIAN (Julian date of production; January 1=1 to December 31=354),

whose affect was assumed to vary by specie (D=1 for pollock, 0 for whiting). Thus, interaction terms (Z_jD) were used to obtain the unique effects of time before processing, fish size, and production date for pollock surimi. Table 1 contains the average for each variable and the autocorrelation-corrected estimation results.

WEIGHT was the only variable to have a significant affect on the same surimi characteristics for each species. No single variable significantly affected all of the characteristics. The interactive dummy variables indicated that the quality of pollock surimi was higher in terms of water content and gel strength, but lower in terms of impurities. Overall, specie (i.e., D) had the largest effect on the levels of the surimi characteristics, however, all elasticities of significant variables were close to zero.

The longer the time between harvest and processing, the lower the quality of whiting surimi in terms of whiteness and gel strength. For pollock, increasing the time improved final gel strength and lowered impurity levels. These improved quality effects were accompanied, however, by a slight (undesirable) increase in moisture content. Results indicate that in order to produce the highest quality surimi (i.e., improve the level of each characteristic), the time fish are held before processing should vary by species.

The heavier the individual pollock, the greater the improvement in water content, impurities, and whiteness. This result was expected since fillet machines work better with larger fish (Hall and Ahmad). Conversely, larger whiting resulted in greater impurities and lower whiteness. This is because older (i.e., heavier) whiting have a higher incidence of parasites. Although this does not affect the functionality of the product, dark spots are visible and undesirable in final products (Park and Morrissey).

When production occurred later in the year (at a higher Julian date), water content and gel strength of whiting surimi improved. As the pollock season progressed, however, water content increased while whiteness and gel strength fell (i.e., quality deteriorated).

Hedonic Model Development

In 1974, Rosen proposed the hedonic method to determine the implicit price of objectively measured characteristics, which completely describe a differentiated product. Since that time, hedonics has been used to successfully estimate implicit characteristic prices for various agricultural products (Jordan et al.; Ethridge and Neeper; Davis). The technique has also been used to examine the appropriateness of federal food grading systems (Ethridge and Neeper). Since surimi quality is measured by both buyers and sellers and is graded on a subset of characteristics that varies by company, the hedonic technique is particularly appropriate for this product. Also, given the multispecie, multisector, multiproduct nature of the industry, this technique can provide unique and important information for a variety of uses.

In its simplest form, the hedonic regression is specified as: $\mathbf{P} = f(\mathbf{X})$ where $\mathbf{P}$ is a vector of prices and $\mathbf{X}$ is a matrix of characteristics. This is the equilibrium price function for the characteristic X_i that is implicit in $f(\mathbf{X})$. Evaluating $d\mathbf{P}/dX_i$ at observed characteristic levels generates the implicit value of each characteristic. The estimated coefficients are frequently referred to as marginal implicit prices (MIPs; Rosen). If characteristics are qualitative and represented by dummy variables, the implicit prices are price differentials (i.e., premiums or discounts).

According to Ethridge and Davis, product definitions should be truncated to include only 'distinct' characteristics since a high degree of collinearity between explanatory variables can prevent estimation of distinct effects. Correlation matrices for each data set revealed high levels of linear correlation between certain variables, most notably between identical measures on the raw and heated or cooled surimi. Consequently, for this analysis, only the characteristics tested on the raw surimi were included. Since each characteristic is measured at a cost to the buyer, all characteristics tested on the raw surimi are assumed important in the production of the final product and, therefore, all were retained to prevent specification bias.

Product characteristics are not the only factors that impact price; outside influences such as supply and demand conditions in different periods or locations may also be important and can be accounted for with dummy variables (Ethridge and Davis; Bowman and Ethridge). Dummy and continuous variables can also be used to account for production information that captures real or perceived quality differences (Ethridge and Neeper). In this study, dummy variables (*D*) were defined for different surimi grades, processing locations, and years. Continuous variables (*Z*) were defined for information such as processing date. The general hedonic specification is: $\mathbf{P} = f(\mathbf{X}, \mathbf{D}, \mathbf{Z})$.

Hedonic equations are reduced form equations and, as such, economic theory does not specify the correct functional form (Jordan et al.). To use hedonic results in subsequent analysis, nonlinearity is frequently imposed (e.g., Bowman and Ethridge; Beach and Carlson). In this study, linearity is appropriate for the following reasons: (1) only the hedonic estimates are of concern (Bowman and Ethridge), (2) dummy variables are included (Beach and Carlson), and (3) the linear form produces the smallest maximum bias if the function is misspecified (Davis). The latter argument is particularly strong given the large number of potential explanatory variables.

Empirical Results

The data set from the final processor in Japan included price, grade, and quality measurements taken at the time of purchase on 36 lots of pollock surimi. The company purchased three different grades, we refer to as: A, B, and C (A being the highest), from multiple U.S. producers in mid-January 1995. Given the short time period during which purchases were made, the market conditions were assumed constant between sales.

The MIPs of the qualitative and continuous descriptors (D_k and Z_j, respectively) and the surimi characteristics (X_i) were compared between four different model specifications. Alternative specifications were needed to test the maintained hypotheses regarding the relative importance of different types of information, for example, that grades alone can adequately explain price. In general form, the models are defined as follows: (1) $\mathbf{P} = f(\mathbf{D})$, (2) $\mathbf{P} = f(\mathbf{D}, \mathbf{Z})$, (3) $\mathbf{P} = f(\mathbf{X})$, and (4) $\mathbf{P} = f(\mathbf{D}, \mathbf{Z}, \mathbf{X})$,

where: $D_{k=3}$ (D_1=1 if grade A, D_2=1 if grade B, D_3=1 if produced at-sea; else=0)

$Z_{j=1}$ (JULIAN date of production)

$X_{i=8}$ (WATER, PH, IMPURITY, WHITE, LIGHT, FORCE, DEPTH, GEL) .

There are three additional quality characteristics in this analysis. LIGHT measures the lightness of the surimi (L value in L,a,b scoring). A score of 0 represents black and 100 indicates a pure white color. FORCE is an indication of firmness as reflected by the force applied to a gelled sample at 'failure' (in grams), that is, when the mixture breaks. DEPTH is the corresponding measure of the indentation depth at failure (in centimeters). The interaction between FORCE and DEPTH reflects the overall gel strength or texture of the sruimi (i.e., FORCE*DEPTH = GEL).

Preliminary analysis indicated that (1) company dummies had no statistically significant affect on price and (2) the MIPs for each characteristic were not company-specific, therefore, company dummies were excluded from the equation. According to Marris, company preferences (if they exist) are based on a reputation for quality consistency in all attributes; if so, heteroskedasticity would not be correlated with any particular variable in the model, and (at least in large samples) the OLS computations would not be misleading. In addition, characteristics should be valued identically across firms in a competitive market (Jordan et al.). Assuming a competitive market, and given the results of the preliminary analysis, it was unnecessary to correct for heteroskedasticity. Moreover, we did not correct for autocorrelation because (1) all lots were purchased at effectively the same time, (2) the lots were tested in random order, and (3) production did not occur at regular intervals throughout the year (Beach and Carlson). Table 2 contains the OLS regression results for each model. Since the OLS technique estimated statistically significant distinct coefficients for each variable in equation (3), multicollinearity was not perceived as a significant problem.

The dummy variables representing grade and production location explained only 40% of the variation in price (equation (1)). The result concerning grade is surprising since the grade-quality relationship is frequently emphasized in the literature (Park and Morrissey). Perhaps more surprising is the higher coefficient on the lower grade. This could be due to the market conditions at the time of purchase or the need for the characteristic levels offered in the B grade by some of the suppliers. In terms of the production location, surimi produced at-sea was paid a higher price.

Perhaps the most influential variable was the date of production; including the Julian date in equation (2) increased the explanatory power of the model from 40% to

96%. This variable indicates that surimi processed later in the season was paid a higher price. This could be due to perceived or actual quality differences. For example, surimi processed later in the season may be *precieved* as a higher quality product since it would have been frozen for a shorter period of time. However, surimi can maintain its quality for over a year while frozen (Marris; Hall and Ahmad) such that *actual* quality may not differ. On the other hand, this variable could be capturing the observed seasonal reduction in the standard deviations of each characteristic.

Equation (3) indicates that the surimi characteristics explained 93% of the price variation. The characteristics were, therefore, a much better indication of quality than the grade or whether production occurred at-sea. The high explanatory power of equation (3) suggests that the simple linear functional form was adequate. In addition, given that 75% of the characteristics were significant in this equation, including the collinear attributes was appropriate. Specifically, six of the eight characteristics were significant and five had the expected sign. Gel strength was expected to be positive, however, given the inclusion of the underlying force and depth measures this value is acceptable; the gel strength coefficient reduces (but not offsets) the increase in price predicted from improvements in force and depth. Overall, these results have important implications for grading schedules. For example, using LIGHT or WHITE as a proxy for color, or GEL as a proxy for overall texture (and ignoring the underlying force and depth measures) may be insufficient or misleading given the unique explanatory power of each.

Price elasticity estimates are frequently used to compare price effects by assuming an equal percentage increase in each explanatory variable. Price elasticities are not, however, an effective means to compare the price effects of surimi characteristics since equal percentage increases are not realistic. Alternatively, we assumed a one standard deviation improvement (not increase) in the level of each variable. The largest price effects were from the components of gel strength; depth and force improvements would increase price 9.5% and 8.4%, respectively. The effects of the color variables were identical, a one standard deviation improvement resulted in equal 5.3% price increases. The next largest effect was produced by a decrease in pH (1.3%). The insignificant variables, water content and impurities, had only minimal effects (0.4% and 0.3%

respectively). These variables may be insignificant due to their relatively small deviations in the data; consequently, their effects may be underestimated.

When all of the independent variables were included (equation (5)), the explained price variation increased to 98%. As with equation (2) and as expected, the highest-grade surimi (i.e., grade A) was paid a higher premium (although only slightly). The production-related variables remained significant and robust compared to the model specification that excluded the characteristics (equation (3)). The characteristics were, however, not robust to the inclusion of the additional variables. The high correlation between Julian date and some of the characteristics (e.g., WATER and GEL, Table 1) may have prevented the regressions from estimating statistically significant individual price effects.

Summary

In the first stage of this analysis, several production and management-controlled factors were used to explain observed variation in surimi quality characteristics. In the second stage, transaction prices were used to estimate the MIPs of these characteristics and other factors under the control of private and public managers, and hypothesized to influence price. These results can be used to predict price effects from, for example, reducing the time fish are held before processing or delaying the season opening. Collectively, these results are important to fishery managers, fishermen, and surimi processors since (1) fishery management plans include allocations among harvest sectors (onshore versus at-sea) that are partially based on assumed price and quality differences; (2) pollock and whiting seasons occasionally overlap; (3) seasonal growth affects surimi quality and price; (4) surimi is an optional product form; and (5) surimi quality can be controlled.

References

Anderson, J.G. and J.L. Anderson. "Seafood Quality: Issues for Consumer Researchers." *J. Cons. Affairs* 25,1(1991):144-163.

Beach, E.D. and G.A. Carlson. "A Hedonic Analysis of Herbicides: Do User Safety and Water Quality Matter?" *Amer. J. Agr. Econ.* 75(August 1993):612-623.

Bowman, K.R. and D.E. Ethridge. "Characteristic Supplies and Demands in a Hedonic Framework: U.S. Market for Cotton Fiber Attributes." *Amer. J. Agr. Econ.* 74(November 1992):991-1002.

Davis, G.C. "Consumer Specie Knowledge and the Values of Natural Christmas Tree Characteristics." *J. Agr. Applied Econ.* 25(July 1993):266-277.

Ethridge, D.E. and B. Davis. "Hedonic Price Estimation for Commodities: An Application to Cotton." *West. J. Agr. Econ.* 7(1982):293-300.

Ethridge, D.E. and J.T. Neeper. "Producer Returns From Cotton Strength and Uniformity: An Hedonic Price Approach." *So. J. Agr. Econ.* 19(July 1987):91-96.

Freese, S., J. Glock, and D. Squires. "Allocation of Resources and Cost-Benefit Analysis in Fisheries: An Application to Pacific Whiting." *Mar. Pol.* 19(1995):199-211.

Hall, G.M. and N.H. Ahmad. "Surimi and Fish-Mince Products." In *Fish Processing Technology*, 2nd ed., G.M. Hall [ed.], pp. 74-92. Blackwell Publishers, 1997.

Jordan, J.L., R.L. Shewfelt, S.E. Prussia, and W.C. Hurst. "Estimating Implicit Marginal Prices of Quality Characteristics of Tomatoes." *So. J. Agr. Econ.* 17(December 1985): 139-145.

Marris, K. "All Surimi is Not Created Equal." *Seafood Business* (July 1990):98-110.

National Marine Fisheries Service (NMFS). *Fisheries of the United States, 1995*. Current Fishery Statistics No. 9500. U.S. DOC-NOAA, Silver Spring MD, 1996.

Park, J. and M. Morrissey. "The Need for Developing Uniform Surimi Standards." In *Quality Control & Quality Assurance for Seafood*, eds., G. Sylvia, A. L. Shriver, and M. Morrissey, pp. 64-71. Corvallis OR: Oregon Sea Grant, 1993.

Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *J. Pol. Econ.* 82(1974):34-55.

Sonu, S.C. *Surimi*. NOAA Technical Memorandum, NMFS-SWR-013. U.S. DOC, 1986.

Sproul, J.T. and L.E. Queirolo. "Trade and Management: Exclusive Economic Zones and the Changing Japanese Surimi Market." *Mar. Fish. Rev.* 56(1994.):31-39.

Table 1. Statistical significance of specie, season, fish size, and production time

		Estimated Parameters [a]				
Variables	Average	WATER	IMPURITY	WHITE	GEL	GEL2
Average		74.6	7.7	71.9	1,150.0	2,084.0
Intercept		77.78***	3.05	50.41***	783.5***	1765.1***
		(0.47)	(3.27)	(1.36)	(131.8)	(324.5)
$Z_{1: \text{HOURS}}$	9.7	-0.026	-0.034	-0.082**	-8.29**	-23.27**
		(0.018)	(0.119)	(0.039)	(4.01)	(10.3)
$Z_{2: \text{WEIGHT}}$	591.8	-0.005***	0.013**	-0.008***	0.052	0.195
		(0.0008)	(0.006)	(0.002)	(0.22)	(0.561)
$Z_{3: \text{JULIAN}}$	99.4	-0.004***	-0.007	0.009	2.13***	2.74***
		(0.0008)	(0.007)	(0.0056)	(0.456)	(1.03)
$D_{: \text{POLLOCK}}$	0.63	-2.75***	11.72***	-1.877	336.9**	25.64
		(0.526)	(3.61)	(1.597)	(150.1)	(367.6)
Z_1D	7.6	0.047***	-0.369***	0.065	0.946	29.86***
		(0.0202)	(0.13)	(0.042)	(4.37)	(11.23)
Z_2D	373.9	0.004***	-0.019***	0.009***	0.035	-0.153
		(0.0008)	(0.006)	(0.002)	(0.237)	(0.602)
Z_3D	84.7	0.005***	0.011	-0.027***	-1.456***	-1.64
		(0.0008)	(0.008)	(0.006)	(0.508)	(1.14)
R^2		0.29	0.30	0.86	0.66	0.52
DW		2.00	2.36	2.18	2.40	2.38

[a] For each equation *n*=651. Standard errors are reported in parentheses. Single, double, and triple asterisks (*) indicate significance at the 10%, 5%, and 1% level, respectively.

Table 2. Hedonic results for surimi purchased by a manufacturer of traditional products

		Parameter Estimates[a]			
Variable	Average	(1)	(2)	(3)	(4)
Intercept		320.00*** (9.14)	282.62*** (2.92)	-586.67*** (238.8)	-93.16 (217.7)
$D^1_{1: ATSEA}$	0.54	15.29** (7.18)	13.93*** (1.84)		10.95*** (3.35)
$D^1_{2: GRADE\_A}$	0.58	20.00* (11.19)	55.11*** (3.30)		45.41*** (5.99)
$D^1_{3: GRADE\_B}$	0.36	39.61*** (9.82)	51.25*** (2.57)		42.41*** (5.93)
$Z_{1: JULIAN}$	78.1		0.17*** (0.008)		0.155*** (0.022)
$X_{1: WATER}$	74.7			-1.45 (1.29)	0.11 (0.95)
$X_{2: PH}$	7.3			-46.97*** (12.73)	-2.27 (17.8)
$X_{3: IMPURITY}$	2.6			0.59 (0.55)	0.30 (0.29)
$X_{4: WHITE}$	53.0			-7.67*** (1.64)	-1.98 (1.18)
$X_{5: LIGHT}$	78.4			14.41*** (2.36)	5.16*** (1.72)
$X_{6: FORCE}$	763.3			0.914*** (0.14)	0.117 (0.145)
$X_{7: DEPTH}$	1.4			441.7*** (65.8)	60.25 (73.08)
$X_{8: GEL}$	1,091.8			-0.607*** (0.095)	-0.074 (0.098)
R^2		0.40	0.96	0.93	0.98
F-value		7.01***	194.46***	44.54***	133.5***

[a] Price measured in yen per kilogram. All equations were estimated with 36 observations. Standard errors are reported in parentheses. Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% level, respectively.