Journal of Agricultural and Applied Economics, 33,3(December 2001):403–411

The Impact of Inventory on Tuna Price: An Application of Scaling in the Rotterdam Inverse Demand System

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Abstract

This study adopted the scaling approach to examine the impacts of inventories on tuna auction prices in Japan using the Rotterdam inverse demand system. The inclusion of two inventory variables in the model only increases the number of parameters by two. Results indicate that frozen tunas are more likely to be close substitutes, fresh and frozen tunas of the same species are also likely to be substitutes, and inventory had significant impacts on auction prices.

Key Words: *scaling, Rotterdam inverse demand system, tuna, inventory.*

Japan is the world's leading producer and consumer of *sashimi* grade tuna.[1] *Sashimi* grade tuna is produced from three types of tuna: yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*), and bluefin tuna (*Thunnus thynnus*) (Williams, 1986). Most fresh and frozen tuna harvests are used for high-value-added *sashimi* tuna consumption in Japan. Fresh tuna is more expensive and ordinarily available only in fine restaurants. Because of the scarcity of fresh bluefin tuna in Japan, substituting among different tuna species and between fresh and frozen tuna is common (Yamamoto, 1994; Owen and Troedson, 1994; Bose and McIlgorm, 1996). For example, fresh bluefin tuna, with high quality and controlled quantity of production, is the most expensive type of tuna. In contrast, frozen tuna is cheaper and available in supermarkets nationwide for the purpose of household consumption.

The landing and prices of frozen *sashimi* grade tuna at Japan's markets have been steady and firm in the past several years. However, consumers' preferences for *sashimi* products seem to have changed in 1997 and 1998, apparently as a result of the Asian financial crisis. During this period Japanese consumers shifted their demands toward cheaper products, such as frozen yellowfin and bigeye that are red meat species, instead of expensive fresh/chilled *sashimi* grade tuna. Because of the economic recovery in 1999, all *sashimi* grade tuna products are expected to be more in demand in Japan.

In Japan, tuna are harvested by ice-chilled or deep-frozen longline fishing boats, and most tuna are landed at 42 major fishing ports and sold immediately at these wholesale auction markets.[2] From January 1984 through September 1999, yellowfin tuna, bigeye tuna, and bluefin tuna accounted for 16.8 percent,

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[1] Japan harvested 459,300 MT of tuna for canned and *sashimi* use in 1995 (FAO GLOBEFISH—Tuna Commodity Update, 1997).

[2] There were 51 wholesale fish markets in 1992.

51.8 percent, and 31.4 percent of the revenue from all tuna sold at those local wholesale fish markets, respectively. During this period the average landing was about 10,686 tons per month. Prices at wholesale markets at producing localities are determined by the interaction between broker demand and landings. In this study prices were calculated as the monthly total auction value divided by the monthly total auction quantity sold in the markets. Price differences among the three types of tuna are due to quality, quantity, and consumer preference.

Over the 1984–98 period, the average monthly frozen tuna inventory was 30,780 tons, about 288 percent of the average quantity sold at wholesale fish markets at producing localities, or about three months' supply. Note that the wholesale markets are not able to hold fresh tuna as inventory.

The Rotterdam inverse demand system (RIDS) has been used to study the formation of fish prices at Belgian fishery ports (Barten and Bettendorf) and the price formation of citrus fruits in the United States (Brown et al.). However, the RIDS applied by Barten and Bettendorf assumed that prices are functions of quantities supplied and did not consider the possibility of other price-influencing variables such as inventory levels. The current study extends Barten and Bettendorf's analysis and uses the scaling approach to incorporate inventory levels in the RIDS.

The Rotterdam Inverse Demand System

In a study of price formation of fish, Barten and Bettendorf developed a RIDS using the direct utility function and Wold-Hotelling identity. The RIDS used in Barten and Bettendorf's study can be written as

$$(1) \qquad w_{it} d \ln \pi_{it} = h_i DX + \sum_j h_{ij} d \ln x_{jt}.$$

where subscript t represents time; π_{it} is the normalized price ($\pi_{it} = p_{it}/m_t$) of good i; with p_{it} and m_t being the price and total expenditure, respectively; x_{it} is the quantity of good i; $w_{it} = x_{it}\pi_{it}$ is the budget share of x_{it}; $d \ln \pi_{it} = \log(\pi_{it}/\pi_{it-1})$; $d \ln x_{it} = \log(x_{it}/x_{it-1})$; $h_{ij} = w_i\Delta^*_{ij}$, with Δ^*_{ij} being the compensated quantity elasticity; $h_i = w_i\Delta_i$, with Δ_i being the scale elasticity; and $DX = \Sigma_j w_{jt} d \ln x_{jt}$ is the Divisia volume index. For simplicity, subscript t will be deleted in the following discussion. The above inverse-demand system satisfies the following demand restrictions

$$\sum_i h_i = -1 \quad \text{and}$$

$$\sum_i h_{ij} = 0 \quad \text{(adding-up)}^3$$

$$\sum_j h_{ij} = 0 \quad \text{(homogeneity)}$$

$$h_{ij} = h_{ji} \quad \text{(Antonelli symmetry).}$$

Note that the adding-up condition $\Sigma_i h_i = \Sigma_i w_i\Delta_i = -1$ is based on the reference quantity vector or the reference quantity vector has a scale factor $k = 1$ (Anderson).

For scaling, let $x^*_i = \varphi_i x_i$, $p^*_i = p_i/\varphi_i$, $m^* = m$; and $\varphi_i = \varphi_i(z_i)$ (Barten, 1964; Brown et al.). The impact of non-quantity, non-income variables, z, is introduced through parameters φ_i. In this study, variables z_i are defined as the beginning inventory of various types of tuna. It is assumed that the existence of tuna inventories may affect the auction price. For example, high inventory levels may have an impact on minimum auction prices and buyers' willingness to offer high prices, i.e., $\varphi_i > 1$, or in other words, $p^*_i < p_i$. The existence of inventories may also affect buyers' perceptions of quantities available for sale (i.e., it amplifies buyers' perceptions of actual physical quantities available for sale, or $x^*_i > x_i$), thus affecting the auction prices of tuna.

The general form of the inverse-demand equations (1) for scaling is

$$(2) \qquad w_i d \ln \pi^*_i = h_i d \ln X^* + \sum_j h_{ij} d \ln x^*_j.$$

Given the scaling definitions of x^* and p^*, $d \ln x^*_i = d \ln x_i + d \ln \varphi_i$, $d \ln \pi^*_i = d \ln \pi_i - d \ln \varphi_i$, and $d \ln X^* = \Sigma_j w_j \, d \ln x^*_j$ (note that $w^*_i = p^*_i x^*_i/m = p_i x_i/m = w_i$). Also, we can write $d \ln \varphi_i = (d \ln \varphi_i/d \ln z_i) d \ln z_i$. Therefore, (2) can be written as

$$(3) \quad w_i d \ln \pi_i = w_i \eta_i d \ln z_i + h_i\left(d \ln X + \sum_j w_j \eta_j d \ln z_j\right) + \sum_j h_{ij}(d \ln x_j + \eta_j d \ln z_j)$$

where $\eta_j = d \ln \varphi_j / d \ln z_j$. Equation (3) shows that variable z_i has three impacts on the normalized price π_i: a direct impact, $w_i \eta_i d \ln z_i$; an indirect impact through the scale effect (h_i); and an indirect impact through the Antonnelli coefficients (h_{ij}). The total impact of inventory z_i on the normalized price π_i equals $(w_i \eta_i + h_i w_i \eta_i + h_{ii} \eta_i) d \ln z_i$. Note that when all η_is are zero, (3) collapses to (1).

In order to examine the impacts of financial crisis on tuna prices during 1997 and 1998, a dummy variable, fc, was added to (3)

$$(4) \quad w_i d \ln \pi_i = \alpha_i fc + w_i \eta_i d \ln z_i + h_i\left(d \ln X + \sum_j w_j \eta_j d \ln z_j\right) + \sum_j h_{ij}(d \ln x_j + \eta_j d \ln z_j);$$

where $fc = 1$ for 1997 and 1998 and $fc = 0$ otherwise.

Data and Results

The above three model specifications—(1), (3), and (4)—were applied to the Japanese monthly wholesale data on bluefin tuna, bigeye tuna, and yellowfin tuna. Note that (1) is nested in (3) and (3) is nested in (4); hence, (1) and (3) can be used to examine the importance of inventory variables and (3) and (4) for the impacts of financial crisis on tuna prices. The data cover from January 1984 through September 1999. Six types of tuna were considered: fresh and frozen yellowfin tuna, fresh and frozen bluefin tuna, and fresh and frozen bigeye tuna. The data were collected from various monthly issues of *Annual Statistics of Fishery Products Marketing* (Ministry of Agriculture, Forestry and Fisheries, Japan, 1984–1999), which are Japanese official fishery publications. The data are for monthly Japanese catches from 42 fishing areas in Japan and include the amounts of tuna sold at the respective wholesale fish markets in tons, the average monthly prices in yens per kilogram, and the amounts of tuna in inventory in tons. The inventory variables include frozen yellowfin and bigeye tuna.

Bluefin tuna is protected by the Convention on International Trade of Endangered Species of Wild Fauna and Flora. There are quotas for each fishing country and each bluefin tuna caught has to come with a certification of product of origin issued by the fishing country's authority. Therefore, the landings of frozen bluefin tuna are limited and unstable (Table 1). As a result of the unstable and limited supply of bluefin tuna and its premium quality and taste, bluefin tuna commands the highest price among the three tunas studied. Also, due to the limited and unstable supply, bluefin tuna inventories are very small and not reported.

The price differences among the six types of tuna are due to differences in quality, supplies, and consumer preferences. Based on Table 1, the average monthly prices of fresh tuna are higher than the prices of frozen tuna. In addition, the average monthly prices of bluefin tuna are higher than the prices of bigeye and yellowfin tuna. The average monthly prices of fresh and frozen bluefin tuna are about three and four times the prices of fresh and frozen bigeye and yellowfin tuna, respectively. Note that higher price levels also have higher standard deviations.

For the six types of tuna mentioned above, the following difference forms of (1), (3), and (4) were estimated

$$(1') \quad w^*_{it} \Delta \ln \pi_{it} = h_i \Delta \ln X + \sum_j h_{ij} \Delta \ln x_{jt} + v_{it};$$

$$(3') \quad w^*_{it} \Delta \ln \pi_{it} = w^*_{it} \eta_i \Delta \ln z_{it} + h_i\left(\Delta \ln X_t + \sum_j w^*_{jt} \eta_j \Delta \ln z_{jt}\right) + \sum_j h_{ij}(\Delta \ln x_{jt} + \eta_j \Delta \ln z_{jt}) + v_{it};$$

Table 1. Sample Statistics

	Mean	Standard Error	Minimum	Maximum
Quantity Sold (metric tons)				
Fresh Yellowfin	1,109	854	172	6,178
Frozen Yellowfin	2,153	810	513	5,295
Fresh Bigeye	769	311	184	1,701
Frozen Bigeye	5,306	2,237	1,395	11,712
Fresh Bluefin	330	622	1	4,052
Frozen Bluefin	1,020	614	50	3,296
Average Auction Price (Yens/kilogram)				
Fresh Yellowfin	807	193	396	1,337
Frozen Yellowfin	592	119	311	1,054
Fresh Bigeye	1,419	497	479	2,777
Frozen Bigeye	1,025	175	606	1,544
Fresh Bluefin	3,535	2,160	822	10,328
Frozen Bluefin	3,491	1,118	644	6,871
Inventory (metric tons)				
Frozen Yellowfin	14,914	3,287	5,439	21,789
Frozen Bigeye	15,865	3,464	5,913	23,919
Revenue Share				
Fresh Yellowfin	0.068	0.040	0.015	0.224
Frozen Yellowfin	0.101	0.028	0.052	0.185
Fresh Bigeye	0.093	0.054	0.020	0.268
Frozen Bigeye	0.422	0.106	0.171	0.647
Fresh Bluefin	0.052	0.078	0.000	0.411
Frozen Bluefin	0.263	0.118	0.017	0.663

$$(4') \quad w_i^* \Delta \ln \pi_i = \alpha_i fc + w_{ii}^* \eta_i \Delta \ln z_{it} + h_i\left(\Delta \ln X_t + \sum_j w_{ji}^* \eta_j \Delta \ln z_{jt}\right) + \sum_j h_{ij}(\Delta \ln x_{jt} + \eta_j \Delta \ln z_{jt}) + v_{it}.$$

To account for seasonality, 12-month differences, as opposed to first differences, were taken in transforming the data as required by these three models. In the above three equations, $w_{it}^* = (w_{it} + w_{it-12})/2$ is the 12-month moving average in the share of good i in total sales, $\Delta \ln y_t = \ln y_t - \ln y_{t-12}$ for y_t being π_{it}, x_{it}, and z_{it}, respectively, and $\Delta \ln X_t = \Sigma_j w_{jt}^* \Delta \ln x_{jt}$. The h_i, h_{ij}, and η_j are assumed to be constants. The disturbance terms, v_{it}s, were assumed to be normally distributed with mean zero and the errors across equations are contemporaneously correlated.

The sets of six equations for (1′), (3′) and (4′) have been estimated jointly by an iterative seemingly unrelated regression procedure. As the data add up by construction, the error covariance matrix is singular and the equation for frozen bluefin tuna was excluded from the system for estimation. As shown by Barten (1969), the estimates are invariant with respect to the equation excluded from the system. The likelihood ratio test (Chow) was used to test model (1′) against unrestricted model (3′) and model (3′) against (4′).[4] The χ^2 test statistic for (1′) and (3′) is 61.86 (the table value of $\chi^2_{(2)} = 5.99$ at $\alpha = 0.05$ level), an indication that the addition of inventory variables in the analysis improves the model's explanatory power. The χ^2 test statistic for (3′) and (4′) is

[3] Note that $\Sigma_i \pi_i x_i = 1$; therefore, $\Sigma_i (x_i d\pi_i + \pi_i dx_i) = 0$, or $\Sigma_i (\pi_i x_i(d\pi_i/\pi_i) + x_i\pi_i(dx_i/x_i)) = 0$, or $\Sigma_i w_i d \ln x_i = -\Sigma_i w_i d \ln \pi_i$.

[4] The log likelihood function values for (1′), (3′), and (4′) are 1920.52, 1951.45, and 1958.30, respectively.

13.70 (the table value of $\chi^2_{(5)} = 11.07$ at $\alpha = 0.05$ level), an indication that financial crisis during 1997 and 1998 had significant impacts on tuna prices. Based on these test results, model (4′) was used in the following discussion. Table 2 shows the estimates for α_i, η_i, h_i and h_{ij} together with their corresponding standard errors in parentheses for model (4′).

As Table 2 shows, the financial crisis in 1997 and 1998 had a negative impact on frozen bigeye tuna price and a positive impact on fresh yellowfin tuna price while the financial crisis impact on other tuna prices was not statistically different from zero. The scale effects h_i are all negative and statistically different from zero at $\alpha = 0.01$ level. These negative scale effects are to be expected. With a fixed budget m, a proportional increase of all quantities means a decrease in prices, p_is; hence a decrease in $\pi_i = p_i/m$. The scale coefficient h_i can be divided by w_i and converted into scale elasticities. The estimated (at sample means of w_i) scale elasticities are presented in Table 3. Results show that the scale elasticities for the three types of frozen tuna are smaller than those for the three types of fresh tuna. The scale elasticities for frozen yellowfin and bigeye tuna are less than unity in absolute value, while the rest of the scale elasticities are greater than unity in absolute value. This result may reflect that fresh tuna are more perishable than frozen tuna; hence, fresh tuna prices are more responsive to scale changes than frozen tuna prices.

The own substitution effects (h_{ii}) are all negative and significantly different from zero except the ones for frozen bigeye tuna and frozen bluefin tuna. The estimated compensated own-quantity elasticities are derived by dividing h_{ii} by the sample mean w_i and are presented in Table 3. Similar to the scale elasticity pattern, the own-quantity elasticities for fresh tuna prices are greater in absolute value than those for frozen tuna.

The matrix $H = [h_{ij}]$ reflects to a certain degree the interactions between the goods in their ability to satisfy wants. More of good i is generally sold at a lower price for i. One may also say that a good is its own substitute. Extending the notion of substitution to all negative h_{ij}, it is natural to consider a positive h_{ij} as an indication of complementarity between i and j. Note that the adding-up condition $\Sigma_i h_{ij} = 0$ together with $h_{jj} < 0$ means that $\Sigma_{i \neq j} h_{ij} > 0$; therefore, for $i \neq j$ complementarity may dominate in an inverse-demand system. The dominance does not come from the structure of preferences but from the condition $\pi' x = 1$, which makes the h_{ij}s imperfect measures of the interaction of goods in their satisfaction of wants.

Barten and Bettendorf worked with a transformation of the H. Using the vectors $h = [h_i]$ and $w = [w_i]$ they derived the counterpart of the Allais coefficients for the inverse-demand system. By selecting r and s as the standard pair of goods, the Allais coefficient for the inverse demand system can be defined as

$$a_{ij} = h_{ij}/w_i w_j - h_{rs}/w_r w_s + (h_i/w_i - h_r w_r) + (h_j/w_j - h_s/w_s).$$

In the definition of $a = [a_{ij}]$, the subscripts r and s refer to some standard pair of goods r and s. The above equation indicates that $a_{rs} = 0$. Thus $a_{ij} > 0$ indicates that i and j are more complementary than r and s, while $a_{ij} < 0$ indicates that i and j are stronger substitutes than r and s, and $a_{ij} = 0$ indicates that i and j have the same type interaction as r and s. Based on the Allais coefficient the measure of the intensity of interaction can be defined as

$$\alpha_{ij} = a_{ij}/(a_{ii}a_{jj})^{1/2}$$

which for a negative definite matrix $A = [\alpha_{ij}]$, α_{ij} varies between -1 (perfect substitution) and $+1$ (perfect complementarity).

To apply this relation to the results in Table 2, one has to identify a standard pair of goods. Following Barten and Bettendorf, we have selected the interaction between fresh and frozen yellowfin tuna as the standard pair of goods for the simple reason that this makes all other Allais interactions negative. This expresses the intuitive idea that all the types of tuna considered here are substitutes in consumption. Sample means of w_i were used in the calculation of Allais interaction intensity. Results are pre-

Table 2. Demand Parameter Estimates

	Financial Crisis Dummy	Scale Effect	Antonelli Effect					
			Fresh Yellowfin	Frozen Yellowfin	Fresh Bigeye	Frozen Bigeye	Fresh Bluefin	Frozen Bluefin
Fresh Yellowfin	0.0102*	−0.0864*	−0.0198*	0.0064*	−0.0001	0.0089*	0.0008	0.0038
	(0.0042)	(0.0070)	(0.0030)	(0.0024)	(0.0026)	(0.0037)	(0.0010)	(0.0024)
Frozen Yellowfin	−0.0057	−0.0821*		−0.0147*	0.0058	0.0003	0.0037*	−0.0015
	(0.0039)	(0.0066)		(0.0042)	(0.0031)	(0.0044)	(0.0009)	(0.0023)
Fresh Bigeye	−0.0043	−0.1059*			−0.0145*	−0.0007	0.0004	0.0091*
	(0.0042)	(0.0073)			(0.0043)	(0.0042)	(0.0011)	(0.0025)
Frozen Bigeye	−0.0295*	−0.3520*				−0.0130	0.0058	−0.0012
	(0.0105)	(0.0171)				(0.0084)	(0.0023)	(0.0060)
Fresh Bluefin	0.0100	−0.0659*					−0.0095*	−0.0011
	(0.0071)	(0.0106)					(0.0017)	(0.0027)
Frozen Bluefin	0.0194	−0.3076*						−0.0091
	(0.0141)	(0.0228)						(0.0080)
Inventory				−0.1568		−0.1206		
				(0.0224)		(0.0198)		

Numbers in parentheses are standard errors of parameter estimates.
* Statistically different from zero at $\alpha = 0.01$ level.

Table 3. Scale Elasticities, Own-Quantity Elasticities, And Allais Interaction Intensity Coefficients

	Elasticity		Allais interaction intensity $\alpha_{12} = 0$					
	Scale	Own-quantity	Fresh Yellowfin	Frozen Yellowfin	Fresh Bigeye	Frozen Bigeye	Fresh Bluefin	Frozen Bluefin
Fresh Yellowfin	−1.2783	−0.2921	−1.0000	0.0000	−0.3197	−0.3571	−0.2225	−0.3946
Frozen Yellowfin	−0.8207	−0.1470		−1.0000	−0.0789	−0.4635	−0.0767	−0.5584
Fresh Bigeye	−1.1481	−0.1575			−1.0000	−0.6582	−0.3181	−0.4088
Frozen Bigeye	−0.8260	−0.0305				−1.0000	−0.4140	−0.9831
Fresh Bluefin	−1.3073	−0.1888					−1.0000	−0.5370
Frozen Bluefin	−1.1674	−0.0345						−1.0000

sented in Table 3. Note that the diagonal entries are −1, which is consistent with the notion that a good is its own perfect substitute. Also, by construction, the Allais interaction intensity between fresh and frozen yellowfin tuna is zero. Of the 14 Allais intensity coefficients, only four are greater than 0.50 in absolute value.

Note that the base of comparison is the substitution relationship between fresh and frozen yellowfin tuna. As Table 3 shows, the highest Allais interaction intensity coefficient is the one between frozen bigeye tuna and frozen bluefin tuna (−0.98). The second highest Allais interaction intensity coefficient is that between frozen bigeye tuna and fresh bigeye tuna (−0.66), followed by the substitution relationships between frozen yellowfin tuna and frozen bluefin tuna (−0.56), and between fresh bluefin tuna and frozen bluefin tuna (−0.54). These findings—frozen tunas are more likely to be close substitutes and fresh and frozen tunas of the same species are more likely to be substitutes—seem to be quite reasonable.

The inventory effects are computed at sample means of w_i and presented in Table 4. The direct and indirect impacts of inventory are presented in the first three columns and the total inventory impact and inventory elasticity estimates are presented in the last two columns. Results show that inventory had direct impacts on frozen yellowfin tuna and frozen bigeye tuna on normalized price, $w_{ii}^{*}\eta_i$, are negative.

Equation (4′) shows that a negative direct effect, η_i, would reduce the quantity ($d \ln X + \Sigma_j w_j\eta_j d \ln z_j$), and, with the negative scale effect h_i, the result is a positive indirect scale inventory effect. For the indirect substitution effect, a negative η_j is also equivalent to a decrease in $d \ln x_j$; therefore, the impact of this indirect substitution effect depends on the sign of h_{ij}. When h_{ij} is negative, the result is a positive effect; when h_{ij} is positive, the indirect inventory effect would be negative.

Results presented in Table 4 show that the direct inventory effects for frozen yellowfin tuna and frozen bigeye tuna are negative. All

Table 4. Inventory Effects

	Inventory Effect and Inventory Elasticity				
	Direct (1) ($w_i\eta_i$)	Scale (2) ($h_i w_j \eta_j$)	Substitution (3) ($h_{ij}\eta_j$)	Total (4) (1) + (2) + (3)	Elasticity (4)/w_i
Yellowfin Tuna Inventory					
Fresh Yellowfin		0.0014*	−0.0010*	0.0003	0.0051
		(0.0002)	(0.0004)	(0.0004)	
Frozen Yellowfin	−0.0157*	0.0013*	0.0023*	−0.0121*	−0.1209*
	(0.0022)	(0.0002)	(0.0008)	(0.0018)	
Fresh Bigeye		0.0017*	−0.0009*	0.0007	0.0081
		(0.0003)	(0.0005)	(0.0005)	
Frozen Bigeye		0.0055*	0.0000	0.0055*	0.0129*
		(0.0008)	(0.0007)	(0.0010)	
Fresh Bluefin		0.0010*	−0.0006*	0.0005*	0.0090*
		(0.0002)	(0.0002)	(0.0002)	
Frozen Bluefin		0.0048*	0.0002	0.0051*	0.0192*
		(0.0008)	(0.0004)	(0.0007)	
Bigeye Tuna Inventory					
Fresh Yellowfin		0.0044*	−0.0011*	0.0034*	0.0499*
		(0.0008)	(0.0005)	(0.0008)	
Frozen Yellowfin		0.0042*	0.0000	0.0042*	0.0419*
		(0.0008)	(0.0005)	(0.0010)	
Fresh Bigeye		0.0054*	0.0001	0.0055*	0.0599*
		(0.0010)	(0.0005)	(0.0011)	
Frozen Bigeye	−0.0514*	0.0181*	0.0016	−0.0317*	−0.0744*
	(0.0084)	(0.0031)	(0.0010)	(0.0056)	
Fresh Bluefin		0.0034*	−0.0007*	0.0027*	0.0534*
		(0.0008)	(0.0003)	(0.0008)	
Frozen Bluefin		0.0158*	0.0001	0.0159*	0.0605*
		(0.0029)	(0.0007)	(0.0026)	

Numbers in parentheses are standard errors of the estimates.
* Statistically different from zero at $\alpha = 0.01$ level.

indirect scale inventory effects are positive, indicating that inventory had positive scale impacts on prices. The own-substitution inventory effect for frozen yellowfin tuna is positive and not statistically different from zero for frozen bigeye tuna. The cross-substitution inventory effects are either negative or statistically not different from zero. As shown in Table 4, the indirect scale inventory effects dominated the total inventory effects in the six types of tunas studied.

The total own-inventory effects for frozen yellowfin and bigeye tunas are negative; in other words, when the inventories of these two types of tunas increase, their auction prices would decrease. Result shows that for a 1-percent increase in the inventories of frozen yellowfin and bigeye tunas, the auction prices of these tunas would decrease by 0.12 percent and 0.07 percent, respectively. Results also show that when inventories of frozen yellowfin and frozen bigeye tunas increase, the auction prices of other tunas would increase. The estimated inventory elasticities indicate that bigeye tuna inventory had larger impacts on auction prices than the inventory of yellowfin tuna. The total inventory elasticity estimates presented in Table 4 indicate that a 1-percent increase in frozen yellowfin tuna inventory would increase the prices of other tunas by less than 0.02 percent, while a 1-percent increase in frozen bigeye tuna inventory would increase the prices of other tunas by more than 0.04 percent.

Concluding Remarks

The addition of inventory variables to an inverse demand system may result in a large increase in parameter space and make estimation difficult. The scaling approach adopted in this study does not add a large number of additional parameters to be estimated. The inclusion of two inventory variables in the model only increases the number of parameters by two. In addition, the results found in the study seem reasonable. Although the results of this study are specific for the Japanese tuna markets, the approach used in this study is easy to apply to other problems. One of these problems could be whether generic advertising increases growers' returns.

Theoretically there should be other ways to incorporate inventory variables in the inverse demand systems. A possible alternative approach would be using a translation approach in the inverse demand system, a concept that inventories are necessary for orderly marketing. Another approach is to assume use of the Tintner-Ichimura conditions (Tintner; Ichimura). In this latter alternative approach, inventories would be considered as factors that influence indirect utility. The empirical estimable models using these alternative approaches need to be developed.

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