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Title: Demand Analysis for *Surimi*-Based Products in Japan

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Since the "200 miles" fishery conservation zones were established by some coastal countries, new arrangements between countries to participate jointly in fishing, processing, and marketing of fish products have emerged. One such fish product is *surimi*. As a result of extended jurisdiction, each coastal country's interest in the *surimi* industry is increasing and many efforts for market research and development of *surimi* technology are being taken in these countries. To understand this market it is important to know the nature of the demand for *surimi*-based products. However, there are not enough data available for demand analysis of *surimi*-based products due to the short history of the *surimi* industry on a global basis and the uncertain supply situation. Therefore, the Japanese market for

surimi-based products, which has a long history and is the world's largest market for *surimi*, was chosen to improve understanding of the global market for *surimi*-based products.

The approach adopted to meet this goal is the demand system approach, which allows the analysis to model the interdependencies among prices and consumption in consumer demand. Careful specification of demand relationships in the Japanese market for *surimi*-based products permits the testing of hypotheses about the impact of changes in availability of other seafoods and red meats on the demand for *surimi*-based products in Japan.

Two different demand system models, the almost ideal demand system (AIDS) model and the habit formation (HF) model, are used for this demand analysis. Especially in the AIDS model, the homogeneity and symmetry restrictions are tested and the simultaneous impacts on consumption of *surimi*-based products, red meats, and other seafood of changes on the prices of these commodities are examined. The habit formation model is used mainly to investigate habit persistence in the Japanese market.

The results of estimating the AIDS model show that the expenditure elasticities of *surimi*-based products are greater than unity and that the demands for *surimi*-based products are generally price-inelastic, while the own price elasticity of *kamaboko* is greater than unity. Also, these results show that *surimi*-based products are more likely to have complementary relationships with other fish products. However, the nature of substitutional relationships with red meats could not be determined by this analysis.

The estimation results of the habit formation model show that habit persistence of consumers exists in Japan's fish and meat market, including *surimi*-based products.

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DEMAND ANALYSIS FOR SURIMI-BASED PRODUCTS IN JAPAN

1. INTRODUCTION

Surimi-Based Production and Markets

Following establishment of "200-mile" fishery conservation zones by some coastal countries, including the United States, foreign countries working in these zones have gradually withdrawn from them. As a result, new arrangements between countries to participate jointly in fishing, processing, and marketing have emerged, such as joint ventures or trade arrangements. This has also happened with respect to *surimi*, an intermediate fishery product that is made out of minced fish flesh and used to manufacture finished consumer products (in general, called *surimi* products or *surimi*-based products). Japan currently participates in joint ventures with U.S. fishermen in harvesting and processing Alaska pollock, much of which goes into *surimi* production.

Surimi was developed in Japan about 1,000 years ago. There are four major types of *surimi*-based products in Japan: *kamaboko*, *chikuwa*, *satsumaagé*, and fish ham and sausage (Miyake, Hirasawa, & Miyanabe, 1985, pp. 3-5). According to this report, prepared for the United Nations FAO (Food and Agriculture Organization), all types of *surimi*-based products found today were developed between the 12th and 17th centuries. The earliest *surimi* product was *chikuwa*, developed in the 12th century. *Chikuwa* is a broiled product, made from *surimi*, which is mixed and kneaded in a mortar with seasonings and other ingredients. *Kamaboko* is made by steaming or broiling *surimi* mixed in a mortar with seasonings and other ingredients. Crab-leg *kamaboko* (or imitation crab), shrimp *kamaboko*, and scallop *kamaboko* are examples of *kamaboko*. *Satsumaagé* is fried and kneaded *kamaboko*. Finally, fish ham and sausage is an analog product of pressed ham and sausage, developed in the 1930s in Japan (Miyake, Hirasawa, & Miyanabe, 1985, pp. 4-5). Table 1 shows the ingredients of *surimi* products.

Table 1. Ingredients of *Surimi*-Based Products (as a percentage of total weight) (Source: Miyake, Hirasawa, & Miyanabe, 1985, p. 6).

	Kamaboko	*Chikuwa*	Fried *Kamaboko*	Fish Ham & Sausage
Surimi	65.7	67.4	49.9	52.2
Subsidiary materials	14.6	15.8	25.2	21.8
Vegetable protein	0.5	1.0	1.0	1.0
Starch	6.1	7.7	8.0	8.3
Egg white	1.0	0.5	-	-
Sugar	1.0	-	1.5	-
Seasonings	2.0	2.0	1.0	1.0
Fats, oils	-	1.0	-	7.9
Salt	2.4	2.3	2.4	2.5
Other	1.6	1.3	10.0	1.1
Water	19.7	16.8	24.9	26.0
Total:	100.0	100.0	100.0	100.0

Some characteristics of *surimi* which make it possible to produce *surimi* products are as follows (Miyake, Hirasawa, & Miyanabe, 1985, p. 3): First, it can be shaped into different forms since it has stickiness; second, it can be mixed easily with other ingredients; third, it can be broiled, steamed, boiled, fried, and smoked; and lastly, it can be colored. It is also well-known that *surimi* has less cholesterol than most red meats and shell fish and contains much high quality protein. In 1960, Japan developed "frozen *surimi*" by utilizing Alaska pollock, following which mass *surimi* production by mother ships and trawler ships was made possible. Table 2a and 2b show the production of *surimi* and *surimi* products in Japan.

Table 2a. Production of *Surimi*-Based Products in Japan (Source: Miyake, Hirasawa, & Miyanabe, 1985, p. 3).

Product	weight (in tons)
Chikuwa	194,931
Kamaboko	346,557
Satsumaagé	297,257
Fish ham & sausage	81,362
Total:	920.107

Table 2b. Production of *Surimi* In Japan (in metric tons) (Source: Gwinn, 1985, p. 76).

Year	Sea-based *Surimi*	Land-based *Surimi*	Total	Exports to U.S.A.
1981	192,264 (63)	114,393 (37)	306,657	829
1982	198,534 (58)	142,000 (42)	340,534	1,114
1983	208,110 (55)	168,887 (45)	376,997	1,709
1984	224,444 (55)	183,315 (45)	407,759	

Note: Figures in parentheses represent % of total production.

Most species of fish can be used as raw material for the production of *surimi*. However, it is known that species living in cold waters, white meat fishes, and demersal fishes are better for high-quality *surimi* products than species living in warm waters, dark meat fishes, and fresh water fishes, even those with white meats (Miyake, Hirasawa, & Miyanabe, 1985, p. 2). The following fishes are the major sources of raw material used to produce *surimi*: white-fleshed deep-sea cod family, sardines, Pacific mackerel, Antarctic krill, sharks, hoki (New Zealand), deep-sea whiptail (New Zealand), blue whiting, and forked hake (Alaska). Table 3 shows Japan's catch of fish species used primarily to produce *surimi*.

Table 3. Japan's Catch of Fish Species Used Primarily to Produce *Surimi* (in thousands of metric tons) (Source: Sonu, 1986, p. 37).

Year	Alaska Pollock	AM*	Cr*	STE*	LF*	CF*	Sh*	Total
1976	2,445 (38)	229	39	17	20	31	44	2,825
1977	1,928 (47)	235	40	19	22	28	49	2,321
1978	1,546 (52)	135	37	18	21	28	42	1,827
1979	1,551 (52)	119	39	16	22	31	42	1,820
1980	1,552 (56)	117	32	17	25	38	42	1,823
1981	1,595 (54)	125	33	16	24	35	38	1,866
1982	1,567 (53)	103	30	14	18	36	35	1,803
1983	1,434 (51)	56	27	12	15	35	36	1,615
1984	1,621 (45)	66	24	11	14	34	35	1,805

Note: Figures in parentheses represent % of Japanese catches of Alaska pollock in U.S. waters.

* AM = Atka mackerel; Cr = Croaker; STE = Sharp-toothed eel; LF = Lizard fish; CF = Cutlass fish; Sh = Shark.

The price of *surimi* in Japan varies in accordance with the quality. For example, the *surimi* processed by trawler ships or mother ships at sea is more expensive than that processed on shore because on-shore *surimi* has less freshness. More than 90 percent of the total Japanese frozen sea-based *surimi* is from Alaska pollock (Table 3). However, Alaska pollock *surimi* alone cannot be used to produce high quality *kamaboko* without adding *surimi* made out of other good quality fish. The report by Miyake, Hirasawa, & Miyanabe (1985) indicated that the mixing ratio between Alaska pollock *surimi* and other good quality *surimi* is preserved as a trade secret by Japanese firms.

The U.S. market for *surimi*-based seafood products climbed to approximately 70 million pounds in edible weight in 1984, doubling each year between 1981 and 1984 (see Table 4). Imported Japanese imitation crab accounted for more than 80 percent of total consumption in 1984 (Table 5).

Table 4. Estimated U.S. Supply of Surimi-Based Products (cooked, edible weight in metric tons) (Source: Vondruska, 1985, p. 2).

	Imported from Japan			Consumption in U.S.		
Year	Imitation Crab	Other[1]	Total	Processed[2] in U.S.	Imitation[3] Crab	Total
1980	2,765	502	3,267	3,100	(3,000)	6,367
1981	4,912	827	5,739	3,611	(5,500)	9,350
1982	14,879	1,259	16,138	4,912	(17,000)	21,050
1983	30,474	2,555	33,029	7,531	(35,000)	40,560
1984	58,986	790	59,776	10,168	(66,000)	69,944

[1] Total, less imitation crab.
[2] Japanese exports of *surimi* to U.S., multiplied by 2 to obtain approximate finished product weight.
[3] Estimated.

Table 5. *Kamaboko* Exports from Japan (in metric tons) (Source: Gwinn, 1985, p. 78).

Year	Total Exports	Exports to U.S.A.	% to U.S.A.
1981	4,033	2,604	64
1982	9,330	7,332	78
1983	18,829	14,982	79
1984	32,462	26,756	82

The U.S. share of Japan's *surimi* exports was 89.4 percent of total Japanese exports in 1984 (Table 5). Therefore, the American government and the American seafood industry are trying to produce an American version of *surimi* and *surimi* products by phasing out foreign fishing and processing, with the expectation of exporting American *surimi* and *surimi*-based products to foreign countries.

As *surimi* products increase in economic value, each coastal country's interest in the *surimi* industry has increased. However, coastal countries are very cautious in entering the *surimi* products market and investing in this industry due to their lack of knowledge of the *surimi* products market and the flexible *surimi* supply situation. This is mainly due to the short history of the *surimi* industry on a global basis. Therefore, many efforts for market research and development of *surimi* technology are being undertaken in these countries, but little data is available for the demand analysis of *surimi* products. Japan, which produces and consumes 90 percent of the world *surimi* production, and which has produced *surimi* products for many centuries, has data. However, it is not possible to generalize results from an analysis of the Japanese *surimi* products market to the rest of the world because of differences between Japanese and other dietary and consumption patterns. Nonetheless, because Japan is an important market for *surimi*, it is of interest to understand that market. Little is known about substitutional relationships in demand among seafoods and between seafoods and other protein sources, such as beef, pork, and poultry. Careful specification of demand relationships in the Japanese market may permit the testing of hypotheses about the impact of changes in availability of other seafoods and red meats in the demand for *surimi* products in Japan. Further, the results from this analysis might allow the generation of testable hypotheses regarding demand elsewhere.

Objectives of the Research

The goal of this research is to improve understanding of the *surimi*-based products market by identifying the effect on consumption patterns of changes in prices and food expenditure in the *surimi* products market through the analysis of data on Japanese household consumption. The demand system approach is used to meet this goal. This approach allows the analysis to model the interdependencies among prices and consumption in consumer demand. Specifically, it permits an examination of the simultaneous impacts on consumption (and expenditure) of *surimi* products, red meats, and other seafood of changes in the prices of these commodities. Further, the cross-price elasticities between two different *surimi* products and between *surimi* products and *surimi* product substitutes, including other fish products, beef, pork, and chicken, can be estimated. It will be possible to test the argument that "kneaded fish products,[1] except for special luxury items of *kamaboko*, have strong substitutional relationships with pork and chicken" (Miyake, Hirasawa, & Miyanabe, 1985, p. 49), but not with beef. The demand system approach also allows the user to test the properties of Hicksian and Marshallian demand functions: adding-up, homogeneity, symmetry, and negativity.[2] In the present study, a particular system, the almost

[1] *Surimi* products are generally called "kneaded fish products" in Japan.

[2] Properties of Hicksian and Marshallian demand function: Hicksian demand function (or compensated demand function) is derived from cost minimization and represented as the function of prices (p) and utility (u), that is, $h_i(u,p)$; Marshallian demand function is derived from utility maximization and represented as the function of prices (p) and expenditures (x), that is, $q(x,p)$.

Cost minimization and utility maximization form the duel problem, i.e., they are alternative ways of representing the same information. Both demand functions have the following properties:

1) Adding-up. The sum of individual expenditures for each commodity, i, is total expenditure,

$$\Sigma p_i h_i(u,p) = e(p,u), \ \Sigma p_i q_i(x,p) = x .$$

2) Homogeneity. The Marshallian demand function is homogeneous of degree 0 in prices and total expenditure and the Hicksian demand function is homogeneous of degree 0 in prices,

$$h_i(u,\theta p) = h_i(u,p), \text{ and } q_i(\theta x,\theta p) = q_i(x,p) ,$$

where θ is a positive scalar.

3) Symmetry. The Slutsky matrix in the Hicksian demand function is symmetric for all $i \neq j$.

$$\frac{\partial h_i(u,p)}{\partial p_j} = \frac{\partial h_j(u,p)}{\partial p_i}$$

4) Negativity. The n x n Slutsky matrix (or substitution matrix) is negative semidefinite.

Adding-up and homogeneity are "the consequences of the specification of a linear budget constraint" and symmetry and negativity are "derived from the existence of consistent preferences" (Deaton & Muellbauer, 1980, p. 45). Especially in estimation, the adding-up condition is satisfied automatically because adding-up comes from that total expenditure is the sum of $p_i q_i (x = \Sigma p_i q_i)$. Other properties are tested by imposing those restrictions on demand equations and comparing the results with those obtained without restrictions.

ideal demand system (AIDS) model, suggested by Deaton and Muellbauer in 1980 (1980a), is mainly used (see Chapter 2).

In their report to the FAO, Miyake, Hirasawa, & Miyanabe (1985, pp. 46-49) indicated that it has been argued that the diet pattern of the Japanese people is changing. They added that

> the demand for kneaded fish products except for fish ham and sausage is affected extensively by the dietary pattern of the Japanese people. This is also the case for the demand for fish and fish products in general, and would require a careful study in view of the changing dietary pattern of the people. (p. 45).

Therefore, the habit formation (HF) model, developed by R. A. Pollak and T. J. Wales in 1969, is also used to investigate whether it can be said that habit persistence exists in the Japanese *surimi* products market.

In both of the above models, the weak separability of utility function[3] is implicitly assumed in that only

[3]Separability of utility function (Johnson, Hassan, & Green, 1984, pp. 48-50):

1) Weak separability. The utility function U(q) is weakly separable with respect to a commodity grouping set $\{n_1, n_2,\ldots,n_m\}$ if

$$\frac{\partial(U_i/U_j)}{\partial q_k} = 0$$

for all i, $j \in I$, and $k \notin I$, where

$$U_i = \frac{\partial U}{\partial q_i}$$

and I is a subset of the grouping set.

2) Strong separability. The utility function U(q) is strongly separable with respect to a commodity grouping set $\{n_1, n_2,\ldots,n_m\}$ if

$$\frac{\partial(U_i/U_j)}{\partial q_k} = 0$$

for all $i \in I$, $j \in J$ and $k \notin I$ and $k \notin J$, where I and J are different subsets of the grouping set. (continued on next page)

consumer expenditure for fish and meat products are considered as an exogenous variable. (Implicitly, we assume that consumer expenditure for fish and meat products has a positive relationship to total consumer income.)

3) Pearce separability. The utility function U(q) is Pearce separable with respect to a commodity grouping set $\{n_1, n_2, \ldots, n_m\}$ if

$$\frac{\partial(U_i/U_j)}{\partial q_k} = 0$$

for all i, $j \in I$ and $k \neq i,j$, where I is a subset of the grouping set. Pearce separable utility function is weakly separable between groups and additive and strongly separable within groups.

2. MODEL SPECIFICATION

The AIDS Model

Since 1954, when R. Stone, using annual data for the United Kingdom, developed the linear expenditure system (LES), based on the Klein-Kubin utility function,[4] several flexible functional forms have been developed. One of them is the almost ideal demand system (AIDS) model. In comparison to the LES, the AIDS model provides more flexibility of parameters. Deaton and Muellbauer (1980a, p. 312) demonstrated that

> it gives an arbitrary first-order approximation to any demand system; it satisfies the axioms of consumer choice; it aggregates over consumers without invoking parallel linear Engel curves; it has a functional form which is consistent with known household budget data.

In addition, it has an econometric advantage in that it can be estimated by the ordinary least squares (OLS) method or the seemingly unrelated regression (SUR) method when the original price-independent, generalized

[4]The Klein-Rubin utility function is sometimes called the Stone-Geary utility function. It is represented as

$$U(q) = \sum_{i=1}^{n} \beta_i \log(q_i - r_i) ,$$

where r_i is the subsistence level for the i^{th} commodity. This function is directly additive because each of the subsets of the commodity grouping set contains exactly one good, i.e., the number of groups is equal to the number of goods. The linear expenditure system is derived from the Klein-Rubin utility function.

logarithmic (PIGLOG) class price index (explained below) is replaced (actually, approximated) by Stone's price index,[5]

$$\log P^* = \sum_k w_k \log p_k ,$$

and autocorrelation is not present.

The AIDS model can be specified as the following:

$$w_i = a_i + \sum_j r_{ij} \log p_i + b_i \log(Y/P) ,$$

where w_i is the share of i^{th} commodity in total expenditure, Y is total expenditure, P is PIGLOG class price index, and a_i, r_{ij}, and b_i are estimated coefficients. A particularly attractive feature of the AIDS model is its treatment of aggregation, that is the movement from individual data to market data. In dealing with the aggregation problem in general, the market demand can be specified as the average of the individual demands, that is,

[5]In R. Stone's 1954 publication, *The Measurement of Consumer's Expenditure and Behaviour in the United Kingdom, 1920-1938*, vol. I, the demand function estimated is expressed as

$$\log q_i = \alpha_i + e_i \log y + \Sigma e_{ij}^* \log P_j ,$$

when changing components of tastes and habits are not present, where e_i is income elasticity, e_{ij}^* is compensated price elasticity, and Y is real income. Here, y is expressed as Y/P, where Y is nominal income and P is a general price index. Stone defined this value, P, to obtain real income, i.e., $\log P = \Sigma w_i \log p_i$ (Stone, 1954, p. 277). Deaton and Muellbauer (1980a) called this index number "Stone's price index." This index is justified when Marshallian cross price elasticities are decomposed into income elasticities and compensated cross price elasticities ($e_{ik} = e_{ik}^* - e_i w_k$), given the logarithmic demand function,

$$\log q_i = \alpha_i + e_i \log y + \sum_{j=1}^{n} e_{ij} \log p .$$

$$w_i = \frac{p_i \sum_h q_i^h}{Y} = \frac{p_i \sum_h q^h}{\sum_h y^h} = \sum_h \frac{y^h}{\sum_h y^h} w_i^h ,$$

where h indicates the individual, w_i^h is the i^{th} commodity's share of the h^{th} individual's total expenditure, q_i^h is the quantity demanded of the i^{th} commodity by the h^{th} individual, p_i is the price of the i^{th} commodity, y^h is the expenditure of the h^{th} individual, and Y is total expenditure. Here, the weighted individual demands can be a representative of market demand. This permits aggregation that is different from the exact linear aggregation in which average market demand should be a function of average total expenditure and which implies linear Engel curves.

According to Muellbauer (1974), the conditions for consistent nonlinear aggregation, named generalized linearity (GL), lead to a generalization of the linear cost function. In other words, GL underlies the aggregate demand function consistent with exact linear aggregation. In GL the different Engel curves for each consumer or household, which are not necessarily linear themselves, vary linearly with one another as total expenditure changes at constant prices. The resulting aggregated demand is expressed as a function of "representative," as opposed to "average," expenditures. When the representative expenditure level is independent of prices and depends only on the distribution of dent of prices and depends only on the distribution of expenditures, there exists a "price independent generalized linear" (PIGL) cost function. According to Muellbauer, the PIGL cost function is given by

$$C(U_0,p)/k_h = [g(p)^{\alpha}(1-U_0) + h(p)^{\alpha}U_0]^{1/\alpha} ,$$

where U_0 is the utility index or function of the representative, and k_h is a kind of index for individual household, which measures "different household sizes" (Muellbauer, 1974, p. 537, referred to it as the "household income equivalence scale") or "which measures household size, taking account of age composition, other household characteristics, and economics of household size" (Deaton & Muellbauer, 1980a, p. 314). This k_h permits "a limited amount of taste variation across households." If the same consumer tastes are assumed, that is if $k_h = 1$ for all h, we can have the following PIGL cost function for the representative.

$$C(U_0,p) = [g(p)^{\alpha}(1-U_0) + h(p)^{\alpha}U_0]^{1/\alpha} .$$

When the value of the parameter α of this PIGL class cost function goes to zero and $0 \leq U_0 \leq 1$, the PIGLOG class cost function, which is used for the AIDS model, is given by

$$\log C(U_0,p) = (1-U_0)\log g(p) + U_0 \log h(p) .$$

In this PIGLOG class cost function, nonlinearity of the Engel curve is implied and the exact nonlinear aggregation can be given by choosing the appropriate functional forms for g(p) and h(p), which should be homogeneous of degree 1 in prices. The PIGL is a special case of the generalized Gorman polar form,

$$C(U_0, p) = a(p) + U_0 b(p) ,$$

and the generalized Gorman polar form is a special case of the GL. The chosen g(p) and h(p) are represented as

$$\log g(p) = a_0 + \sum_h a_k \log p_r + \tfrac{1}{2}\sum_k\sum_j r^*_{kj} \log p_k \log p_j ,$$

$$\log h(p) = \log g(p) + b_0 p_k^{\,b_k}$$

From those relationships, the budget share equation, the AIDS model, is obtained as

$$w_i = a_i + \sum_j r_{ij} \log p_j + b_i \log\{Y/P\} ,$$

where $w_i = \dfrac{\partial \log C(U,p)}{\partial \log p_i} = \dfrac{p_i q_i}{C(U,p)}$,

$$r_{ij} = \tfrac{1}{2}(r^*_{ij} + r^*_{ji}) ,$$

Y = total expenditure, and

$$\log P = a_0 + \sum_k a_k \log p_r + \tfrac{1}{2}\sum_j\sum_k r_{kj} \log p_r \log p_j .$$

Thus, the AIDS model can be estimated with aggregate data without imposing the assumption that individual Engel curves are linear. Deaton and Muellbauer (1980a) had shown that Stone's price index,

$$\log P^* = \sum_k w_k \log p_k ,$$

approximates logP very well, at least with annual data from the United Kingdom. With this substitution, the final functional form to be established becomes

$$w_i = a_i^* + \sum_j r_{ij} \log p_j + b_i \log(Y/P^*) + e_i ,$$

where e_i is the i^{th} disturbance term.

The restrictions on the parameters of this equation, which are given by imposing the conditions of adding-up, homogeneity, and symmetry on this estimated equation, can be represented as the following:

1. Adding-up: $\sum_i a_i = 1$, $\sum_i r_{ij} = 0$ for all $j = 1,\ldots,n$, $\sum_i b_i = 0$,

2. Homogeneity: $\sum_j r_{ij} = 0$ for all $i = 1,\ldots,n$ and

3. Symmetry: $r_{ij} = r_{ji}$ for all $i,j = 1,\ldots,n$.

The Habit Formation Model

In 1970, R. A. Pollak[6] suggested the habit formation model, based on the directly additive Klein-Kubin utility function. He introduced consumer taste changes into demand system specifications insofar as an individual's current preferences depend on his past consumption patterns, which is to say "goods may be habit forming" (Pollak, 1970, p. 745). As indicated earlier, such a pattern may characterize consumption of *surimi*-based products in Japan. In the present study, the persistence of habit formation is evaluated by using three different demand system models. One is the

[6]Before this paper was published, R. A. Pollak and T. J. Wales had in 1969 published the "Estimation of the Linear Expenditure System," which concerned the estimation of the LES model and the dynamic specification of the LES model.

linear expenditure system (LES), the second is the proportional habit formation (PHF) model, and the third is the linear habit formation (LHF) model.

The estimated functional forms for the demand relationships of the LES, LHF, and PHF models can be represented as follows (Pollak & Wales, 1969):.

1) LES model:

$$p_{it}q_{it} = p_{it}r_{it} + b_i(Y_t - \sum_j p_{jt}r_{jt}) ,$$

$$i = 1, \ldots, n$$

The following restrictions on the parameters given by imposing adding-up, homogeneity, symmetry, and negativity conditions hold:

a) $0 < b_i < 1$,

b) $q_i - r_i > 0$,

c) $\Sigma b_i = 1$,

where r_i is the minimum consumption level or subsistence consumption level.

2) PHF model:

$$p_{it}q_{it} = [(1-b_i)h_i]p_{it}q_{i,t-1} - \sum_j (b_i h_j)p_{jt}q_{j,t-1} + b_i y_t ,$$

where r_{it} of LES is replaced with $h_i q_{i,t-1}$. That is, in the PHF model, $r_{it} = h_i q_{i,t-1}$ and h_i is the coefficient of the i^{th} r equation which indicates the proportional habit effect. The difference between the PHF and LHF models is that r_{it} of the LHF model becomes zero. The following restrictions hold:

a) $0 \leq h_i < 1$,

b) $q_i - r_i > 0$, and

c) $\sum_i b_i = 1$.

3) LHF model:

$$p_{it}q_{it} = [(1-b_i)r_i^*]p_{it} - \sum_{j \neq i}(b_i r_j^*)p_{it}$$
$$+ [(1-b_i)h_i]p_{it}q_{i,t-1}$$
$$-\sum_{j \neq i}(b_i h_j)p_{it}q_{i,t-1} + b_i y_t ,$$

where r_{it} in the LES model was replaced by $h_i q_{i,t-1} + r_i^*$. This $h_i q_{i,t-1} + r_i^*$ is the general expression used to introduce habit persistence. The following restrictions hold:

a) $0 \leq h_i < 1$,

b) $q_i - r_i > 0$, and

c) $\Sigma b_i = 1$.

As may be seen, habit formation is tested within the linear expenditure system and the LES and PHF models are nested in the LHF model. That is, the $r_{it} = h_i q_{i,t-1} + r_i^*$ term becomes $r_{it} = h_i q_{i,t-1}$ in the PHF model and $r_{it} = r_i^*$ in the LES model. Therefore, the nested hypothesis test can be used to tell whether there exists habit persistence.

3. HYPOTHESIS TESTED

The adding-up, homogeneity, symmetry, and negativity conditions obtained from the assumption of utility maximization behavior restrict the demand system model. Adding-up and homogeneity restrictions result from the specification of a linear budget constraint and symmetry and negativity restrictions from the axioms of consumer choice. Therefore, these restrictions should be tested to see whether the empirical result is consistent with the underlying theory of consumer choice. On the other hand, Varian's non-parametric approach (1982) can be used to test the consistency between the utility maximization hypothesis and the given data. However, this non-parametric test was not performed in this analysis.

In complete systems of demand equations, the adding-up restriction is automatically satisfied. This also happens to the AIDS model. Symmetry and negativity restrictions can be determined by testing the restrictions on the Slutsky substitution matrix, although the negativity restriction, i.e., negative semi-definiteness of the Slutsky matrix, is not tested here.

Gallant and Golub (1984) have shown how to impose the curvature condition on flexible functional forms. Deaton and Muellbauer (1980a, p. 321) recommend starting with Stone's price index, calculating OLS regressions, computing a new price index, and repeating the estimation for the symmetry-restricted equations with the new (original) price index P. However, if Stone's price index really approximates the original price index P very well, there will be no reason not to use the Stone's index in testing the symmetry restriction, although the accuracy of estimation might be reduced. Symmetry is tested by a large-sample likelihood-ratio test for the system as a whole in the AIDS model. The homogeneity restriction can be tested equation-by-equation, using an F-ratio test or likelihood-ratio test. The restricted functional form for homogeneity is

$$w_i = a_i^* + \sum_{j=1}^{n-1} r_{ij} \log(p_j/p_n) + b_i \log(Y/P^*) .$$

Then, the likelihood-ratio λ is calculated as

$$\lambda = \frac{\text{max. value of likelihood function restricted}}{\text{max. value of likelihood function unrestricted}}.$$

To test the habit effects or persistence in the habit formation model, the above likelihood-ratio test can be used again. It has been proven that

$$-2\ln\lambda = T(\ln|\Sigma_{restricted}| - \ln|\Sigma_{unrest.}|)$$

is asymptotically distributed as chi-square (Theil, 1971, pp. 396-397). The degrees of freedom are equal to the number of restrictions to be tested under the null hypothesis.

4. ESTIMATION PROCEDURE

The AIDS Model

First, the AIDS model with 11 food items, including fresh fish, salted and dried fish, beef, pork, chicken, ham, sausage, *kamaboko*, *chikuwa*, *satsumaagé*, and fish ham and sausage is estimated equation-by-equation, using the ordinary least squares (OLS) procedure. As indicated in Chapter 1, it has been argued that *surimi*-based products have substitutional relationships with pork and chicken. These 11 items are chosen in this analysis to include every item which may be related to *surimi*-based products. There are 252 monthly observations (1965 to 1985) available for this analysis and Stone's price index is used instead of the original price index to permit estimation by OLS. Then, this model is corrected for first order autocorrelation. Also, the Lawless-Wang ridge regression is used because the prices of food generally change in the same direction, so that severe multicollinearity problems may be present. Again, the seemingly unrelated regression (SUR) method suggested by A. Zellner (1962) is used to test the symmetry restriction under Stone's price index. In the present case, the SUR estimates are the same as the OLS estimators because the explanatory variable matrices Xi's are identical. Finally, the restricted functional forms with homogeneity imposed are estimated equation-by-equation by the OLS method. The computer program used is SHAZAM, version 5 (White and Horsman, 1986).

To deal with the autocorrelation problem, SHAZAM uses either a Cochrane-Orcutt type iterative procedure or a grid search to estimate *rho* (ρ) values, which are the parameters that give the degree and direction of autocorrelation when the estimates are obtained in an equation-by-equation basis. One problem with SHAZAM is that a system equation with autocorrelation terms cannot be estimated by the SUR technique. Therefore, a nonlinear regression technique should be used for this case.

Generally, it is very likely that a severe multicollinearity problem exists in food demand analysis because the prices of food tend to change in the same direction, especially when the chosen food items are closely related. Therefore, revised models, in which some commodities are combined and others deleted, are specified. In one such model, six commodity groups were formed by combining all *surimi* products except for fish ham and sausage into one commodity and deleting three commodities, ham, sausage, and fish ham and sausage, because *surimi* products are different types of products which are made of the same materials, *surimi*, and ham, sausage, and fish ham and sausage reflect only small percentages of the total expenditure (the average share percentages of ham, sausage, and fish ham and sausage in total expenditure were 0.044, 0.024, and 0.010, respectively). In another model, beef, pork, and chicken were combined as one commodity, red meats, and fresh fish and salted and dried fish were combined in another commodity, fresh, salted, and dried fish, to form a new three-commodities group. Therefore, a six-items model, fresh fish, salted and dried fish, beef, pork, chicken, and *surimi*-based products (combined with *kamaboko, chikuwa*, and *satsumaagé*), and a three-items model, red meats (beef, pork, and chicken combined), fresh, salted, and dried fish (combining the three types of fish), and *surimi*-based products are estimated again for the purpose of reducing the multicollinearity problem. Both of these models are corrected for first-order autocorrelation. To further address the multicollinearity problem, the Lawless-Wang ridge estimators are obtained for the three-items model. In addition to this, the three-items model with the original price index, logP, is estimated to determine how well Stone's price index approximates the original price index.

In the estimation of the AIDS model with the original price index logP, "the parameter a_0 is only identified from a_i's in

$$w_i = (a_i - b_i a_0) + \sum_j r_{ij} \log p_j + b_i \{ \log y - \Sigma a_k \log p_r - \tfrac{1}{2} \sum_k \sum_j r_{kj} \log p_k \log p_j \} ,$$

by the presence of these latter inside terms in braces" (Deaton & Muellbauer, 1980a, p. 316). Deaton and Muellbauer stated that the above equation can be estimated by assigning a value to a_0 a priori. This procedure is directly applied to the three-items model with the original price index. In the SUR estimation, iterations continue until the covariance matrix of residuals across equations converges.

The LES, PHF, and LHF Models

Habit persistence in food consumption is examined, using the 3 types of commodity groups (3, 6, and 11 items) described in the previous section. Because both annual and monthly data are available for the 1965-1985 period, the LES, PHF, and LHF models are estimated by using both data sets. In using the annual data there is a difference in the structure of $r_i = h_i q_{i,t-1} + r_i^*$ from the case using the monthly data because the annual data have a longer time interval than the monthly data. That is the h_i's will play a major role in determining habit persistence when monthly data are used because monthly data have short-time intervals, which are not long enough for consumers to change their persistence consumption patterns (or subsistence levels of consumption). Conversely, the r_i^* or r_i's will play a major role in determining habit persistence when annual data are used. Every model is corrected for first-order autocorrelation, except for the six-items model. The prices used are deflated by the annual GNP deflators on the basis of 1970 prices.

As may be seen, the LES, PHF, and LHF models are nonlinear in their parameters. As a result, least squares and maximum likelihood (ML) methods cannot be directly applied to these models. Therefore, "parameter values implied by nonlinear first-order conditions for minimizing the sum of squared residuals or maximizing the value of the likelihood function must be numerically approximated" (Johnson, Hassan, & Green, 1984, p. 94). The general nonlinear equation form is represented as

$$Y_i = f(X_i, b_i) + e_i \ ,$$

where X_i = (Tx1) vector of independent variables,

b_i = (Kx1) parameter vector,

Y_i = (Tx1) vector of observable random variables, and

e_i = (Tx1) vector of random errors.

In addition to being nonlinear in their parameters, the three models are also characterized by correlation among error terms across equations since autocorrelation problems also exist in the estimation of systems of nonlinear equations, i.e., evidence of autocorrelation has been found in the estimation of systems of nonlinear equations (Capps, 1983, p. 51).

In 1962, A. Zellner suggested the seemingly unrelated regression (SUR) method which assumes the contemporaneous correlation between different disturbances at a given point in time. Following Zellner's notation, the system of demand equations can be represented as

$$\begin{bmatrix} Y1 \\ Y2 \\ . \\ . \\ Ym \end{bmatrix} + \begin{bmatrix} f(X1,b_1) \\ f(X2,b_2) \\ . \\ . \\ f(Xm,b_m) \end{bmatrix} + \begin{bmatrix} e1 \\ e2 \\ . \\ . \\ em \end{bmatrix}$$

or in a vector form, $\underline{Y}_t = f(\underline{X}_t,\underline{b}) + \underline{e}_t$. Introducing the first-order autocorrelation of disturbance term, the general disturbance term matrix becomes

$$\underline{e}_t = R\underline{e}_{t-1} + v_t \text{ for } t = 2, 3,..,T.$$

where R is a diagonal (MxM) parameter matrix and $v2,..,v_t$ are independently and identically distributed normal random vectors with means 0 and contemporaneous covariance matrix Σ (Johnson, Hassan, & Green, 1984). The contemporaneous covariance matrix is singular since the total expenditure is equal to the sum of the individual expenditures. Therefore, it could be expected that an equation could be deleted in estimating without affecting the estimations (Barten, 1969). However, even though the maximum likelihood parameter estimates can still be obtained by arbitrarily deleting an equation in the present models and these estimators are invariant to the deleted equation, this result does not hold for autocorrelated disturbances because the adding-up property for expenditures implies certain restrictions on the autoregressive parameter matrix R (Johnson, Hassan, & Green, 1984, p. 143). That is, the fact that the total expenditure Y is equal to the sum of the Y_i's implies that

$$\sum_{i=1}^{m} e_i = 0$$

(Judge, Hill, Griffiths, & Lutkepohl, 1985). Therefore, the autocorrelation coefficients must be the same for each equation.[7]

There are two well-known methods for estimating the nonlinear demand systems when disturbances are both serially and contemporaneously correlated. One is the maximum likelihood method and the other is the iterative version of Zellner's SUR procedure (Capps, 1983). In the ML procedure the estimators are obtained by maximizing the log of likelihood function l(b),

$$l_{ML}(b) = -\frac{MT}{2}\log(2\pi) - \frac{T}{2}\log|\Sigma| - \tfrac{1}{2}\underline{v}'_t(\Sigma^{-1}\otimes I)\underline{v}_t ,$$

[7]E. R. Berndt and N. E. Savin showed these results in detail in their 1975 paper. They found that the adding-up property imposes restrictions on the parameters of the autoregressive process. That is, "each column of R, where R is from $\underline{e}_t = R\underline{e}_{t-1} + U_t$, must sum to the same unknown constant k" ($i'R = k'$, where i is an n × 1 vector whose elements are all 1's and k' is an 1 × n vector whose elements are all k's). Also, "when these restrictions are not imposed, the specification of the model is conditional on the equation deleted" (p. 939). In the present study, these restrictions are imposed.

where $E(\underline{v}_t \underline{v}'_t) = \Omega = \Sigma \otimes \underline{T}$. Here, the first order condition for maximizing $l_{ML}(b)$ (or nonlinear or normal equation),

$$\frac{\partial l_{ML}(b)}{\partial b} = 0 ,$$

is nonlinear. Therefore, the estimated coefficient implied by this nonlinear first order condition must be numerically approximated.

To obtain the iterative version of the SUR, first obtain least squares estimates by minimizing

$$\frac{1}{T} v_i' v_i$$

equation-by-equation, and then take the variance-covariance matrix $\hat{\Sigma}$, whose elements are

$$\hat{\sigma}_{ij} = \frac{1}{T} \hat{v}_i \hat{v}_j ,$$

where i,j = 1,2,..,M. Finally, we obtain the Aitken type estimator b by minimizing

$$\frac{1}{T} \underline{v}_t' (\hat{\Sigma}^{-1} \otimes I) v_t .$$

(Actually, minimizing

$$\frac{1}{T} \underline{v}_t' (\hat{\Sigma}^{-1} \otimes I) v_t .$$

is equivalent to maximizing $l_{ML}(b)$ and the first order condition for minimizing

$$\frac{1}{T} \underline{v}_t' (\hat{\Sigma}^{-1} \otimes I) v_t .$$

is also nonlinear.) (Capps, 1983, pp. 51-53)

SHAZAM basically uses the Quasi-Newton algorithm to calculate the nonlinear estimators. The Quasi-Newton algorithm, which is one of the gradient methods,

> approximates the inverse of the Hessian matrix of the objective function,
>
> $$[\partial^2 l_{ML}(b)/\partial b \partial b']^{-1}_{b=\hat{b}_{ML}} ,$$
>
> in each iteration by adding a correction matrix to the approximate inverse of the Hessian used in the most recent step. (Judge, Hill, Griffiths, & Lutkepohl, 1985, p. 958)

In 1974, A. R. Pagan suggested a nonlinear estimation procedure to deal with autocorrelation. According to Pagan, if D is a (TXk) matrix of derivatives $\partial v/\partial b$, the Gauss-Newton algorithm prescribes the following sequence of iterations for minimizing $s = v'v$. The sequence is represented as

$$b(n) - b(n-1) = -(D'D)^{-1} Dv$$

where D and v are evaluated with estimates of b at the $(n-1)^{th}$ iteration, that is, $\hat{b}(n-1)$. Then, the above equation converges to a minimum of s (Pagan, 1974, pp. 266-267). Thus, Pagan's computer algorithm is combined with the ML procedure in SHAZAM to solve the autocorrelation problem.

5. DATA

Japanese aggregated consumption data for fresh fish, salted and dried fish, beef, pork, chicken, ham, sausage, and *surimi*-based products--*kamaboko*, *chikuwa*, *satsumaagé*, and fish ham and sausage--are used for this demand system analysis. The aggregated monthly and annual data are provided from the *Annual Report on the Family Income and Expenditure Survey* (Japan, Prime Minister's Office, Statistics Bureau). However, the prices of *kamaboko* were not available from this report. *Kamaboko* prices were calculated as a weighted average of *kamaboko* prices in 30 Japanese cities, where the weights are the shares of the city populations in the combined populations of all 30 cities. *Kamaboko* prices in the 30 cities were available in the *Annual Report on the Retail Price Survey* (Japan, Prime Minister's Office, Statistics Bureau). Population data for the 30 cities were taken from the *Japan Statistical Year Book* (Japan, Prime Minister's Office, Statistics Bureau). The formula used to calculate *kamaboko* prices is

$$P_k = \frac{\sum_{i=1}^{30} IP_i Xp_i}{TP}$$

where TP = total population of 30 cities,

IP_i = population of i^{th} city, and

p_i = *kamaboko* price of i^{th} city.

The list of 30 cities and their population ratios are as follows:

Akita	(0.009)	Kochi	(0.009)	Sapporo	(0.033)
Chiba	(0.016)	Kofu	(0.007)	Sendai	(0.019)
Fukui	(0.007)	Kure	(0.009)	Shizuoka	(0.014)
Fukuoka	(0.030)	Kyoto	(0.052)	Tokushima	(0.008)
Fukushima	(0.007)	Nagano	(0.008)	Tokyo ku-	(0.324)
Hakodate	(0.010)	Nagasaki	(0.015)	Tottori	(0.004)
Hiroshima	(0.021)	Nagoya	(0.071)	Tsu	(0.005)
Kagoshima	(0.014)	Nara	(0.007)	Urawa	(0.009)
Kitakyushu	(0.039)	Oita	(0.009)	Yokohama	(0.074)
Kobe	(0.046)	Osaka	(0.112)	Yokosuka	(0.012)

Each population ratio was averaged by using four years' data: 1960, 1965, 1970, and 1975. One thing which should be noted about this data set is that in 1980 the Japanese government (i.e., the Statistics Bureau) excluded some items from the "salted and dried fish" category which had existed until 1979. Therefore, this might affect the results, although it is probably not very important. However, the corrected data are used for the case of the annual data model. Finally, the annual GNP deflators were calculated by using the real and nominal GNP data which are available in the *Monthly Statistics of Japan* (Japan, Prime Minister's Office, Statistics Bureau). Expenditures data were obtained by calculating

$$\sum_{i=1}^{n} p_i q_i \ .$$

6. EMPIRICAL RESULTS

The AIDS Model

11-Items Case

Once the AIDS model is estimated, the own-price, cross-price, and expenditure elasticities can be obtained by the following formulas:

1) Own-price elasticity

$$e_{ii} = -1 + r_{ii}/w_i - b_i \ ,$$

2) Cross-price elasticity

$$e_{ij} = r_{ij}/w_i - b_i(w_j/w_i) \ ,$$

3) Expenditure elasticity

$$\eta_i = 1 + b_i/w_i \ ,$$

where w_i can be replaced with predicted values or mean values (Chalfant, 1987, p. 234). Mean values of the w_i's were used in this study to obtain elasticities. Own-price and cross-price elasticities are Marshallian elasticities. In the 11-items case, all of the own-price elasticities are negative, except for fish ham and sausage (Table 6). The own-price elasticity of *kamaboko* was obtained from an r value, a coefficient of $\log p_i$, which was not statistically significant at the 5% level. *Kamaboko* and *satsumaagé* have elasticities greater than one in absolute value, although this is not the case for the other two *surimi*-based products. Expenditure elasticities for fish and *surimi* products (except for fish ham and sausage) are greater than one. In particular, the expenditure elasticity for *kamaboko* is quite high (η = 2.223). We can see from Table 6 that many pairs of cross-price elasticities, expected to show symmetric relationships, have different signs. The Slutsky symmetry restriction, in elasticity form $w_i e_{ij}^* = w_j e_{ji}^*$ (where e_{ij}^* = Hicksian cross-price elasticity), does not hold in most cases (see Table 7, where Marshallian price elasticity, e_{ij}, was decomposed into $e_{ij}^* - w_j e_i$ to obtain Hicksian price elasticity e_{ij}^*). We can see from Tables 6 and 7 many differences between Marshallian and Hicksian elasticities. This suggests that there exists strong income effect. When this model is estimated under the symmetry restriction, most of the pairs of Marshallian cross-price elasticities, e.g., beef and pork, and pork and beef, have the same signs as in the unrestricted case, except for chicken and salted and dried fish, beef and sausage, pork and sausage, pork and *kamaboko*, and sausage and fish ham and sausage. However R^2 values are reduced significantly by imposing the symmetry restriction. Table 8 shows the Marshallian elasticities obtained from the symmetry-restricted coefficients estimated.

Table 6. Elasticities Obtained from OLS Estimators--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	η**	R^2
e1	-0.722	-0.431	-0.396	-0.222	0.329	0.011	0.138	0.338	0.108	-0.290	0.101	1.051	0.704
e2	0.206	-0.002	0.104	0.017	-0.490	-0.194	-0.168	-0.943	-0.571	1.065	-0.586	1.490	0.789
e3	0.029	-0.182	-1.391	0.059	-0.239	1.387	-0.751	0.189	0.129	0.038	0.019	0.577	0.838
e4	-0.184	0.112	0.735	-0.684	0.318	-1.163	0.354	0.099	0.054	-0.213	0.219	0.623	0.879
e5	-0.261	0.010	0.750	0.240	-1.117	-0.542	0.341	-0.511	0.110	-0.044	0.333	0.753	0.576
e6	-0.645	1.184	-0.143	-0.150	-0.506	-0.293	0.264	0.767	-0.117	-0.844	-1.245	0.991	0.663
e7	-1.251	0.173	0.040	0.225	0.384	-0.838	-0.311	1.504	0.321	-1.791	0.984	0.817	0.652
e8	-0.170	-1.471	0.239	-0.195	-0.005	1.093	-1.486	-1.901	0.288	1.023	1.546	1.295	0.579
e9	-0.189	-0.786	0.345	0.402	-0.654	-0.262	-0.454	-0.386	-0.866	0.666	1.231	1.152	0.647
e10	-1.139	0.777	-1.226	0.030	-0.481	-1.235	2.074	0.243	0.637	0.478	-1.850	0.651	0.941
e11	-0.396	-0.135	0.407	-0.368	-1.247	2.091	-1.071	-1.655	-0.229	0.931	-1.199	2.223	0.751

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

** η indicates expenditure elasticity.

Table 7. Hicksian Elasticities Obtained from OLS Estimators--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11
e1	-0.345	-0.279	-0.256	-0.057	0.407	0.057	0.164	0.352	0.122	-0.279	0.126
e2	0.742	0.213	0.302	0.251	-0.379	-0.129	-0.132	-0.919	-0.551	1.080	-0.550
e3	0.236	-0.099	-1.314	0.150	-0.196	1.412	-0.737	0.198	0.137	0.044	0.033
e4	0.040	0.202	0.818	-0.586	0.364	-1.136	0.369	0.109	0.063	-0.207	0.234
e5	0.009	0.119	0.850	0.358	-1.066	-0.509	0.359	-0.499	0.120	-0.036	0.351
e6	-0.289	1.327	-0.011	0.006	-0.433	-0.249	0.288	0.783	-0.103	-0.834	-1.221
e7	-0.958	0.291	0.149	0.353	0.445	-0.802	-0.291	1.517	0.332	-1.783	1.004
e8	0.295	-1.284	0.411	0.008	0.091	1.150	-1.454	-1.880	0.306	1.036	1.577
e9	0.225	-0.620	0.498	0.583	-0.569	-0.211	-0.426	-0.368	-0.850	0.678	1.259
e10	-0.905	0.871	-1.140	0.132	-0.433	-1.206	2.090	0.253	0.646	0.485	-1.834
e11	0.402	0.186	0.702	-0.019	-1.082	2.189	-1.017	-1.619	-0.199	0.954	-1.145

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

Table 8. Elasticities Obtained from SUR Estimators Restricted by Symmetry--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	η**	R^2
e1	-0.690	-0.253	-0.100	0.796	0.442	0.012	0.082	-0.014	0.005	-0.011	-0.035	0.940	0.399
e2	-0.903	-0.428	0.036	-0.398	-0.179	0.172	-0.290	-0.139	-0.088	0.032	-0.007	1.706	0.575
e3	-0.155	0.197	-0.118	0.437	0.200	-0.201	0.447	0.086	0.029	-0.104	0.109	0.617	0.354
e4	0.331	-0.204	0.374	-0.890	0.081	-0.248	-0.107	0.036	0.027	-0.025	0.003	0.581	0.631
e5	0.203	-0.251	0.303	0.102	-0.955	-0.402	0.135	0.093	-0.006	-0.109	-0.102	1.025	0.317
e6	0.059	0.660	-0.664	-0.957	-0.679	0.666	-0.547	-0.184	-0.228	0.280	-0.206	1.039	0.185
e7	1.350	-1.526	2.430	-0.663	0.443	-0.960	-2.060	0.130	-0.115	-0.363	0.828	0.539	***
e8	-0.483	-1.203	0.612	0.228	0.402	-0.521	0.184	-0.222	0.355	-0.634	-0.115	1.390	0.273
e9	0.036	-0.854	0.202	0.209	-0.048	-0.741	-0.225	0.419	-0.808	0.098	0.504	1.205	0.502
e10	-0.105	0.679	-1.297	-0.322	-0.734	1.260	-0.829	-0.986	0.148	2.494	-1.707	0.131	0.915
e11	-1.191	-0.203	0.305	-0.333	-0.447	-0.453	0.764	-0.099	0.264	-0.741	-1.238	2.814	0.608

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

** η indicates expenditure elasticity.

*** Elasticities for sausage were calculated by using the adding-up restriction.

Table 9. Hicksian Elasticities When Symmetry is Imposed--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11
e1	-0.352	-0.117	0.025	0.944	0.512	0.053	0.105	0.001	0.018	-0.002	-0.012
e2	-0.290	-0.182	0.263	-0.130	-0.052	0.247	-0.248	-0.112	-0.065	0.049	0.034
e3	0.067	0.286	-0.036	0.534	0.246	-0.174	0.462	0.096	0.038	-0.098	0.124
e4	0.540	-0.120	0.451	-0.799	0.124	-0.222	-0.093	0.045	0.035	-0.019	0.017
e5	0.571	-0.251	0.439	0.263	-0.879	-0.357	0.160	0.109	0.008	-0.099	-0.077
e6	0.432	0.810	-0.526	-0.794	-0.602	0.712	-0.522	-0.167	-0.214	0.291	-0.181
e7	1.544	-1.448	2.502	-0.578	0.483	-0.936	-2.047	0.139	-0.108	-0.358	0.841
e8	0.016	-1.002	0.797	0.446	0.505	-0.460	0.218	-0.200	0.374	-0.620	-0.081
e9	0.469	-0.680	0.362	0.398	0.041	-0.688	-0.196	0.438	-0.792	0.108	0.533
e10	-0.058	0.698	-1.280	-0.302	-0.724	1.266	-0.826	-0.984	0.150	2.495	-1.704
e11	-0.180	0.204	0.679	0.108	-0.238	-0.329	0.833	-0.054	0.303	-0.713	-1.170

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

The estimated Marshallian own-price elasticities for *satsumaagé* and *chikuwa* are low and the own-price elasticity of *kamaboko* was still obtained from a non-significant r value. The own-price elasticity of fish ham and sausage has a positive sign again. In the case of *surimi*-based products--*satsumaagé*, *chikuwa*, and *kamaboko*--they seem to have substitution relationships with beef, pork, and chicken (Table 9). *Satsumaagé* and *chikuwa* have substitutional relationships with chicken and *kamaboko* has a complementary relationship with chicken. *Kamaboko* has a complementary relationship with fresh fish and *satsumaagé* and *chikuwa* have substitution relationships with fresh fish. No strong substitution relationships exist among the *surimi*-based products, although *satsumaagé* and *chikuwa*, *chikuwa* and fish ham and sausage, and *kamaboko* and *chikuwa* are substitutes for each other, respectively.

Imposing symmetry does not have much effect on the estimated expenditure elasticities. In both models, the expenditure elasticities for *satsumaagé*, *chikuwa*, and *kamaboko* show that they are luxuries. (In the AIDS model, the i^{th} commodity is classified as a luxury if $b_i > 0$, and a necessity if $b_i < 0$.)

The value of $-2\ln\lambda$ for the test of the symmetry restriction is 1936.2. (The value of the log of the maximum likelihood function restricted by symmetry is 10333.8 and that unrestricted by symmetry is 11301.9.)

Therefore, the null hypothesis that the symmetry restriction holds is rejected at the 1% level. That is, the present data set does not show the symmetric relationships among r values.

An F-ratio test can be used to test the homogeneity restriction. Sausage was used to give the homogeneity restriction, i.e.,

$$r_{i7} = -\sum_{\substack{j \neq 7 \\ j=1}}^{11} r_{ij} .$$

Table 10 shows the results of the test of the homogeneity restriction[8] and Table 11 shows the Durbin-Watson values and rho (ρ) values for each equation. As shown in Table 10, the null hypothesis that homogeneity holds is rejected in some equations. As Deaton and Muellbauer (1980a, p. 77) suggested, this rejection of homogeneity might have been caused by an inappropriate specification of the dynamics of behavior or omitted variables, like time trends and lagged dependent variables. Looking at Table 11, we can see that Durbin-

[8]The value of the F-ratio can be given by

$$F = \frac{(e'^{*}e^{*} - e'e)/q}{e'e/(n-k)} ,$$

where $e'^{*}e^{*}$ is the residual sum of squares for the equation restricted with homogeneity, $e'e$ is the residual sum of square for the unrestricted equation, q is the number of restrictions, and n-k is the number of observations less the number of coefficients estimated. The relevant critical value of $F_{1,239}$ is greater than 3.8 at both 5% and 1% levels, where 1 is the number of restrictions and 239 is the number of observations less the number of coefficients estimated.

Table 10. Hypothesis Test Results for Homogeneity Restriction.

	No Correction for Autocorrelation RSS/n			Corrected for 1st-Order Autocorrelation RSS/n		
	No Homogeneity	Homogeneity	F-ratio	No Homogeneity	Homogeneity	F-ratio
eq1	0.0001309	0.0001304	-0.913	0.0000956	0.0000952	-0.995
eq2	0.0001537	0.0001541	0.638	0.0001176	0.0001173	-0.731
eq3	0.0000427	0.0000428	0.526	0.0000383	0.0000383	-0.449
eq4	0.0000398	0.0000462	38.45	0.0000204	0.0000205	1.019
eq5	0.0000133	0.0000143	18.93	0.0000105	0.0000113	18.08
eq6	0.0000271	0.0000295	21.80	0.0000119	0.0000116	-6.453
eq7	0.0000063	0.0000063	2.870	0.0000029	0.0000030	9.690
eq8	0.0000051	0.0000051	0.865	0.0000021	0.0000021	-0.854
eq9	0.0000010	0.0000010	3.186	0.0000005	0.0000005	15.87
eq10	0.0000027	0.0000029	23.15	0.0000012	0.0000013	20.92
eq11	0.0000126	0.0000133	11.38	0.0000084	0.0000084	-0.170

Note:

1 - Sausage (equation 7) was used to give the homogeneity restriction.

2 - RSS = residual sum of squares, $(= \sum_i e_i^2)$

3 - $$F = \frac{(e^{*\prime}e^{*} - e'e)/q}{e'e/(n-k)}$$

Table 11. Durbin-Watson Values and Rho (ρ) values.

	Unrestricted w/Homogeneity		Restricted w/Homogenity	
	DW	ρ	DW	ρ
eq1	1.0631	0.582	1.0623	0.582
eq2	1.1990	0.604	1.1770	0.599
eq3	1.3927	0.354	1.3797	0.358
eq4	1.0077	0.946	0.8847	0.952
eq5	1.2028	0.565	1.1895	0.548
eq6	1.0089	0.961	1.1178	0.995
eq7	0.7440	0.878	0.7297	0.801
eq8	0.7843	0.868	0.8177	0.968
eq9	0.6627	0.815	0.6950	0.773
eq10	1.6617	0.772	0.7381	0.876
eq11	1.0446	0.737	1.0247	0.771

Watson values and rho values do not change much when the homogeneity restriction is imposed, i.e., imposing the homogeneity restriction did not affect the degree of serial correlation in the equations for chicken, ham, *chikuwa*, and fish ham and sausage.[9] All rho values in Table 11 are significant at the 1% level. Table

[9]Deaton and Muellbauer (1980a) suggested four reasons for the failure of homogeneity when the serial correlation of residual terms were introduced. The plausible explanations for this failure of homogeneity are: (1) the omission of variables whose expenditure is relatively inflexible in the short run; (2) the omission of price expectations; (3) the assumption that the index k_n, the household equivalence scale, is independent of the average budget and the price vector; and (4) the assumption of weak intertemporal separability of nondurable goods in the intertemporal utility function may be inappropriate.

11 also shows that the residuals are positively serially correlated.

Table 12 shows the elasticities obtained from the coefficient estimators when the residuals were corrected for first-order autocorrelation. The commodity groups, salted and dried fish, ham, and fish ham and sausage, all have positive own-price elasticities. The own-price elasticities for fresh fish, pork, chicken, and *chikuwa* are less than one and those for beef, sausage, *satsumaagé*, and *kamaboko* exceed one. However, the postive Hicksian own-price elasticities of salted and dried fish, ham, and fish ham and sausage imply that the curvature condition may not be satisfied. The expenditure elasticities did not change much. *Kamaboko* still has an expenditure elasticity which is more than one. In Table 13, kamaboko shows a substitutional relationship with fresh fish, chicken, and *chikuwa*.

In the AIDS model, the multicollinearity problem can be reduced by using Stone's price index. However, it seems that multicollinearity among explanatory variables is still severe, even when using Stone's price index. This is revealed by examining the values of the variance inflation factors (VIF). Table 15 shows the value of the VIF for each explanatory variable, where each VIF is obtained from the main diagonal elements of the inversed standardized $(X'X)$ matrix. Empirically,

Table 12. Elasticities When the Residuals are Corrected for 1st Order Autocorrelation--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	η**	R^2
e1	-0.612	-0.456	-0.295	-0.155	0.166	-0.021	0.130	0.251	0.009	-0.082	0.057	1.014	0.784
e2	-0.344	0.538	0.178	-0.206	-0.147	-0.612	0.264	-0.728	-0.309	0.478	-0.532	1.390	0.838
e3	0.050	-0.170	-1.338	0.060	-0.307	1.085	-0.444	0.171	0.118	0.033	0.023	0.602	0.854
e4	-0.067	-0.232	-0.167	-0.369	-0.239	-0.167	0.015	0.133	0.057	-0.002	0.557	0.636	0.938
e5	-0.341	-0.045	0.493	0.210	-0.719	-0.077	-0.176	-0.542	0.228	-0.126	0.560	0.953	0.663
e6	0.508	0.187	-1.629	0.486	-1.473	1.168	-0.422	0.898	-0.398	-0.672	-1.194	1.418	0.804
e7	-0.875	-0.234	-0.798	0.751	0.689	-0.618	-1.091	1.066	-0.028	-0.466	1.224	1.188	0.839
e8	-1.235	-0.921	1.430	-0.859	0.669	0.158	-0.323	-1.325	0.210	0.505	1.710	0.921	0.830
e9	-0.518	-0.704	0.368	0.080	0.328	-0.164	-0.250	-0.342	-0.732	0.241	1.279	1.040	0.835
e10	-0.418	-0.258	-0.824	-0.094	-1.379	-0.598	1.791	0.798	0.158	0.627	-2.496	0.976	0.973
e11	-0.086	0.101	-0.334	-1.695	1.557	2.174	-1.075	-1.147	0.381	-0.685	-1.621	2.087	0.834

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

** η indicates expenditure elasticity.

Table 13. Hicksian Elasticities When the Residuals are Corrected for 1st Order Autocorrelation--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11
e1	-0.248	-0.310	-0.160	0.004	0.241	0.024	0.155	0.267	0.023	-0.072	0.082
e2	0.155	0.739	0.363	0.012	-0.044	-0.551	0.298	-0.706	-0.290	0.492	-0.498
e3	0.266	-0.083	-1.258	0.154	-0.262	1.112	-0.429	0.181	0.126	0.039	0.038
e4	0.161	-0.140	-0.083	-0.269	-0.192	-0.139	0.031	0.143	0.066	0.004	0.572
e5	0.001	0.093	0.620	0.360	-0.648	-0.035	-0.153	-0.527	0.241	-0.116	0.583
e6	1.017	0.392	-1.441	0.708	-1.368	1.230	-0.387	0.921	-0.379	-0.658	-1.160
e7	-0.448	-0.062	-0.640	0.937	0.777	-0.566	-1.062	1.085	-0.012	-0.454	1.253
e8	-0.904	-0.788	1.552	-0.715	0.737	0.199	-0.300	-1.310	0.223	0.514	1.732
e9	-0.145	-0.554	0.506	0.243	0.405	-0.118	-0.225	-0.325	-0.718	0.252	1.304
e10	-0.068	-0.117	-0.694	0.059	-1.307	-0.555	1.815	0.814	0.171	0.637	-2.472
e11	0.664	0.403	-0.057	-1.368	1.712	2.266	-1.034	-1.114	0.410	-0.664	-1.571

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

Table 14. Estimated Coefficients When the Residuals are Corrected for 1st Order Autocorrelation--11 Items* Case.

	r1	r2	r3	r4	r5	r6	r7	r8	r9	r10	r11
eq1	0.139	-0.163	-0.105	-0.055	0.060	-0.007	0.047	0.090	0.003	-0.029	0.021
eq2	-0.030	0.222	0.033	-0.021	-0.017	-0.086	0.040	-0.104	-0.044	0.070	-0.076
eq3	-0.012	-0.030	-0.045	-0.0003	-0.045	0.142	-0.060	0.022	0.015	0.004	0.002
eq4	-0.031	-0.045	-0.034	0.099	-0.042	-0.029	0.001	0.020	0.008	-0.001	0.086
eq5	-0.027	-0.004	0.036	0.015	0.021	-0.006	-0.013	-0.040	0.017	-0.009	0.041
eq6	0.029	0.011	-0.069	0.024	-0.063	0.095	-0.018	0.040	-0.017	-0.029	-0.052
eq7	-0.020	-0.005	-0.019	0.019	0.017	-0.015	-0.002	0.026	-0.001	-0.011	0.030
eq8	-0.020	-0.015	0.023	-0.014	0.011	0.002	-0.005	-0.009	0.003	0.008	0.027
eq9	-0.007	-0.010	0.005	0.001	0.005	-0.002	-0.003	-0.005	0.004	0.003	0.018
eq10	-0.004	-0.003	-0.008	-0.001	-0.014	-0.006	0.018	0.008	0.002	0.016	-0.025
eq11	0.007	0.006	-0.005	-0.037	0.040	0.054	-0.025	-0.027	0.010	-0.016	-0.015

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

Table 15. Values of VIF.

	r_{11}	r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	r_{17}	r_{18}	r_{19}	r_{110}	r_{111}	b_1
VIF_1	185.1	100.7	93.5	53.5	65.5	321.5	393.2	360.7	111.8	193.8	131.7	2.6

it could be said that the multicollinearity problem is severe if the value of the VIF is more than 80 or 100, although the absolute criteria values are not yet known. Therefore, the Lawless-Wang ridge regression procedure was used to reduce the multicollinearity problem.[10]

However, the results of ridge regression seem to be not much better than those from OLS estimation. Most of the values of the signal to noise ratio,

$$\frac{\Sigma \hat{Q}_i^{\,2}}{\hat{\sigma}_u^{\,2}} = \frac{\Sigma \hat{\beta}_i^{\,2}}{\hat{\sigma}_u^{\,2}},$$

are very large. (It ranges from 32.413 to 3981.423.) One condition among three conditions for favorable ridge regression does not hold.[11] Also, most of the signs of elasticities did not change, compared to elasticities obtained from the OLS procedure. On the other hand, the curvature condition, i.e., negative semi-definiteness, appears to be improved in that only fish ham and sausage has a positive Hicksian own-price elas-

[10]The ridge values were calculated by the following formula (Lawless & Wang, 1976, p. 307-323):

$$K_{\lambda-w} = \frac{p\hat{\sigma}_u^{\,2}}{\Sigma \lambda_i \hat{Q}_i^2} = \frac{p\hat{\sigma}_u^{\,2}}{R^2 \sum_{i=1}^{n} y_i^2},$$

where p = the number of variables,
$\hat{\sigma}_u^{\,2}$ = the sample variance of equation,
y_i = Wi − $\bar{W}$i ($\bar{W}$i is the mean value of Wi),
λ_i = characteristic root (or eigen value) of $X'X$,
$\hat{Q}_i$ = $P'\beta$, where $\beta = (X'X)^{-1}X'Y$ and P is a matrix such that $P'XXP = \Lambda$ and Λ is a diagonal matrix consisting of λi's.

[11]According to Lawless (1978, p. 156), the favorable conditions for the ridge estimators are: (1) one or more eigen values are quite small, (2) the signal to noise ratio, $\Sigma\hat{\beta}_i^{\,2}/\hat{\sigma}_u^{\,2}$, is not too large, and (3) α_i's, $\alpha_i = p'\beta$, corresponding to small λ_i's are not too large. The signal to noise ratio is a kind of index number defined by Lawless to measure the efficiency of ridge regressors. In the Lawless paper, the values of the signal to noise ratio less than 300 were treated as a favorable case in the ridge regression. However, we unfortunately do not know the general criteria values for a "not too large" signal to noise ratio. Therefore, we have to decide "not too large" values by empirical experience.

ticity. Table 16 indicates the values of the signal to noise ratio.

Table 16. Signal to Noise Ratio.

eq1	874.03	eq2	514.29	eq3	2347.74
eq4	1793.94	eq5	270.40	eq6	32.41
eq7	293.41	eq8	169.30	eq9	507.26
eq10	3981.42	eq11	418.97		

Table 17 shows the elasticities obtained from the ridge regression. Comparing Table 17 to Table 6, none of the signs of the own-price elasticities has been changed. The own-price elasticity of *satsumaagé* fell to 0.9 and that of *kamaboko* continues to have the properties of a luxury, whose expenditure elasticity is greater than 2. It seems that *surimi* products, except for fish ham and sausage, have substitutional relationships with fresh fish and beef (Table 18). It is not clear whether there exist complementary or substitutional relationships among *surimi* products or between *surimi* products and red meats since many pairs of cross-price elasticities, expected to have symmetric relationships, have different signs. (An example is e_{12}^* and $e_2{}^*{}_1$, where $e_2{}^*{}_1$ is the Hicksian cross-price elasticity of fresh fish with respect to salted and dried fish and e_{12}^* ;is the Hicksian cross-price elasticity of salted and dried

Table 17. Elasticities Obtained from Lawless-Wang Ridge Estimators--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	η**	R^2
e1	-0.928	-0.120	-0.123	-0.038	0.042	0.015	0.073	0.069	0.031	-0.008	0.118	0.936	0.483
e2	-0.129	-0.567	-0.039	-0.169	0.026	-0.067	-0.118	-0.274	-0.190	0.074	-0.493	1.747	0.707
e3	0.053	-0.057	-1.126	-0.001	-0.371	0.380	0.136	0.078	0.090	0.077	0.075	0.673	0.782
e4	0.057	0.019	0.472	-0.648	0.420	-0.416	-0.224	0.038	-0.006	-0.076	0.128	0.511	0.831
e5	0.021	0.001	0.200	0.117	-0.918	-0.066	-0.087	-0.040	-0.007	-0.060	0.034	0.822	0.326
e6	-0.159	0.225	-0.125	-0.130	-0.426	-0.889	0.042	-0.023	-0.023	-0.124	-0.210	1.467	0.362
e7	0.023	-0.029	0.120	0.246	-0.060	-0.074	-1.079	0.221	-0.065	-0.282	0.555	0.582	0.410
e8	-0.138	-0.409	0.086	-0.248	-0.034	0.040	-0.003	-0.965	0.094	0.262	0.265	0.943	0.401
e9	-0.019	-0.254	0.147	0.051	-0.180	-0.067	-0.070	0.064	-0.925	0.126	0.339	0.805	0.437
e10	-0.818	0.365	-1.205	-0.069	-0.307	-0.436	1.139	0.079	0.646	0.628	-1.784	0.648	0.938
e11	-0.593	-0.097	-0.004	-0.586	-0.759	0.338	-0.008	-0.324	-0.041	0.039	-1.037	2.543	0.686

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

** η indicates expenditure elasticity.

Table 18. Hicksian Elasticities by Lawless-Wang Ridge Regression--11 Items* Case.

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11
e1	-0.592	0.015	0.001	0.109	0.111	0.056	0.096	0.084	0.044	0.001	0.141
e2	0.498	-0.315	0.193	0.105	0.156	0.010	-0.075	-0.246	-0.166	0.092	-0.451
e3	0.295	0.040	-1.307	0.105	-0.321	0.410	0.152	0.089	0.099	0.084	0.091
e4	0.241	0.093	0.540	-0.568	0.458	-0.394	-0.211	0.046	0.001	-0.071	0.140
e5	0.338	0.128	0.317	0.255	-0.853	-0.027	-0.065	-0.026	0.005	-0.051	0.055
e6	0.368	0.437	0.070	0.100	-0.317	-0.824	0.078	0.001	-0.003	-0.109	-0.175
e7	0.232	0.055	0.197	0.337	-0.017	-0.048	-1.065	0.230	-0.057	-0.276	0.569
e8	0.201	-0.273	0.211	-0.100	0.036	0.081	0.020	-0.950	0.107	0.272	0.288
e9	0.270	-0.138	0.254	0.177	-0.120	-0.032	-0.050	0.077	-0.914	0.134	0.358
e10	-0.585	0.459	-1.119	0.033	-0.259	-0.407	1.155	0.689	0.655	0.635	-1.768
e11	0.320	0.270	0.334	-0.187	-0.570	0.450	0.054	-0.283	-0.006	0.065	-0.975

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = satsumaage; e9 = chikuwa; e10 = fish ham & sausage; e11 = kamaboko.

fish with respect to fresh fish.) The interesting result of the ridge regression is that the own-price elasticities obtained from ridge estimators are closer to -1 than those obtained from OLS estimators (the own-price elasticity is given by $e_{ii} = -1 + r_{ii}/w_i - b_i$). That is, the variation of own-price elasticity from -1 is reduced in the case of elasticities obtained from ridge estimators. This result could be due to the general characteristics of the ridge estimator: i.e., smaller coefficient values in absolute value and smaller covariances, although this is not always the case.

For the AIDS model, the nominal prices were used and the expenditure data were deflated by Stone's price index. Furthermore, there was little difference between estimators given by deflated prices and estimators given by non-deflated prices. Therefore, it is assumed in this study that in the estimation of the AIDS model, non-deflated prices do not result in the severe problem of money illusion. Table 19 shows the estimators given by deflated prices when the residuals were corrected for first-order autocorrelation (Table 14 showed the case for non-deflated prices).

Table 19. Estimated Coefficients by Deflated Prices When the Residuals are Corrected for 1st Order Autocorrelation--11 Items* Case.

	r1	r2	r3	r4	r5	r6	r7	r8	r9	r10	r11
eq1	0.139	-0.161	-0.107	-0.056	0.052	-0.006	0.033	0.093	0.001	-0.029	0.001
eq2	-0.030	0.224	0.020	-0.022	-0.024	-0.079	0.014	-0.110	-0.049	0.068	-0.108
eq3	-0.013	-0.031	-0.043	0.001	-0.036	0.137	-0.041	0.009	0.018	0.005	0.024
eq4	-0.031	-0.045	-0.028	0.093	-0.062	-0.027	-0.001	0.033	0.011	0.004	0.082
eq5	-0.020	-0.008	0.047	0.016	0.002	-0.007	-0.024	-0.010	0.014	-0.005	0.026
eq6	0.030	0.007	-0.075	0.036	-0.073	0.101	-0.011	0.058	-0.009	-0.016	-0.018
eq7	-0.021	-0.004	-0.008	0.017	-0.003	-0.016	-0.009	0.038	0.001	-0.013	0.026
eq8	-0.021	-0.013	0.024	-0.018	0.019	0.0004	-0.009	-0.018	-0.002	-0.0001	0.015
eq9	-0.006	-0.009	0.007	0.001	-0.005	-0.002	-0.009	0.002	0.004	0.004	0.011
eq10	-0.004	-0.004	-0.014	0.001	0.001	-0.005	0.025	-0.002	-0.0002	0.014	-0.016
eq11	0.009	0.005	-0.007	-0.039	0.062	0.052	-0.015	-0.030	0.010	-0.019	0.001

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = ham; e7 = sausage; e8 = <u>satsumaage</u>; e9 = <u>chikuwa</u>; e10 = fish ham & sausage; e11 = <u>kamaboko</u>.

6-Items Case

When the 6-items model is estimated by the OLS procedure, the own-price elasticities have negative signs, except for salted and dried fish, for which the new prices are the weighted means; i.e., prices weighted by the expenditure ratios,

$$p_i = \sum_j w_j p_j \ .$$

Surimi-based products are, as a group, estimated to have a price-inelastic demand (the own-price elasticity is -0.572) (Table 20). Also, they appear to have substitution relationships with fresh fish and beef (Table 21). The expenditure elasticity of *surimi* products is high, just as with the 11-items case. However, the values of the variance inflation factors and correlation coefficients among explanatory variables show that ~~there~~ a multicollinearity problem still exists, even though the 11 commodities are combined to form a 6 commodity group. Table 22 shows the values of the VIFs for the 6-items case.

When the residuals are corrected for second-order serial correlation, the expenditure elasticities change very little. Their rho (ρ) values are shown in Table 23. (The coefficient values estimated with first-order autocorrelation correction, not reported herein, were

Table 20. Elasticities Obtained from OLS Estimators--6 Items* Case.

	e1	e2	e3	e4	e5	e6	η**	R^2
e1	-0.637	-0.384	-0.387	-0.097	0.269	0.411	0.947	0.543
e2	-0.461	0.237	-0.151	-0.305	0.010	-1.325	1.680	0.718
e3	-0.078	-0.067	-1.315	0.132	-0.076	1.053	0.608	0.675
e4	-1.509	0.065	0.819	-0.605	-0.082	-0.655	0.510	0.706
e5	-0.268	-0.005	0.690	0.260	-1.435	-0.045	0.951	0.387
e6	-0.607	-0.685	0.384	-0.324	-0.710	-0.572	1.879	0.766

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = <u>surimi</u> products.
** η indicates expenditure elasticity.

Table 21. Hicksian Elasticities Obtained from OLS Estimators--6 Items* Case.

	e1	e2	e3	e4	e5	e6
e1	-0.271	-0.237	-0.252	0.063	0.345	0.473
e2	0.189	0.499	0.089	-0.021	0.144	-1.215
e3	0.157	0.028	-1.228	0.235	-0.027	1.093
e4	-1.312	0.144	0.892	-0.519	-0.041	-0.622
e5	0.100	0.143	0.826	0.421	-1.359	0.017
e6	0.120	-0.393	0.053	-0.007	-0.560	-0.449

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = <u>surimi</u> products.

Table 22. Values of the VIFs for the 6 Items Case.

	r_{i1}	r_{i2}	r_{i3}	r_{i4}	r_{i5}	r_{i6}	b_i
VIFi	128.47	91.87	74.66	44.44	26.47	74.38	1.83

Table 23. Rho (ρ) Values for the 6-Items* Model.

	rho 1		rho 2	
eq1	0.8446	(13.42)	0.0346	(0.55)
eq2	0.6516	(10.99)	0.1729	(2.79)
eq3	0.5551	(9.27)	0.3114	(5.20)
eq4	1.0267	(16.46)	-0.1386	(-2.22)
eq5	0.7321	(11.80)	0.1747	(2.82)
eq6	1.1383	(19.10)	-0.3241	(-5.44)

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = surimi products.

Note: Numbers in parentheses are t-ratio values.

not that much different from the coefficient values estimated with second-order autocorrelation correction.) The results of this estimation show that the *surimi*-based products have complementary relationships with fresh fish, and salted and dried fish, but a substitutional relationship with chicken (Table 24). The expenditure elasticity for *surimi*-based products is still high (Table 25). When comparing data in Table 20 with that in Table 25, it may be seen that all of the fish items, fresh fish, salted and dried fish, and *surimi*-based products, have expenditure elasticities greater than 1, except for fresh fish in Table 20. (However, the expenditure elasticity for fresh fish in Table 20 is very close to 1 (=0.947).)

Table 24. Hicksian Elasticities When the Residuals are Corrected for Second Order Autocorrelation--6 Items* Case.

	e1	e2	e3	e4	e5	e6
e1	-0.613	-0.265	0.044	0.254	0.412	-0.097
e2	0.123	0.835	-0.056	-0.612	-0.282	-0.716
e3	0.416	0.043	-0.676	0.438	-0.479	0.204
e4	0.139	-0.216	0.334	-0.015	-0.109	0.122
e5	-0.078	-0.012	0.066	0.209	-0.775	0.894
e6	-0.004	-0.138	-0.036	-0.910	0.748	0.178

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = surimi products.

Table 25. Elasticities Obtained from Estimators Corrected for Autocorrelation--6 Items* Case.

	e1	e2	e3	e4	e5	e6	η**	R^2
e1	-1.022	-0.429	-0.107	0.076	0.328	-0.166	1.056	0.755
e2	-0.439	0.609	-0.264	-0.857	-0.398	-0.811	1.452	0.840
e3	0.139	-0.069	-0.779	0.317	-0.536	0.157	0.717	0.845
e4	-0.104	-0.314	0.244	-0.121	-0.159	0.081	0.628	0.919
e5	-0.410	-0.146	-0.057	0.064	-0.844	0.838	0.859	0.691
e6	-0.570	-0.366	-0.245	-1.157	0.631	0.082	1.462	0.912

* e1 = fresh fish; e2 = salted and dried fish; e3 = beef; e4 = pork; e5 = chicken; e6 = surimi products.
** η indicates expenditure elasticity.

As may be seen, there is substantial difference between the results of the 11-items model and the 6-items model, for example, in Hicksian elasticities. This seems to be consistent with Deaton and Muellbauer's (1980b, p. 79) observation that "as more detailed commodities are distinguished and the range of potential substitutes widens, price responses will be larger."

3-Items Case

Without the correction for serial correlation in the residuals, all items showed negative own-price elasticities (Table 26). The expenditure elasticity of *surimi*-based products is greater than unity. Table 27 shows that *surimi*-based products have a substitutional relationship with red meats. When the residuals were corrected for first-order autocorrelation, only the sign of the elasticity of red meats with respect to fish (e_{32}) was changed (Table 28). *Surimi*-based products show their complementary relationship with fish (Table 29). The elasticities obtained from ridge estimators have values which are very close to the elasticities obtained from OLS estimators. Table 30 displays the elasticities obtained from the ridge regression. Testing the symmetry restriction, $-2\ln\lambda = 21.90$, is larger than $\chi_{1,}{}^{2}{}_{.05} = 3.841$. Therefore, the symmetry restriction is still rejected.

Summary, the AIDS Model

To this point, only the estimation results of using the AIDS model have been shown. In testing the

Table 26. Elasticities Obtained from OLS Estimators--3 Items* Case.

	e1	e2	e3	η**	R^2
e1	-0.572	-0.864	-0.660	1.725	0.743
e2	-0.183	-0.915	-0.266	1.215	0.650
e3	0.167	0.021	-0.566	0.621	0.842

* e1 = *surimi*-based products, combined with *satsumaagé*, *chikuwa*, and *kamaboko*; e2 = fresh, salted, and dried fish; e3 = red meats.
** η = indicates expenditure elasticity.

Table 27. Hicksian Elasticities Obtained from OLS Estimators--3 Items* Case.

	e1	e2	e3
e1	-0.462	0.038	0.056
e2	-0.108	-0.280	0.238
e3	0.206	0.346	-0.308

* e1 = *surimi*-based products, combined with *satsumaagé*, *chikuwa*, and *kamaboko*; e2 = fresh, salted, and dried fish; e3 = red meats.

Table 28. Elasticities for the Case of First-Order Autocorrelation--3 Items* Case.

	e1	e2	e3	η**	R^2
e1	-0.177	-0.867	-0.826	1.544	0.905
e2	-0.344	-0.674	-0.364	1.169	0.857
e3	0.307	-0.269	-0.426	0.702	0.916

* e1 = *surimi*-based products, combined with *satsumaagé*, *chikuwa*, and *kamaboko*; e2 = fresh, salted, and dried fish; e3 = red meats.

** η = indicates expenditure elasticity.

Table 29. Hicksian Elasticities for the Case of First-Order Autocorrelation--3 Items* Case.

	e1	e2	e3
e1	-0.081	-0.059	-0.185
e2	-0.272	-0.063	0.121
e3	0.351	0.098	-0.135

* e1 = *surimi*-based products, combined with *satsumaagé*, *chikuwa*, and *kamaboko*; e2 = fresh, salted, and dried fish; e3 = red meats.

Table 30. Elasticities by Lawless-Wang Ridge Regression--3 Items* Case.

	e1	e2	e3	η**	R^2
e1	-0.767	-0.737	-0.589	1.704	0.740
e2	-0.122	-1.006	-0.226	1.231	0.634
e3	0.148	0.063	-0.595	0.613	0.840

* e1 = *surimi*-based products, combined with *satsumaagé*, *chikuwa*, and *kamaboko*; e2 = fresh, salted, and dried fish; e3 = red meats.
** η = indicates expenditure elasticity.

symmetry and homogeneity restrictions, the symmetry restriction was rejected and the homogeneity restriction was also rejected for some equations. Severe autocorrelation and multicollinearity problems existed in the present data set. Because symmetric relationships among r values did not hold in many cases, finding consistent relationships, i.e., substitutional or complementary relationships, between different commodities was not successful. In addition, the reduction of 11 commodity groups to 6 or 3 commodity groups did not result in substantial improvement. However, the own-price elasticities and expenditure elasticities were comparatively consistent in every case. One interesting finding is that there wasn't sufficient evidence to establish a strong substitutional relationship between *surimi*-based products and pork or chicken in the 11-items case, although it seemed that *kamaboko* and *chi-*

kuwa had substitutional relationships with chicken. The results of testing the approximation of Stone's price index (log P^*) to the original price index (log P) are shown in Table 31. The value .3 was assigned to the parameter a_0. The approximation was close: globally, the difference between the two indices did not exceed .07 when both values were normalized by the price of December, 1985. This difference would be reduced if the 11-items case were tested and the more accurate value were assigned to a_0. Table 31 shows only the data for December of each year, 1965 to 1985.

Table 31. Comparison of log P and log P^*.

Year	log P^*	log P	Year	log P^*	log P
1965	0.210	0.190	1976	0.754	0.746
1966	0.227	0.191	1977	0.817	0.777
1967	0.263	0.223	1978	0.859	0.805
1968	0.286	0.258	1979	0.885	0.839
1969	0.312	0.268	1980	0.904	0.878
1970	0.332	0.286	1981	0.940	0.917
1971	0.373	0.308	1982	0.974	0.951
1972	0.427	0.354	1983	0.937	0.932
1973	0.533	0.487	1984	0.978	0.975
1974	0.609	0.560	1985	1	1
1975	0.698	0.731			

LES, PHF, AND LHF Models

In the estimation of the AIDS model, only the monthly data were used since 21 annual observations were thought to have a lack of degree of freedom. However, in the estimation of the habit formation model, both annual and monthly data were used since the fact that "habit formation" was not expected to be a short-time period behavior might play a more crucial role in finding the existence of habit persistence than the lack of degree of freedom.

In the case of annual data, the LHF explains consumer behavior better than the LES and PHF in that the null hypotheses that $h_i = 0$ and $r_i^* = 0$ for the LES and PHF, respectively, were rejected at the 5% level. This also happened in the case of estimation corrected for first-order autocorrelation and the case of monthly data, where the estimates were not corrected for autocorrelation. The estimation corrected for first-order autocorrelation for monthly data offers interesting results. The value of $-2\ln\lambda$ for LES vs. LHF, corrected for first-order autocorrelation, is negative. This value was expected to be positive because the LES is a nested model of the LHF. However, Table 32 indicates that the rho (ρ) value for the LES is very high (close to 1), suggesting almost perfect autocorrelation. Therefore, it may be seen that the maximum value of the log of the likelihood function for the LES is substantially increased by the introduction of almost perfect autocorrelation. As a result, habit persistence does not show up in the case of LES vs. LHF corrected for autocorrelation, even though the habit effect

Table 32. *Rho* (ρ) Values.

	LES	PHF	LHF
11-Items, Monthly Data	0.9958 (.0022)	-0.0743 (.1439)	-0.0460 (.0250)
11-Items, Annual Data	0.7735 (.0162)	0.0771 (.0268)	0.0560 (.0001)
3-Items, Monthly Data	0.9940 (.0043)	-0.0220 (.0451)	-0.0226 (.0461)
3-Items, Annual Data	0.9100 (.0470)	0.0133 (.0398)	-0.0074 (.0385)

Note: Numbers in parentheses are standard errors.

coefficients, h_i's, have significant values. Except for the case of the LES, the rho (ρ) values for the PHF and LHF are very low. This might suggest that the LES has the model specification error in that the LES does not include the past term's quantity demanded data. Table 33 shows the main results of estimations for the LES, PHF, and LHF models. Table 34 indicates the results of testing the existence of autocorrelation and Table 32 shows the rho (ρ) values for each case. Table 35 shows the h_i values of the 11-items equations.

Examining the results from the estimation with annual data for the 11-items case, it may be seen that *surimi*-based products have small habit effect coefficients, h_i's, in the LHF model, except for fish ham and

Table 33. Estimation Results for the LES, PHF, and LHF Models.

		Log of ML			$-2\ln\lambda$	
		LES	PHF	LHF	LES vs LHF	PHF vs LHF
			11-Item Case			
Annual Data	$\rho=0$	-1309.725	-1321.065	-1164.070	291.31	313.99
	$\rho\neq0$	-1262.758	-1268.582	-1075.446	374.624	386.272
Monthly Data	$\rho=0$	-12258.91	-11278.93	-11227.90	2062.02	102.06
	$\rho\neq0$	-11084.60	-11206.70	-11162.37	-155.54	88.66
			6-Items Case			
Annual Data	$\rho=0$	-759.494	-757.868	-738.727	41.534	38.282
Monthly Data	$\rho=0$	-7193.488	-6546.215	-6502.243	1382.49	87.944
			3-Items Case			
Annual Data	$\rho=0$	-319.598	-313.842	-368.236	22.724	11.213
	$\rho\neq0$	-300.009	-300.644	-298.051	3.917	5.186
Monthly Data	$\rho=0$	-3154.154	-2674.009	-2668.878	970.552	10.262
	$\rho\neq0$	-2674.183	-2671.085	-2667.069	14.228	8.032

Note: $\chi^2_{12},.05 = 21.026$; $\chi^2_{11},.05 = 19.675$; $\chi^2_{7},.05 = 14.067$; $\chi^2_{6},.05 = 12.592$; $\chi^2_{4},.05 = 9.488$; $\chi^2_{3},.05 = 7.815$; $\chi^2_{1},.05 = 3.841$

Table 34. Test Results for Autocorrelation ($H_0:\rho = 0$).

	LES	PHF	LHF
11 Items, Annual Data	93.934	104.966	137.98
11 Items, Monthly Data	2348.62	144.46	131.06
3 Items, Annual Data	39.177	26.397	10.185
3 Items, Monthly Data	959.942	5.848	3.618

Table 35. Estimated h_i Values for the PHF and LHF Models.

	PHF, ρ=0	PHF, $\rho\neq$0	LHF, ρ=0	LHf, $\rho\neq$0
	1. 11-Items Model Estimated with Monthly Data			
eq1	0.936 (.008)	0.948 (.011)	0.809 (.033)	0.823 (.031)
eq2	0.894 (.018)	0.916 (.014)	0.848 (.056)	0.877 (.049)
eq3	0.941 (.009)	0.953 (.007)	0.926 (.020)	0.937 (.017)
eq4	0.965 (.005)	0.973 (.006)	0.915 (.014)	0.925 (.012)
eq5	0.927 (.009)	0.941 (.012)	0.905 (.015)	0.915 (.014)
eq6	0.867 (.019)	0.892 (.016)	0.729 (.034)	0.760 (.032)
eq7	0.932 (.009)	0.961 (.015)	0.872 (.022)	0.881 (.022)
eq8	0.950 (.011)	0.959 (.018)	0.813 (.028)	0.828 (.026)
eq9	0.939 (.008)	0.949 (.017)	0.842 (.022)	0.857 (.020)
eq10	0.957 (.009)	0.968 (.009)	0.977 (.022)	0.986 (.016)
eq11	0.794 (.023)	0.824 (.027)	0.830 (.033)	0.837 (.033)
	2. 11-Items Model Estimated with Annual Data			
eq1	0.228 (.092)	0.572 (.120)	0.150 (.002)	0.533 (.004)
eq2	0.283 (.127)	0.330 (.146)	1.156 (.001)	0.680 (.002)
eq3	0.172 (.083)	0.307 (.078)	0.779 (.001)	0.619 (.003)
eq4	0.362 (.071)	0.335 (.063)	0.991 (.00003)	0.611 (.001)
eq5	0.244 (.091)	0.116 (.108)	0.777 (.0002)	0.722 (.002)
eq6	0.102 (.082)	-0.041 (.137)	0.449 (.001)	0.523 (.013)
eq7	0.291 (.093)	0.419 (.103)	0.819 (.001)	0.796 (.004)
eq8	0.365 (.087)	0.632 (.082)	-0.197 (.0004)	0.098 (.002)
eq9	-0.098 (.065)	-0.196 (.054)	-0.133 (.0002)	-0.085 (.0004)
eq10	0.681 (.084)	0.803 (.069)	0.629 (.0004)	0.734 (.002)
eq11	0.412 (.085)	0.552 (.097)	0.015 (.0001)	-0.022 (.0002)

Note: 1 = fresh fish; 2 = salted and dried fish; 3 = beef; 4 = pork; 5 = chicken; 6 = ham; 7 = sausage; 8 = *satsumaagé*; 9 = *chikuwa*; 10 = fish ham and sausage; 11 = *kamaboko*. Numbers in parentheses are standard errors.

Table 35 (continued).

	Monthly Data		Annual Data	
	PHF	LHF	PHF	LHf
		3. 6-Items Model		
eq1	0.958 (.010)	0.697 (.031)	0.453 (.086)	0.930 (.216)
eq2	0.929 (.025)	1.014 (.056)	0.610 (.085)	0.537 (.096)
eq3	0.959 (.012)	0.928 (.023)	0.458 (.094)	0.424 (.041)
eq4	0.978 (.006)	0.898 (.014)	0.548 (.085)	0.537 (.050)
eq5	0.951 (.013)	0.893 (.018)	0.569 (.081)	0.562 (.039)
eq6	0.932 (.018)	0.925 (.026)	0.348 (.113)	-0.008 (.088)

Note: 1 = fresh fish; 2 = salted and dried fish; 3 = beef; 4 = pork; 5 = chicken; 6 = *surimi*-based products. Numbers in parentheses are standard errors.

	PHF, ρ=0	PHF, $\rho\neq$0	LHF, ρ=0	LHf, $\rho\neq$0
		4a. 3-Items Model Estimated with Annual Data		
eq1	0.833 (.080)	1.042 (.058)	0.759 (.055)	0.906 (.058)
eq2	0.871 (.064)	0.485 (.128)	0.640 (.036)	0.163 (.203)
eq3	0.921 (.053)	0.624 (.082)	0.977 (.042)	0.552 (.125)
		4b. 3-Items Model Estimated with Monthly Data		
eq1	0.969 (.019)	0.971 (.020)	1.014 (.029)	1.010 (.028)
eq2	0.979 (.014)	0.980 (.014)	0.978 (.033)	0.973 (.019)
eq3	0.578 (.010)	0.985 (.010)	0.957 (.015)	0.963 (.013)

Note: 1 = *surimi*-based products; 2 = fresh, salted and dried fish; 3 = red meats. Numbers in parentheses are standard errors.

sausage, and they have relatively high h_i's in the PHF, except for *chikuwa*. This coincides with the fact that the null hypothesis that $r_i^* = 0$ is rejected at the 5% level in Table 33. The null hypothesis for testing the existence of autocorrelation, $H_0: \rho = 0$, was rejected in every case, except for the LHF model with 3 commodity groups, estimated with monthly data. The results of the 6-items case were not substantially different from the 11-items case. The h_i value for the *surimi*-based products in the LHF estimated with annual data is very low and not significant. When the estimation for the 3-items case was performed by correcting for first-order autocorrelation, the null hypothesis was not rejected as was the case of LES vs. LHF for the 11-items case. This would have resulted for the same reasons as with the 11-items case. The null hypothesis, $H_0: \rho = 0$, was accepted only in the LHF estimated with monthly data. The main results may be summarized as follows.

The null hypotheses, $h_i = 0$ or $r_i^* = 0$, were rejected in each estimation when the residuals were not corrected for first-order autocorrelation. However, when the residuals were corrected, the null hypotheses were not rejected, except for the cases of LES vs. LHF and PHF vs. LHF of the 11-items model. This failure to reject the null hypotheses seems to be due to the presence of almost perfect autocorrelation. Therefore, when the estimation is performed by correcting the residuals for autocorrelation, the LHF model is not better than the PHF or LES model in explaining habit persistence, except for the 11-items model estimated with annual data. It is shown that the rho (ρ) values for the LES model are very high (ranging from .77 to .99) and those for the PHF and LHF models are very low (less than .08). Seemingly, the dynamic specification in which autocorrelation is addressed is better than the habit formation model to explain the habit persistence of consumers in this analysis insofar as the former includes lagged endogenous regressor. That is, the former might be a better specification of habit persistence.

7. SUMMARY, CONCLUSIONS, AND SUGGESTIONS FOR FUTURE RESEARCH

Summarizing the objectives, approach, and principal findings, the Stone's price index was used in the estimation of the AIDS model, rather than the original price index. Stone's index is supposed to reduce the multicollinearity problem. However, examination of the values of the variance inflation factor and correlation coefficient suggests that the reduction of multicollinearity was not significant. In the present case it seems that severe multicollinearity problems result from the selection of food items whose prices are very likely to change in the same direction. The results of reducing 11-items to 6- or 3-items improved matters very little. Moreover, the residual terms were serially correlated. Seemingly, the AIDS model is not the best approach for the analysis of the present data set.

However, some hypotheses may be derived from this analysis of *surimi*-based products. For example, the own-price elasticity of *kamaboko* is greater than unity, while demands for the other *surimi*-based products are generally price-inelastic. The expenditure elasticities of *surimi*-based products are greater than unity, suggesting that they are luxuries.

In actuality, at the beginning of this project it was expected that *surimi*-based products would have substitutional relationships with fish and red meats. Moreover, it was stated earlier that *surimi*-based products, except for special *kamaboko* luxury items, would have strong substitutional relationships with pork and chicken, but not with beef. However, it seems that *surimi*-based products are more likely to have complementary relationships with fish and substitutional relationships with red meats, although their substitutional relationship with red meats is not guaranteed, other than for chicken.

Specifically, in the 11-items model, *surimi*-based products, with the exception of fish ham and sausage, appear to have complementary relationships with fresh fish and salted and dried fish. When the symmetry restriction was imposed, *satsumaagé* and *chikuwa* had a substitutional relationships with red meats, fish ham and sausage had a complementary relationship with red meats, and *kamaboko* had a substitutional relationship with beef and pork and a complementary relationship with chicken. When the residuals were corrected for first-order autocorrelation, *kamaboko* showed a complementary relationship with beef and pork. Furthermore, when the residuals were corrected for second-order autocorrelation for the 6-items model, *surimi*-based products had a complementary relationship with fish. However, the substitutional relationship with red meats was not retained. When the 3-items model, corrected for first-order autocorrelation, was estimated, *surimi*-based products showed a complementary relationship with fish. The relationship with red meats was less clear.

These results suggest that if supplies of fish increase in Japan, leading to lower fish prices, then demand for *surimi*-based products might increase. In the short-run there may be little substitution away from *surimi*-based products in response to lower red meat prices. This may be the result of habit persistence and a relatively large income effect. Eventually, however, consumers may switch from *surimi*-based products to red meats. In a sense, the uncertainty in substitutional relationships between *surimi*-based products and red meats is a good explanation of the particular consumption patterns of Japanese people in the *surimi*-based products market. That is, if it is true that habit persistence exists in the Japanese *surimi*-based products market, then this habit persistence might reduce the substitution effect between *surimi*-based products and red meats.

It should be added that the treatment of the aggregation problem in the AIDS model has persisted. It had earlier been assumed that there was the same consumer taste in the AIDS model, i.e., $k_h = 1$, where k_h was termed the "household income equivalence scale." This was to be the advantage of the AIDS model in solving the aggregation problem. However, there could be cases where k_h is not equal to 1, which would mean that the estimation results in this study would have been distorted. Therefore, since an accurate estimation technique for k_h has not been developed, further research will be required to solve the aggregation problem.

Severe multicollinearity and autocorrelation problems also existed in the case of the LES, PHF, and LHF models, used to test for the existence of habit persistence in the Japanese fish and meats market. One of the main results was that correcting the residuals for autocorrelation offset the effect of introducing the habit effect coefficients, h_i and r_i^*, into the LES model, especially when almost perfect autocorrelation exists. As a result, the habit effect coefficients, h_i, for the PHF and LHF models had very low values. This would explain why the dynamic specification by autocorrelation could be used to analyze the dynamic behaviors of consumers. Also, it could be concluded that the habit persistence of consumers still exists in Japan's fish and meat market, including *surimi*-based products.

There were also analytical differences between the use of monthly and annual data in the classification of food items for this project. First, there was a difference between using annual data and using monthly data in estimating the habit formation model, i.e., the habit effect coefficients (h_i and r_i^*) showed significant differences between annual data and monthly data. When the habit formation models (PHF and LHF) were estimated with monthly data, the PHF model h_i values were relatively higher than those for the annual case, playing a major role in determining the existence of habit persistence. However, in the case of annual data, the r_i^* terms of the LHF model also played significant roles in determining habit persistence. In some equation estimates, the h_i terms had negative values because of the r_i^* terms. Generally, it is believed that the consumer consumption pattern (behavior) does not change easily over short periods of time, such as a month. Therefore, the present results have confirmed this phenomenon. If this is true, then the habit formation model estimated with annual data would be better than those estimated with monthly data. Unfortunately, there were not enough annual observations to provide a solution for this problem in this study, although the habit formation model was estimated with annual data. In the estimation of the AIDS model, annual data were not used because of the expectation of the lack of degree of freedom. If the AIDS model were estimated again with sufficient annual data, the results could be different.

It should be noted that seasonality was not considered in this study. Examining the monthly data used in the study, it could safely be predicted that a seasonality effect might exist, particularly in the *surimi*-based products market. Consumption and prices for *surimi*-based products increase in the winter and decrease at the end of winter, and prices and consumption in the summer are at a low level. There is a probability that the introduction of seasonality into this study would produce different results. One way to introduce seasonality will be to use variables with lag periods of 12 months.

Another problem was in the classification of food items included in this study. In the classification of fish, only two subgroups, fresh fish and salted and dried fish, were used. As a result, the share of fresh fish in total expenditure was larger when compared with other items. (It was more than 35% of total expenditure; however, the shares of ham, sausage, and *surimi*-based products ranged from 1% to 5%.) This large share of fresh fish in total expenditure produced large differences between Marshallian elasticities and Hicksian elasticities for fresh fish, i.e., a relatively high income effect existed in the case of fresh fish, due to the classification of fresh fish as a large group. Since the price of fish ranges from very low levels to very high levels according to quality, popularity, marketability, and scarcity conditions, dividing fresh fish into smaller subgroups according to price, e.g., high class fish, middle class fish, and low class fish, might improve the classifications for fresh fish.

In addition, more than 50% of the total ingredients of *surimi*-based products consists of *surimi*. This means that the prices of all *surimi*-based products are very likely to change in the same direction. Consumption patterns for each *surimi*-based product might not be so different since all *surimi*-based products have almost the same ingredients. Moreover, each *surimi*-based product was only a small portion of the total expenditure examined in this study. Therefore, combining all *surimi*-based products into one group may improve the classification. If a new classification of fish and red meat items is required for further analysis of this market, then a grouping of high class fish, middle class fish, low class fish, beef, pork, chicken, and *surimi*-based products may be one solution.

Finally, if the goal of this study had been confined to the analysis of *surimi*-based products, then another approach, such as H. Theil's supply conjugate model or simultaneous equation model, might be a better approach because of the particular characteristics of *surimi*-based products discussed above, i.e., the importance of the supply side in the *surimi*-based products market.

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