Journal of Agricultural and Resource Economics, 19(1): 210–224

A Comparison of Demands for Meat Products in the Pacific Rim Region

Oral Capps, Jr., Reyfong Tsai, Raymond Kirby, and Gary W. Williams

The Rotterdam model is used to obtain estimates of demand parameters for meat products in Taiwan, South Korea, and Japan. Unlike most previous studies of demand systems, the model takes into account simultaneous-equation bias which arises due to the endogeneity of total expenditure. Beef, pork, and chicken are separable from marine products for each Pacific Rim country. However, demand elasticities for beef, pork, and chicken are different among the various Pacific Rim nations. One may not then use the elasticity estimates of a particular country and apply them to other Pacific Rim markets.

Key words: meat products, Pacific Rim, Rotterdam model, separability, simultaneous-equation bias.

Introduction

Developing marketing programs for meat products in international markets is currently of great interest to U.S. domestic producers. In a recent survey of livestock and meat industry leaders, nearly 75% of the respondents believed that events in international markets are now as important as events in domestic markets in determining potential profitability for U.S. producers. Nearly 90% of the respondents believed that this scenario will hold in the future (Texas Beef Industry Council).

Certain target markets are centered in the Pacific Rim region. In fact, the fastest growing international markets for meat products are in this region. A gradual opening of the Japanese beef market has played a positive role in boosting export demand for U.S. beef. Notable policy changes are taking place in Japan regarding the import of beef from the United States through the Beef Market Access Agreement (Lambert). At the same time, economic growth in several middle-income countries in the Pacific Rim region, including Taiwan and South Korea, has induced a substantial shift in their food consumption patterns away from traditional, low value-added products like rice, toward higher quality, greater value-added products like beef. A number of events currently are taking shape that likely will encourage an even greater rate of growth in foreign demand for U.S. beef in the near future. The Japanese and Korean government agencies, for example, have agreed to a phased reduction of their long-standing restrictions on beef imports. The Taiwanese government has also consistently lowered its beef import tariff. All these policy changes may stimulate beef import demands in these Pacific Rim countries.

To understand the potential demands for U.S. beef, as well as those for other products, it is essential that we undertake a rigorous analysis of demand in these potentially profitable markets. An analysis of Pacific Rim markets would provide public and private decision

Oral Capps, Jr. and Gary Williams are professors in the Department of Agricultural Economics, Texas A&M University; Reyfong Tsai is a graduate research assistant in the Department of Agricultural Economics, Texas A&M University; and Raymond Kirby is an analyst with the American Express Corporation, Phoenix, Arizona.

Support for this research came from the Texas Agricultural Experiment Station. This is Technical Article No. 31286 of the Texas Agricultural Experiment Station.

The authors gratefully acknowledge comments made by two anonymous reviewers of this journal. Any errors or omissions are the responsibility of the authors.

Table 1. Summary of Per Capita Consumption Levels and Budget Shares for Meat, Poultry, and Marine Products in the Pacific Rim

	Taiwan (1968–91)		South Korea (1960–88)		Japan (1962–91)	
Commodity	Avg. Per Capita Consump. Levels (kg)	Avg. Budget Share of Meat Products (%)	Avg. Per Capita Consump. Levels (kg)	Avg. Budget Share of Meat Products (%)	Avg. Per Capita Consump. Levels (kg)	Avg. Budget Share of Meat Products (%)
Beef	1.25	3.75	1.87	6.02	4.04	15.92
Pork	30.07	44.88	4.31	7.82	10.24	21.56
Chicken	10.21	8.48	1.78	2.15	7.99	11.81
Fish	37.53	42.87	38.03	83.99	32.39	50.68

makers with guidelines in ongoing efforts to penetrate foreign markets. Investigations of meat demands in the Pacific Rim region have been few.

In this light, we employ a systems approach to estimate the demand for meat products in Japan, South Korea, and Taiwan. The use of demand systems models permits the exploration of interdependencies among products. Additionally, we use the results to analyze the nature of these demands and the differences in demands for different meat products in these countries. We assume that people living in different regions might have different tastes and preferences for meat products, and consequently, there may be different consumption patterns for meat products among the Pacific Rim countries. Our work then allows a study of demand for meat products in the Pacific Rim in one setting.

Consumption Trends

Historical consumption trends for meat, poultry, and marine products in the Pacific Rim over the last 20 to 25 years are described in this section. A summary of the historical average per capita consumption levels, as well as the average budget shares, appears in table 1. The average budget shares of the products for each of the Pacific Rim countries are graphically depicted in figures 1–3. Per capita consumption figures are shown graphically in figures 4–6.

Both the consumption levels and average budget shares for the products are dissimilar for Taiwan, South Korea, and Japan. Nevertheless, the principal product in the Pacific Rim region is unequivocally marine products. Marine products comprise nearly 85% of the budget in South Korea, compared to about 50% and 43% of the budget in Japan and in Taiwan, respectively. The Taiwanese spend roughly 45% of the budget on pork compared to 8% in South Korea and 21% in Japan. Beef and chicken comprise a relatively small share of the budget in the Pacific Rim. The budget shares for beef are roughly 4% in Taiwan, 6% in South Korea, and almost 16% in Japan. The relatively small budget share for beef may be attributable, in part, to import limitations. The budget shares for chicken are 9% in Taiwan, 2% in South Korea, and roughly 12% in Japan.

In Taiwan, pork is the most popular livestock product. Nevertheless, the per capita consumption of beef has risen from .36 kg to 2.42 kg, and the per capita consumption of chicken has risen from 3.17 kg to 19.23 kg over the past 25 years. Per capita consumption of pork and marine products has grown from 19 kg to 44 kg and from 30 kg to 48 kg, respectively. More than 85% of the beef supplied in Taiwan is imported, and most of the imports come from Australia.

Consumption of meat products in South Korea has been growing at rapid rates. The higher levels of consumption of meat, poultry, and marine products have been attributed to higher rates of personal income and an urbanization of the Korean population (Dyck

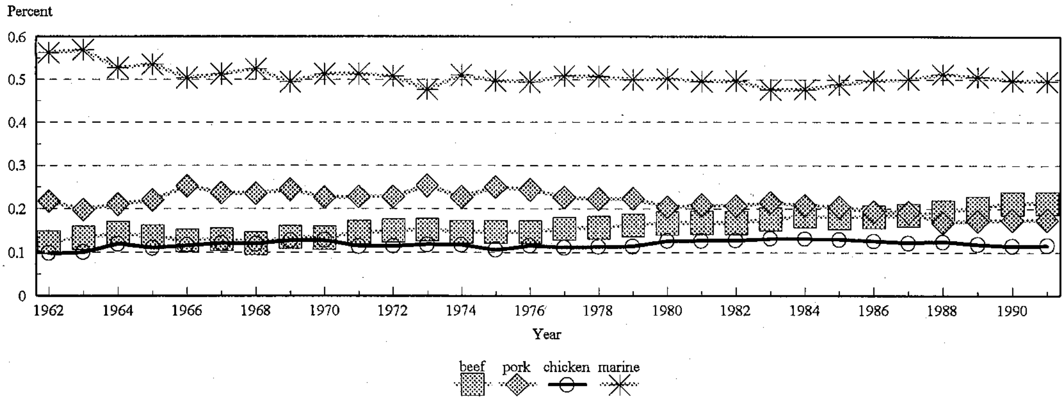

Figure 1. Pacific Rim budget shares of meat products in Japan

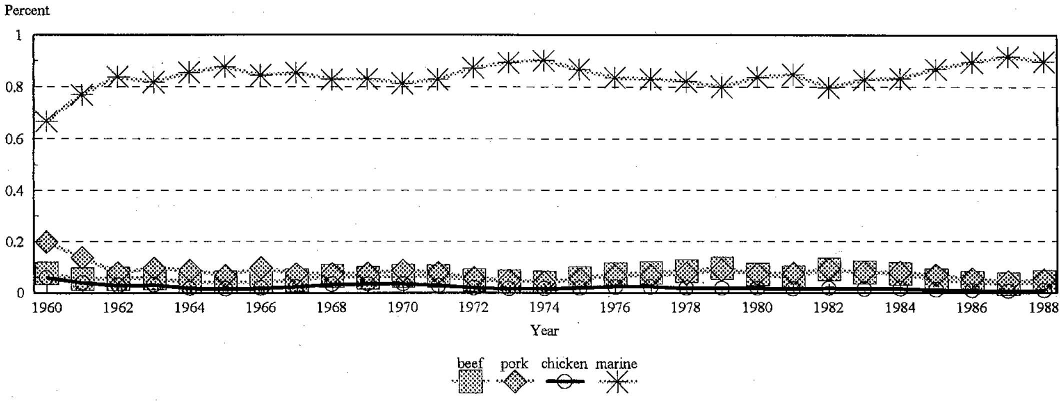

Figure 2. Pacific Rim budget shares of meat products in South Korea

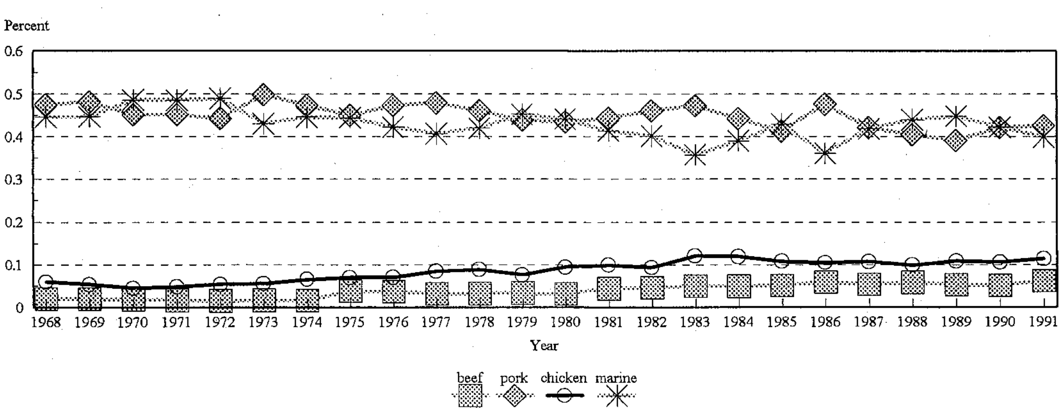

Figure 3. Pacific Rim budget shares of meat products in Taiwan

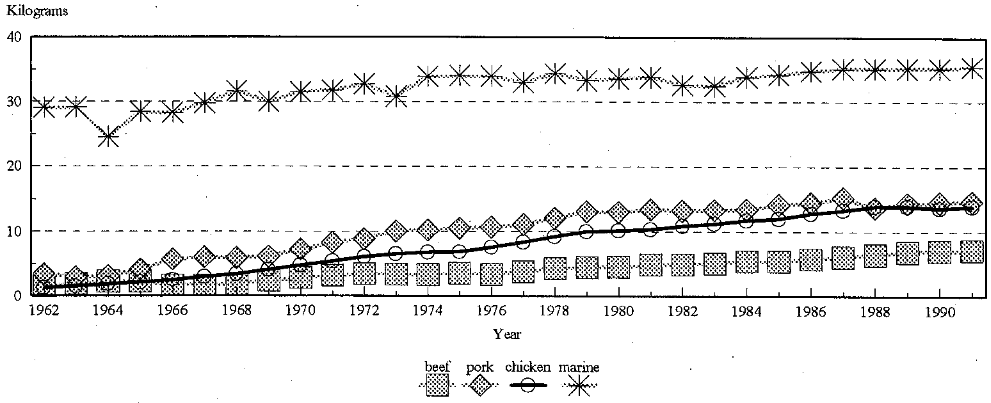

Figure 4. Per capita consumption of meat products in Japan

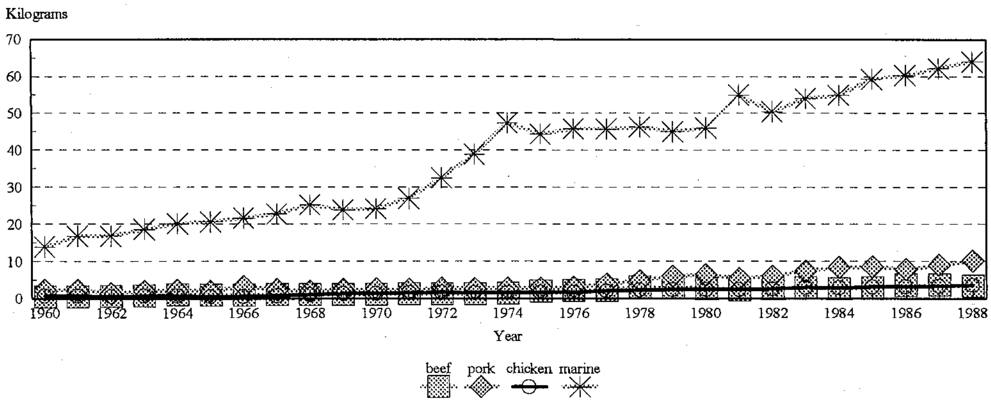

Figure 5. Per capita consumption of meat products in South Korea

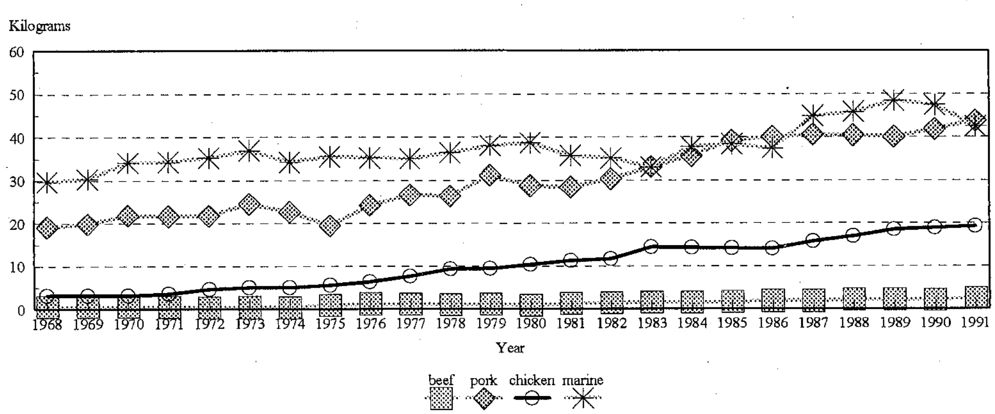

Figure 6. Per capita consumption of meat products in Taiwan

and Sillers). Per capita beef consumption moved from a low of .52 kg in 1960 to a high of 3.65 kg in 1987. Per capita pork consumption was at an all-time high of 10.14 kg in 1988, almost triple that of beef. In 1988, per capita consumption of chicken was at an all-time high of 3.55 kg, up from a low level of .51 kg in 1965. In 1988, Koreans consumed an all-time high level of 64 kg of marine products. When compared to per capita consumption of beef, pork, and chicken in 1988, per capita consumption of marine products is four times greater than all three combined.

Over the period of 1962 to 1991, per capita consumption of marine products in Japan was on the order of 30 to 35 kg. Per capita consumption of pork over this period grew from 3 kg in 1963 to 15 kg in 1987. Per capita consumption of chicken rose as well, from about 1 kg in 1962 to almost 14 kg in 1991. Per capita beef consumption also rose from 1.5 kg in 1962 to about 7 kg in 1991. Although meats make up only a small portion of the Japanese diet, consumption is growing due in part to income levels and "westernization" of tastes (Lambert; Hayes, Wahl, and Williams). Fifty years ago, the Japanese consumed almost no meat, and beef consumption in particular was restricted on religious grounds (Gorman, Mori, and Lin).

On the basis of historical per capita consumption and budget shares for meat, poultry, and marine products, we may expect the demands for various products to differ in Taiwan, South Korea, and Japan. To determine these demand relationships in the Pacific Rim region, the absolute price version of the Rotterdam model is employed (Theil). The data used in the ensuing empirical analysis consist of annual observations corresponding to the periods reported in table 1. A discussion of the Rotterdam model appears in the next section.

Rotterdam Model and Separability

Rotterdam Model

The absolute price version of the Rotterdam model (Theil) may be written as:

$$(1) \qquad w_i \text{dlog}(q_i) = \Theta_i \text{dlog}(Q) + \sum_{j=1}^{n} \pi_{ij} \text{dlog}(p_j),$$

where $\text{dlog}(Q) = \Sigma_i\, w_i \text{dlog}(q_i)$ is the Divisia volume index.

In this model, w_i corresponds to the expenditure share of meat item i in time period t, q_i denotes per capita consumption of meat item i in time period t, and p_j corresponds to real price of meat item j in time period t. The subscripts i and j refer to beef, pork, chicken, and marine (fish) products. Unlike the studies for Japan conducted by Hayes, Wahl, and Williams, and by Lambert, import-quality beef and domestic beef are not treated as separate commodities in this model specification.

In empirical application, log differentials are approximated by log differences. Consequently, the Rotterdam model cannot be considered as an exact representation of preferences unless restrictive conditions are imposed. Nevertheless, the Rotterdam model is a flexible approximation to an unknown demand system (Barnett; Mountain). This model necessitates the use of classical restrictions so that the estimates of demand parameters conform to theory.

The restrictions for the Rotterdam model are as follows:

$$(2) \qquad \sum_j \Theta_j = 1 \text{ (adding up)}, \quad \sum_j \pi_{ij} = 0 \text{ (homogeneity)}, \quad \text{and} \quad \pi_{ij} = \pi_{ji} \text{ (symmetry)}.$$

Operationally, when estimating demand systems, one equation must be omitted to avoid singularity of the variance-covariance matrix of disturbance terms. For all Pacific Rim countries, the omitted equation corresponds to chicken. Through the classical constraints, the demand parameters associated with the omitted equation are subsequently recovered.

Separability

Hayes, Wahl, and Williams suggest that fish be considered separately from beef, pork, and chicken, especially at an aggregate level. To be sure, consumers in Japan and South Korea spend far more on fish than on all other meat products combined. In Taiwan, consumers allocate approximately the same proportion of their budget to pork and fish. These two commodities together account for 90% of the consumer budget for meat expenditures in Taiwan.

In developing models to analyze the likely effects of the increasing openness of meat markets in the Pacific Rim, whether or not to include fish in a demand system for meats has been a controversial issue (Hayes, Wahl, and Williams). In this light, Hayes, Wahl, and Williams offer a test of separability of fish from other meat products in the LA/AIDS model. They state that this test is "particularly important when modeling demand systems of foreign markets where social and cultural differences affect dietary habits and preferences" (p. 556). When a test for quasi-separability of the cost function of the LA/AIDS was employed by Hayes, Wahl, and Williams, they found that separability between meats and fish in Japan could not be rejected.

In this analysis, we also employ a test of separability between fish and other meat products. However, our test is based on the assumption of weak separability of the direct utility function. Pudney, however, demonstrates that, for a constant elasticity model, the alternative separability assumptions make little difference to the empirical results. This finding may not necessarily be true for the Rotterdam model.

With the assumption of weak separability of the direct utility function, Goldman and Uzawa show that

$$S_{ij} = \phi_{IJ}\frac{\partial q_i}{\partial y}\frac{\partial q_j}{\partial y}, \qquad i \in I, j \in J, \tag{3}$$

where I refers to the group of meat commodities, namely beef, pork, and chicken; J refers to the single commodity, fish (marine products); S_{ij} represents the Slutsky substitution term; ϕ_{IJ} is a proportionality constant or, alternatively, a measure of the substitutability between commodities in group I and in group J; and $\partial q_i/\partial y$ and $\partial q_j/\partial y$ represent derivatives of commodities i and j with respect to total meat expenditure.

With some algebraic manipulation, it can be shown that (3) is tantamount to

$$\epsilon_{ij}^{*} = \left(\frac{\phi_{IJ}}{y}\right) n_i\, n_j\, w_j, \tag{4}$$

where ϵ_{ij}^{*} is the compensated cross-price elasticity between commodities in group I and in group J, n_i and n_j represent expenditure elasticities of commodities in the two respective groups, and w_j represents the budget share of commodity j.

Now, for $i, k \in I$ and $j \in J$, using (4), it can be shown that

$$\frac{\epsilon_{ij}^{*}}{\epsilon_{kj}^{*}} = \frac{n_i}{n_k}. \tag{5}$$

That is, under the assumption of weak separability of the direct utility function, the ratio of compensated cross-price elasticities of two commodities within the same group (I), with respect to a third commodity in another group (J), is equal to the ratio of their expenditure elasticities.

From (5), for the Rotterdam model, this result implies a nonlinear restriction on the parameters π_{ij}, where $i, k \in I$ and $j \in J$. This restriction is given by

$$\frac{\pi_{ij}}{\pi_{kj}} = \frac{\Theta_i}{\Theta_k}. \tag{6}$$

In our analysis, $i, k \in I$ consists of the three commodities, beef, pork, and chicken, while $j \in J$ consists of the single commodity fish. With this definition of the groups I and J, there are two restrictions associated with this test of separability. Operationally, then, this test is based on a likelihood ratio test statistic (χ^2 statistic) with two degrees of freedom. The key feature of (6) is that the separability restrictions hold not only locally but also globally. This result sets the Rotterdam model apart from other functional forms such as the AIDS.

In sum, for each Pacific Rim country, a test of separability between fish and other meats is made. If this separability hypothesis is rejected, then the Rotterdam model is estimated using a four-commodity system. If this separability hypothesis is supported by the data, the Rotterdam model is estimated using a three-commodity system, namely beef, pork, and chicken. Thus, this separability test can be used to determine whether a particular commodity, in this case fish, should be included in the demand system. Hayes, Wahl, and Williams found that the assumption of the quasi-separability of the cost function between fish and other meats for Japan was not an incorrect specification. In this analysis, we extend the work of Hayes, Wahl, and Williams in testing the separability hypothesis to other Pacific Rim countries, but we assume a different type of separability; also, we assume a different functional form for the demand system.

Endogeneity of Total Expenditure

One of the concerns in the literature on demand systems is that of endogeneity of the total expenditure variable, or put another way, simultaneous-equation bias in conditional demand models (LaFrance; Attfield 1985, 1991). Since total expenditure is defined as the sum of expenditures on individual commodities, and since these expenditures are assumed to be endogenous, then we might expect total expenditure to be endogenous. If total expenditure, a right-hand-side variable in demand models, is correlated with the equation errors, the parameter estimates will indeed be biased and inconsistent. In the absolute price version of the Rotterdam model, the endogeneity issue relates directly to $\text{dlog}(Q) = \Sigma_j w_j \text{dlog}(q_j)$.

To circumvent this problem, we apply the technique developed by Attfield (1985) and by Hausman. The procedure requires the estimation of the following n-equation model:

$$\begin{aligned} &w_i \text{dlog}(q_i) = \Theta_i\left[\alpha_0 + \sum_{k=1}^{m} \alpha_k Z_k\right] + \sum_{j=1}^{n} \pi_{ij} \text{dlog}(p_j) + u_i, \qquad i = 1, \ldots, n-1; \\ &\text{dlog}(Q) = \alpha_0 + \sum_{k=1}^{m} \alpha_k Z_k + \epsilon, \end{aligned} \tag{7}$$

where Θ_i, π_{ij}, α_0, and α_k are structural parameters; Z_k, $k = i, \ldots, m$ corresponds to a set of predetermined variables, including $\text{dlog}(p_j)$, $j = 1, \ldots, n$. Thus, we augment the demand system with a regression of the total expenditure variable, $\text{dlog}(Q)$, on a set of exogenous variables. In this analysis, this set of exogenous factors includes the log differences of the prices of beef, pork, chicken, and marine products, as well as the log difference of real income.

The model given by (7) is nonlinear in parameters, and consequently, the structural parameters of the system are estimated by a nonlinear maximum likelihood routine; estimates of the asymptotic standard errors are constructed from the negative of the inverse of the Hessian matrix. Given this augmentation of the demand system, if we reject the test of the hypothesis that the parameters α_k are jointly equal to zero, then parameter estimates of both the price and expenditure coefficients in the demand system would have been biased and inconsistent had the correlation of total expenditure and the disturbance terms not been taken into account. If we fail to reject this hypothesis, then there exists no simultaneity or endogeneity of total expenditure. To quote Attfield (1985, p. 209), "This estimation procedure . . . can be routinely applied by investigators analyzing systems of demand equations."

Data

Quantity and price data used in this analysis are from various yearbooks and reports published by the various countries. For South Korea, quantities and prices of beef, pork, and chicken are taken from *Materials on Price, Demand, and Supply for Livestock Products* (National Livestock Cooperatives Federation), the *Agricultural Cooperative Yearbook* (Agricultural Cooperative Federation), the *South Korea Statistical Yearbook* (Economic Planning Board), and the *Economic Statistics Annual Book* (The Bank of Korea). Quantities and prices of marine products are taken from the *Yearbook of Fisheries Statistics* (Ministry of Agricultural Fisheries) and the *Annual Statistics on Cooperative Sale of Fishery Products* (National Federation of Fisheries Cooperatives). For Taiwan, per capita consumption figures come from the *Taiwan Food Balance Sheet* (Taiwan Council of Agriculture), and retail prices come from *Taiwan Agricultural Prices and Costs Monthly* (Taiwan Department of Agriculture and Forestry). Retail and wholesale price indices come from *Commodity-Price Statistics Monthly, Taiwan Area* (Directorate-General of Budget, Accounting, and Statistics). For Japan, the data come from Wahl, but are updated to 1991. This data series is described in detail in the work by Hayes, Wahl, and Williams (p. 558).

For Taiwan and South Korea, representative prices for marine products were difficult to obtain. For Taiwan, a weighted average price of 18 marine products was used as the price of marine products. The respective products used to develop the weighted average price series were: yellow sea bream, red sea bream, crimson sea bream, black pomfret, milk fish, sailfish, silver carp, tuna, butter fish, cuttle fish, hairtail, mackerel, white croaker, lizard fish, sea eel, numipterid, striped prawn, and shrimp.

The retail price series for marine products in South Korea was constructed by regressing the retail price for marine products in Japan on the wholesale marine price index in South Korea, available annually. The predicted price from this relationship was converted to the retail price of marine products in South Korea by using the exchange rate of won to yen.

Descriptive statistics of per capita consumption, nominal prices, and the average budget shares are exhibited in table 2. In the Pacific Rim countries, on average, beef is the most expensive product, generally because of import quotas. Chicken, on the other hand, is the least expensive product. In addition, beef (chicken) prices are the most (least) volatile. In the respective analyses of the demand systems for the Pacific Rim countries, real prices are used. Real prices are obtained by dividing the nominal price series by the Consumer Price Index.

Empirical Results

Tests of Separability

As previously discussed, a likelihood ratio test was performed to determine if separability between fish and other meats was supported by the data for each of the Pacific Rim countries. The χ^2 statistics for Japan, Taiwan, and South Korea were 4.23, 3.45, and 2.1, respectively. The .05 level of significance of the χ^2 distribution with two degrees of freedom is 5.99. In fact, the .05 level of significance is chosen throughout this analysis. Therefore, the hypothesis of separability between meats and fish in the Pacific Rim is not rejected. This result corroborates the result of Hayes, Wahl, and Williams for the case of Japan. Given that there exists sample evidence to support the separability between meats and

Table 2. Descriptive Statistics of Variables Used in the Analyses of Pacific Rim Countries

	Taiwan				South Korea				Japan			
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Per Capita Consumption:	(kg)											
Beef	1.25	.63	.36	2.42	1.87	1	.51	3.65	4.04	1.74	1.53	7.16
Pork	30.07	8.24	19.10	43.77	4.31	2.57	1.43	10.13	10.24	3.99	2.91	15.24
Chicken	10.21	5.47	3.17	19.23	1.78	.94	.5	3.55	7.99	4.28	1.27	13.96
Marine Products	37.53	4.94	29.69	48.37	38.03	16.18	13.85	63.99	32.39	2.62	24.56	35.5
Nominal Prices:	NT$/kg				Won/kg				Yen/kg			
Beef	197.4	87.7	51.6	288.1	2,916.3	3,023.6	116	8,316	2,516.1	1,117.8	964	3,910
Pork	90.8	27.9	41.7	128.7	1,403.4	1,341.3	67	3,838	1,248.6	368.1	569	1,680
Chicken	54.6	15.7	28.9	74.4	710.3	576.3	63	1,629	945.8	186.3	686	1,200
Marine Products	70.6	29	25.2	112.5	2,277.2	2,872	38	10,092	1,014.8	581.8	173	1,830
Avg. Budget Shares:												
Beef	.0375	.0158	.0149	.0618	.0602	.0166	.0341	.0949	.1592	.0263	.1204	.2135
Pork	.4488	.0271	.3910	.4981	.0782	.0302	.0413	.1990	.2157	.0237	.1693	.2535
Chicken	.0848	.0244	.0446	.1205	.0215	.0109	.0064	.0582	.1182	.0085	.0974	.1316
Marine Products	.4287	.0338	.3571	.4892	.8399	.0480	.6658	.9170	.5068	.0209	.4767	.5691

Table 3. Parameter Estimates of the Rotterdam Model for Japan Assuming Endogeneity of the Expenditure Variable, Homogeneity, and Slutsky Symmetry

Commodity	Expenditure Coefficient	Price Coefficients: Beef	Pork	Chicken	R^2	DW
Beef	.3532	−.2117	.2176	.0059	.7657	2.04
	(8.05)	(−8.22)	(7.63)			
Pork	.3198		−.2525	.0349	.5782	2.07
	(6.01)		(−6.68)			
Chicken	.3270			−.0290		

Auxiliary Regression of Total Expenditure:[a]

$$\text{dlog}(Q) = \underset{(3.42)}{.0261} + \underset{(.23)}{.0178}\text{dlog}(p_1) - \underset{(-3.67)}{.3201}\text{dlog}(p_2)$$

$$+ \underset{(.12)}{.0183}\text{dlog}(p_3) + \underset{(4.27)}{.6877}\text{dlog}(p_4) + \underset{(1.59)}{.2225}\text{dlog}(inc)$$

$$R^2 = .4884, \quad \text{DW} = 1.90$$

Notes: t-statistics are in parentheses; R^2 = square of the correlation between observed and predicted values.

[a] Test of the hypothesis that the coefficients associated with the predetermined variables are jointly equal to zero (χ^2_5 = 135.96); p_1, p_2, p_3, and p_4 correspond to the real price of beef, pork, chicken, and marine products, respectively; *inc* corresponds to real per capita income.

fish, subsequent analyses are based on the three-commodity system involving beef, pork, and chicken.

Estimates of Structural Parameters

Estimates of the structural parameters of the demand models subject to circumvention of simultaneous-equation bias are derived by using the nonlinear maximum likelihood algorithm in the econometrics package SHAZAM (White et al.). Serial correlation was not evident in each of the system specifications. The estimated coefficients and associated asymptotic standard errors of the parameters in the respective demand systems for the three countries are presented in tables 3, 4, and 5. Because of the adding-up constraint, only two of the three equations which correspond directly to the Rotterdam model are independent. To circumvent this problem, the usual procedure (followed in this study) is to drop one of the equations and estimate the remaining system. The omitted equation in this analysis corresponds to chicken.

In the regression of meat group expenditure on prices and income, the hypothesis that the coefficients are jointly equal to zero is rejected in all cases. Given the use of the maximum likelihood estimation procedure, a likelihood ratio test is used. The .05 level of significance of the χ^2 distribution with five degrees of freedom is 11.07. Consequently, there is sample evidence to indicate that at least one of the coefficients associated with the predetermined variables is nonzero; thus, if correlation of total expenditure with the disturbance terms were not taken into account, parameter estimates of both the price and expenditure coefficients of the Rotterdam model would have been biased and inconsistent.

Compensated price elasticities are given in table 6. Similarly, uncompensated price elasticities as well as expenditure elasticities for meat products in the Pacific Rim region are exhibited in table 7. All elasticities are derived using the sample means of the data. The estimated elasticities for the Taiwanese, South Korean, and Japanese demand systems are, in general, in accordance with a priori expectations. All Marshallian own-price elas-

Table 4. Parameter Estimates of the Rotterdam Model for South Korea Assuming Endogeneity of the Expenditure Variable, Homogeneity, and Slutsky Symmetry

Commodity	Expenditure Coefficient	Price Coefficients			R^2	DW
		Beef	Pork	Chicken		
Beef	.4972	−.1700	.1206	.0494	.5173	1.69
	(3.37)	(−3.25)	(2.26)			
Pork	.4007		−.1193	.0013	.0681	2.63
	(2.47)		(−2.04)			
Chicken	.1021			−.0481		

Auxiliary Regression of Total Expenditure:[a]

$$\text{dlog}(Q) = \underset{(.56)}{.0140} + \underset{(.22)}{.0358}\text{dlog}(p_1) + \underset{(.91)}{.1213}\text{dlog}(p_2) - \underset{(-1.52)}{.2163}\text{dlog}(p_3) - \underset{(-.44)}{.0404}\text{dlog}(p_4) + \underset{(2.25)}{.4446}\text{dlog}(inc)$$

$R^2 = .1503$, DW = 2.51

Notes: t-statistics are in parentheses; R^2 = square of the correlation between observed and predicted values.
[a] Test of the hypothesis that the coefficients associated with the predetermined variables are jointly equal to zero ($\chi^2_5 = 55.20$); p_1, p_2, p_3, and p_4 correspond to the real price of beef, pork, chicken, and marine products, respectively; *inc* corresponds to real per capita income.

ticities are negative, and most compensated cross-price elasticities are positive, indicative of net substitutes.

The own-price elasticity for beef ranges from −.94 (South Korea) to −1.16 (Taiwan). For pork, the own-price elasticity ranges from −.65 (South Korea) to −.92 (Taiwan). Finally, the own-price elasticity of demand for chicken is in the range of −.28 (Taiwan) to −.47 (South Korea) in the Pacific Rim. There appear to be notable differences in the own-price elasticity for pork between South Korea and the other Pacific Rim countries, as well as for chicken between Taiwan and the other Pacific Rim nations. Conversely, the own-price elasticity for beef is similar for Japan, South Korea, and Taiwan.

Beef and pork are unquestionably net substitutes in the Pacific Rim nations. Beef and chicken are substitutes in South Korea, but they are complements in Japan and Taiwan. Pork and chicken are substitutes in Japan and Taiwan, but they are complements in South Korea. One could impose net substitutability econometrically, as done by Hayes, Wahl, and Williams, but in light of the magnitudes of the negative compensated cross-price elasticities, this restriction may not be necessary.

The magnitudes of the expenditure elasticities differ, not only across countries but also across commodities, in some cases substantially (table 7). For example, the expenditure elasticity for beef ranges from 1.09 (Japan) to 1.29 (South Korea); for pork, the expenditure elasticity ranges from .73 (Japan) to 1.01 (South Korea); and finally, for chicken, the expenditure elasticity ranges from .78 (South Korea) to 1.36 (Japan).

The income elasticity of Japanese demand for meat, poultry, and marine products was estimated to be 1.54 by Sasaki and Fukagawa. The income elasticity of demand for meats in South Korea was estimated to be 1.25 by Kim. No prior information is available regarding the income elasticity of demand for meats in Taiwan. Multiplying these figures by the various expenditure elasticities for the meat products in Japan and South Korea gives rise to income elasticities for the individual commodities in these countries (Blanciforti and Green). Therefore, a 10% increase in real income in South Korea (Japan) leads to a 16.1% (16.8%) increase in the demand for beef, a 10.3% (11.2%) increase in the demand for pork, and a 9.7% (21%) increase in the demand for chicken.

Table 5. Parameter Estimates of the Rotterdam Model for Taiwan Assuming Endogeneity of the Expenditure Variable, Homogeneity, and Slutsky Symmetry

Commodity	Expenditure Coefficient	Price Coefficients: Beef	Pork	Chicken	R^2	DW
Beef	.0731	−.0704	.0724	−.0020	.2575	1.98
	(1.59)	(−2.67)	(2.04)			
Pork	.7971		−.0962	.0238	.6910	2.11
	(10.53)		(−1.62)			
Chicken	.1298			−.0218		

Auxiliary Regression of Total Expenditure:[a]

$$dlog(Q) = \underset{(.85)}{.0143} - \underset{(-2.43)}{.2621}dlog(p_1) - \underset{(-1.20)}{.1240}dlog(p_2)$$

$$+ \underset{(.72)}{.0928}dlog(p_3) + \underset{(2.89)}{.3105}dlog(p_4) + \underset{(3.41)}{.6123}dlog(inc)$$

$$R^2 = .7217, \quad DW = 2.00$$

Notes: t-statistics are in parentheses; R^2 = square of the correlation between observed and predicted values.

[a] Test of the hypothesis that the coefficients associated with the predetermined variables are jointly equal to zero ($\chi^2_5 = 92.74$); p_1, p_2, p_3, and p_4 correspond to the real price of beef, pork, chicken, and marine products, respectively; *inc* corresponds to real per capita income.

For comparison purposes, estimates from the literature of Marshallian own-price elasticities for selected meat products in the Pacific Rim are shown in table 8. Hayes, Wahl, and Williams; Lambert; and Wahl, Hayes, and Johnson have used the LA/AIDS model to estimate demand relationships for meat products in Japan. Shue employed a single-equation approach, in lieu of a demand systems approach, to estimate demand relationships for meat products in Taiwan. Given the lack of published studies for South Korea, no comparisons can be made. Our own-price elasticity estimate for beef in Taiwan (−1.15) is below that given by Shue (−1.87); our own-price elasticity estimate for pork in Taiwan (−.91) is above that given by Shue (−.56). However, our own-price elasticity for chicken (−.28) corresponds to that given by Shue (−.28). The data period from the Shue study runs from 1968(69)–84, while the data period for our study runs from 1968–91.

For Japan, our own-price elasticity of beef is composed both of Wagyu and import

Table 6. Compensated Price Elasticities for Meat Products in Taiwan, South Korea, and Japan (evaluated at the means of the data)

		Beef	Pork	Chicken
Japan	Beef	−.6568	.6751	−.0183
	Pork	.4967	−.5764	.0797
	Chicken	−.0246	.1457	−.1210
South Korea	Beef	−.4421	.3137	.1285
	Pork	.2488	−.2461	−.0027
	Chicken	.3777	−.0099	−.3677
Taiwan	Beef	−1.0847	1.1156	−.0308
	Pork	.0919	−.1221	.0302
	Chicken	−.0136	.1617	−.1481

Table 7. Uncompensated Price Elasticities and Expenditure Elasticities for Meat Products in Taiwan, South Korea, and Japan (estimated at the means of the data)

		Uncompensated Price Elasticities			Expenditure Elasticities
		Beef	Pork	Chicken	
Japan	Beef	−1.0100	.1951	−.2808	1.0957
	Pork	.2614	−.8962	−.0952	.7300
	Chicken	−.4646	−.4522	−.4480	1.3648
South Korea	Beef	−.9393	−.3132	−.0407	1.2931
	Pork	−.0690	−.6468	−.1108	.8265
	Chicken	.0775	−.3884	−.4698	.7806
Taiwan	Beef	−1.1578	.2280	−.1966	1.1263
	Pork	.0262	−.9192	−.1187	1.0115
	Chicken	−.0708	−.5332	−.2779	.8818

quality types. Consequently, our estimate is not directly comparable to the estimates of disaggregate beef types provided by Hayes, Wahl, and Williams, and by Lambert. Our demand elasticity for beef (−1.01) lies between the estimates of Hayes, Wahl, and Williams [−.46 (import quality beef) and −1.89 (Wagyu beef)], and between the estimates of Wahl, Hayes, and Johnson [−.98 (import quality beef) and −2.48 (Wagyu beef)]. Our estimate also falls within the interval of Lambert [−.58 (import quality beef) and −1.05 (Wagyu beef)]. Our demand elasticity estimate for pork (−.90) lies above that of Wahl, Hayes, and Johnson (−.73), and above that of Hayes, Wahl, and Williams (−.76); however, our estimate for chicken (−.45) is below that of Hayes, Wahl, and Williams (−.59), and below that of Wahl, Hayes, and Johnson (−.91).

Concluding Remarks

We employ a Rotterdam model to estimate demand relationships for meat products in the Pacific Rim region. Similar to the findings of Hayes, Wahl, and Williams, we find that beef, pork, and chicken are weakly separable from marine products for each nation. Also, the Rotterdam model in our study takes into account simultaneous-equation bias.

Table 8. Estimates of Marshallian Own-Price Elasticities for Selected Meat Products in the Pacific Rim Region from the Extant Literature

Researcher(s)	Approach	Data Period	Product	Mashallian Own-Price Elasticity
Shue	Single-Equation	1968–84	Pork/Taiwan	−.56
Shue	Single-Equation	1969–84	Beef/Taiwan	−1.87
Shue	Single-Equation	1968–84	Chicken/Taiwan	−.28
Hayes, Wahl, and Williams	LA/AIDS	1962–86	Wagyu Beef/Japan	−1.89
Hayes, Wahl, and Williams	LA/AIDS	1962–86	Import Quality Beef/Japan	−.46
Hayes, Wahl, and Williams	LA/AIDS	1962–86	Pork/Japan	−.76
Hayes, Wahl, and Williams	LA/AIDS	1962–86	Chicken/Japan	−.59
Lambert	LA/AIDS	1974–88	Wagyu Beef/Japan	−1.05
Lambert	LA/AIDS	1974–88	Import Quality Beef/Japan	−.58
Wahl, Hayes, and Johnson	LA/AIDS	1962–89	Pork/Japan	−.73
Wahl, Hayes, and Johnson	LA/AIDS	1962–89	Wagyu Beef/Japan	−2.48
Wahl, Hayes, and Johnson	LA/AIDS	1962–89	Import Quality Beef/Japan	−.98
Wahl, Hayes, and Johnson	LA/AIDS	1962–89	Chicken/Japan	−.91

We use the procedure developed by Attfield (1985) and by Hausman to account for endogeneity of total expenditure.

Demand elasticities for beef, pork, and chicken differ among Japan, South Korea, and Taiwan. Then, for example, one may not use the elasticity estimates of Japan and apply them to other Pacific Rim markets. Or, alternatively, one may not necessarily wish to pool data for the Pacific Rim countries and estimate demand elasticities for the aggregate market. The own-price elasticity estimates for beef range from −.93 (South Korea) to −1.15 (Taiwan). Similarly, the own-price elasticity estimates for chicken range from −.28 (Taiwan) to −.47 (South Korea). The own-price elasticities for pork in this region range from −.65 (South Korea) to −.92 (Taiwan). Beef and pork are unquestionably net substitutes for the Pacific Rim countries.

The next step is to integrate the estimates of the demand systems with livestock supply models in Taiwan, South Korea, and Japan. The purpose of this integration is to conduct simulations to analyze the effects of fewer restrictions, particularly on beef imports, into major Pacific Rim markets. Alternative beef import policy schemes include the 1988 Japanese Beef Market Access Agreement and the removal of the South Korean embargo against beef imports. Given that Hayes, Wahl, and Williams reject the hypothesis that in Japan, domestic (Wagyu) and import-quality beef are perfect substitutes, future analyses in the Pacific Rim region may need to consider treating each type of beef as a separate commodity in order to analyze more appropriately the effects of beef import policies. In sum, the demand systems approach not only provides information with regard to meat products in the Pacific Rim region, but also may be a valuable input when analyzing alternative international trade scenarios.

[*Received January 1992; final revision received September 1993.*]

References

Agricultural Cooperative Federation (South Korea). *Agricultural Cooperative Yearbook.* Seoul, South Korea, various issues, 1960–88.

Attfield, C. L. F. "Estimation and Testing When Explanatory Variables Are Endogenous." *J. Econometrics* 48(1991):395–408.

———. "Homogeneity and Endogeneity in Systems of Demand Equations." *J. Econometrics* 27(1985):197–209.

The Bank of Korea. *Economic Statistics Annual Book.* Seoul, South Korea, various issues, 1960–88.

Barnett, W. A. "Theoretical Foundations for the Rotterdam Model." *Rev. Econ. Stud.* 46(1979):109–30.

Blanciforti, L., and R. Green. "The Almost Ideal Demand System: A Comparison and Application to Food Groups." *Agr. Econ. Res.* 35(1983):1–10.

Directorate-General of Budget, Accounting, and Statistics (Taiwan). *Commodity-Price Statistics Monthly, Taiwan Area.* Executive Yuan, Taipei, Taiwan, Republic of China, various issues, 1968–91.

Dyck, J. H., and D. Sillers. "South Korea: An Export Market Profile." U.S. Department of Agriculture, Economic Research Service, Washington DC, 1986.

Economic Planning Board (South Korea). *South Korea Statistical Yearbook.* Seoul, South Korea, various issues, 1960–88.

Goldman, S. M., and H. Uzawa. "A Note on Separability in Demand Analysis." *Econometrica* 32(1964):387–98.

Gorman, W. D., H. Mori, and B. H. Lin. "Beef in Japan: The Challenge for U.S. Exports." *J. Food Distrib. Res.* 21(1990):17–29.

Hausman, J. A. "Errors in Variables in Simultaneous Equation Models." *J. Econometrics* 5(1977):389–401.

Hayes, D. J., T. I. Wahl, and G. W. Williams. "Testing Restrictions on a Model of Japanese Meat Demand." *Amer. J. Agr. Econ.* 72(1990):556–66.

Kim, C. S. "A Study of Supply and Demand for Livestock Products in Korea." Special Rep., Korea Institute for Science and Technology, Seoul, South Korea, June 1977.

LaFrance, J. T. "When Is Expenditure 'Exogenous' in Separable Demand Models?" *West. J. Agr. Econ.* 16(1991): 49–62.

Lambert, B. "Demand Estimates for U.S. Beef in Japan." Unpub. paper, Dept. Agr. Econ. and Agribus., Louisiana State University, 1991.

Ministry of Agricultural Fisheries (South Korea). *Yearbook of Fisheries Statistics.* Seoul, South Korea, various issues, 1960–88.

Mountain, D. C. "The Rotterdam Model: An Approximation in Variable Space." *Econometrica* 56(1988): 477–84.

National Federation of Fisheries Cooperatives (South Korea). *Annual Statistics on Cooperative Sale of Fishery Products.* Seoul, South Korea, various issues, 1960–88.
National Livestock Cooperatives Federation (South Korea). *Materials on Price, Demand, and Supply for Livestock Products.* Seoul, South Korea, various issues, 1960–88.
Pudney, S. E. "An Empirical Method of Approximating the Separate Structure of Consumer Preferences." *Rev. Econ. Stud.* 48(1981):561–78.
Sasaki, K., and Y. Fukagawa. "An Analysis of the Japanese Expenditure Pattern: An Application of a Dynamic Linear Expenditure System to the 1961–1982 Data." *Agribusiness* 3(1987):51–68.
Shue, W. F. "Research on Demand for Taiwanese Main Agricultural Products—Livestock Section." Staff Pap., Dept. Agr. Econ., National Taiwan University, Taiwan, Republic of China, 1987.
Taiwan Council of Agriculture. *Taiwan Food Balance Sheet.* Executive Yuan, Taipei, Taiwan, Republic of China, various issues, 1968–91.
Taiwan Department of Agriculture and Forestry. *Taiwan Agricultural Prices and Costs Monthly.* Provincial Government of Taiwan, Republic of China, various issues, 1968–91.
Texas Beef Industry Council. "Survey of U.S. Livestock Procedures on International Livestock and Meat Marketing." Special report prepared by the U.S. Meat Export Federation for the Texas Beef Industry Council, Austin TX, 1989.
Theil, H. *The System-Wide Approach to Microeconomics.* Chicago: The University of Chicago Press, 1980.
Wahl, T. I. "Modeling Dynamic Adjustment in Japanese Livestock Markets under Trade Liberalization." Unpub. Ph.D. diss., Iowa State University, 1989.
Wahl, T. I., D. J. Hayes, and S. R. Johnson. "Impacts of Liberalizing the Japanese Pork Market." *J. Agr. and Resour. Econ.* 17(1992):121–37.
White, K. J., S. A. Haun, N. G. Horsman, and S. D. Wong. *SHAZAM User's Reference Manual.* New York: McGraw-Hill, 1988.