

NCCC-134

APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

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Suggested citation format:

Wahl, T., V. McCracken, and D. Reed. 1991. "Forecasting Japanese Meat Demand Using a Two-Stage Consumer Demand System." Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL.
[<http://www.farmdoc.uiuc.edu/nccc134>].

FORECASTING JAPANESE MEAT DEMAND USING A TWO-STAGE CONSUMER DEMAND SYSTEM

Thomas I. Wahl, Vicki A. McCracken, and David A. Reed¹

Meat demand models based upon expenditure share specifications, such as Deaton and Muellbauer's Almost Ideal Demand System (AIDS), are becoming more popular with agricultural economists because these specifications are theoretically consistent and easily estimated. These demand systems generally invoke weak separability to justify including only meats in the analysis, thus significantly reducing the size of the estimation problem.

While these disaggregated meat demand systems are theoretically appealing and manageable, the weak separability assumption that justifies focusing only on the meat group becomes a problem for partial equilibrium forecasting. In particular, given weak separability, total meat expenditures are generally treated exogenously or are estimated as a function of macro variables. However, the underlying allocation mechanism is a two-stage process. In the first stage expenditures are allocated among aggregate groups. In the second stage the expenditures on each of the aggregate groups is allocated among the individual items in the group.

Estimation of only the second stage of the allocation process assumes that the first stage process is exogenous. Treating total meat expenditures as exogenous essentially eliminates adjustments in expenditures on the group and forces all adjustments to occur within the group. As a result of the income effects being distributed only within the group rather than over all groups, forecasts based on these models may be misleading particularly if there are adjustments between groups.

This distortion of forecasts is particularly problematic for policy analysis such as the GATT proposal to reduce trade barriers. In countries with trade barriers for all meats, it is likely that all meat prices and total meat expenditures will change under these proposals. In countries such as Japan, that have trade barriers for only some commodities, it is also likely that total meat expenditures and at least some of the meat prices will be affected by changing policies. In either case a model that does not permit changing meat expenditures may generate seriously distorted predictions.

The purpose of this paper is to examine the implications of ignoring the income effects at the second stage by using a two-stage AIDS of Japanese food expenditures. Japanese meat demand is used as an example because of Japan's relatively low meat consumption levels, extensive data sources, and the recent implementation of the Beef

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Market Access Agreement which replaces the restrictive beef import quota with a tariff.² In addition, future reductions in pork trade barriers may be plausible under the GATT proposals.

The paper is organized as follows. First, the two stage model is developed. The Japanese meat expenditure data used to quantify the model are then discussed. The estimation and simulation results including the estimated elasticities and forecasts developed by using the model are then presented. And finally, the results are summarized and conclusions drawn.

The Two-Stage Model

Estimating meat demand as a separate system and the assumption of weak separability of meats from other foods and non foods, which justifies this separation, is based upon the two-stage budgeting process. In the first stage, expenditures are allocated among major groups such as food, housing, and clothing. In the next stage, group expenditures are allocated among the group's commodities. For example, food expenditures are allocated among meats, fish, and other food. Meat expenditures can then be further allocated among beef, pork, and chicken. It is at this latter (lower) level that most meat demand systems are estimated. The level immediately above the individual meats, the level including meat, fish, and other food, is generally ignored. However, it may be at this upper level where income effects are actually allocated (to other groups). Ignoring this upper level forces the income effects to be allocated within the group rather than being distributed over other groups and may lead to the distorted forecasts.

If both levels are allowed to change due to income effects, the two-stage demand system becomes an applied problem of aggregation and linkages between the levels. The expenditures and prices in the upper level must be aggregates of the lower level expenditures and prices they represent. Mount and Dyck, following the work of Segerson and Mount, suggest that the price indices created in the lower level demand system provide a theoretically consistent aggregation of the lower level prices. Using these lower level price indices in the upper level also avoids making the assumption of homotheticity in the lower level. With these assumptions, the estimation problem becomes that of two separate but related models: an upper level of aggregates and a lower level of disaggregates. The linkages between the levels are provided by the identities used to aggregate expenditures and the lower level indices to aggregate prices. The components of the demand system can be defined as meat, fish and other foods at the upper level and beef, pork and chicken at the lower level for meats and four fish groups at the lower level for fish.

² See Wahl, Hayes, and Williams for further details.

The AIDS is derived by specifying an expenditure function representing the PIGLOG³ class of preferences, which Muellbauer (1975, 1976) has shown to permit perfect aggregation over consumers. This PIGLOG class of preferences leads to following the cost function:

$$\ln c(u, P) = (1 - u) \ln a(P) + u \ln b(P), \quad (1)$$

where the positive, linearly homogenous functions $a(P)$ and $b(P)$ may be regarded as the costs of subsistence and bliss, respectively. The functional forms for $a(P)$ and $b(P)$ are chosen such that the first and second derivatives of the cost function can be set equal to those of an arbitrary cost function, thus satisfying the necessary condition for flexibility of functional form. These forms may be written as:

$$\ln a(P) = \alpha_0 + \sum_k \alpha_k \ln p_k + 1/2 \sum_k \sum_j \gamma_{kj} \ln p_k \ln p_j \quad (2)$$

and

$$\ln b(P) = \ln a(P) + \beta_0 \prod p_k^{\beta_k}. \quad (3)$$

Shepherd's lemma is used to derive an expression relating budget shares to prices, p , and utility, u . The cost function is then solved for u , and the resulting term is substituted for u in the expenditure share equation. This later substitution results in an expression relating budget shares, w , to prices such that:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln (X/P), \quad (4)$$

where P is a price index defined by:

$$\ln P = \alpha_0 + \sum_j \alpha_j \ln p_j + 1/2 \sum_j \sum_i \gamma_{ij} \ln p_i \ln p_j \quad (5)$$

Equation (5) is normally replaced with Stone's Price Index to allow for linear estimations such that:

$$\ln P = \sum_j w_j \ln p_j \quad (6)$$

Following the linear approximation of Deaton and Muellbauer's Almost Ideal Demand System, the upper level or first stage is:

$$W_s = \alpha_s + \sum_j \gamma_{sj} \ln(P_j) + \beta_s \ln\left(\frac{X}{P}\right) \quad (7)$$

³PIGLOG is a special form of the price independent, generalized linearity (PIGL) class of preferences.

$$X_g = W_g X \quad (8)$$

$$\ln P = \sum_g W_g \ln P_g \quad (9)$$

The second level demand system is:

$$W_{gi} = \alpha_{gi} + \sum_k \gamma_{gik} \ln(p_{gk}) + \beta_{gi} \ln\left(\frac{X_g}{P_g}\right) \quad (10)$$

$$\ln P_g = \sum_i W_{gi} \ln p_{gi} \quad (11)$$

$$E_{gi} = W_{gi} X_g \quad (12)$$

$$q_{gi} = \frac{E_{gi}}{P_{gi}} \quad (13)$$

W_g is the share of food expenditure for meat, fish, or other foods. P_g is the price of meat, fish, or other food. X is total food expenditure. P is Stone's price index. The $\ln P_g$'s in (7) are replaced by the $a_g(p)$ and $b_g(p)$ indices from the lower level systems to avoid imposing homotheticity on the lower systems. E_g and X_g are the expenditure on meat, fish or other foods. The prices, P_{gi} , in the lower level and total expenditures, X , in the upper level model are exogenous to the demand system. The model presented above can easily be extended by adding additional aggregate or disaggregate levels and appropriately endogenizing prices and expenditures.

Japanese Meat Expenditure Data

Detailed monthly expenditure and price data for Japanese food consumption is available in the *Annual Report on the Family Income and Expenditure Survey* that is published by the Statistics Bureau of the Japanese Prime Minister's Office. This data is the monthly averages from about 10,000 household expenditure surveys that include information on expenditures and many of the prices for numerous consumer expenditure categories. One of the shortfalls of the survey, however, is that the beef category includes all types of beef. Much of the research about Japanese meat consumption surrounds the issue of "beef is not beef in Japan." There are several distinct types of beef in Japan, Wagyu beef, dairy beef, and imported beef. Wagyu beef is very highly marbled and is used by restaurants, on special

occasions, and for gifts to bosses during the gift giving season at year end. Wagyu beef generally sells for 2-3 times the price of dairy beef. Dairy beef consumption is 3-4 times that of Wagyu beef. Dairy beef is comparable to U.S. choice beef and is more commonly used in daily meals that include beef. Imported beef is primarily from Australia and the U.S.. Imported beef is considered to less desirable than Japanese beef because Australian beef is very lean grass fed beef and U.S. beef is usually frozen, a process which decreases quality in the eyes of Japanese consumers. As a result of the aggregated single beef category it is likely that elasticity estimates will be much less meaningful than those of more disaggregated studies.

Estimation and Simulation Results

The first stage, equation (7), and the second stage, equation (10), of the Japanese meat demand system are estimated by using the SYSNLIN procedure in SAS. The first stage includes meat, fish, and other foods. The $a_i(p)$, equation (2), and $b_i(p)$, equation (3), indices for meat and fish replace the single price indices for meat and fish. The $a_i(p)$ and $b_i(p)$ elasticities can be interpreted to reflect the substitution and real expenditure effects, respectively, (Segerson and Mount). The estimated elasticities are presented in Table 1. The own-price elasticities associated with the $a_i(p)$ and $b_i(p)$ are all non-positive.

Table 1. Food demand system price and expenditure elasticities

	Meat $a(p)$ Price	Meat $b(p)$ Price	Fish $a(p)$ Price	Fish $b(p)$ Price	Other Food Price	Expendi- ture
Compensated:						
Meat	-0.80	-0.41	0.19	0.14	0.06	0.44
Fish	-0.03	0.28	-1.06	-0.58	0.07	0.24
Other Food	0.19	0.04	0.14	0.07	-0.03	1.25
Uncompensated:						
Meat	-0.87	-0.47	0.13	0.09	-0.25	0.44
Fish	-0.07	0.24	-1.09	-0.61	-0.10	0.24
Other Food	-0.02	-0.16	-0.02	0.08	-0.93	1.25

The second stage meat demand system includes beef, pork and chicken. The second stage fish demand system included four fish aggregates, high valued fish, two medium valued fish groups, and a low valued fish group. The estimated elasticities and standard errors for the meat and fish models are presented in Tables 2 and 3. The meat demand system was estimated by using Bayesian procedures described in Chalfant, Gray, and White to incorporate the prior information that all of the meats are assumed to be substitutes. The compensated price elasticities for both meat and fish models have the expected signs and reasonable magnitudes. The uncompensated elasticities, however, exhibit complementarity between chicken and the other meats and between the two medium price fish groups.

The two-stage model was simulated to examine the effects on consumption as a result of changing meat prices. First, a baseline was established by simulating the model under the historical assumptions. The beef price was then decreased by 50% under the assumption of a single-stage model (only the lower level) and under the assumption of a two-stage model. The average difference between the two-stage model results compared to the single-stage model results is less than 100 grams per household. However, when the results are aggregated up to total consumption at the national level the difference is several thousand metric tons. The differences between the forecasts for total beef, pork, and chicken consumption are presented in Figure 1.

Table 2. Meat demand system price and expenditure elasticities

	Beef Price	Pork Price	Chicken Price	Expendi- ture
Compensated:				
Beef	-0.56	0.10	0.72	1.05
Pork	0.08	-0.32	0.31	0.99
Chicken	0.32	0.16	-0.72	0.93
Uncompensated:				
Beef	-0.91	0.29	-0.16	1.05
Pork	-0.30	-0.65	-0.04	0.99
Chicken	0.29	-0.05	-1.18	0.93

Table 3. Fish demand system price and expenditure elasticities

	High Price	Medium /high Price	Medium /low Price	Low Price	Expendi- ture
Compensated:					
High	-1.07	0.33	0.40	0.34	0.94
Medium/high	0.56	-0.77	0.13	0.09	1.09
Medium/low	0.47	0.09	-0.80	0.24	1.63
Low	0.52	0.08	0.31	-0.91	0.20
Uncompensated:					
High	-1.37	0.15	0.15	0.14	0.94
Medium/high	0.21	-0.98	-0.18	-0.14	1.09
Medium/low	-0.05	-0.26	-1.29	-0.13	1.63
Low	0.44	0.08	0.30	0.92	0.20

The prices of beef, pork, and chicken were then simultaneously decreased by 50% under the assumptions of single and two-stage models. This large reduction in the price of all of the commodities within a group might occur for the EC or other countries which maintain high levels of protection on many commodities. The differences in the total consumption forecasts of the single-stage and two-stage models are presented in Figure 2.

The results of the scenarios assuming all meat prices change indicate there is a significant distortion of the forecast when only the single stage model is used. Beef, pork, and chicken consumption are overestimated by an average of 11,000 mt, 32,000 mt, and 26,000 mt, respectively. For Japan these overestimations represent a significant prediction error. Similar errors would be expected for AIDS meat demand forecasts for other countries.

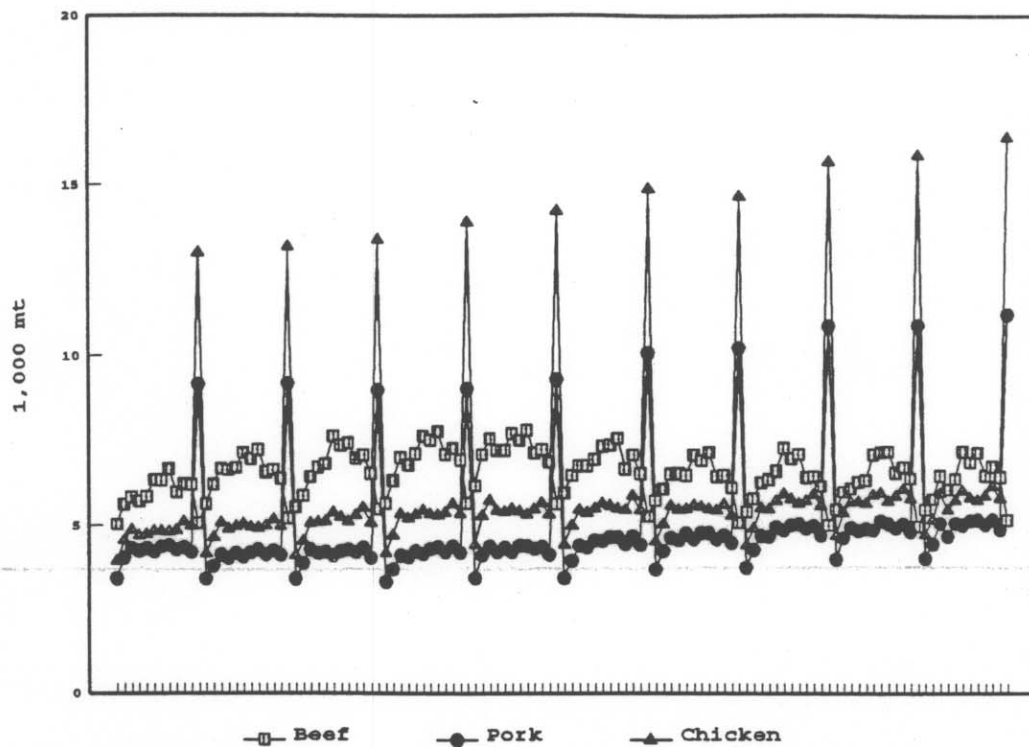


Figure 1 Forecast differences for single- versus two-stage models for monthly Japanese beef, pork, and chicken consumption under the assumption of a 50% decrease in beef price.

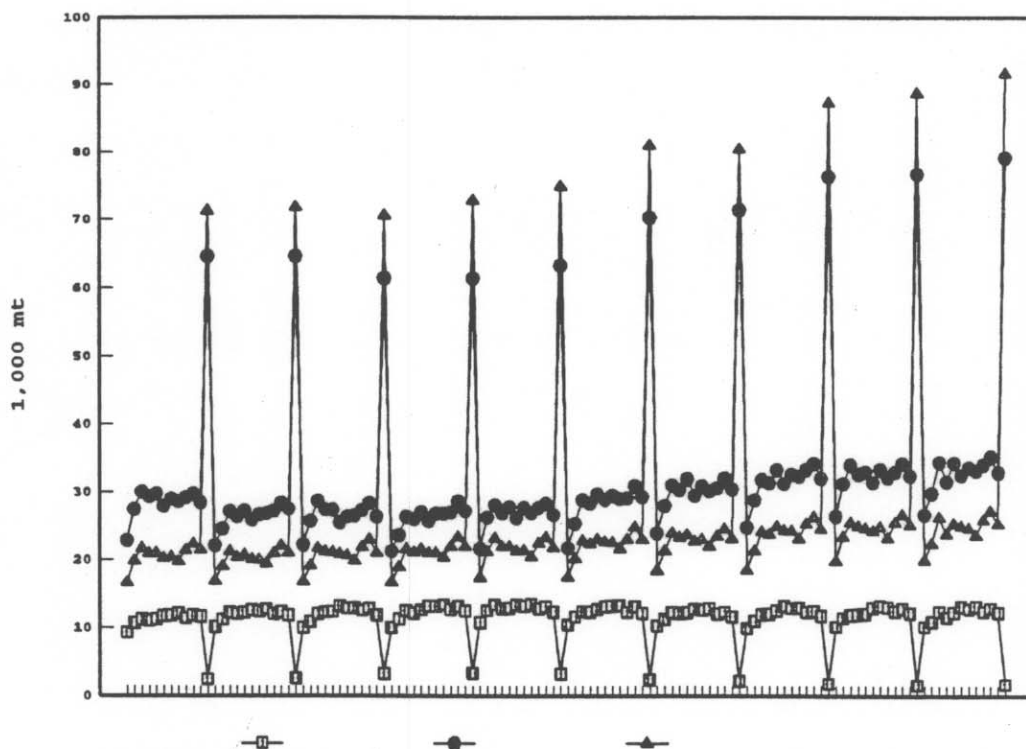


Figure 2 Forecast differences for single- versus two-stage models for monthly Japanese beef, pork, and chicken consumption under the assumption of a 50% decrease in beef, pork, and chicken prices.

Summary and Conclusions

A two-stage AIDS for Japanese food expenditures was developed and estimated. The model allows the income effects from price changes in a lower level group to be distributed over other lower level groups via the upper level demand system. Forecasts using the two-stage model were compared to the results of a conventional single stage model. The two stage model resulted in improvements in the forecasts of beef, pork, and chicken consumption.

The results indicate that ignoring the first-stage in a meat demand system may result in significant prediction errors. This result has particular significance for policy analysis of the reduction of trade barriers. For Japan, the results indicate that the single stage model would overpredict beef, pork, and chicken consumption by 132,000 mt, 384,000 mt, and 312,000 mt on an annual basis. Incorporating the two-stage food demand model into policy analysis models may significantly improve the accuracy of the analysis.

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