Comparing Heterogeneous Consumption in US and Japanese Meat and Fish Demand

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Abstract

This article uses national, quarterly data to conduct an empirical analysis of pre-committed meat and fish demand by US and Japanese households using the Generalized Almost Ideal Demand System (GAIDS). US consumers are found to hold pre-committed demand for beef and pork, while Japanese consumers appear to possess significant pre-committed demand for beef and fish. This provides evidence to partly explain observed differences in Japanese and US consumer reactions to non-price and non-income effects in beef, pork, poultry, and fish. In addition, the first known empirical comparison of how the GAIDS and more traditional AIDS models assess meat and fish demand is offered with both in- and out-of-sample evaluations.

Keywords: US/Japanese meat demand, demand forecasting, food safety, Generalized Almost Ideal Demand System, pre-committed consumption

Introduction

Researchers have long sought to better understand consumer preferences for various foods and their attributes. Significant research has been conducted analyzing meat demand issues such as consumer willingness-to-pay (WTP) for various meat attributes (Lusk, Roosen, and Fox; McCluskey et al.; Alfnes and Rickertsen), examining the effect of negative food safety and product recall news on meat demand (Piggott and Marsh; Marsh, Schroeder, and Mintert; Burton and Young), and on the occurrence of structural changes in the meat industry (Eales and Unnevehr). Our interest is to investigate if and how consumers respond differently to income, price, and non-price information using aggregate market data for the US and Japan.

Research on food demand by Japanese consumers has generally focused on separability issues (Eales and Wessells), seasonality issues (Johnson, Durham, and Wessells; Wessells and Wilen), and on testing theoretical restrictions (Hays, Wahl, and Williams). It also appears that Japanese consumer meat and fish preferences, in particular for attributes perceived to offer additional food safety, may be much stronger than those held by US consumers (McCluskey et al.; Lusk, Roosen, and Fox). Combining this observation with the fact that Japan historically has represented a large portion of US beef and pork exports, further research comparing Japanese and US consumer meat and fish expenditures appears to be warranted.[1]

This paper adds to the literature in several important ways. First, it empirically compares food consumption patterns of consumers from two distinctly different cultures to help provide better understanding of observed differences in representative consumer reactions to food safety scares. Secondly, this paper is the first known article to empirically estimate pre-committed levels of meat and fish consumption among Japanese consumers and subsequently provide a

[1] Forty-one percent and forty-eight percent, respectively, of US beef and pork exports between 2000 and 2002 were destined for Japan (United States Dept. of Agriculture, Economic Research Service).

comparison to pre-committed meat and fish demand held by US consumers. An empirical investigation into the existence of pre-committed consumption is significant both empirically and theoretically. If in fact pre-committed demand does exist, failing to account for it in developing demand models effectively forces what are actually pre-committed effects to be attributed to other factors explicitly included in the model. This leads to models that are mis-specified both theoretically and empirically leading to erroneous conclusions. Therefore it is vital to develop and use models that are specified properly and successfully incorporate and distinguish how meat and fish demand are affected by price, income, pre-committed consumption, and demand shifters. In this study, differences in pre-committed levels of demand and consumption sensitivity to price changes across the Japanese and US cultures are evaluated using the Generalized Almost Ideal Demand System (GAIDS). The final main contribution of this paper is the empirical evaluation comparing the Generalized Almost Ideal Demand System with the more traditional Almost Ideal Demand System in analyzing meat and fish demand for consumers from strikingly differing cultures.

The paper proceeds by presenting a brief review of previous research and a development of the conceptual models underlying this research. The empirical models and a description of the data used for the analysis follow. The paper then presents the results of the study and concludes with a discussion of the implications of these results.

Literature Review

With the increasing availability of sound data, the past couple of decades have seen an increase in the study of Japanese meat and fish expenditure patterns. Several of these studies estimate income, own-price, and cross-price effects while addressing the more specific goals of investigating regionality (Wessells and Wilen), seasonality (Wessells and Wilen; Johnson, Durham, and Wessells), and separability issues (Eales and Wessells; Hays, Wahl, and Williams). Likewise, research on US meat consumption has estimated own-price, cross-price, and income effects while examining food safety effects (Piggott and Marsh), estimating pre-committed consumption levels (Raper, Wanzala, and Nayga Jr.; Piggott and Marsh), and evaluating food demand of different incomes sectors within the population (Park et al.).

An array of food consumption differences exist between US and Japanese consumers. Historically the Japanese diet has consisted of rice, barley, soybean products, vegetables, and fish. It was only about one century ago that the Japanese began eating meat (Johnson, Durham, and Wessells). Sasaki and Fukagawa note that "the Japanese type of dietary life is still deeply rooted, centering on rice, fish, soybean products, and vegetables" (pg 66). Eales and Wessells recognize that seafood constitutes approximately 50% of Japanese expenditures on animal protein products and found fish to not be separable from other meat products using survey data over the 1981 to 1995 time period. Johnson, Durham, and Wessells noted that US consumers have four times more beef and two-thirds less seafood in their diet than the average Japanese consumer.

In addition to noted differences in consumption tendencies, some research has suggested Japanese quantities demanded of beef, pork, chicken, and some fish products to change little in response to own-price changes (Johnson, Durham, and Wessells). While this suggests the possible existence of pre-committed demand (that is demand that is not sensitive to income or price effects) in meat and fish products by the representative Japanese consumer, this has not been empirically tested.

The literature on pre-committed food demands is relatively sparse and has primarily been focused on US consumers. Blaylock and Blisard found food expenditures by US consumers to be more equally distributed than income, possibly due to pre-committed requirements and government efforts to provide adequate diets. Park et al. found pre-committed quantities and marginal budget shares to differ significantly among lower and upper income groups of the US population. More recently, Piggott and Marsh found US pre-committed quantities to be larger for beef products than for pork or poultry products.

These past findings of the existence of pre-committed quantities by US consumers and the historical importance of Japan as an export market for US meat products suggests that further empirical examination of pre-committed meat and fish demand by Japanese consumers, and comparison of these pre-committed demands to those held by US consumers, is warranted and necessary. This should provide additional insight that may prove priceless in understanding relative consumer meat preference differences and thus in more effectively re-establishing and maintaining viable international meat and fish trade.

Conceptual Model

The AIDS (Almost Ideal Demand System) model as proposed by Deaton and Muellbauer (1980) has frequently been used in applied meat demand analysis studies. The AIDS model is commonly used as it provides a flexible functional form facilitating easy imposition of theoretical demand restrictions. In this paper the AIDS model and a more generalized version of the AIDS model as developed by Bollino will both be estimated. This will facilitate a comparison of meat demand not only across countries, but also across model specifications.

The Marshallian budget share equations underlying the AIDS model are expressed as:

$$W_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} * \ln(p_j) + \beta_i * \ln(\mathbf{X}/\mathbf{P}) \qquad (1)$$

where W_i is the budget share associated with the i^{th} good, α_i is the constant coefficient in the i^{th} share equation, γ_{ij} is the slope coefficient associated with the j^{th} good in the i^{th} share equation, and p_j is the price on the j^{th} good. **X** is the total expenditure on the system of goods given by $\mathbf{X} = \sum_{i=1}^{n} p_i q_i$ in which q_i is the quantity demanded for the i^{th} good and **P** is the nonlinear price index defined by $\ln(\mathbf{P}) = \alpha_o + \sum_{j=1}^{n} \alpha_j \ln p_j + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j$. Here $i, j = b$ for beef, p for pork, c for poultry, and f for fish.

Homogeneity, Engle aggregation, and symmetry are imposed by:

$\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \beta_i = 0, \quad \sum_{i=1}^{n} \gamma_{ij} = 0, \quad \sum_{j=1}^{n} \gamma_{ij} = 0,$ and $\gamma_{ij} = \gamma_{ji} \forall i \neq j$. To incorporate seasonality and trend components, the intercepts of the share equations have been augmented to include shift variables (e.g., quarterly dummy and time trend variables). This modifies the budget share equations to:

$$W_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} * \ln(p_i) + \beta_i * \ln(\mathbf{X}/\mathbf{P}) + \sum_{k=1}^{3} iqt_k * qt_k + \alpha_i^{time} * t + \alpha_i^{time^2} * t^2 \qquad (2)$$

where iqt_k, α_i^{time}, and $\alpha_i^{time^2}$ are quarterly, time trend, and time trend squared parameters, respectively. The budget shares will sum to one by imposing:

$\sum_{i=1}^{n} iqt_k = 0, \quad \sum_{i=1}^{n} \alpha_i^{time} = 0,$ and $\sum_{i=1}^{n} \alpha_i^{time^2} = 0$.

However, care must be taken in deciding how to incorporate demand shifters into complete demand systems to avoid some less than obvious problems that can arise. For instance, modifying the intercepts of the AIDS model which has previously been a common approach (following the suggestion of Deaton and Muellbauer) has the unfortunate implication that estimated economic effects (e.g., elasticities) are no longer invariant to units of measurement (Alston, Chalfant, and Piggott). One possible solution that was offered by these authors is to adopt a generalized model that allows for pre-committed goods and utilize a translation procedure, allowing the pre-committed goods to be functions of demand shifters, the specification that is adopted herein.

Generalized AIDS Model

Bollino presents a generalized version of the AIDS model referred to as the Generalized Almost Ideal Demand System (GAIDS). Bollino generalizes this model to incorporate pre-committed quantities which are independent of price and income effects. The generalized expenditure function underlying the GAIDS is given by:

$$\ln(\mu - \mathbf{c}'*\mathbf{p}) = \ln(\mathbf{P}) + u * \ln(b)$$

where $\mathbf{c}$ is an N-vector of pre-committed quantity parameters and $\mathbf{p}$ is a N-vector of prices. Making use of dual properties and Roy's Identity, the Marshallian demand functions (in share form) are given by:

$$W_i = (C_i * P_i) / \mu + (\mathbf{Z} / \mu) * [\alpha_i + \sum_{j=1}^{n} \gamma_{ij} * \ln(p_i) + \beta_i * \ln(\mathbf{Z} / \mathbf{P})] \qquad (3)$$

where $\mathbf{Z} = (\mu - \sum_{i=1}^{n} C_i * P_i)$ represents supernumerary expenditure and

$$\ln(\mathbf{P}) = \delta + \sum_{j=1}^{n} \alpha_j * \ln(p_j) + (1/2) * \sum_{k=1}^{n} \sum_{j=1}^{n} \gamma_{kj} * \ln(p_k) * \ln(p_j) .$$

The mathematical representation of pre-committed expenditure is $\sum_{i=1}^{n} C_i * P_i$. This provides for a model with variables as denoted above and $C_i, \alpha_i, \gamma_{ij}, \beta_i$, and δ being parameters to estimate. The GAIDS model is subject to the same theoretical demand restrictions as the AIDS model. Homogeneity requires $\sum_{j=1}^{n} \gamma_{ij} = 0$, adding-up requires $\sum_{i=1}^{n} \beta_i = 0$ and $\sum_{i=1}^{n} \alpha_i = 1$, and symmetry is imposed by $\gamma_{ij} = \gamma_{ji} \; \forall \, i \neq j$.

Quarterly dummy, time trend, and time trend squared variables can also be incorporated in the GAIDS model. These components can be introduced into the pre-committed quantity expressions and yet preserve the desired theoretical properties held by the AIDS model. Incorporating shift variables in this manner, results in the following modifications to the GAIDS model:

$$\tilde{C}_i = C_{io} + \sum_{k=1}^{3} iqt_k * qt_k + \alpha_i^{time} * t + \alpha_i^{time^2} * t^2 \tag{4}$$

$$W_i = (\tilde{C}_i * P_i) / \mu + (\mathbf{Z} / \mu) * [\alpha_i + \sum_{j=1}^{n} \gamma_{ij} * \ln(p_i) + \beta_i * \ln(\mathbf{Z} / \mathbf{P})] \tag{5}$$

A priori expectations of applying the GAIDS model to Japanese and US meat and fish consumption data are to find pre-committed levels of beef products to be lower among Japanese consumers. Furthermore, pre-committed levels of fish products are anticipated to be lower among US consumers. This follows from the thought that the comparatively young, US culture has developed with red meat being a significant underlying “staple” in their diet, whereas the much older, Japanese culture has developed under different circumstances, where possibly fish products are significantly more "staple" items than red meat. Furthermore, it is anticipated to find expenditure elasticities of red meat products to be higher for Japanese consumers; confirming the expectation that Japanese consumers view red meat products as more of a "luxury" type of good than do US consumers.

Data and Procedures

Data used in this analysis consists of quarterly per capital disappearance and price series for beef, pork, poultry, and fish for both the US and Japanese domestic markets. This data was collected over the 1976(1) -2001(4) period yielding 104 total observations for each market. Quarterly US price and disappearance data ranging from 1976(1) through the 1993(4) were obtained from Dr. Henry Kinnucan and are identical to that used by Kinnucan et al. Subsequent US beef, pork, and poultry per capita disappearance data from 1994(1) to 2001(4) were obtained from the United States Department of Agriculture (USDA), Economic Research Service (ERS) supply and utilization tables published in the *Red Meat Yearbook*. Corresponding US fish per capita disappearance data were obtained following the same procedure used by Kinnucan et al. and discussed in more detail by Schmitz and Capps. US beef, pork, and poultry price data are average retail prices obtained from ERS.[2] Using a fish price consumer price index obtained from ERS and a base price from 1983 (1), quarterly US fish price data spanning from 1994 (1) to 2001 (4) were derived for this analysis.[3]

[2] More specifically, the beef and pork prices used have variable names BFVRCCUS and PKVRCCUS, respectively. Furthermore, the poultry price is calculated as the sum of expenditures on whole fryers and turkey divided by the sum of per capita disappearance of chicken and turkey.

[3] A regression analysis, utilizing the seasonal pattern present in quarterly fish prices, was used to quarterize annual per capita consumption data obtained from the ERS Food Consumption Data System. While this may not be the ideal way to develop fish price and consumption data, as noted by previous authors (Kinnucan et. al.; Dameus et. al.), US fish data is poor and procedures undertaken in this study are necessary to analyze US fish demand. This data and additional details on this procedure are available upon request.

Data on Japanese consumption patterns over the same time period for similar goods was obtained from Dr. James Eales of Purdue University. The data is the same as originally used by Eales, Durham, and Wessells and was updated through 2001 by Dr. Eales. The original source of this data was *The Annual Report on the Family Income and Expenditure Survey* which is conducted by the *Statistics Bureau* in Japan. This survey obtains data from approximately 8,000 households who maintain journals to record requested price and expenditure information. From these journals, the *Statistics Bureau* creates national average expenditure and consumption data series. To facilitate an accurate comparison of Japanese and US models, the consumption quantities were converted from grams to pounds and prices/expenditures were converted to US dollar equivalent amounts using historical exchange rate information obtained from the United States Federal Reserve System. Individual fish and seafood quantities were aggregated into one category and a simple weighted average was used as the price of fish.[4]

Tables 1a and 1b provide summary statistics of the entire dataset and the estimated expenditure share allocated to beef, pork, poultry, and fish consumption for US and Japanese consumers, respectively. Upon inspection of the budget share estimates, it is apparent that the representative US household allocates a higher percentage of its animal protein expenditures (with nearly 50% being distributed to beef) to beef, pork, and poultry and a lower percentage to fish than does the typical Japanese household who allocates over 50% of its meat and fish expenditures to fish products alone. Furthermore, the tables show that US per capita consumption of meats in general is higher than that of Japanese households.

[4] Admittedly, the US and Japan data sets used in this analysis differ slightly. They are derived from different samples (by definition) with different sampling techniques. However, both sets are believed to be sound and representative of consumers in each country. Furthermore, in order to get a sufficient time series for this analysis these data sets had to be adopted.

Results

Beef, pork, poultry, and fish are treated as a weakly separable group for the empirical analysis. Data from 1998(1) to 2001(4) was withheld from the estimation process and is used in a subsequent out-of-sample investigation. With homogeneity, Engle aggregation, and symmetry imposed, iterated seemingly unrelated regression estimates were calculated while dropping one equation to avoid singularity of the error covariance matrix. The parameters of this omitted equation are obtained by utilizing the imposed theoretical restrictions noted above and the selection of which equation to be omitted is irrelevant (Capps).

A system of 3 equations (with the fish equation omitted) as described by equation (2) was estimated for the AIDS model and a system derived collectively from equations (4) and (5) was estimated for the GAIDS model. These systems were estimated for each country using iterative seemingly unrelated regression procedures in SAS using quarterly data spanning from 1976(1) to 1997(4).

Following Piggott and Marsh and Piggott, Chalfant, Alston, and Griffith, three Berndt and Savin autocorrelation corrections were evaluated. These three corrections consisted of 1) a correction matrix (Null Matrix) restricting all elements to zero (specifying no autocorrelation correction, $\rho_{ij} = 0 \; \forall_{ij}$), 2) a correction matrix (Diagonal Matrix) with all off-diagonal elements restricted to zero and all diagonal elements to be identical ($\rho_{ij} = 0 \; \forall_{i \neq j}$ and $\rho \neq 0 \; \forall_{i=j}$), and 3) a correction matrix (Complete Matrix) allowing all elements to differ individually from zero ($\rho_{ij} \neq 0 \; \forall_{ij}$). Bewley adjusted likelihood ratio (LR_B) tests were used to compare alternative model specifications.[5] Table 3 presents the results of these LR_B tests for the GAIDS model

[5] To conserve space details from rejected models are not presented here but are available upon request.

specification and both the no-autocorrelation correction (Null Matrix) and identical diagonal element correction (Diagonal Matrix) specifications are rejected in favor of the correction matrix (Complete Matrix) with all elements varying individually from zero for both the US and Japanese models. This differs from the findings of Piggott and Marsh that a Diagonal Matrix is a sufficient correction for autocorrelation in US models omitting food safety index information. However, their study did not incorporate fish products and used a shorter time series than the one used in this analysis.[6] The parameter estimates presented in table 2 reflect this correction and corresponding elasticities in table 6 were derived from this model.

The GAIDS for each country does a sound job of fitting the data in-sample, with R-Squared statistics ranging from 85% to 99% and approximately one-half of the estimated coefficients being found statistically significant in each model.[7] The constant components (C_{i0}) of the estimated pre-committed quantities differ considerably across the US and Japanese models. It appears that a significant portion of US consumer demand for beef and pork and Japanese consumer demand for beef and fish is pre-committed. This implies that factors other than price, income, seasonality, and time trend significantly impact the demand for these products. Conversely, the lack of statistically significant pre-committed quantities by US consumers for poultry and fish and by Japanese consumers for pork and poultry suggest that price, income, seasonality, and time trend variables do in fact statistically capture all relevant components of underlying consumer demand. The finding of pre-committed consumption of 13.608 pounds of beef and 9.291 pounds of pork is similar to the estimates by Piggott and Marsh

[6] This is noteworthy because many studies have suggested there has been structural change in meat demand over the current study period.
[7] Throughout this paper, coefficients with estimated p-values less than 0.10 will be referred to as being statistically different from zero.

of 11.126 and 5.472 pounds of beef and pork, respectively, found in their model estimated without food safety index information.

While comparing the quantities of pre-committed foods is useful, it may be more insightful to compare the percentage of consumption deemed as being pre-committed. Making use of the estimated expenditure shares (Tables 1a and 1b) and the statistical significance of relevant parameters from table 2, pre-committed consumption for US consumers appears to be 74%, 73%, 0%, and 0% of total estimated consumption for beef, pork, poultry, and fish, respectively. Piggott and Marsh estimated 63%, 43%, and 41% to be the percentages of beef, pork, and poultry consumption, respectively, that is pre-committed. As noted above, differences between the two studies can be attributed to different assumptions regarding the weakly separable bundle of animal protein sources and the time series analyzed.

Conversely, Japanese pre-committed meat consumption is estimated to contain 67%, 0%, 0%, and 60% of overall consumption for beef, pork, poultry, and fish, respectively. As previously noted, no known research has empirically estimated the pre-committed meat and fish demand by Japanese consumers, and as such there are no known papers to compare these results to. These results do provide evidence that factors besides price and expenditures do in fact contribute significantly to both US and Japanese consumer demand responses for these products. Both consumer groups appear to have beef demand affected by factors not explicitly incorporated into the model. The finding of significant pre-committed beef quantities and the absence of corresponding pork and poultry pre-committed quantities helps to empirically explain why Japanese consumers have reacted differently to beef safety scares than they have to other meat safety scare incidents. The observation that US beef demand is driven relatively more by pre-committed factors than that of Japanese consumers supports the previously mentioned notation that US consumers hold beef as more of a staple item. Likewise, the finding of pre-committed fish demand by Japanese consumers, and not by US consumers, validates the hypothesis that fish is more of a staple item for Japanese households. What is also interesting is how US pork demand is found to be significantly affected by pre-committed factors, but Japanese demand is not. Furthermore, it is surprising to find that poultry demand is not statistically affected by pre-committed consumption in either consumer group.

It is interesting that the proportion of total beef consumption estimated to be pre-committed is higher for US consumers relative to Japanese consumers. This suggests that beef demand is more influenced by non-price and non-income factors for US consumers than for Japanese consumers, but the finding of pre-committed consumption in both consumer groups indicates that both possess positive pre-committed beef demand. Note needs to be taken that this research can not explicitly indicate exactly what underlies and affects these pre-committed quantities. The work of Piggott and Marsh suggest that food safety impacts, albeit small and contemporaneous, may impact these quantities. Food safety index information relevant for Japanese consumers is not currently available and hence a further investigation of food safety impacts on these pre-committed estimates is not currently feasible. Furthermore, it is likely that other non-food safety factors impact these pre-committed quantities.

The finding of significant pre-committed consumption by both US and Japanese consumers does raise the question of how food safety and other non-price and non-income effects impact pre-committed and total meat and fish demand for each consumer group. This remains an empirical question to be addressed in future research. The findings of this current research fail to provide additional understanding of why Japanese consumer reaction to non-price events affecting beef, pork, or poultry (especially food safety scares) has previously been estimated to be more dramatic than that of US consumers.[8]

AIDS Model Results

Besides offering the first comparison of pre-committed meat demand held by US and Japanese consumers, this paper also offers the first known empirical evaluation of how AIDS and GAIDS models compare in analyzing meat and fish demand for the two consumer groups. Table 4 presents the estimated coefficients of the AIDS model for each country. As with the GAIDS model, the analysis of alternative autocorrelation corrections suggested using the Complete Matrix that allows each correction matrix element to differ individually from zero (see table 5 for LR_B test results). The estimates provided in table 4 and corresponding elasticity estimates in table 7 reflect this finding. Each AIDS model does a reasonable job of fitting the data, with R-Squared statistics ranging from 81% to 99% and over one-half of the estimated coefficients being found statistically significant in each model.

Elasticity Estimates

Elasticity estimates for the preferred GAIDS and AIDS models are provided in tables 6 and 7, respectively.[9] The estimated US AIDS model failed to hold curvature. This is observed by noting that the fish own-price elasticity estimate is positive. This is one noteworthy difference from the GAIDS model where curvature held for all models without be directly

[8] This may potentially serve as a signal that this model is partially mis-specified. More specifically, directly incorporating food safety and other non-price and non-income information into the model may produce a less restrictive model and may lead to different conclusions on the extent of difference across cultures in how consumers react to non-price and non-income events.
[9] Elasticity equations are provided with each table of elasticity estimates.

imposed on the model. With the exception of this US own-price fish elasticity, all other own-price elasticities were estimated to be inelastic.

By visually comparing the elasticities for each consumer group across model specifications we can see some marked differences regarding demand sensitivity to expenditure and price effects. To test which model is preferable and hence which set of elasticities estimates to use, we conduct a LR_B test comparing the preferred GAIDS model (table 2) with the preferred AIDS model (table 8) for each country. Both tests suggest that the GAIDS model has superior in-sample fit to the AIDS model. Using the compensated GAIDS elasticity estimates, we can see that Japanese consumers appear to be more sensitive to beef and pork price changes and less sensitive to poultry price changes than US consumers. Furthermore, pork and poultry are estimated to be luxury goods for Japanese households while fish is the only luxury product for US consumers.[10]

Out-of-Sample Evaluations

As noted by Kastens and Brester, more research modeling food demand should incorporate out-of-sample testing as part of its analysis. Thus the final analysis conducted in this study is an out-of-sample comparison of the AIDS and GAIDS models within each country group. As is common in evaluating model forecasting accuracy (Piggott; Chambers and Nowman), one-period forecasts were generated for four models: 1) US GAIDS model, 2) US AIDS model, 3) Japan GAIDS model, and 4) Japan AIDS model.[11,12]

[10] It is noteworthy to mention that the AIDS model estimates contradict this in suggesting that Japanese hold beef and fish as luxury goods and consider pork and poultry to be normal goods. This is the exact opposite conclusion one draws using the GAIDS estimates and again demonstrates the importance of identifying the appropriate underlying model.

[11] Each of these models was estimated using the autocorrelation correction procedures previously discussed.

One-period ahead forecast of meat and fish expenditure shares are derived as follows. The demand model is estimated using all information available one quarter prior to the one being forecasted. The resulting parameter estimates, lagged quantities and expenditure shares, and prices for the forecasted quarter are used to predict expenditure shares. The procedure is then repeated by re-estimating the demand model with one additional quarterly observation and then predicting the subsequent quarter. This process is repeated a total of 16 times, as each quarter from 1998(1) to 2001(4) is predicted in one-period ahead forecasts. The resulting forecasts are used to calculate prediction errors defined as $w_{i,t} - \tilde{w}_{i,t}$ with $w_{i,t}$ being actual expenditure shares and $\tilde{w}_{i,t}$ being the predicted expenditure shares.

Root mean square forecast errors (RMSE), mean absolute forecasts errors (MAE), and mean absolute percentage forecast errors (MAPE) are used to compare model forecasting performance. These errors are defined as follows:

$$\text{RMSE}_i = \sqrt{(1/16)\sum_{j=1998(1)}^{2001(4)} (w_{i,j} - \tilde{w}_{i,j})^2} \qquad i = 1,\ldots,n \tag{6}$$

$$\text{MAE}_i = (1/16)\sum_{j=1998(1)}^{2001(4)} | w_{i,j} - \tilde{w}_{i,j} | \quad i = 1,\ldots,n \tag{7}$$

$$\text{MAPE}_i = (1/16)\sum_{j=1998(1)}^{2001(4)} | (w_{i,j} - \tilde{w}_{i,j}) / w_{i,j} | \quad i = 1,\ldots,n \tag{8}$$

Table 9 summarizes the results of this forecasting analysis by commodity, model, and country. In general, the GAIDS model does a better job of forecasting meat and fish expenditure shares one quarter into the future. This holds for both the US and Japanese consumer groups.

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[12] Note that there are an infinite number of forecasting evaluations one could conduct, including dynamic forecasting (e.g. forecasting multiple periods into the future). Alternative forecasting analyses were not evaluated in this analysis, primarily to conserve degrees of freedom and keep the forecasting analysis succinct.

This finding further validates the conclusion, based on in-sample adjusted likelihood ratio tests, that the GAIDS model is superior to the AIDS model in this analysis.

Conclusion and Implications

This article applies the Generalized Almost Ideal Demand System (GAIDS) to Japanese and US quarterly data to estimate meat demand and to investigate cultural differences in meat and fish pre-committed diets. It was found that US consumers have higher pre-committed levels of beef and pork in their diet while Japanese consumers have a higher level of pre-committed fish consumption. Furthermore, a higher percentage of total beef and pork consumption is estimated to be pre-committed for US households than for Japanese consumers. Japanese consumers on the other hand are found to have significant pre-committed beef and fish quantities but not pre-committed consumption of pork or poultry in their diet.

These findings offer additional insight on why Japanese consumers have reacted differently to non-price and non-income changes for beef than for other meats and why non-price and non-income effects cause subsequent heterogeneous responses by consumers in different countries. Effectively, the findings of this research imply that consumers from different countries do in fact empirically differ in their sensitivity to issues such as meat safety scares. Furthermore, these findings may offer supplemental support for claims that Japanese willingness-to-pay for various beef attributes exceeds that of US consumers (McCluskey et al.).

In-sample and out-of-sample evaluations indicate that the more general GAIDS model is preferable to the more traditionally used AIDS model in analyzing Japanese and US consumer meat and fish demand. This conclusion has several important implications. It suggest that prior work that analyzed issues such as advertising effect, structural shifts, and estimation of elasticities may have been derived from mis-specified models. As such, the underlying conclusions put forth from these papers may potentially be highly sensitive to the underlying models used to derive them. In short, meat and fish demand models that fail to incorporate pre-committed consumption may lead to erroneous conclusions.

While this paper does provide a nice discovery of some previously unexamined differences in consumer meat and fish demand formation, its conclusion should be tempered by a few noted constraints of the analysis. Future work should expand upon this paper by using alternative data sources that may capture longer or more frequent time spans than used in this analysis. Furthermore, opportunity exists to develop food safety indexes for beef, pork, poultry, and fish in both countries to facilitate an explicit examination of how food safety information impacts different products in different consumer groups. Non-price and non-income factors other than food safety information should also be evaluated in subsequent work use some modification of the GAIDS model used here. Finally, alternative functional forms to the GAIDS can be derived and used to evaluate the conclusions of this research.

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Table 1a. Summary Statistics of Quarterly US Data (1976-2001)

	Mean	Std. Dev.	Minimum	Maximum
Beef Consumption (lbs per capita)	18.40	2.09	15.90	24.50
Pork Consumption (lbs per capita)	12.72	0.91	10.10	15.30
Poultry Consumption (lbs per capita)	19.87	4.83	10.80	27.20
Fish Consumption (lbs per capita)	3.62	0.66	2.00	5.30
Beef Retail Price ($/lb)	2.52	0.45	1.42	3.45
Pork Retail Price ($/lb)	1.91	0.40	1.20	2.75
Poultry Retail Price ($/lb)	0.87	0.13	0.60	1.11
Fish Retail Price ($/lb)	2.51	0.77	1.10	3.65
Meat and Fish Expenditure ($/capita)	96.93	18.80	57.55	136.53
Beef Expenditure Share	0.48	0.06	0.38	0.59
Pork Expenditure Share	0.25	0.01	0.22	0.29
Poultry Expenditure Share	0.18	0.04	0.11	0.24
Fish Expenditure Share	0.09	0.02	0.05	0.13

Table 1b. Summary Statistics of Quarterly Japanese Data (1976-2001)

	Mean	Std. Dev.	Minimum	Maximum
Beef Consumption (lbs per capita)	8.525	1.122	4.515	11.532
Pork Consumption (lbs per capita)	14.826	1.48	12.596	18.554
Poultry Consumption (lbs per capita)	10.916	1.37	8.525	14.398
Fish Consumption (lbs per capita)	41.946	4.698	33.174	52.885
Beef Retail Price ($/lb)	3.432	0.614	2.501	4.704
Pork Retail Price ($/lb)	1.665	0.325	1.313	2.68
Poultry Retail Price ($/lb)	1.143	0.264	0.901	1.973
Fish Retail Price ($/lb)	1.683	0.095	1.454	1.893
Meat and Fish Expenditure ($/capita)	137.306	23.71	95.27	191.962
Beef Expenditure Share	0.21	0.021	0.111	0.245
Pork Expenditure Share	0.18	0.023	0.14	0.237
Poultry Expenditure Share	0.09	0.009	0.075	0.108
Fish Expenditure Share	0.52	0.019	0.485	0.584

Table 2. GAIDS Model Estimated Coefficients

US Model			Japanese Model		
Parameter	Estimate	Std. Dev.	Parameter	Estimate	Std. Dev.
γ_{bb} *	-0.529	0.317	γ_{bb}	0.131	0.465
γ_{bp}	-0.031	0.196	γ_{bp}	-0.117	0.169
γ_{bc}	0.196	0.137	γ_{bc}	-0.340	0.451
γ_{pp} *	-0.441	0.232	γ_{pp} *	0.180	0.091
γ_{pc}	0.103	0.110	γ_{pc}	0.120	0.244
γ_{cc}	0.020	0.035	γ_{cc} **	0.617	0.280
α_b	-0.734	0.462	α_b	-3.415	4.858
α_p **	-0.798	0.367	α_p	1.331	2.797
α_c **	0.721	0.321	α_c ***	7.002	1.776
C_{bo} ***	13.608	4.180	C_{bo} *	5.705	2.952
bqt_1 ***	-0.347	0.178	bqt_1	-0.265	0.466
bqt_2 ***	0.498	0.162	bqt_2 **	-0.842	0.324
bqt_3 ***	0.860	0.148	bqt_3 ***	-1.230	0.330
α_b^{time}	0.112	0.098	α_b^{time}	-0.023	0.029
$\alpha_b^{time^2}$	-0.001	0.001	$\alpha_b^{time^2}$	0.000	0.000
C_{po} ***	9.291	2.996	C_{po}	-0.758	3.714
pqt_1 ***	-1.073	0.124	pqt_1	0.257	0.526
pqt_2 ***	-1.245	0.106	pqt_2 **	0.890	0.398
pqt_3 ***	-1.048	0.088	pqt_3 ***	1.656	0.402
α_p^{time} ***	0.176	0.054	α_p^{time}	0.031	0.031
$\alpha_p^{time^2}$ ***	-0.001	0.000	$\alpha_p^{time^2}$	0.000	0.000
C_{co}	-2.717	6.796	C_{co}	2.452	2.760
cqt_1 ***	-2.435	0.143	cqt_1 *	-0.725	0.432
cqt_2 ***	-1.457	0.111	cqt_2	-0.225	0.320
cqt_3 ***	-1.049	0.095	cqt_3	-0.009	0.322
α_c^{time} ***	0.396	0.122	α_c^{time} ***	0.110	0.031
$\alpha_c^{time^2}$ *	-0.002	0.001	$\alpha_c^{time^2}$ ***	-0.001	0.000
C_{fo}	-18.005	6.798	C_{fo} **	25.096	12.050
β_b ***	0.321	0.101	β_b	-0.051	0.064
β_p ***	0.222	0.083	β_p	0.020	0.037
β_c **	-0.148	0.061	β_c ***	0.093	0.024

Table 2. GAIDS Model Estimated Coefficients (continued)[a]

US Model			Japanese Model		
Parameter	Estimate	Std. Dev.	Parameter	Estimate	Std. Dev.
ρ_{bb} ***	0.367	0.121	ρ_{bb} ***	0.473	0.101
ρ_{bp}	-0.068	0.163	ρ_{bp}	-0.049	0.154
ρ_{bc} ***	-1.167	0.248	ρ_{bc} *	-0.506	0.261
ρ_{pb}	0.037	0.085	ρ_{pb}	0.023	0.062
ρ_{pp} ***	0.502	0.126	ρ_{pp} ***	0.888	0.083
ρ_{pc}	0.004	0.173	ρ_{pc}	0.214	0.156
ρ_{cb} ***	-0.235	0.053	ρ_{cb}	-0.057	0.039
ρ_{cp} ***	-0.252	0.073	ρ_{cp} ***	0.177	0.056
ρ_{cc} ***	0.410	0.116	ρ_{cc} ***	0.631	0.099
LL	1053.082		LL	1251.323	
R^2 Beef	0.981		R^2 Beef	0.960	
R^2 Pork	0.853		R^2 Pork	0.991	
R^2 Poultry	0.990		R^2 Poultry	0.976	

[a] Here *i*, *j* = *b* for beef, *p* for pork, *c* for poultry, and *f* for fish. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Table 3. Hypothesis Testing: Significance of Autocorrelation Corrections in the GAIDS[a]

	US Model		
	Ho: Null Matrix Ha: Diagonal Matrix	Ho: Diagonal Matrix Ha: Complete Matrix	Ho: Null Matrix Ha: Complete Matrix
LR_B	24.594*	38.857*	62.603*
df	1	8	9
$\lambda^{0.05,df}$	3.841	15.507	16.919
	Japanese Model		
	Ho: Null Matrix Ha: Diagonal Matrix	Ho: Diagonal Matrix Ha: Complete Matrix	Ho: Null Matrix Ha: Complete Matrix
LR_B	38.691*	32.746*	70.104*
df	1	8	9
$\lambda^{0.05,df}$	3.841	15.507	16.919

[a] Reported test statistics are Bewley adjusted likelihood ratio test statistics calculated as: $LR_B = 2*(LL^{Unrestricted} - LL^{\text{Re}stricted})*[(MT - p^{un})/MT]$. where $LL^{Unrestricted}$ and $LL^{\text{Re}stricted}$ are the maximum log likelihood values of the unrestricted and unrestricted models, respectively. M denotes the number of estimated equations, T is the sample size used, and p^{un} denotes the number of parameters in the unrestricted model. *denotes statistical significance at the 5% level and *df* denotes the degrees of freedom for each test.

Table 4. AIDS Model Estimated Coefficients

US Model			Japanese Model		
Parameter	Estimate	Std. Dev.	Parameter	Estimate	Std. Dev.
γ_{bb}**	0.067	0.027	γ_{bb}***	0.079	0.027
γ_{bp}	0.000	0.034	γ_{bp}	-0.014	0.032
γ_{bc}	-0.062	0.044	γ_{bc}	-0.025	0.016
γ_{pp}	-0.012	0.049	γ_{pp}	-0.009	0.036
γ_{pc}***	-0.140	0.031	γ_{pc}**	-0.038	0.019
γ_{cc}	0.002	0.042	γ_{cc}***	0.042	0.012
α_b	0.610	0.395	α_b	0.044	0.283
α_p***	1.014	0.276	α_p***	1.132	0.176
α_c***	1.195	0.187	α_c***	0.400	0.122
β_b	-0.004	0.043	β_b	0.013	0.030
bqt_1***	0.018	0.003	bqt_1	0.003	0.005
bqt_2***	0.018	0.002	bqt_2	-0.003	0.004
bqt_3***	0.011	0.002	bqt_3	0.004	0.004
α_b^{time}***	-0.002	0.001	α_b^{time}***	0.002	0.001
$\alpha_b^{time^2}$	0.000	0.000	$\alpha_b^{time^2}$**	0.000	0.000
β_p***	-0.081	0.030	β_p***	-0.097	0.018
pqt_1***	-0.013	0.002	pqt_1	-0.004	0.003
pqt_2***	-0.026	0.002	pqt_2	-0.001	0.003
pqt_3***	-0.025	0.002	pqt_3	-0.001	0.003
α_p^{time}*	0.000	0.000	α_p^{time}***	-0.001	0.000
$\alpha_p^{time^2}$*	0.000	0.000	$\alpha_p^{time^2}$	0.000	0.000
β_c***	-0.119	0.021	β_c**	-0.031	0.013
cqt_1***	-0.019	0.001	cqt_1***	-0.008	0.002
cqt_2***	-0.012	0.001	cqt_2***	-0.007	0.002
cqt_3***	-0.010	0.001	cqt_3***	-0.010	0.002
α_c^{time}***	0.002	0.000	α_c^{time}	0.000	0.000
$\alpha_c^{time^2}$	0.000	0.000	$\alpha_c^{time^2}$	0.000	0.000

Table 4. AIDS Model Estimated Coefficients (continued)[a]

US Model			Japanese Model		
Parameter	Estimate	Std. Dev.	Parameter	Estimate	Std. Dev.
ρ_{bb}	0.014	0.142	ρ_{bb} ***	0.494	0.124
ρ_{bp} **	-0.357	0.169	ρ_{bp}	0.010	0.233
ρ_{bc} ***	-1.216	0.256	ρ_{bc} *	-0.562	0.302
ρ_{pb}	0.030	0.104	ρ_{pb}	-0.017	0.080
ρ_{pp} ***	0.362	0.125	ρ_{pp} ***	0.528	0.149
ρ_{pc}	-0.043	0.187	ρ_{pc}	0.234	0.192
ρ_{cb} **	-0.148	0.070	ρ_{cb} *	-0.087	0.050
ρ_{cp} *	-0.157	0.084	ρ_{cp} **	0.231	0.094
ρ_{cc} ***	0.557	0.128	ρ_{cc} ***	0.502	0.122
LL	1019.718		LL	1220.250	
R^2 Beef	0.9774		R^2 Beef	0.947	
R^2 Pork	0.8136		R^2 Pork	0.9862	
R^2 Poultry	0.9857		R^2 Poultry	0.965	

[a] Here *i*, *j* = *b* for beef, *p* for pork, *c* for poultry, and *f* for fish. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Table 5. Hypothesis Testing: Significance of Autocorrelation Corrections in the AIDS[a]

	US Model		
	Ho: Null Matrix Ha: Diagonal Matrix	Ho: Diagonal Matrix Ha: Complete Matrix	Ho: Null Matrix Ha: Complete Matrix
LR_B	41.634*	50.549*	90.772*
df	1	8	9
$\lambda^{0.05,df}$	3.841	15.507	16.919

	Japanese Model		
	Ho: Null Matrix Ha: Diagonal Matrix	Ho: Diagonal Matrix Ha: Complete Matrix	Ho: Null Matrix Ha: Complete Matrix
LR_B	83.537*	35.430*	116.135*
df	1	8	9
$\lambda^{0.05,df}$	3.841	15.507	16.919

[a] Reported test statistics are Bewley adjusted likelihood ratio test statistics calculated as: $LR_B = 2*(LL^{Unrestricted} - LL^{\mathrm{Re}stricted})*[(MT - p^{un})/MT]$. where $LL^{Unrestricted}$ and $LL^{\mathrm{Re}stricted}$ are the maximum log likelihood values of the unrestricted and unrestricted models, respectively. M denotes the number of estimated equations, T is the sample size used, and p^{un} denotes the number of parameters in the unrestricted model. *denotes statistical significance at the 5% level and *df* denotes the degrees of freedom for each test.

Table 6. GAIDS Model Estimated Uncompensated, Compensated, and Expenditure Elasticities[a]

Uncompensated US Model Elasticities				
	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.663	-0.060	-0.102	-0.059
Pork	-0.011	-0.502	-0.141	-0.008
Poultry	-0.015	-0.120	-0.205	0.031
Fish	-1.838	-0.840	-0.562	-0.692

Uncompensated Japanese Model Elasticities				
	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.576	-0.174	-0.049	0.370
Pork	-0.380	-0.413	-0.105	-0.686
Poultry	-0.543	0.052	-0.522	-0.833
Fish	0.052	-0.144	-0.028	-0.767

Compensated US Model Elasticities				
	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.227	0.159	0.048	0.020
Pork	0.316	-0.339	-0.028	0.051
Poultry	0.138	-0.043	-0.153	0.058
Fish	0.102	0.133	0.105	-0.340

Compensated Japanese Model Elasticities				
	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.485	-0.096	-0.010	0.590
Pork	-0.042	-0.126	0.039	0.129
Poultry	-0.149	0.386	-0.355	0.117
Fish	0.242	0.017	0.053	-0.311

US Model Expenditure Elasticities	
Beef	0.885
Pork	0.662
Poultry	0.309
Fish	3.932

Japanese Model Expenditure Elasticities	
Beef	0.429
Pork	1.584
Poultry	1.846
Fish	0.886

[a] Uncompensated (Marshallian) price elasticities were calculated as:

$$m_{ij} = -\delta_{ij} + (1/Xw_i)[C_i p_i (1 - w_i^*) + X^*(\gamma_{ij} - \beta_i\{C_i p_i / X^* + \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j\})]$$

Expenditure elasticities were calculated as:

$$e_{ix} = 1 + (1/w_i) * \{\beta_i + (1/X) * (-C_i p_i + X^* w_i)\}$$

Compensated (Hicksian) price elasticities were calculated as:

$$h_{ij} = m_{ij} + w_j e_{ix}$$

where $w_i^* = p_i(q_i - C_i)/X^*$, $X^* = (X - \sum_{i=1}^{n} C_i p_i)$, and δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j, \delta_{ij} = 0$ for $i \neq j$).

Table7. AIDS Model Estimated Uncompensated, Compensated, and Expenditure Elasticities[a]

Uncompensated US Model Elasticities

	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.929	0.007	-0.053	-0.017
Pork	0.172	-0.687	0.273	-0.430
Poultry	0.306	0.554	-0.117	-1.042
Fish	-1.199	-2.097	-2.656	2.678

Uncompensated Japanese Model Elasticities

	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.927	-0.078	-0.047	-0.006
Pork	0.037	-0.428	0.166	-0.241
Poultry	0.008	0.336	-0.826	-0.174
Fish	-0.061	-0.182	-0.065	-0.916

Compensated US Model Elasticities

	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.440	0.253	0.115	0.072
Pork	0.504	-0.521	0.387	-0.369
Poultry	0.454	0.628	-0.067	-1.015
Fish	0.416	-1.287	-2.100	2.972

Compensated Japanese Model Elasticities

	Beef	*Pork*	*Poultry*	*Fish*
Beef	-0.701	0.113	0.049	0.539
Pork	0.136	-0.343	0.209	-0.001
Poultry	0.148	0.454	-0.766	0.164
Fish	0.200	0.040	0.046	-0.286

US Model Expenditure Elasticities

Beef	0.993
Pork	0.672
Poultry	0.298
Fish	3.274

Japanese Model Expenditure Elasticities

Beef	1.059
Pork	0.466
Poultry	0.656
Fish	1.224

[a] Uncompensated (Marshallian) price elasticities were calculated as:

$m_{ij} = \gamma_{ij} - \beta_i\{w_j - \beta_j(\ln X - \ln P)\}/w_i - \delta_{ij}$

Expenditure elasticities were calculated as:

$e_{ix} = \beta_i / w_i + 1$

Compensated (Hicksian) price elasticities were calculated as:

$h_{ij} = m_{ij} + w_j(1 + \beta_i / w_i)$

where δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j, \delta_{ij} = 0$ for $i \neq j$).

Table 8. Hypothesis Testing: GAIDS vs. AIDS Model Specification[a]

	US Model
	Ho: AIDS Model Complete Autocorrelation Correction Matrix Ha: GAIDS Model Complete Autocorrelation Correction Matrix
LR_B	56.618*
df	4
$\lambda^{0.05,df}$	9.488
	Japanese Model
	Ho: AIDS Model Complete Autocorrelation Correction Matrix Ha: GAIDS Model Complete Autocorrelation Correction Matrix
LR_B	52.730*
df	4
$\lambda^{0.05,df}$	9.488

[a] Reported test statistics are Bewley adjusted likelihood ratio test statistics calculated as: $LR_B = 2*(LL^{Unrestricted} - LL^{\mathrm{Re}stricted})*[(MT - p^{un})/MT]$. where $LL^{Unrestricted}$ and $LL^{\mathrm{Re}stricted}$ are the maximum log likelihood values of the unrestricted and unrestricted models, respectively. M denotes the number of estimated equations, T is the sample size used, and p^{un} denotes the number of parameters in the unrestricted model. *denotes statistical significance at the 5% level and *df* denotes the degrees of freedom for each test.

Table 9. Out-of-Sample Analysis of One-Quarter Forecasting Performance

Root mean square forecast errors (RMSE)

Model	Commodity			
	Beef	Pork	Poultry	Fish
US GAIDS	0.045	0.018	0.021	0.048
US AIDS	0.073	0.030	0.030	0.133
Japan GAIDS	0.080	0.061	0.010	0.012
Japan AIDS	0.094	0.016	0.051	0.020

Mean absolute forecast errors (MAE)

Model	Commodity			
	Beef	Pork	Poultry	Fish
US GAIDS	0.029	0.012	0.010	0.025
US AIDS	0.072	0.030	0.030	0.132
Japan GAIDS	0.079	0.061	0.010	0.012
Japan AIDS	0.088	0.016	0.051	0.020

Mean absolute percentage forecast errors (MAPE)

Model	Commodity			
	Beef	Pork	Poultry	Fish
US GAIDS	0.070	0.047	0.045	0.224
US AIDS	0.177	0.113	0.136	0.126
Japan GAIDS	0.019	0.023	0.046	0.115
Japan AIDS	0.214	0.612	0.228	0.192