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# Model Selection of Meat Demand System Using the Rotterdam Model and the Almost Ideal Demand System (AIDS)

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Aggregated time series data for differentiated meat products namely, beef, pork, poultry, and mutton were used to estimate and analyze Malaysian market demand for meats. The study aimed to select the most appropriate demand model between the equally popular Rotterdam model and the first difference Linear Approximate Almost Ideal Demand System (LA/AIDS) model by using a non-nested test. Both models were accepted, but further diagnostic tests revealed that the first difference LA/AIDS represents more appropriately the Malaysian market demand for meat than the Rotterdam model. Also, the elasticities from the first difference LA/AIDS were found to be more reliable than the Rotterdam model.

Keywords: Non-nested test, Rotterdam, AIDS, meat demand, Malaysia

## Introduction

The consumer demand literature abounds with studies in which different models and estimation techniques of demand functions are applied. The two most widely adopted especially in food demand studies are the Rotterdam model introduced by Theil (1965) and Barten (1969) and Deaton and Muelbauer's (1980) almost ideal demand system (AIDS). Both models are derived from consumer theory, and are used to impose or test behavioral restrictions that are deduced from that theory (Kastens & Brester, 1996). However, neither economic theory nor statistical analysis provides clear *a priori* criteria for choosing between these two models (Lee, Brown, & Seale, 1994). Thus, the choice between which models fits better for a particular data set is an empirical question.

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Jung and Koo (2000), in their study of the structure of Korean meat and fish product demand, compared the Linear Approximate Almost Ideal Demand System (LA/AIDS) and Rotterdam model to determine which of the two models is more appropriate for the data. Their study indicated that the LA/AIDS fits better than the Rotterdam model. In the study made by Tridimas (2000) in analyzing the pattern of consumer demand in Greece, the General Dynamic model of the AIDS fits better than the Static AIDS and the Rotterdam model.

In Malaysia, some studies have been conducted to analyze consumer demand for meat. Abdullah (1994) estimated both static and the dynamic AIDS in analyzing demand for fish and meat products in the country using time series data from 1960 to 1990. His results showed that the dynamic AIDS performed better than the static version. In an earlier study, Baharumshah (1993) used LA/AIDS and tested the model for serial correlation. A recent study by Milad (2003) adopted the Rotterdam model using data from 1970-2000. An *ex post* analysis was done to validate the model. In these studies, either only one functional form is used, so the choice of the model is made arbitrarily or the demand model is selected based on diagnostic tests. No study has been done to select the correct model by using a non-nested hypothesis test. Limited or no study has been done to compare different model specifications that best fit the demand for meat in Malaysia.

The purpose of this article is to analyze meat demand in Malaysia during the period of 1961-2002. The two systems of demand equations, the well-known AIDS and the Rotterdam model, are compared using a non-nested hypothesis test adapted from the compound model approach of Alston and Chalfant (1993). The dynamic structure and the empirical validity of the constraints of demand theory are systematically explored.

Rotterdam versus Almost Ideal Demand System (AIDS)

The estimable absolute price version of the Rotterdam model for $n$ goods is written in the form:

$$\begin{aligned} &\bar{w}_{i,t}\Delta \log q_{i,t} \\ &= a_i + \sum_{j=1}^{n} \gamma_{ij}\, \Delta \log p_{j,t} \\ &+\beta_i\,(\Delta \log X_t \\ &-\textstyle\sum_j \bar{w}_{j,t-1}\Delta \log p_{j,t}) + \varepsilon_{i,t} \end{aligned} \tag{1}$$

where $\bar{w}_{i,t}$ is the average budget share weight between consecutive time periods $t$ and $t-1$ for good $i$ $(i=1,\dots,n)$, $\Delta$ is the across-periods first difference operator $q_{i,t}$, denotes the quantity demanded on good $i$ at time $t$, $p_{j,t}$ is the nominal price of good $j$ at time $t$, $X_t$ is the total expenditure on the $n$ goods at time $t$, $a_i$ , $\gamma_{ij}$ and $\beta_i$ are the parameters to be estimated, and $\varepsilon_{i,t}$ is a zero-mean, normally distributed constant error variance.

The constraints of demand theory can be directly applied to the Rotterdam parameters. These are adding up, $\sum_i \beta_i = 1$, $\sum_i \gamma_{ij} = 0$; homogeneity, $\sum_j \gamma_{ij} = 0$; and symmetry, $\gamma_{ij} = \gamma_{ji}$. The AIDS model on the other hand derives demand function for each consumption item in budget share form. However, in the time series context, the AIDS model is often estimated in the first difference form to reduce the autocorrelation effect. And so, to make it consistent with the Rotterdam form, first difference LA/AIDS is then specified as:

$$\begin{aligned} &\Delta w_{i,t} \\ &= a_i + \sum_{j=1}^{n} \gamma_{ij}\Delta \log p_{j,t} \\ &+\beta_i[\Delta \log X_t \\ &-\sum_{j=1}^{n} w_{j,t-1}\Delta \log p_{j,t}] + \varepsilon_{i,t} \end{aligned} \tag{2}$$

Where the only difference in notation from equation (1) involves $w$, which is actual expenditure share weight at time $t$ rather than a two-period average in equation (1). The theory of demand implies the following restriction on the parameters: adding up, $\sum_j \gamma_{ij} = 0, \sum_i \beta_i = 0$; homogeneity, $\sum_j \gamma_{ij} = 0$; and symmetry, $\gamma_{ij} = \gamma_{ji}$ .

It is obvious that the Rotterdam model and the first difference LA/AIDS model are non-nested models. They are not directly comparable, because they have different dependent variables. However, comparisons of the right-hand sides of equations (1) and (2) indicate their similarity. Ex post analysis via statistical tests from estimating both models may suggest one is preferable but these kinds of comparisons are necessarily incomplete. Thus, when comparing these models, one needs an alternative procedure for the competing alternatives (Lee et. al, 1994).

Non-nested Test

Non-nested hypothesis tests select between two regression models where one model cannot be written as a special case of the other. In such a case, the models themselves are said to be non-nested (http://go.okstate.edu/~brorsen/aidsvsrotterdam). Alston and Chalfant (1993) developed a compound model approach in testing the two alternative models in which the right hand sides are identical but the dependent variables are not.

Let the two models be defined as:

Model 1: $y = f(x)$
Model 2: $z = f(x)$

Using the Box-Cox transformation to nest both alternatives, and to test each against the more general alternative, the compound model is estimated as:

$$\lambda y + (1-\lambda) z = f(x) \quad (3)$$

Thus, following Alston and Chalfant (1993) in testing for the Rotterdam model, the two alternative models can be combined as:

Test 1:
$$(1-\phi)\Delta\bar{w}_i \log(q_i) + \phi\Delta w_i = \sum_{j=1}^{n} \gamma_{ij} \Delta \log(p_j) + \beta_i[\Delta \log X - \sum_{j=1}^{n} \bar{w}_j \Delta \log p_j] \quad (4)$$

Equation (4) is a linear combination of the first difference LA/AIDS and the Rotterdam model. If $\phi = 0$, Equation (4) reduces to the Rotterdam model. A test of the hypothesis that $\phi = 0$ can be interpreted as a test of the hypothesis that the Rotterdam is the correct model.

The LA/AIDS can be tested directly as well. In the alternative compound model,

Test 2:
$$(1-\lambda)\Delta w_i + \lambda\Delta\bar{w}_i \log(q_i) = \sum_{j=1}^{n} \gamma_{ij} \Delta \log(p_j) + \beta_i[\Delta \log X - \sum_{j=1}^{n} w_j \Delta \log p_j] \quad (5)$$

a $\lambda = 0$ test implies that the first difference LA/AIDS is the correct model. And as with any pair of non-nested models, there are four possible outcomes from such a test: reject both, neither or either one of the two hypotheses. It is only when neither models are rejected that discrimination criteria via diagnostic tests could be used to select the best model (Doran, 1993).

Data

Time series data from 1961-2002 is used to estimate the meat demand model. Beef, pork, mutton, and poultry per capita annual consumption data are obtained from the FAOSTAT database (http://faostat.fao.org). The prices are average annual retail prices obtained from various reports of Division of Veterinary Services (DVS) (www.jphpk.gov.my) and Federal Agricultural Marketing Authority (FAMA) of Malaysia.

Model Estimation

The demand model consists of four equations, including beef, pork, poultry, and mutton. The iterated seemingly unrelated regression procedure available in SAS is used as an estimation method. Symmetry, adding up, and homogeneity conditions were all imposed to make the models consistent with underlying economic theory. The mutton equation was not included in the system during the estimation process to avoid singularity in the covariance matrix. The parameters of the deleted equation were recovered using the adding up restriction.

## Results

The test for the Rotterdam model as the correct specification is not rejected at any reasonable significance level. The estimated value of $\phi$ is 0.4853 with a p-value of 0.1658. Therefore, imposing the Rotterdam model as a restriction on the compound model is supported by this data. However, the test on the first difference LA/AIDS as an alternative model, the $\lambda = 0$ test is also not significant. The estimated value of $\lambda$ is 0.1560 with a p-value of 0.1389. In other words, imposing the LA/AIDS as a restriction on the compound model is also supported by this data. Therefore, the outcome of the tests reveals that both models are accepted. This implies that this specific data is not rich enough to discriminate between the Rotterdam and the first-difference LA/AIDS models.

In order to discriminate between the two systems, the empirical performance was

Table 1. Parameter Estimates with Homogeneity and Symmetry Imposed

| | Rotterdam Model | | | | First Difference LA/AIDS | | | |
|---|---|---|---|---|---|---|---|---|
| | Beef | Pork | Poultry | Mutton | Beef | Pork | Poultry | Mutton |
| $\gamma_{1i}$ | -0.046 | | | | 0.086* | | | |
| | (0.032) | | | | (0.033) | | | |
| $\gamma_{2i}$ | 0.013 | 0.010 | | | -0.048* | 0.230* | | |
| | (0.016) | (0.020) | | | (0.017) | (0.021) | | |
| $\gamma_{3i}$ | 0.013 | -0.008 | 0.005 | | -0.050* | -0.160* | 0.228* | |
| | (0.018) | (0.015) | (0.019) | | (0.018) | (0.014) | (0.018) | |
| $\gamma_{4i}$ | 0.018 | -0.036 | 0.025 | 0.020 | 0.017 | -0.045 | 0.009 | 0.020 |
| | (0.032) | (0.041) | (0.034) | | (0.033) | (0.042) | 0.032 | |
| $\beta_i$ | 0.103* | 0.644* | 0.219* | 0.017 | -0.020 | 0.182* | -0.179* | 0.017 |
| | (0.047) | (0.060) | (0.051) | | (0.050) | (0.065) | (0.050) | |
| Constant | 0.002 | -0.014* | 0.013* | 0.999 | 0.001 | -0.014* | 0.015* | 0.999 |
| | (0.003) | (0.004) | (0.003) | | (0.003) | (0.004) | (0.003) | |
| Adj. $R^2$ | 0.0307 | 0.7449 | 0.2831 | | 0.234 | 0.806 | 0.870 | |
| RMSE | 0.0165 | 0.0216 | 0.0182 | | 0.017 | 0.023 | 0.017 | |

*Denotes significance at the 5 per cent, based on asymptotic t-ratios. $i =$ 1,2,3 and 4, where 1 = beef, 2 = pork, 3 = poultry, 4 = mutton

examined with regard to goodness-of-fit, forecasting accuracy, and the elasticity behaviors of the demand systems.

The parameter estimates for both models are reported in Table 1. Five of the 18 coefficients are significantly different from zero in the Rotterdam model, although ten coefficients are statistically significant for the first difference LA/AIDS model. No price coefficient is statistically significant in the Rotterdam model.

The first difference LA/AIDS model performs better than the Rotterdam model as indicated by the adjusted $R^2$ in each meat equation. The first difference LA/AIDS model has the highest adjusted $R^2$.

Based on the predictive accuracy of the model, the RMSE measures the *ex post* forecasting performance. From table 1, the RMSEs are the lowest from the first difference LA/AIDS model, suggesting a better fit than the Rotterdam model.

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Demand systems are consistent with the assumptions of utility maximization if they satisfy homogeneity and symmetry restrictions. Testing and imposing of demand restrictions are central to the empirical analysis of demand. Table 2 reports the results of the joint symmetry and homogeneity restriction test. Both models accept the null hypothesis of joint symmetry and homogeneity at 5 % significance levels. Thus, the data confirms with the theoretical restrictions of demand in both models.

Choosing between alternative specifications of the model by a purely statistical test is the interest of model selection. The influence of model choice on elasticity estimates is also worth considering. The parameter estimates obtained from both models are used to calculate the demand elasticity estimates in each model.

The following elasticity formulas were calculated using the formula from Barten[6] :

Table 2. Joint Symmetry and Homogeneity Restriction Test

| Model | Alternative Hypothesis | Number of restrictions | F-Value | Pr>F | Conclusion |
|---|---|---|---|---|---|
| Rotterdam Model | No Restriction | 6 | 0.83 | 0.5517 | Accept Ho |
| LA AIDS Model | No Restriction | 6 | 0.99 | 0.4360 | Accept Ho |

| | Rotterdam Model | LA/AIDS model | |
|---|---|---|---|
| Expenditure Elasticity | $\eta_i = \beta_i / \overline{w}_i$ | $\eta_i = 1 + \beta_i / \overline{w}_i$ | (6) |
| Compensated Elasticity | $e_{ij}^c = \gamma_{ij} / \overline{w}_i$ | $e_{ij}^c = -\delta_{ij} + (\gamma_{ij} / \overline{w}_i) + \overline{w}_j$ | (7) |
| Uncompensated Elasticity | $e^u{}_{ij} = (\gamma_{ij} - \beta_i \overline{w}_j) / \overline{w}_i$ | $e^u{}_{ij} = (\gamma_{ij} - \beta_i \overline{w}_j) / \overline{w}_i$ | (8) |

Where $\delta = 1$ for $i = j$ and $\delta = 0$ otherwise. $\overline{w}$ is the average budget share in each meat equation a. $\beta_i$ and $\gamma_{ij}$ are the estimated parameters.

The estimated elasticities exhibit some similarities and minor differences between the two models. Looking at Table 3, the calculated expenditure elasticity estimates are similar for both models and suggest that beef and poultry are necessities in Malaysia, while pork and mutton are luxury meat products.

Table 3. Estimated Expenditure Elasticities: Rotterdam and Almost Ideal Specification

| | Rotterdam Model | LAAIDS Model |
|---|---|---|
| Beef | 0.62 | 0.88 |
| Pork | 1.54 | 1.44 |
| Poultry | 0.57 | 0.54 |
| Mutton | 1.13 | 1.56 |

Table 4 summarizes the uncompensated and compensated price elasticity estimates of both models. The own-price elasticities of the first difference LA/AIDS model have all the correct negative signs while the Rotterdam model compensated own-price elasticity for pork (0.02) and poultry (0.01) are positive, which are unexpected. All the own-price elasticities are less than 1 implying that these meat commodities are price inelastic. In all cases, the absolute value of own-price elasticity is greater in the LA/AIDS model (both uncompensated and compensated). Pork has the greatest uncompensated own-price elasticity. Beef, mutton, and poultry follow it.

With respect to the cross price elasticity estimates, the results from the first difference LA/AIDS model are similar to the results obtained from the cross price elasticity estimates of the Rotterdam model. However, they do differ in the value of the estimates generated. The Marshallian cross price elasticity estimates are mostly negative which indicate gross complements among the meat products.

The results are in accordance to the results obtained by Wohlgenant and Hahn (1992) and Alston and Chalfant (1993), in their studies in the US. Their studies have found that the elasticity estimates from the Rotterdam model and first difference LA/AIDS model have minor differences despite the variation in their implications and their consistency with the data. Their results produce very similar elasticities although one model is rejected in favor of the other.

However, the results reported in the preceding paragraphs revealed that though the estimates from both models are quite similar. The estimates from the Rotterdam model are found to be in question based on their signs. This result is comparable to the study made by Lee et al. (1994) on general consumption patterns in Taiwan; they concluded that elasticity estimates from the Rotterdam model are questionable. Thus, choice of functional form and demand elasticity estimates for the Rotterdam and Almost Ideal Demand models may vary with the data set (Xu & Veeman, 1996).

Table 4. Estimated Elasticities: Rotterdam and LA/Almost Ideal Demand Specification

| Quantity | Price | Uncompensated | | Compensated | |
|---|---|---|---|---|---|
| | | Rotterdam | LA AIDS | Rotterdam | LA AIDS |
| Beef | Beef | -0.38 | -0.46 | -0.28 | -0.31 |
| | Pork | -0.22 | -0.19 | 0.03 | 0.05 |
| | Poultry | -0.06 | -0.05 | 0.03 | 0.04 |
| | Mutton | 0.40 | 0.46 | 0.59 | 0.72 |
| Pork | Beef | -0.18 | -0.24 | 0.08 | 0.13 |
| | Pork | -0.62 | -0.63 | 0.02 | -0.03 |
| | Poultry | -0.26 | -0.22 | -0.02 | 0.005 |
| | Mutton | -1.65 | -1.73 | -1.18 | -1.07 |
| Poultry | Beef | -0.16 | -0.26 | 0.08 | 0.08 |
| | Pork | -0.61 | -0.55 | -0.02 | 0.004 |
| | Poultry | -0.21 | -0.23 | 0.01 | -0.02 |
| | Mutton | 0.39 | 0.07 | 0.83 | 0.67 |
| Mutton | Beef | 0.08 | 0.11 | 0.11 | 0.13 |
| | Pork | -0.13 | -0.12 | -0.08 | -0.08 |
| | Poultry | 0.05 | 0.04 | 0.07 | 0.05 |
| | Mutton | -0.28 | -0.37 | -0.24 | -0.32 |

## Conclusion

The purpose of the article is to analyze the market demand for differentiated meat products in Malaysia during the period 1961-2002. The functional forms selected have been the popular Rotterdam and Almost Ideal Demand models. Comparison of the two models required the use of a non-nested test. Moreover, economic criteria and the behavior of the elasticity estimates were used to evaluate the demand systems.

For this particular data, the compound model approach suggested by Alston and Chalfant (1993) was used to nest and select the appropriate model in this study. The results suggested that the first difference LA/AIDS or the Rotterdam models are both appropriate to represent Malaysian demand for differentiated meat products. Also, turning to the empirical validity or testing for the joint symmetry and homogeneity restrictions showed that both models satisfy the theoretical restriction of demand.

However, the first difference LA/AIDS gained superiority over the Rotterdam model based on its goodness of fit and reliability of estimates. The first differenced LA AIDS fits well with the data as reflected by its higher Adjusted $R^2$ and lower RMSE relative to the Rotterdam model. Compensated own- price elasticity estimates of pork and poultry from the Rotterdam model do not carry the expected signs, which render the estimates from the Rotterdam model questionable. Thus, the first difference LA/AIDS is chosen in favor of the Rotterdam model.

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