

# final report

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## Updating a Model of Meat Demand in Australia to Test for the Impact of MSA

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## **Abstract**

Empirical systems of equations modelling approaches were used to (i) try and ascertain the impacts of MSA graded meat on domestic quantities of meat demanded and to (ii) generate updated estimates of consumer responses to price and expenditure changes with respect to domestic retail meat demand. Little evidence was found to suggest that aggregate consumer preferences have changed since the introduction of the MSA grading scheme. However, consumer demand for beef, lamb and pigmeat has become less responsive to changes in their respective prices in recent years. The data compiled for this project provides an updated and consistent set of data that can be used to examine other influences on Australian domestic meat demand.

## Executive Summary

The Meat Standards Australia voluntary meat grading system commenced in 1999/2000. The benefits from this scheme have been estimated using MLA survey data on premiums paid for MSA graded cuts each year to the number of carcasses that are graded each year and that achieve at least a 3 star score. However no data exist on actual quantities of beef that is sold as MSA.

The aims of this project were to update a basic set of data used in earlier analyses of Australian domestic meat demand to determine if the availability of the MSA system has impacted on the aggregate demand for beef.

The aggregate demand for beef was analysed in the context of a number of formal demand systems models inclusive of substitute meats in consumption. Tests were undertaken to try and detect structural change associated with the introduction of the MSA grading system in 1999-2000. Pre-and-post introduction of MSA subsets of the data were used to generate expenditure and own-price elasticity of demand estimates for the different types of meat. Expectations are that substitution in consumption is likely to occur from non-MSA to MSA graded meat. A more inelastic own-price elasticity of demand for beef in the MSA period would indicate evidence of this. However the results from the structural change test and elasticity comparison proved inconclusive.

Three distinct structural changes were identified in the data with the latter of the three occurring in 1988 with the introduction of pigmeat imports into Australia. Based on these results the preferred own-price and expenditure elasticity estimates derived from the modelling correspond to the data sub sample covering the period inclusive of pigmeat imports. The own-price elasticity of demand estimates over this period imply that consumer demand for beef, lamb and pigmeat has become less responsive to changes in their prices in recent years.

The data compiled for this project provides an updated and consistent set of data that can be used to examine other influences on Australian domestic meat demand.

## Contents

<b>1 Background .....</b>	<b>5</b>
<b>2 Project Objectives .....</b>	<b>5</b>
<b>3 Methodology .....</b>	<b>5</b>
3.1 Description of the models .....	5
3.2 Updating the data .....	6
3.3 Estimation of the models.....	10
<b>4 Results .....</b>	<b>12</b>
4.1 Coefficient estimates .....	12
4.2 Elasticity estimates .....	14
4.3 Comparison with previous elasticity estimates.....	15
4.4 Testing for structural change .....	18
4.5 Structural change and MSA .....	21
4.6 Structural change and elasticity estimates.....	22
<b>5 Discussion and conclusions .....</b>	<b>28</b>
<b>6 Bibliography .....</b>	<b>30</b>
<b>7 Appendix: Data descriptions.....</b>	<b>32</b>

## 1 Background

The Meat Standards Australia (MSA) voluntary meat grading system has generated large net industry benefits since it commenced in 1999/2000 (Griffith *et al.* 2009). These benefits have been estimated by applying MLA survey data on premiums paid for MSA graded cuts each year to the number of carcasses that are graded each year and that achieve at least a 3 star score. Unfortunately there are no data available that gives actual quantities of beef that is sold as MSA. While the calculations take account of the proportion of the carcass that is MSA cuts, all the values are calculated on a carcass equivalent basis.

A possible way to obtain more information about the quantity side is to analyse the aggregate demand for beef in the context of a formal demand systems model to determine if any impact on the demand for beef due to the availability of the MSA scheme can be isolated after accounting for all of the other factors that are known to influence the demand for different meats. Such formal demand systems models have been specified and validated in the past (Goddard and Griffith 1992, Hutasuht 1995, Piggott *et al.* 1996) but they are now quite dated and predate MSA.

## 2 Project Objectives

The objectives of this project were to:

1. update the existing demand systems models using quarterly price and quantity data from 1965 to 2010.
2. generate updated estimates of price and expenditure elasticities of domestic demand for beef, lamb, pigmeat and chicken.
3. assess the updated estimates of price and expenditure elasticities of domestic demand for beef, lamb, pigmeat and chicken against previous estimates.
4. estimate the demand system models to try and ascertain the influence on beef demand of the availability of MSA-graded beef.

## 3 Methodology

### 3.1 Description of the models

Different empirical approaches can be used in estimating demand, ranging from single equation models to systems of equations approaches, as is used in this study. A systems approach is desirable in that it is more consistent with demand theory. An added advantage is that cross-commodity relationships are captured within a systems framework. This is an important consideration in modelling meat demand given the interrelatedness in consumption of the different types of meat.

The existing demand systems models used in the estimations in this study are flexible functional form models which are preferable for use in demand system analyses because (i) they are able to “approximate a wider range of underlying sets of preferences” and (ii) have “a smaller risk of specification bias arising from either incorrect functional forms or using a model that is not fully consistent with the theory of consumer demand” (Piggott *et al.* 1996).

It is desirable to estimate a number of flexible demand system models to determine the sensitivity of results to model choices as empirical results also depend on model choices (Alston and Chalfant 1991).

The models updated in this project are<sup>1</sup>:

1. the Almost Ideal Demand System (AIDS)
2. the (LA/AIDS) model which is a linear approximation of AIDS
3. the first differenced form of the LA-AIDS
4. the Rotterdam Model

### 3.2 Updating the data

A number of studies have used the same basic set of data with different time spans in analyses of Australian domestic meat demand (Main *et al.* 1976; Reynolds 1978; Fisher 1979; Martin and Porter 1985; Cashin 1991; Piggott 1991; Goddard and Griffith 1992; Hutasukhut 1995; Piggott *et al.* 1996).

An updated version of this base data set is used in this project. The data comprise quarterly observations on retail prices and apparent consumption of beef, lamb, pigmeat and chicken beginning in the first quarter 1965 and ending in the fourth quarter 2010<sup>2</sup>. Annual data are considered too sparse to represent one complete consumption adjustment, whereas monthly data are too short to allow the full transmission of the effects of exogenous shocks on consumption. The data consists of four quantity variables (kilograms per capita) and four retail price variables (cents per kilogram):

- beef consumption
- lamb consumption
- pigmeat consumption
- chicken consumption
- beef price
- lamb price
- pigmeat price
- chicken price.

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<sup>1</sup> Detailed descriptions of the models can be found in Deaton and Muellbauer (1980); Barten (1969); Theil (1980).

<sup>2</sup> Data descriptions and sources are listed in Appendix 1.

Nominal retail prices for each of the four meat types were deflated by the Consumer Price Index (1989/90 = 100) to convert them into real prices.

Figure 1 depicts the quarterly per capita consumption of the four meat types in Australia over the past 45 years. Both beef and lamb consumption have fallen over the period but have remained relatively stable since the early 1990s. Average quarterly per capita beef and lamb consumption from 1990 to 2010 was approximately 9.2kg and 2.8kg, respectively. Conversely per capita consumption of pigmeat and chicken has increased. From 1965 to 2010 average quarterly per capita consumption of pigmeat and chicken increased by around 240 per cent and 600 per cent, respectively.

**Figure 1: Australian quarterly meat consumption (kg/capita), 1965 to 2010**

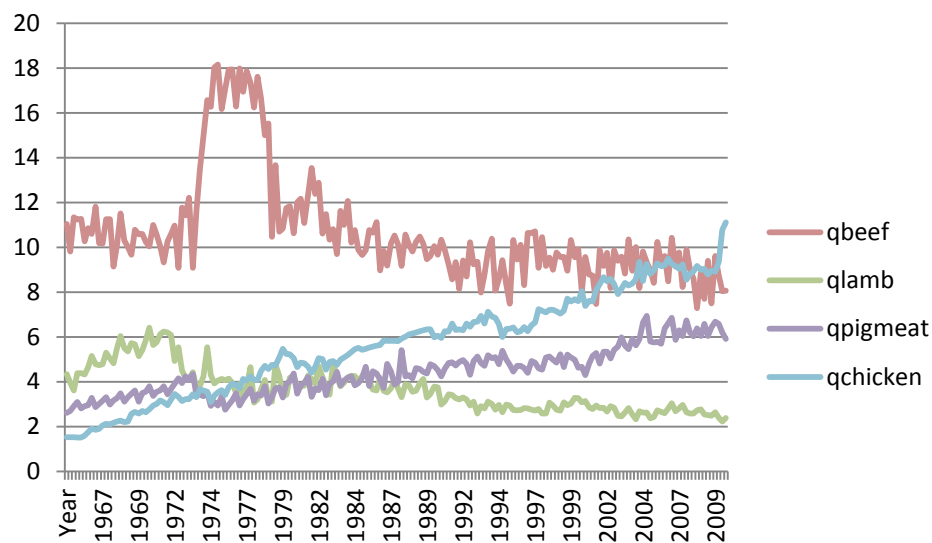
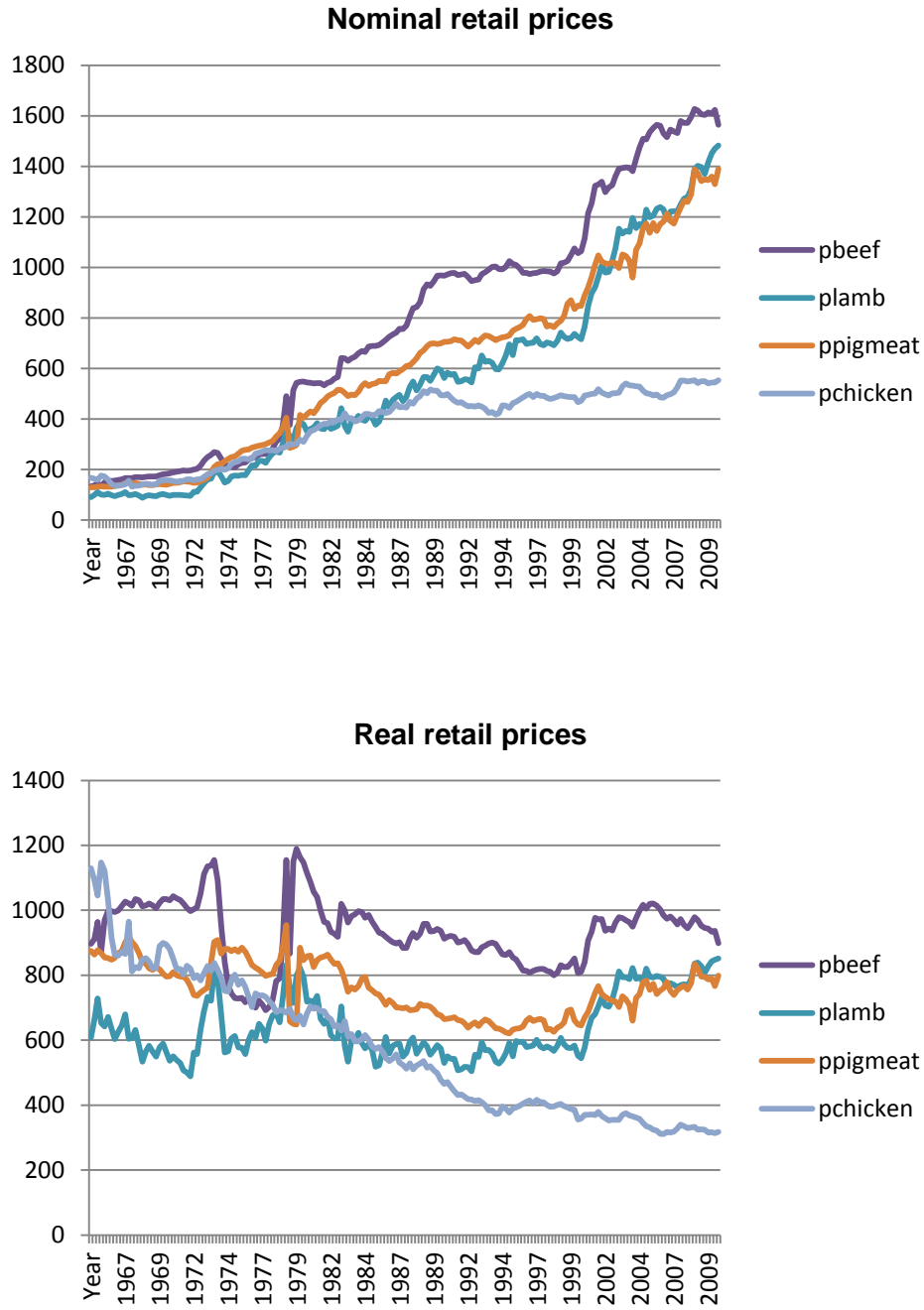


Figure 1 and Figure 3 indicate there was a significant increase in beef consumption in Australia in the mid-to-late 1970s. This coincides with a period of increased trade restrictions in Australia's major export markets. Consequently large export quantities of beef were diverted back onto the domestic market resulting in the suppression of domestic beef prices. The increased supply of beef also impacted on domestic lamb and pigmeat in terms of lower levels of consumption and lower real retail prices as can be seen in Figure 1 and in the bottom part of Figure 2. This highlights the importance of including related products in empirical analyses.

Nominal and real retail prices for the four meat types are plotted in Figure 2. In real terms retail beef prices in 2010 were similar to prices in 1965 while real lamb prices were higher. Both pigmeat and chicken prices were lower. Since the mid to late 1990s real retail prices for beef, lamb and pigmeat have steadily increased, however real chicken prices have been falling steadily over the entire sample period.

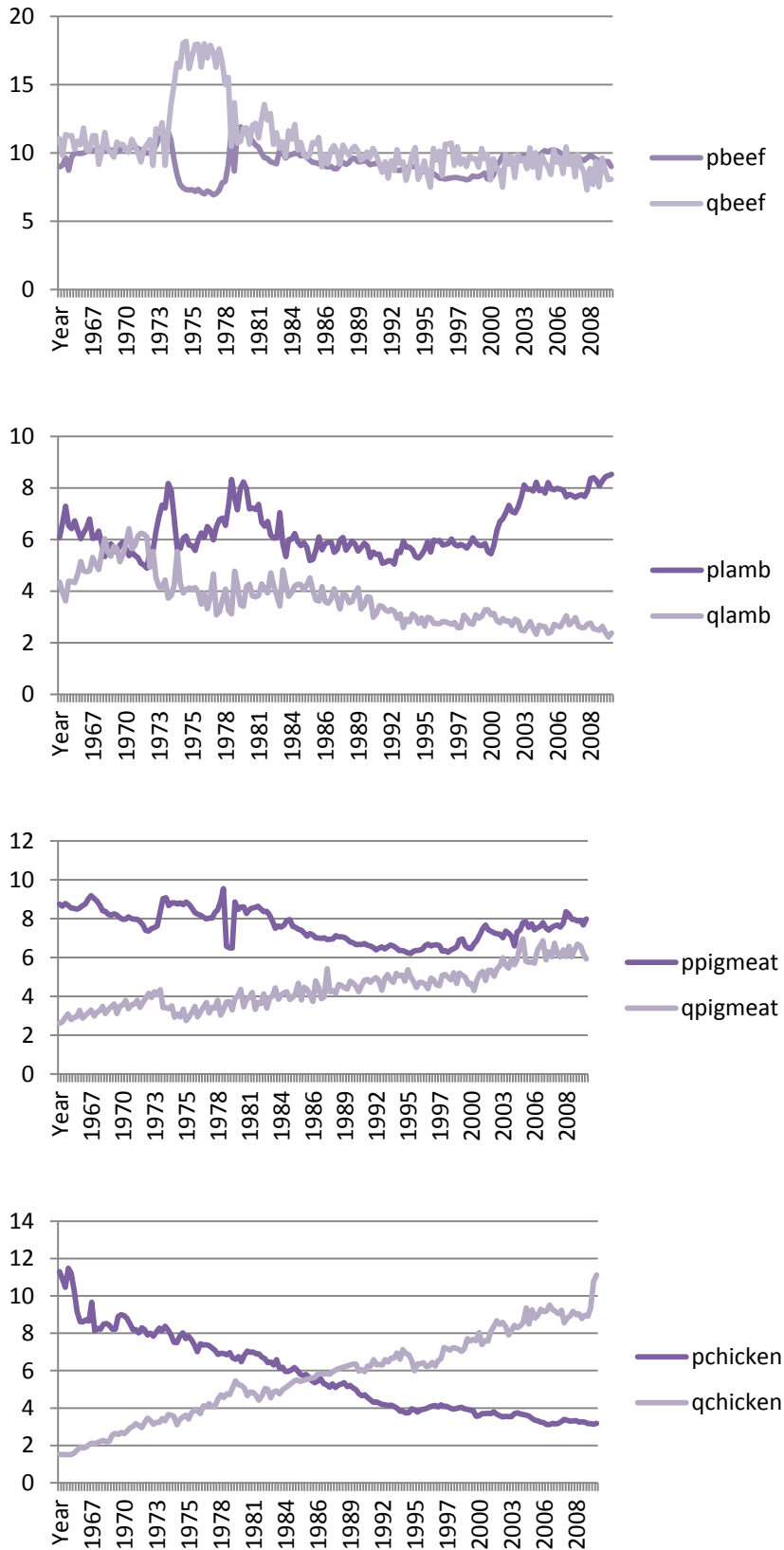
In Figure 3 real retail prices are plotted with per capita consumption of each meat. In general, it is evident that higher real meat prices are associated with lower per capita consumption levels and vice versa.

**Figure 2: Nominal and real retail prices (c/kg), 1965 to 2010**





**Figure 3: Real retail price (\$/kg) and quantity consumed (kg/capita), 1965 to 2010**



### 3.3 Estimation of the models

All of the demand systems were estimated using Shazam (Version 10). The model specifications used in these demand systems exhibit similar characteristics in that they are flexible functional forms which are linear in the parameters and they utilise the same data requirements. The equations in the models are expressed in terms of budget shares (expenditure shares on each type of meat). In the estimation procedures it is necessary to omit one share equation from the model to avoid matrix singularity problems. In each of the specifications the chicken share equations were excluded from the estimations. The coefficients for the chicken equations were obtained from the parameters of the equations included in the systems using the adding up restriction:

$$\sum \beta_i = 0 \quad \sum \gamma_{ik} = 0 \quad \sum \tau_i = 0$$

Certain restrictions that specify key relationships among demand elasticities were implemented and tested in each of the models<sup>3</sup>. The relationships are based on the theory of consumer behaviour and assume that; (i) consumers rank commodity bundles in order of preference; (2) the ranking is transitive and (3) non-satiation exists in that more of a good is preferred to less.

The homogeneity restriction implies that an equal proportionate change in all prices and incomes should not alter the quantity demanded of the different meats. Mathematically this means that the sum of the own-price, cross-price and income elasticities are equal to zero:

$$\sum \varepsilon_{ik} = 0$$

The symmetry condition implies that consumer behaviour is consistent between commodities, that is, the substitution effect of a price change is symmetrical:

$$\gamma_{ij} = \gamma_{ji}$$

Likelihood ratio (LR) tests were carried out to test the restrictions and various model specifications. The LR test is based on computing the values of the maximised log-likelihood functions for the unrestricted model and the model with restrictions imposed. The null hypothesis is that the restrictions are true. If the difference between the two maximums is large, then the null hypotheses, and therefore the restrictions, are rejected. In testing the hypothesis the values of the LR test statistic are compared with critical values from chi-square distribution with  $j$  (the number of restrictions) degrees of freedom.

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<sup>3</sup> See Tomek and Robinson (2003, pp.39-45) for a more detailed discussion of these restrictions.

The likelihood ratio test statistic is:

$$LR = -2 (LLF\_R - LLF\_U)$$

Where:

LLF\_R is the maximum value of the log likelihood function with the restriction.

LLF\_U is the unrestricted maximum value of the log likelihood function.

The adjusted likelihood ratio test statistic is:

ALR = ((T-k)/T)LR where T represents the number of observations and k represents the number of explanatory variables.

The likelihood-ratio test results from the imposition of homogeneity, symmetry and combined homogeneity and symmetry restrictions are listed in Table 1. At the 5 per cent level of significance the AIDS model rejected the imposition of the homogeneity and symmetry restrictions, both separately and combined. The LA/AIDS model did not reject the homogeneity restriction individually but did reject the joint restrictions. All three combinations of restrictions were rejected in the Rotterdam model.

**Table 1: Likelihood ratio tests for homogeneity, symmetry and both homogeneity and symmetry restrictions imposed**

Model	LLF_U	LLF_R	LR	ALR	Number of restrictions
<b>homogeneity</b>					
AIDS	1836.87	1850.01	26.28	22.28*	3
LA/AIDS	1829.59	1827.44	4.3	3.67	3
ROTTERDAM	1830.15	1825.42	9.46	8.23*	3
<b>symmetry</b>					
AIDS	1836.87	1846.99	20.24	17.16*	3
LA/AIDS	1829.59	1821.97	15.24	13.00*	3
ROTTERDAM	1830.15	1815.34	29.62	25.76*	3
<b>Homogeneity and symmetry</b>					
AIDS	1836.87	1846.45	19.16	16.24*	6
LA/AIDS	1829.59	1821.62	15.94	13.86*	6
ROTTERDAM	1830.15	1815.14	30.02	26.59*	6

LLF\_U = unrestricted log likelihood value

LLF\_R = restricted log likelihood value

ALR = adjusted LR statistic

Critical values are  $\chi^2(0.10)=6.251$ ,  $\chi^2(0.05)=7.815$ ,  $\chi^2(0.01)=11.345$  for r=3.

Critical values are  $\chi^2(0.10)=10.645$ ,  $\chi^2(0.05)=12.592$ ,  $\chi^2(0.01)=16.812$  for r=6.

\* denotes statistically significant at the 5 per cent level.

Taken at face value the results of the hypotheses tests appear contradictory to expectations. However, closer inspection reveals that the magnitudes of the differences between the maximised log-likelihood functions for the unrestricted and restricted models are not overly large.

Other studies (for example, Goddard and Griffith 1992; Hutasuht 1995) have also found mixed results. In maintaining consistency with the theory of consumer demand, the restrictions were imposed in each of the estimated models.

## 4 Results

### 4.1 Coefficient estimates

The coefficient estimates from the different models are presented in Table 3 (corresponding notation is in Table 2). In almost all cases the expenditure ( $\beta$ ) coefficients and seasonality coefficients ( $\theta$ ) are statistically significant. The time trend coefficients ( $\tau$ ) are significant in all models except the AIDS model. Approximately 40 per cent of the price coefficients across all models are significant at the 5 per cent level.

**Table 2: Notation**

*	denotes statistically significant at the 5 per cent level
#	denotes derived from adding up
$\alpha_0$	Intercept term in the price index for the 'true' AIDS model
$\alpha_i$	Intercepts ( $i = 1, 2, 3, 4$ for beef, lamb, pigmeat and chicken)
$\beta_i$	expenditure coefficients ( $i = 1, 2, 3, 4$ for beef, lamb, pigmeat and chicken)
$\gamma_{ij}$	price coefficients ( $i = 1, 2, 3, 4$ for beef, lamb, pigmeat and chicken)
$\tau_i$	coefficient for time trend ( $i = 1, 2, 3, 4$ for beef, lamb, pigmeat and chicken)
$\theta_{ik}$	seasonality coefficients ( $i = 1, 2, 3, 4$ for beef, lamb, pigmeat and chicken; $k = 2, 3, 4$ for second, third and fourth quarter)
$\eta_i$	expenditure elasticity of demand ( $i = 1, 2, 3, 4$ for beef, lamb, pigmeat and chicken)
$\varepsilon_i$	uncompensated price elasticity of demand for good $i$ with respect to price of good $j$ ( $i = 1, 2, 3, 4$ for beef, lamb, pigmeat and chicken)
LLF	log-likelihood function

**Table 3: Coefficients for system of equations models with homogeneity, Slutsky symmetry and adding-up restrictions imposed and corrected for autocorrelation**

Parameters	LA/AIDS	First Differenced LA/AIDS	AIDS	Rotterdam
$\alpha_0$	-		-5.529	-
$\alpha_1$	-0.254*	-	-1.644	-
$\alpha_2$	0.253*	-	0.389	-
$\alpha_3$	0.433*	-	0.934	-
$\alpha_4$	0.568#	-	1.322#	
$\beta_1$	0.264*	0.282*	0.265*	0.866*
$\beta_2$	-0.027*	-0.023	-0.036	0.070*
$\beta_3$	-0.096*	-0.108*	-0.097*	0.055*
$\beta_4$	-0.141#	-0.151#	-0.133#	0.010#
$\gamma_{11}$	0.149*	0.122*	-0.493	-0.148*
$\gamma_{12}$	-0.024	0.006	0.069	0.077*
$\gamma_{13}$	-0.059*	-0.069*	0.168	0.050*
$\gamma_{14}$	-0.066#	-0.060#	0.256#	0.021#
$\gamma_{22}$	0.016	0.008	-0.007	-0.103*
$\gamma_{23}$	-0.004	-0.009	-0.034	-0.007
$\gamma_{24}$	0.012#	-0.005#	-0.287#	0.033#
$\gamma_{33}$	0.100*	0.1038*	0.017	-0.035*
$\gamma_{34}$	-0.037#	-0.025#	-0.150#	-0.004#
$\gamma_{44}$	0.092#	0.090#	-0.079#	-0.084#
$\tau_1$	-0.001*	-0.0001*	-0.002	0.0001*
$\tau_2$	-0.0002*	0.00002*	0.0131	-0.00002*
$\tau_3$	0.001*	0.00003*	0.706	-0.00002*
$\tau_4$	0.001#	0.00001#	-0.717#	-0.00002#
$\theta_{12}$	0.037*	0.036*	-0.014*	-0.018*
$\theta_{13}$	0.022*	-0.008*	-0.015*	0.001
$\theta_{14}$	0.021*	-0.002	-0.033*	-0.018*
$\theta_{22}$	-0.010*	-0.011*	0.0002	0.001
$\theta_{23}$	-0.009*	-0.002	0.005*	0.004*
$\theta_{24}$	-0.004*	0.004*	0.009*	0.005*
$\theta_{32}$	-0.019*	-0.019*	0.013*	0.014*
$\theta_{33}$	-0.006*	0.009*	0.009*	-0.006*
$\theta_{34}$	-0.010*	-0.004*	0.018*	0.007*
LLF	1821.617	1781.263	1846.45	1815.14

\* denotes statistically significant at the 5 per cent level; # denotes derived from adding up.

## 4.2 Elasticity estimates

Elasticity estimates measure the response in one variable from a change in another variable. Marshallian (uncompensated) own-price elasticity of demand, cross-price elasticity of demand and expenditure elasticity of demand estimates, calculated from the different models, are listed in Table 4. All elasticity estimates were calculated at the sample means.

**Table 4: Uncompensated price and expenditure elasticities for restricted systems of equations models**

	LA/AIDS	First Differenced LA/AIDS	AIDS	Rotterdam
<b>Expenditure</b>				
$\eta_1$	1.492	1.526	1.494	1.613
$\eta_2$	0.783	0.820	0.716	0.555
$\eta_3$	0.477	0.409	0.473	0.299
$\eta_4$	0.092	0.026	0.141	0.063
<b>Price</b>				
$\epsilon_{11}$	-0.986	-1.053	-2.183	-1.141
$\epsilon_{12}$	-0.107	-0.056	0.067	
$\epsilon_{13}$	-0.200	-0.224	0.222	
$\epsilon_{14}$	-0.199	-0.193	0.401	
$\epsilon_{22}$	-0.844	-0.913	-1.019	-0.890
$\epsilon_{23}$	0.009	-0.039	-0.222	
$\epsilon_{24}$	0.127	-0.011	-0.177	
$\epsilon_{33}$	-0.357	-0.330	-0.812	-0.247
$\epsilon_{34}$	-0.123	-0.046	-0.737	
$\epsilon_{44}$	-0.268	-0.270	-1.375	-0.300

The expenditure elasticity of demand is used as a proxy for income and is a measure of how responsive the quantity purchased of a good is to a change in expenditure. Under the assumption of 'weak separability', expenditure in this instance refers only to expenditure on meat<sup>4</sup>. In simple terms the expenditure elasticity of demand is the ratio between the percentage change in quantity demanded and the percentage change in expenditure:

$$\eta_i = \frac{\text{percentage change in quantity demanded of good } i}{\text{percentage change in consumer expenditure}}$$

<sup>4</sup> 'Weak separability' assumes, for example, that the expenditure on meat and the allocation of that expenditure among the four different types of meat will only depend on the prices of the different meats and will be independent of expenditures on other non-meat goods and services.

The own-price elasticity of demand is a measure of how responsive the quantity purchased of a good is to a change in its own price. In simple terms it is the ratio between the percentage change in quantity demanded and the percentage change in price:

$$\varepsilon_{ii} = \frac{\text{percentage change in quantity demanded of good } i}{\text{percentage change in the price of good } i}$$

The cross-price elasticity of demand is a measure of how responsive the quantity purchased of a good is to a change in the price of a related good. In simple terms it is the ratio between the percentage change in quantity demanded and the percentage change in price:

$$\varepsilon_{ij} = \frac{\text{percentage change in quantity demanded of good } i}{\text{percentage change in the price of good } j}$$

Consistent with expectations, the expenditure elasticities of demand in Table 4 are all positive values and the own-price elasticities of demand are all negative values. The expenditure elasticity for beef ( $\eta_1$ ) is the most responsive of the four expenditure elasticities in all four model specifications while the expenditure elasticity for chicken ( $\eta_4$ ) is the least responsive in all models. The estimated Rotterdam model expenditure elasticities for lamb and for pigmeat are both smaller than the values estimated from the other models.

In all models the own-price elasticity of demand estimates indicate that consumption of beef and lamb is much more sensitive (responsive) to changes in their respective prices than pigmeat and chicken. This is consistent with previous studies (Piggott 1991; Alston and Chalfant 1991; Hutasuht 1995). The estimates from the LA/AIDS, First Differenced LA/AIDS and the Rotterdam models are similar in magnitude while the AIDS model estimates are considerably higher than the other models. Hutasuht (1995) also found that the own-price elasticity of demand estimates from the AIDS model were higher than the estimates from the other models.

The cross-price elasticities reported in Table 4 are a mixture of positive and negative values. Positive cross-price elasticities imply substitutes in consumption among meats whereas negative cross-price elasticities imply the meats are complements in consumption. However, as the calculated elasticity values are (uncompensated) Marshallian elasticities it is possible for the income effect of a price change to outweigh the substitution effect thereby giving a negative value in the case of substitutes in consumption<sup>5</sup>.

### 4.3 Comparison with previous elasticity estimates

Comparison of elasticity estimates with other studies is often difficult due to differences in data sets, functional forms chosen for estimation and differences in estimation procedures. Piggott (1991), Alston and Chalfant

<sup>5</sup> Compensated (Hicksian) elasticities represent only the substitution effect of a price change (Nicholson 2002, pp.155-58).

(1991) and Hutasuhut (1995) are three studies that are similar to this study in estimation procedures and data sets for the AIDS and Rotterdam models. Table 5 provides a comparison of the estimated elasticities from this study and those mentioned above.

**Table 5: Comparison of estimated elasticities with other AIDS and Rotterdam model studies**

<b>Elasticity</b>	<b>Piggott (1991) 1977-1988</b>	<b>Alston and Chalfant (1991) 1970-1988</b>	<b>Hutasuhut (1995) 1965-1994</b>	<b>This study 1965-2010</b>
<b>AIDS</b>				
<b>Expenditure</b>				
$\eta_1$	1.692	1.71	1.426	1.494
$\eta_2$	0.602	0.44	0.532	0.716
$\eta_3$	0.106	0.14	0.397	0.473
$\eta_4$	-0.026	-0.11	0.148	0.141
<b>Own-Price</b>				
$\varepsilon_{11}$	-1.253	-1.37	-1.254	-2.183
$\varepsilon_{22}$	-1.227	-1.40	-1.425	-1.019
$\varepsilon_{33}$	-0.936	-0.95	-0.299	-0.812
$\varepsilon_{44}$	-0.722	-0.73	-0.254	-1.375
<b>Rotterdam</b>				
<b>Expenditure</b>				
$\eta_1$	1.698	1.63	1.461	1.613
$\eta_2$	0.603	0.56	0.585	0.555
$\eta_3$	0.187	0.21	0.284	0.299
$\eta_4$	0.073	0.07	0.059	0.063
<b>Own-Price</b>				
$\varepsilon_{11}$	-1.196	-1.30	-1.271	-1.141
$\varepsilon_{22}$	-1.388	-1.59	-1.369	-0.890
$\varepsilon_{33}$	-0.821	-0.71	-0.316	-0.247
$\varepsilon_{44}$	-0.412	-0.21	-0.269	-0.300



Piggott (1991) and Alston and Chalfant (1991) in using an AIDS model both estimated a negative chicken expenditure elasticity. In this study all expenditure elasticities are positive and are similar in magnitude to the Hutasuht (1995) estimates.

In terms of own-price elasticities of demand there are a few notable differences in the AIDS model estimates. The beef and chicken own-price demand elasticity estimates from this study are much higher than any of the comparable studies and the own-price lamb elasticity is lower than previous estimates. The pigmeat own-price demand elasticity is considerably higher than Hutasuht's (1995) value but is similar in size to the other two studies.

All the expenditure elasticities from the Rotterdam model are consistent with the previous studies. The own-price elasticity of demand for lamb is lower than previous estimates while the own-price elasticity of demand for pigmeat is similar to Hutasuht's (1995) value, but is lower than earlier estimates.

Table 6 provides a comparison with other studies of estimated elasticities derived from the LA/AIDS model. The expenditure elasticities do not differ greatly among studies, with the exception of the higher Goddard and Griffith (1992) lamb and chicken values. The own-price elasticities of demand for beef and lamb, estimated in this study, are considerably lower than earlier estimates. The own-price elasticities of demand for pigmeat and chicken are also lower than earlier estimates but are comparable in size to the Hutasuht (1995) values.

**Table 6: Comparison of estimated elasticities with other LA/AIDS model studies**

Elasticity	Piggott (1991) 1977- 1988	Chalfant and Alston (1986) 1962- 1984	Cashin (1991) 1967- 1990	Goddard and Griffith (1992) 1966- 1988	Hutasuht (1995) 1965- 1994	This study 1965- 2010
<b>Expenditure</b>						
$\eta_1$	1.641	1.427	1.650	1.38	1.426	1.492
$\eta_2$	0.671	0.772	0.525	0.90	0.547	0.783
$\eta_3$	0.085	0.234	0.228	0.51	0.414	0.477
$\eta_4$	0.132	0.036	0.061	0.38	0.098	0.092
<b>Own-Price</b>						
$\varepsilon_{11}$	-1.175	-1.493	-1.235	-1.40	-1.159	-0.986
$\varepsilon_{22}$	-1.257	-1.486	-1.326	-1.42	-1.361	-0.844
$\varepsilon_{33}$	-0.923	-0.781	-0.829	-0.94	-0.286	-0.357
$\varepsilon_{44}$	-0.690	-0.424	-0.469	-0.23	-0.137	-0.268

#### 4.4 Testing for structural change

Consumption patterns change over time in response to changes in relative prices and incomes. Trend and seasonal dummy variables were included in each of the model specifications. However shifts in consumption may also occur because of structural change where other factors bring about a change in demand.

In updating the data set used in the demand system models three particular points of interest were noted where structural change may have occurred: a change in the retail price measurement of chicken, a change in pigmeat disappearance data and a change in beef disappearance data.

Tests for structural change in a non-linear system of equations can be undertaken using the Andrews-Fair test (Andrews and Fair 1988). The test checks for constancy in parameter values between two sub samples split at a known point in time. Parameter values are assumed equal under the null hypothesis and different under the alternative. The following sub samples were specified for testing each potential structural change.

- (1) Prior to 1987 the retail price of chicken was based on frozen whole chickens while from 1987 onwards fresh whole chicken retail prices have been used. The data were split into two sub samples at observation 88. The first period comprising 1965:1 to 1986:3 and the second period comprising 1987:1 to 2010:4.
- (2) From 1989 onwards consumption data for pigmeat includes imports. The data were split into two sub samples at observation 96. The first period comprising 1965:1 to 1988:3 and the second period comprising 1989:1 to 2010:4.
- (3) Beef consumption increased markedly in Australia in the mid-to-late 1970s as a consequence of increased trade restrictions in Australia's major export markets. The data were split into two sub samples at observation 58. The first period comprising 1965:1 to 1979:1 and the second period comprising 1979:3 to 2010:4

The Andrews-Fair tests were undertaken using the LA/AIDS and Rotterdam models. In each instance different groups of variables were tested to determine if there are changes in common intercepts or common slopes in the different models.

The results of the likelihood ratio tests for the structural change in chicken meat prices are reported in Table 7. The LA/AIDS model rejects the null hypothesis in each test indicating changes in all price, expenditure and intercept parameters. The Rotterdam model also rejects the null hypothesis in a test inclusive of all the price, expenditure and intercept parameters.

**Table 7: Results of likelihood tests for structural change in chicken meat prices**

Hypothesis	LR (AF) Test Statistic	Critical value
<b>LA/AIDS model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	115.443*	21.03
2. Price parameters	18.743*	12.59
3. Expenditure parameters	20.888*	7.81
4. Intercepts	17.958*	7.81
<b>Rotterdam model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	42.458*	21.03
2. Price parameters	-7.312	12.59
3. Expenditure parameters	8.497*	7.81
4. Intercepts	11.502*	7.81

\* denotes statistically significant at the 5 per cent level

Table 8 presents the results of the likelihood ratio tests for the introduction of pigmeat imports. Both the LA/AIDS and Rotterdam model results are significant for tests in changes in intercepts and changes in expenditure parameters. The LA/AIDS model rejects the null hypothesis in a test of all the price, expenditure and intercept parameters while the Rotterdam model does not.

The test differences between the models for structural change resulting from the 1970s trade restrictions are shown in Table 9. Both the LA/AIDS and Rotterdam model results are significant for tests in changes in intercepts, changes in expenditure parameters and changes in prices parameters. However the Rotterdam model fails to reject the null hypothesis when the test is inclusive of all parameters.

**Table 8: Results of likelihood tests for structural change: Introduction of pigmeat imports**

Hypothesis	LR (AF) Test Statistic	Critical value
<b>LA/AIDS model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	118.294*	21.03
2. Price parameters	11.251	12.59
3. Expenditure parameters	15.003*	7.81
4. Intercepts	13.693*	7.81
<b>Rotterdam model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	11.826	21.03
2. Price parameters	13.233*	12.59
3. Expenditure parameters	12.684*	7.81
4. Intercepts	11.263*	7.81

\* denotes statistically significant at the 5 per cent level

**Table 9: Results of likelihood tests for structural change: 1970s trade restrictions on Australian beef exports**

Hypothesis	LR (AF) Test Statistic	Critical value
<b>LA/AIDS model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	105.067*	21.03
2. Price parameters	21.248*	12.59
3. Expenditure parameters	25.652*	7.81
4. Intercepts	24.456*	7.81
<b>Rotterdam model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	-25.699	21.03
2. Price parameters	14.388*	12.59
3. Expenditure parameters	15.743*	7.81
4. Intercepts	16.600*	7.81

\* denotes statistically significant at the 5 per cent level

#### 4.5 Structural change and MSA

One of the objectives of this project is to try and ascertain the influence on beef demand of the availability of MSA-graded beef. The MSA grading scheme commenced on a national basis in 1999/2000. Andrews-Fair tests were undertaken using the LA/AIDS and Rotterdam models to check for constancy in parameter values between pre-MSA and post-MSA introduction periods. The data were split into two sub samples at observation 136, the first period comprising 1965:1 to 1999:2 and the second period comprising 1999:4 to 2010:4.

The likelihood ratio test results for the introduction of MSA graded meat are presented in Table 10. Both the LA/AIDS and Rotterdam models produced statistically significant results for changes in the intercepts. The LA/AIDS model also rejects the null hypothesis of no change in expenditure parameters.

**Table 10: Results of likelihood tests for structural change: Introduction of MSA grading**

Hypothesis	LR (AF) Test Statistic	Critical value
<b>LA/AIDS model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	100.193*	21.03
2. Price parameters	12.116	12.59
3. Expenditure parameters	11.025*	7.81
4. Intercepts	11.032*	7.81
<b>Rotterdam model</b>		
<b>No structural change in</b>		
1. Price, expenditure and intercept parameters	4.775	21.03
2. Price parameters	10.732	12.59
3. Expenditure parameters	8.847	7.81
4. Intercepts	12.704*	7.81

\* denotes statistically significant at the 5 per cent level

#### 4.6 Structural change and elasticity estimates

Elasticities were estimated from the AIDS, LA/AIDS and Rotterdam models for each sub sample corresponding to the four modelled structural changes.

The uncompensated elasticities for the periods before and after the change in the retail price measurement of chicken are listed in Table 11. The AIDS model results indicate that the expenditure elasticities for beef are of similar magnitudes in both periods. In the AIDS specification lamb expenditure is more elastic in the second period but less elastic in the other two models. The expenditure elasticity for pigmeat is marginally larger in all models while the chicken expenditure elasticity is larger in the two AIDS model specifications.

In the AIDS model the own-price elasticities of demand for each of the four meats are smaller in the period following the chicken price measurement change than prior to the change. Conversely the LA/AIDS and Rotterdam estimates suggest slightly more elastic own-price elasticities in the more recent period.

**Table 11: Uncompensated price and expenditure elasticities for structural change in chicken meat prices**

	AIDS		LA/AIDS		Rotterdam	
	Period 1 : 1965:1 to 1986:3	Period 2: 1987:1 to 2010:4	Period 1 : 1965:1 to 1986:3	Period 2: 1987:1 to 2010:4	Period 1 : 1965:1 to 1986:3	Period 2: 1987:1 to 2010:4
<b>Expenditure</b>						
$\eta_1$	1.560	1.451	1.494	1.487	1.486	1.542
$\eta_2$	0.413	0.713	0.773	0.666	0.710	0.481
$\eta_3$	0.091	0.151	0.029	0.048	0.126	0.233
$\eta_4$	0.215	0.350	0.214	0.380	0.187	0.121
<b>Price</b>						
$\varepsilon_{11}$	-2.769	-1.251	-1.044	-1.148	-0.932	-1.109
$\varepsilon_{12}$	0.281	-0.018	-0.101	-0.039	-0.162	-0.101
$\varepsilon_{13}$	0.502	-0.083	-0.199	-0.153	-0.249	-0.159
$\varepsilon_{14}$	0.426	-0.099	-0.149	-0.142	-0.143	-0.173
$\varepsilon_{22}$	-1.300	-1.026	-0.886	-1.040	-0.722	-0.753
$\varepsilon_{23}$	-0.534	-0.077	0.035	-0.050	0.151	-0.049
$\varepsilon_{24}$	-0.391	0.044	0.073	0.115	0.077	0.128
$\varepsilon_{33}$	-1.367	-0.422	-0.156	-0.294	0.018	-0.266
$\varepsilon_{34}$	-1.069	-0.160	-0.081	-0.037	-0.182	-0.097
$\varepsilon_{44}$	-1.243	-0.467	-0.360	-0.475	-0.274	-0.315

The estimates from all three models in Table 12 indicate little change in the beef expenditure elasticity in the two periods, prior to and after the introduction of pigmeat imports into Australia. The same is also true for the other expenditure elasticities with the exception of the lamb expenditure elasticity estimate in the AIDS model which is considerably higher but consistent with second period estimates in the other models.

The own-price elasticity estimates for all four meats are significantly smaller in the period following the introduction of pigmeat imports under the AIDS model specification. This is also the case for the LA/AIDS and Rotterdam models although the magnitudes of the changes in the elasticity estimates are much smaller than in the AIDS model.

Table 13 lists the estimated uncompensated price and expenditure elasticities for the periods inclusive of, and following, the 1970s trade restrictions on beef. The AIDS model estimate of the beef expenditure elasticity is much smaller in the second period than in the first but is of similar magnitudes in the other model estimates. In all three models the lamb expenditure estimates are more elastic in the post-trade restriction period.

The own-price elasticities of demand estimated from the AIDS model are larger in the 1979-2012 period than in the 1965-1979 period, and in the case of pigmeat and chicken much more elastic. In the LA/AIDS and Rotterdam models, with the exception of chicken, the estimated own-price elasticities of demand are smaller in the latter period.

**Table 12: Uncompensated price and expenditure elasticities for structural change: Introduction of pigmeat imports**

	AIDS		LA/AIDS		Rotterdam	
	Period 1 : 1965:1 to 1988:3	Period 2: 1989:1 to 2010:4	Period 1 : 1965:1 to 1988:3	Period 2: 1989:1 to 2010:4	Period 1 : 1965:1 to 1988:3	Period 2: 1989:1 to 2010:4
<b>Expenditure</b>						
$\eta_1$	1.592	1.445	1.504	1.501	1.513	1.518
$\eta_2$	0.360	0.769	0.698	0.729	0.672	0.638
$\eta_3$	0.097	0.165	0.057	0.056	0.143	0.118
$\eta_4$	0.207	0.284	0.266	0.209	0.165	0.164
<b>Price</b>						
$\epsilon_{11}$	-3.031	-1.192	-1.096	-1.051	-1.071	-0.990
$\epsilon_{12}$	0.320	-0.068	-0.077	-0.102	-0.086	-0.149
$\epsilon_{13}$	0.597	-0.102	-0.173	-0.197	-0.204	-0.223
$\epsilon_{14}$	0.523	-0.083	-0.158	-0.152	-0.152	-0.155
$\epsilon_{22}$	-1.268	-0.893	-0.953	-0.886	-0.837	-0.744
$\epsilon_{23}$	-0.634	-0.008	0.005	0.044	0.016	0.108
$\epsilon_{24}$	-0.451	0.020	0.100	0.080	0.020	0.096
$\epsilon_{33}$	-1.522	-0.376	-0.275	-0.184	-0.137	-0.086
$\epsilon_{34}$	-1.125	-0.206	-0.046	-0.077	-0.105	-0.152
$\epsilon_{44}$	-1.463	-0.450	-0.408	-0.364	-0.286	-0.285

**Table 13: Uncompensated price and expenditure elasticities for structural change: 1970s trade restrictions on Australian beef exports**

	AIDS		LA/AIDS		Rotterdam	
	Period 1 : 1965:1 to 1979:1	Period 2: 1979:3 to 2010:4	Period 1 : 1965:1 to 1979:1	Period 2: 1979:3 to 2010:4	Period 1 : 1965:1 to 1979:1	Period 2: 1979:3 to 2010:4
<b>Expenditure</b>						
$\eta_1$	1.617	1.029	1.550	1.541	1.597	1.520
$\eta_2$	0.152	0.396	0.598	0.715	0.207	0.778
$\eta_3$	0.042	0.124	0.010	0.118	0.026	0.096
$\eta_4$	0.174	0.157	0.061	0.182	0.226	0.207
<b>Price</b>						
$\epsilon_{11}$	-1.258	-1.427	-1.413	-1.031	-1.239	-1.090
$\epsilon_{12}$	-0.082	0.014	0.023	-0.111	0.021	-0.090
$\epsilon_{13}$	-0.149	0.029	-0.073	-0.213	-0.191	-0.168
$\epsilon_{14}$	-0.128	0.027	-0.087	-0.196	-0.187	-0.172
$\epsilon_{22}$	-1.184	-1.262	-1.084	-0.884	-1.402	-0.760
$\epsilon_{23}$	0.368	-0.656	0.037	0.041	0.143	-0.183
$\epsilon_{24}$	0.131	-0.446	-0.193	0.128	0.151	0.128
$\epsilon_{33}$	-0.662	-1.466	-0.710	-0.276	-0.261	-0.215
$\epsilon_{34}$	-0.086	-1.078	-0.032	-0.015	-0.077	-0.031
$\epsilon_{44}$	-0.440	-1.546	-0.316	-0.363	-0.193	-0.427



The uncompensated pre-and-post MSA elasticities are given in Table 14. The expenditure elasticities calculated from the AIDS model for beef and chicken are of similar magnitudes in both periods. The expenditure elasticities for lamb and pigmeat are considerably smaller post MSA, and in fact are both slightly negative. Similar results were gained for the expenditure elasticities estimated from the LA/AIDS model. The notable difference between the three models' estimates is that the Rotterdam model expenditure elasticity for beef is smaller in the post MSA period.

Both the AIDS and Rotterdam models indicate that the own-price elasticities of demand are smaller in value in the period post MSA than in the period pre MSA. While the values are only slightly lower for pigmeat and chicken in the Rotterdam model, the beef and lamb own-price elasticity estimates in the post MSA period are significantly less elastic in both the Rotterdam and AIDS models. The opposite conclusions can be drawn from the LA/AIDS own-price elasticity estimations where the values are more elastic in the latter period, but only marginally so in the case of chicken.

**Table 14: Uncompensated price and expenditure elasticities for structural change: Introduction of MSA grading**

	AIDS		LA/AIDS		Rotterdam	
	Period 1 : Pre-MSA	Period 2: Post_MSA	Period 1 : Pre-MSA	Period 2: Post_MSA	Period 1 : Pre-MSA	Period 2: Post_MSA
<b>Expenditure</b>						
$\eta_1$	1.612	1.689	1.560	1.651	1.586	0.696
$\eta_2$	0.421	-0.032	0.689	0.225	0.647	0.390
$\eta_3$	0.164	-0.015	0.137	-0.027	0.092	0.187
$\eta_4$	0.143	0.168	0.142	0.132	0.122	0.143
<b>Price</b>						
$\epsilon_{11}$	-2.921	-0.362	-1.028	-1.440	-1.142	-0.886
$\epsilon_{12}$	0.254	-0.454	-0.113	-0.023	-0.066	-0.164
$\epsilon_{13}$	0.528	-0.497	-0.212	-0.095	-0.186	-0.181
$\epsilon_{14}$	0.527	-0.376	-0.207	-0.092	-0.192	-0.161
$\epsilon_{22}$	-1.212	-0.567	-0.879	-1.064	-0.877	-0.313
$\epsilon_{23}$	-0.583	0.856	0.027	0.164	-0.145	-0.173
$\epsilon_{24}$	-0.374	0.473	0.158	-0.063	0.133	0.027
$\epsilon_{33}$	-1.331	-0.169	-0.286	-0.703	-0.185	-0.091
$\epsilon_{34}$	-1.003	0.288	-0.017	-0.078	-0.062	-0.071
$\epsilon_{44}$	-1.537	-0.095	-0.354	-0.374	-0.335	-0.288

#### 4.7 Specification tests

Alston and Chalfant (1993) developed a test to determine which model specification best fits the data. The test compares the first differenced LA/AIDS specification against the Rotterdam model. The results of this test are presented in Table 15 and are based on a comparison of the  $\lambda$  values in the first two rows.

**Table 15: Testing the Rotterdam and LA/AIDS specification**

	Rotterdam	First differenced LA/AIDS
$\lambda_1$	1.127*	-
$\lambda_2$	-	-0.330*
$\beta_1$	-0.0003	0.070
$\beta_2$	0.003	-0.070*
$\beta_3$	-0.001	-0.171*
$\beta_4$	0.998	0.171#
$\gamma_{11}$	0.048	0.171*
$\gamma_{12}$	0.012	-0.016
$\gamma_{13}$	-0.005	-0.097*
$\gamma_{14}$	-0.055	-0.058#
$\gamma_{22}$	0.018	0.042*
$\gamma_{23}$	-0.033*	-0.015
$\gamma_{24}$	0.003	-0.011#
$\gamma_{33}$	0.078*	0.152*
$\gamma_{34}$	-0.040	-0.039#
$\gamma_{44}$	0.093	0.108#
$\tau_1$	0.00006*	-0.00006*
$\tau_2$	-0.00001	0.00002*
$\tau_3$	-0.00003*	0.00004*
$\tau_4$	-0.00002	0.000004#
$\theta_{12}$	-0.021*	0.033*
$\theta_{13}$	0.011*	-0.008*
$\theta_{14}$	-0.028*	-0.002
$\theta_{22}$	0.001	-0.011*
$\theta_{23}$	0.001	-0.002
$\theta_{24}$	0.006*	0.004*
$\theta_{32}$	0.015*	-0.020*
$\theta_{33}$	-0.012*	0.009*
$\theta_{34}$	0.014*	-0.004
LLF	1775.617	1799.126

\* denotes statistically significant at the 5 per cent level, # denotes derived from adding up.

A test of the hypothesis that  $\lambda_1 = 0$  indicates the Rotterdam model is the better specification. A test of the hypothesis that  $\lambda_2 = 0$  indicates that the LA/AIDS is the better specification. In other words, if  $\lambda_1 = 0$  the Rotterdam model is the correct specification and if  $\lambda_1 = 1$  we favour the LA/AIDS model.

Conversely, if  $\lambda_2 = 0$  the LA/AIDS model is the correct specification and if  $\lambda_2 = 1$  we favour the Rotterdam model<sup>6</sup>.

In Table 15 the value of  $\lambda_1 = 1.127$  and is statistically significant. The value of  $\lambda_2 = -0.330$  and is also statistically significant. Hence, the LA/AIDS model is not rejected by the data. The Rotterdam model is rejected by the data. The outcomes of this test are consistent with Hutasuht's (1995) test results in using an earlier version of the data used in this study.

Tests were also undertaken to ascertain if the specification test results differ between the periods before and after each modelled structural change. The results of these tests are presented in Table 16 and support the rejection of the Rotterdam model and the non-rejection of the LA/AIDS model.

**Table 16: Lambda values for the specification tests before and after the structural changes**

	$\lambda_1$	$\lambda_2$	Standard error	T-ratio
<b>Change in chicken price</b>				
Pre change				
Rotterdam	1.098		0.016	69.057
LA/AIDS		-0.055	0.098	-0.564
Post change				
Rotterdam	1.205		0.094	12.845
LA/AIDS		-0.962	0.021	-45.990
<b>Introduction of pigmeat imports</b>				
Pre change				
Rotterdam	1.102		0.015	74.460
LA/AIDS		0.022	0.089	0.248
Post change				
Rotterdam	1.207		0.040	29.950
LA/AIDS		-0.830	0.016	-53.532
<b>Introduction of MSA</b>				
Pre change				
Rotterdam	1.111		0.015	75.578
LA/AIDS		-0.242	0.074	-3.254
Post change				
Rotterdam	1.051		0.083	12.709
LA/AIDS		-0.343	0.004	-84.977
<b>1970s beef trade restrictions</b>				
Pre change				
Rotterdam	1.079		0.018	59.286
LA/AIDS		-0.122	0.108	-1.125
Post change				
Rotterdam	1.171		0.029	40.519
LA/AIDS		-0.519	0.045	-11.651

<sup>6</sup> Note that  $\lambda_1$  will not exactly equal one and  $\lambda_2$  will not exactly equal zero. See Alston and Chalfant (1993).

## 5 Discussion and conclusions

The main results from this study are summarised below in relation to the projects objectives.

A data set used in a number of earlier studies with different time spans in analyses of Australian domestic meat demand was updated to include price and per capita consumption data for beef, lamb, pigmeat and chicken from 1965(1) to 2010(4). A number of improvements were made in the collection and collation of the data including accounting for pigmeat imports in per capita consumption calculations. AIDS, LA/AIDS and Rotterdam model specifications were used to test for structural changes in the data, to generate updated expenditure and own-price elasticities of demand, and to try and ascertain the influence on beef demand of the availability of MSA-graded beef.

Both the Rotterdam and the LA/AIDS model specifications showed statistically significant evidence of structural changes in Australian meat demand as a result of changes in the reporting of chicken meat retail prices, increased trade restrictions in major Australian beef exports markets in the 1970s and the commencement of pigmeat imports into Australia.

A specification test determined that the LA/AIDS model was preferred over the Rotterdam model as the best fit of the data. Updated expenditure and own-price elasticity values were estimated from the different model specifications. The LA/AIDS model expenditure elasticities estimated over the complete data set were not dissimilar from previous studies in their magnitudes. However, the own-price elasticities of demand for beef and lamb, in particular, were considerably lower than earlier estimates suggesting more price inelastic demand for these meats in latter years. Own-price elasticity of demand estimates for the pre-and-post structural change periods associated with pigmeat imports and the 1970s trade restrictions on beef lend weight to this hypothesis.

Tests were also undertaken to try and detect structural change associated with the introduction of the MSA grading system in 1999-2000. Although the results were mixed, both the Rotterdam and LA/AIDS models picked up changes in the intercepts while the LA/AIDS model also found evidence of changes in the expenditure parameters.

Expectations are that, with the introduction of the MSA grading scheme, substitution in consumption is likely to occur from non-MSA to MSA graded meat. An indication of this would be a more inelastic own-price elasticity of demand for beef in the MSA period. However the results are inconclusive. While the Rotterdam model own-price elasticity of demand estimates are lower in the post MSA period the reverse is true for the LA/AIDS estimates.

The results of the structural change tests indicate three distinct instances of structural change over the period 1965(1) to 1988(4). Based on these results the preferred uncompensated own-price and expenditure elasticity estimates

correspond to the sub sample of the data covering the period inclusive of pigmeat imports, 1989(1) to 2010(4).

With reference to Table 6 and Table 12 the expenditure elasticities estimated from the LA/AIDS model for beef and lamb over this period are roughly equivalent in magnitude to the estimates from earlier studies that have used similar data over differing time frames. The expenditure elasticity for pigmeat is smaller than most of the previous estimates but is still consistent with Piggott (1991). The chicken expenditure elasticity is slightly larger than previously estimated values.

Of particular interest are the own-price demand elasticity estimates. In comparison with previous studies the demands for beef, lamb and pigmeat are less elastic than estimated in previous studies. These estimates imply that consumer demand for these types of meat has become less responsive to changes in their prices in recent years.

The findings from this project highlight a few areas where complementary work can be undertaken. The first is in determining the most consistent sub sample of the data from which to obtain the most reliable expenditure and own-price elasticity of demand estimates. This would involve tests of both sectional and overlapping data periods.

As noted earlier it is preferable to estimate a number of different model specifications to determine the sensitivity of results to model choices. Therefore additional modelling could be undertaken using a Translog, or alternative, specification.

A third area of complementary work entails sourcing and collecting alternative data that can be used to estimate the impacts of MSA grading on the quantities of meat demanded.

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## 7 Appendix: Data descriptions

The data used in this study are listed in the following table.

Variable	Description
p <sub>1</sub>	average quarterly retail price of beef in cents/kilogram
p <sub>2</sub>	average quarterly retail price of lamb in cents/kilogram
p <sub>3</sub>	average quarterly retail price of pigmeat in cents/kilogram
p <sub>4</sub>	average quarterly retail price of chicken in cents/kilogram
q <sub>1</sub>	per capita consumption of beef in kilograms/quarter
q <sub>2</sub>	per capita consumption of lamb in kilograms/quarter
q <sub>3</sub>	per capita consumption of pigmeat in kilograms/quarter
q <sub>4</sub>	per capita consumption of chicken in kilograms/quarter
CPI	consumer price index 1989/90 = 100

### Prices

All nominal retail price series were sourced from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). The CPI was obtained from the Australian Bureau of Statistics (ABS). Nominal prices were deflated using the CPI.

### Consumption

Carcass weight consumption of beef, lamb and pigmeat were calculated as production minus exports plus imports and changes in stocks using ABS production data and Department of Agriculture, Fisheries and Forestry (DAFF) data on international trade and changes in stocks<sup>7</sup>. Shipped weight was converted to carcass weight equivalents using DAFF conversion factors.

Consumption of chicken was sourced from DAFF and is expressed as dressed weight.

### Per capita consumption

Per capita consumption was calculated as quarterly consumption divided by quarterly Australian population estimates from ABS data. The periods corresponding to the updated data are listed below.

Per capita beef consumption – updated from 1998(3)

Per capita lamb consumption – updated from 1998(3)

Per capita pigmeat consumption – updated from 1989(1)

Per capita chicken consumption – updated from 1995(1)

<sup>7</sup> Imports of beef, lamb and chicken were minimal over the entire sample period and were excluded from the calculations.