1. Introduction

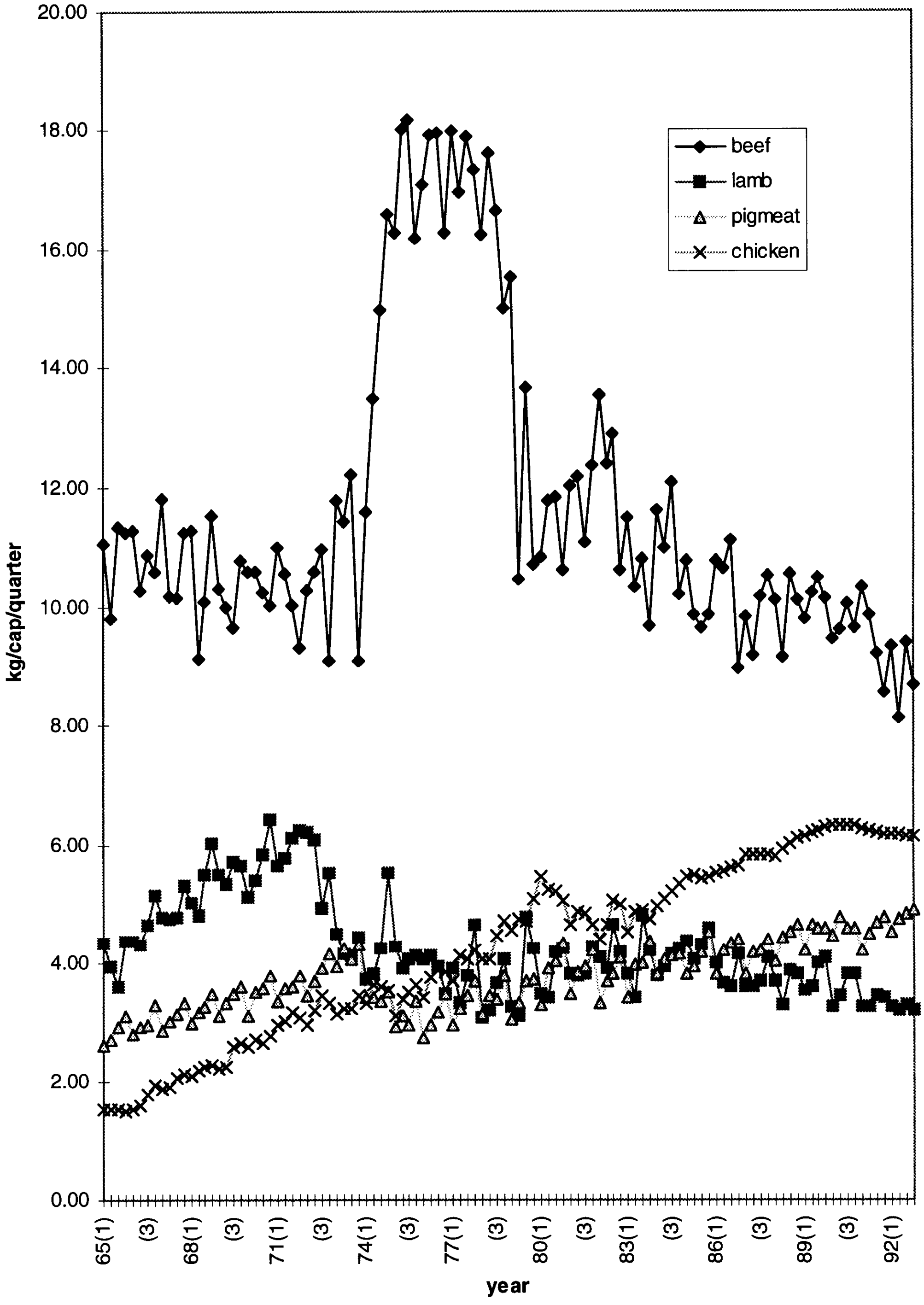
1.1 Background to the study

There have been major changes in the pattern of meat consumption in Australia over the past 25 years or so. These changes are particularly evident for beef and chicken. As shown in Figure 1, on a quarterly per capita basis, beef consumption increased sharply from about 10.86 kg in 1965 to 17.16 kg during 1975, and then reduced to 8.90 kg in 1992. Chicken meat consumption, on the other hand, steadily increased from 1.52 kg in 1965 to 6.16 kg in 1992. A similar pattern to chicken meat consumption was shown by pigmeat consumption, where consumption increased from 2.83 kg during 1965 to 4.76 kg in 1992. During the same period of time, lamb consumption showed a relatively stable consumption pattern, from 4.07 kg in 1965 to 3.25 kg in 1992.

A similar pattern has also occurred in the United States and Canadian meat consumption. Thus, chicken consumption in Australia, the United States and Canada has steadily increased over the last two decades, beef consumption has remained fairly flat in all three countries, with a declining trend in Canada, and pork consumption has also shown a relatively stable pattern across these countries (Moschini and Meilke 1989; Goddard and Griffith 1992).

The high consumption of beef between the mid 1970s and late 1970s (Figure 1) was caused by the imposition of restrictions in export markets (e.g. Japan, Korea and Taiwan). As a result of increased beef supply in the domestic market, the real retail beef price dropped sharply and consumers consumed more beef compared to the other types of meat. Over the same period of time there was a noticeable reduction in lamb and pigmeat consumption.

Figure 1: Australian meat consumption, 1965 to 1992



It is possible that these consumption changes were solely due to the effect of changing relative prices and incomes. An alternative explanation to the changes, as many believe, is that there has been a structural change in meat demand. A structural change occurs when demand for a good changes even when relative prices and incomes are constant, so that consumption changes cannot solely explained by price and income movement. Other factors such as type of occupation, size of family, ethnic background, religious beliefs, diets and food fads, changing preferences and lifestyle as well as advertising may have influenced meat demand (Buse 1989; Piggott *et al.* 1995).

Recent research on meat demand demonstrates the importance in empirical demand analyses of identifying and measuring structural changes (Buse 1989). Evidence of structural change is of considerable interest for the red meat industry because it implies a less favourable climate warranting adjustments in both production and marketing strategies. The implication of structural change for meat industry is different depending on the factors that influenced meat demand. If a consumption shift from beef to poultry can be interpreted as a response to changing relative prices, the beef industry has to respond by reducing its production and marketing costs. If it does not, an adverse effect on beef demand will prevail when further reductions in poultry costs occur. The implication for the meat industry is different when the cause of changes is a changing life-style. For example, in response to recent health concerns about saturated fat and cholesterol, the red meat industry has to deal with different cutting, trimming, labelling and advertising campaigns of meat as perceived by the consumers. These examples indicate that different sources of structural change need different adjustments in the meat industry. Therefore, it is important for the meat industry to know whether structural change is or has occurred and if so the factors that cause the changes.

Information concerning the occurrence of the structural change is also important from a statistical point of view. When a structural change is present in a meat demand system, a basic assumption of a regression model that the parameters do not vary across sample observations, is violated. If this happens, the statistical model is changed and thus the usual ordinary least squares (OLS) or generalised least squares (GLS) estimators lose their optimal properties (Judge *et al.* 1988). Structural changes can also affect the forecasting and policy analysis capabilities of an econometric model because changes in 'data-generating' processes have direct effects on model specification and estimation.

Recent studies of United States meat demand (see Eales and Unnevehr 1988; Thurman 1987; Moschini and Meilke 1989; and Choi and Kim 1990) have found that the structure of the United States meat preferences shifted significantly in the 1970s, away from 'red meat' (beef and pork) toward 'white meat' (chicken and fish). Australian studies, on the other hand, have shown that there has been no change in Australian meat demand. Martin and Porter (1985), for example, employed quarterly data from 1962 to 1983 for beef, lamb, mutton, pigmeat and poultry and concluded that changes in prices and in total consumer expenditure are far more important than changes in tastes as determinants of meat consumption. Later studies using non parametric tests by Chalfant and Alston (1988), Alston and Chalfant (1991a) and Gorny and Ahmadi-Esfahani (1993) and parametric tests by Lee (1991) also suggest there has been no significant change in the demand of meat in Australia. The present study aims at testing for the presence of structural changes using more recent data which is consistent with the quarterly data used in earlier work (especially after 1979). This study also takes the opportunity to compare functional forms and test between them.

1.2 Specific objectives of the study

One specific objective of this study is to test for the presence of structural changes in Australian meat demand by using quarterly data from 1965 to 1992. To evaluate the effects of functional forms choices, the study will employ flexible forms such as the ‘true’ Almost Ideal Demand System (AIDS) and the linear approximation of AIDS (LA/AIDS) and its first-differenced form as well as the Rotterdam models. Another objective of the study is to examine the implications of the findings concerning the presence of structural change in the demand for meats in Australia. The implications for the meat industry in both the production and marketing areas, will be different depending on whether or not a structural change has occurred.

To give guidance to the investigation, the following hypotheses are established.

H_o: Structural change has not occurred in the market for meat in Australia from 1965 to 1992.

H_1: Structural change has occurred in the market for meat in Australia from 1965 to 1992.

1.3 Outline of the dissertation

The dissertation is organised along the following lines. A review of previous studies of structural change in both Australian and United States meat demand is presented in Chapter 2. The concept of structural change and the techniques that can be used to analyse it are also included in this chapter. Description of both economic and econometric models can be found in Chapter 3. Estimation methods which were applied in this study and the data sources and characteristics are outlined in Chapter 4. An overview of the results and discussion of the study can be seen in Chapter 5. A summary of the findings, conclusions, limitations and suggestions for further study are all included in Chapter 6.

2. Literature Review

2.1 Previous studies

There have been several studies of structural change in meat demand in Australia. The study by Martin and Porter (1985) was the first attempt to directly analyse the presence of structural changes in Australian meat demand. Quarterly data for the period 1962:1 to 1983:1 for beef, mutton, lamb, pigmeat and chicken were used. The study employed double logarithmic and logarithmic difference models to estimate the demand by OLS for each equation separately. They showed that the results for dynamic models were similar to those for static models. The results also showed that experimentation with functional forms resulted in only slight revision of the results. Although they concluded that there have been structural changes in the demand for some meats, the shifts in demand were estimated to have had relatively small effects on the consumption of all meats except mutton.

Lee (1991) employed a system approach to estimate meat consumption behaviour with the LA/AIDS method. The data used were monthly data (January 1973 to June 1990) for beef, pigmeat and lamb. Although the study employed different data, functional forms, and estimation techniques to that of Martin and Porter (1985), both studies arrived at the same conclusion that the main factors leading to changes in the consumption of red meat were changes in relative prices and in the level of consumer expenditure.

Goddard and Griffith (1992) employed a number of linear models and two demand systems, the translog and AIDS models, on Australian and Canadian meat consumption data. The study undertook an exhaustive testing of different demand models and different time periods. Although their main aim was not to test and measure the structural change in meat demand in both countries, their results showed that there is an enormous variability in estimated elasticities across time periods.

Chalfant and Alston (1988) were the first to apply non parametric techniques to Australian meat consumption data. Employing the data used by Martin and Porter (1985) and United States data, they concluded that meat consumption data in both countries could have been generated by stable preferences and the main factor that lead to consumption changes was relative prices. A later study on parametric and non parametric techniques by Alston and Chalfant (1991a) on the Australian meat consumption which excluded mutton data for 1970:2 to 1988:4 also found consistency with stable preferences on non parametric tests. Their Monte Carlo experiment showed that when the LA/AIDS model is not the correct functional form, it tends to reject stable preferences more often compared to the Rotterdam model. A recent study by Gorny and Ahmadi-Esfahani (1993) on the non parametric technique supports this finding. Using quarterly disaggregated meat data on beef and veal, lamb and mutton, pigmeat and chicken from 1987 to 1991 collected from the Sydney market, they also concluded that there was no structural change in meat cut demand.

Because of some similarities in the pattern of meat demand and in factors that lead to changes in meat demand between Australia and the United States, it is worthwhile to also review the United States literature concerning the subject. United States meat demand studies split into two categories. Firstly, those which find little or no evidence of structural change include the studies by Moschini and Meilke (1984), Wohlgenant (1984), Dahlgran (1987), Chalfant and Alston (1988), Kelso (1990) and Alston and Chalfant (1991a). Secondly, those which find evidence of a structural change include the studies by Nyankori and Miller (1982), Chavas (1983), Braschler (1983), Eales and Unnevehr (1988), Thurman (1987), Moschini and Meilke (1989), and Choi and Kim (1990).

Those studies which did not find evidence of structural change concluded that there was an increase in beef own-price elasticity and the cross-price elasticity with respect to pork (Moschini and Meilke 1984), an increase in the cross-price elasticity of beef with respect to poultry (Wohlgenant 1984) and an increase in substitutability between beef and chicken (Dahlgran 1987).

Those studies that found evidence of structural change were mixed in their empirical results. For example, Nyankori and Miller (1982) found a structural change for beef and chicken but not in pork or turkey. The later study by Eales and Unnevehr (1988) found that cross-price effects were important for inferior meat products (whole birds, hamburger beef), but preference shifts were important in explaining changes in demand for high quality meat products (table beef, parts/processed chicken). The study questioned the merit of other studies that had found evidence of a structural change with aggregated meat data. Eales and Unnevehr (1988) claimed that consumers allocate expenditure according to product type (eg. hamburger, beef or whole chicken) rather than animal of origin. The study by Moschini and Meilke (1989) found that structural change was biased against beef, in favour of chicken and fish and neutral for pork.

As shown above, even when a structural change was identified, the evidence was not always consistent with other studies. The diversity of the empirical results on this subject might be due to the use of different data, specification errors, the choice of functional forms or a combination of these factors. Smallwood *et al.* (1989) listed the following factors that might cause the diversity of the empirical results:

- the time span and periodicity of the data chosen for the analyses;
- the number of parameters that are included or omitted and, thus, that are allowed to change;
- the number and kinds of parameter changes that are permitted to occur;
- specification of abrupt versus gradual change;
- functional form (e.g. constant slope, constant elasticities [flexibilities], or more flexible relationships);

- price-dependent versus quantity-dependent specifications; and
- the degree to which the theoretical structure is embodied in the empirical structure.

Empirical studies of structural change should attempt to cover as many of these issues as possible.

2.2 Structural change analysis

2.2.1 The general approach

An explanation of structural change was proposed by Chavas (1989) as a change in some basic hypothesis used in the analysis of economic behaviour. A basic hypothesis for consumers is utility maximising behaviour; consumption choices are affected by prices, household income (through budget constraint), and household preferences (represented by a utility function) as suggested by consumer theory (Deaton and Muellbauer 1980b). Because of the difficulties of analysing structural change defined as a shift in consumer preferences, Chavas (1989) argued that a number of economists have adopted a narrower definition of structural change. Any significant shift in a demand parameter overtime is interpreted as structural change. Poirer (1976) in his famous book, for example, defined structural change as whenever the parameters of an economic model change a 'small' number of times in response to forces within or outside the model. The process of structural change can be either a gradual, continuous shift, or changes could occur abruptly in response to a random shock (Chavas 1983). Changes in demand elasticities does not always mean a structural change has occurred in a demand system. Since elasticities are a function of demand parameters (coefficients) and data, then elasticities vary over a sample of observations.

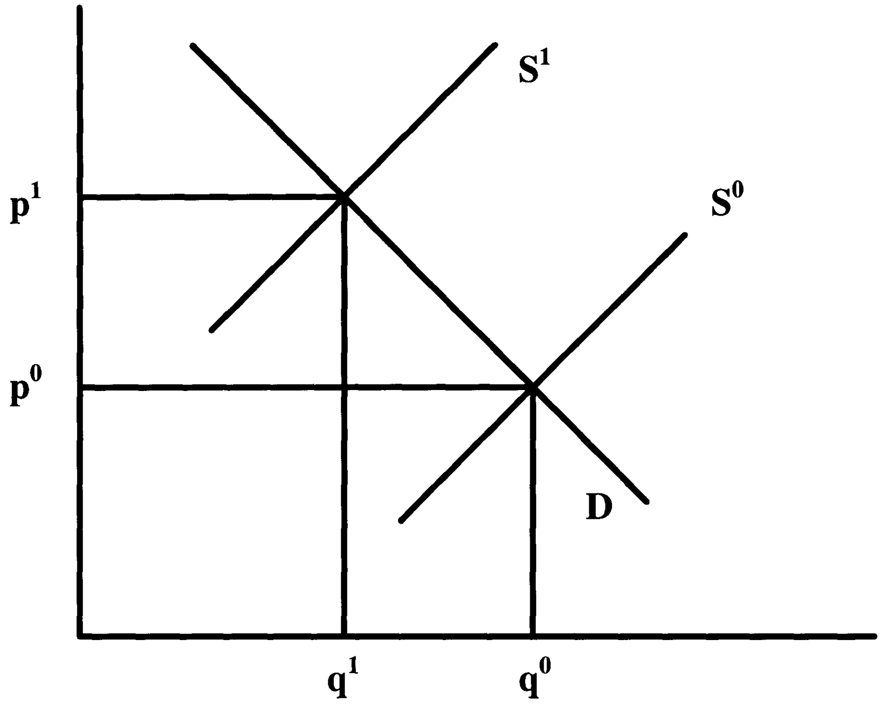
2.2.2 Some basic assumptions of structural change analysis

One important assumption in the analysis of structural change in a meat demand equation is that the supply side is held constant over the period of analysis. This assumption is an over-simplification of the real world situation where observed quantity and price of a meat are usually assumed to be the result of an intersection of demand and supply curves. Therefore, any changes in quantity and price of a meat could have been explained by the movement of both the supply and the demand curves. For example, a leftward shift in supply (S^0 to S^1 in Figure 2) will cause an increase in price of the meat and a reduction in the quantity of meat demanded, given no shifts in demand i.e. no change in other meat prices, meat expenditure, or tastes or preferences. Thus, the important role of the supply side should be kept in mind when analysing changes in the quantity of meat demanded (Haidacher 1989).

Another important assumption is related to the exogeneity of the independent variables (regressors) in a meat demand system. The standard assumption is that all prices and expenditure values are determined outside the system, and none of them are correlated with the error terms of the equation. This assumption could be violated when their values can be determined jointly within the system. An example of this violation is shown by the work of Eales and Unnevehr (1993) where they found that both prices and quantities appear to be endogenous within the entire meat market.

The other common assumption is that the quantity demanded for a commodity, its own-price, related commodity prices, and expenditure will move together and develop a long run economic equilibrium. This implies that all the variables in the demand system have to be stationary which means they have a constant long-run mean and a finite variance that is time-invariant (Enders 1995). This condition is not always satisfied by the variables.

Figure 2: Supply and demand relationships



Source: Haidacher (1989)

2.2.3 Parametric analysis

A general approach to a study of structural change is to first specify a functional form and then apply a technique to test for structural change within that form assuming that the form is a good representation of the relationships of variables in question. The most common technique to study the stability of parameters in a meat demand equation is by using parametric tests. There are many parametric tests that have developed since E. S. Page initiated the study of models that account for a changing distribution of random variables some forty years ago (Broemeling and Tsurumi 1987). Four parametric tests which are considered relevant to this study, are briefly outlined below. The methods are Chow, Farley-Hinich (F-H), Ohtani-Katayama (O-K) and Andrews-Fair (A-F) tests.

a. Chow test

Chow (1960) proposed an F test for the case where there are two regression regimes and the point to separate the observations into two subsamples is known. The F-test is used to test the equality of the coefficients for the two periods (subsamples). The Chow (F test) is calculated as:

$$\mathbf{F} = ((SSE-(SSE1+SSE2)/K)/((SSE1+SSE2)/(N_1+N_2-2K))$$

where

SSE1	sum of squared errors for the first regime
SSE2	sum of squared errors for the second regime
SSE	sum of squared errors for the entire sample
N_1	number of observations in the first regime
N_2	number of observations in the second regime
K	number of estimated parameters

If the test statistic is greater than the critical values from an $F_{(K,\ N_1+N_2-2K)}$ distribution then there is evidence for a structural break.

According to Farley *et al.* (1975) this test is more powerful than the F-H test when the true shift is near the middle of the observations. This test can also be used when a dummy variable is included in the equation. This test assumes that the regression error term does not suffer from autocorrelation and heteroskedasticity. Methods that account for the presence of heteroskedasticity and/or autocorrelation have also been developed (see Broemeling and Tsurumi 1987).

b. Farley-Hinich (F-H) test

This test can be applied if the break point of observations is unknown (Farley and Hinich 1970). The unknown path, h_t, is approximated by the linear path t/T, $t=1,2, \ldots. T$. Farley *et al.* (1975) found that the F-H test is more powerful than the Chow test if the shift occurs away from the centre of the sample. Another advantage of the F-H test is that the smooth structural change path reflects the gradual changes in consumer preference and dietary habit over time.

The F-H test is a joint hypothesis test which has the general form (White 1993) as:

Ho: $A\beta = C$

where

A is a (q x K) known matrix; and
C is a (K x 1) known vector.

The test statistic is computed as:

$$F = \frac{[A\hat{\beta} - C]' [AV(\hat{\beta})A']^{-1} [A\hat{\beta} - C]}{q} \qquad \sim F_{(q,\, N-K)}$$

where

$\hat{\beta}$ the K x 1 estimated coefficient vector

$V(\hat{\beta})$ the estimated variance-covariance matrix of $\hat{\beta}$

q number of parameter restricted to be equal over the whole sample period

N number of observations

K total number of parameters in the equation

If the test statistic is greater than the critical values for an $F_{(q,\ N-K)}$ distribution then there is evidence for a structural break.

c. Ohtani-Katayama (O-K) test

This method is an improvement of the switching regression model proposed by Quandt (1958). The method has two distinct properties: (i) the change in economic relationships is a gradual instead of an abrupt change; and (ii) autocorrelated errors are accounted for (Ohtani and Katayama 1986). The Ohtani-Katayama test postulates the structural change by:

$$\begin{array}{ll} h_t = 0 & \text{for } t = 1, 2, \ldots., t^*_1, \\ h_t = (t - t^*_1)/(t^*_2 - t^*_1) & \text{for } t = t^*_1 + 1, \ldots\ldots., t^*_2 - 1. \\ h_t = 1 & \text{for } t = t^*_2, t^*_2 + 1, \ldots\ldots.., T. \end{array}$$

where t^*_1 represents the end point of the first regime and t^*_2 is the starting point of the second regime. If the $t^*_2 = t^*_1 + 1$, the structural change path becomes a Chow test path, whereas $t^*_1 = 0$ and $t^*_2 = T$ produces a special case of the Ohtani-Katayama structural change path which becomes the F-H parameter path. The test statistic for the O-K test is exactly the same as the F-H test.

d. Andrews-Fair test

The first three tests are only applicable to linear regression models. To determine the presence of structural change in nonlinear regression models a procedure proposed by Andrews and Fair (1988) can be applied. The same test has been applied to Canadian meat consumption data by Chen and Veeman (1991) and to Australian fresh fruit data by Asafu-Adjaye and Ritter (1995). Both studies applied the A-F test in a system of equation of the 'true' AIDS model.

The A-F test postulates the parameter vector Q in the form of $Q=(Q_1, Q_2)$ where the likelihood function for $t_1= -T_1$ ..... -1 depends only on Q_1 and the likelihood function for t_2= 1 .... T_2 depends on Q_2. The null hypothesis of structural stability is given by Q_1=Q_2. To evaluate this, the restricted estimate of $Q(Q_1=Q_2)$ is computed using the whole data set. The unrestricted estimation of Q_1 and Q_2 are computed using data for the subsample periods t_1 and t_2 respectively. The test statistic is:

$$\lambda_{LR} = 2(T_1 + T_2)(log(L_U) - log(L_R)) \quad \sim \chi^2_k$$

where:

λ_{LR} likelihood-ratio-like test statistic

L_U sum of the log likelihood functions of the unrestricted estimates Q_1 and Q_2 evaluated over the two periods T_1 and T_2, respectively.

L_R log likelihood function of the restricted Q for the entire sample period

k number of parameters restricted to be equal over the two periods T_1 and T_2.

$T_1 + T_2 = T$ = sample size for the two subsample periods

Many authors (e.g. Smallwood *et al.* 1989; Alston and Chalfant 1991b, 1991c) have reported that empirical results on the structural change is sensitive to functional form and variable choices, then, another technique which is called non-parametric test was developed. This latter technique does not require a specification of any functional form. The following section is an outline of the technique.

2.2.4 Non-parametric analysis

This technique is based on revealed preference and does not require the use of any functional forms. The revealed preference theory was first developed by Samuelson (1938, 1948). The basic principle of the theory is that by comparing the cost of different combinations of goods at various sets of relative prices, it is possible to determine whether preferences have changed. As an illustration, let bundle A be preferable to bundle B. Suppose a consumer in one period purchased bundle A but in another period bundle B was purchased when bundle A was also affordable. This condition reveals that a preference shift has occurred.

There are two principal axioms of the theory, the weak axiom and the strong axiom. The weak axiom states that if bundle A is revealed preferred to bundle B at one time, but at another time bundle B is purchased, then bundle A cannot be affordable. The strong axiom is based on transitivity of preferences. If A is revealed preferred to B and B to C, then A should also be preferred to C. Any rejection to these axioms indicates unstable preferences and thus a shift in the demand curve which is partly due to factors other that prices and incomes. If both axioms hold, then the data are consistent with utility maximisation by a consumer with stable preferences.

One of the criticisms of this technique is the test's power is unknown (Thurman 1987; Chalfant and Alston 1988). A structural change may have occurred even if both axiom hold. This is likely the case when total expenditure is rising over time so that expenditure changes dominate relative price changes.

2.3 Summary

Several parametric studies on Australian meat demand have found evidence of a structural change but the main factors that lead to consumption changes are changing relative prices and incomes. Results of non parametric studies have confirmed that the Australian meat consumption data could have been generated from stable preferences. Both techniques that are now available for structural changes have some limitations. The parametric test is sensitive to functional forms and specification errors and the non parametric test's power is unknown.

3. The Models

3.1 The economic model

3.1.1 Neoclassical demand theory

Marshall (1890) as quoted by Reynolds (1978) popularised demand theory which focused on the quantity-price relationship for a single commodity and assumed "all other things being equal". This classical demand theory provided a demand function uncompensated for income and other price effects. Later, Slutsky (1915) and Hicks and Allen (1934) as quoted by Reynolds (1978) clarified and extended the basic demand theory and linked utility theory with demand analysis. This development provided the basis of 'neoclassical' demand theory that signified a change in emphasis in demand analysis where the utility maximisation hypothesis has become the empirical framework.

Based on the utility maximisation hypothesis, an individual faced with given prices for goods and services and a given income will select the utility maximising combination of goods and services. The scope of economic behaviour considered in this relationship is limited to decisions on quantities demanded. In order to predict the quantity demanded, a set of demand functions is established where the quantity purchased of each commodity is expressed as a function of its own price, prices of other commodities, and income. Demand elasticities measure quantity reactions to changing prices and incomes.

3.1.2 Restrictions

There are two types of restrictions which apply to a demand system: general (theoretical) and particular restrictions. The theoretical restrictions will be automatically satisfied by a demand function which was derived from a specific utility function. If the functional form for a demand system was not derived from a specific utility function, these restrictions can be imposed to satisfy the theoretical requirements of the demand system. The general restrictions include the Engel aggregation, the Cournot aggregation, the Slutsky symmetry, the homogeneity and the negativity conditions. The particular restrictions are based on available or assume prior information and can be *ad hoc* or systematic. A detailed treatment of the general restrictions can be seen in Tomek and Robinson (1981, pp. 52-7) and Reynolds (1978, pp. 15-24). A brief description of them, heavily drawn from Piggott (1991), is outlined below.

a. Homogeneity

The homogeneity condition requires that the sum of the own- and cross-price elasticities and the income elasticity for a particular commodity is zero. Provided consumers do not suffer 'money illusion', an equal proportionate change in all prices and income should not cause changes in quantities demanded. The relationship can be represented in mathematical form as:

$$\eta_{i1} + \eta_{i2} + \dots\dots\dots + \eta_{in} + \eta_{im} = 0 \qquad (3.1)$$

where

η_{ij} = uncompensated elasticity of demand for good *i* with respect to the price of good *j* (*j=1, ...n)*; and

η_{im} = income elasticity of demand for good *i*.

b. Symmetry

The Slutsky symmetry condition requires that the substitution matrix be symmetrical. Symmetry implies consistency in consumer behaviour between commodities, that is:

$$\sigma_{ij} = \sigma_{ji} \qquad (3.2)$$

where

σ_{ij} = the elasticity of substitution of *i* with respect to *j*; and

σ_{ji} = the elasticity of substitution of *j* with respect to *i*.

The elasticity of substitution between commodities *i* and *j* is given by:

$$\sigma_{ij} = \frac{\eta_{ij}}{w_j} + \eta_{im} \tag{3.3}$$

where

$w_j =$ is the share or expenditure weight for good *j*.

The Slutsky matrix is made up of n^2 elements of σ_{ij} and, because it is symmetrical, can provide *0.5 n(n-1)* restrictions on the parameters.

c. Engel aggregation

The Engel aggregation condition implies that the weighted sum of income elasticities is unity. Mathematically, assuming there are n commodities, the relationship can be represented as:

$$w_1\eta_{1m} + w_2\eta_{2m} + \ldots\ldots + w_n\eta_{nm} = 1 \tag{3.4}$$

where

$$\sum_{k=1}^{n} w_k = 1$$

d. Cournot aggregation

This condition is obtained by differentiating the budget constraint and is used in adding up with respect to the price of p_i and multiplying by w_i/q_i giving the general expression:

$$-w_k = \sum_{i=1}^{n} w_i\eta_{ik} \tag{3.5}$$

The Cournot aggregation condition and the Engel aggregation condition are usually referred to as adding-up restrictions.

3.1.3 Weak separability and the aggregation problem

Two important concepts in applied demand analysis are briefly outlined below. Detailed explanation of both concepts can be found in Deaton and Muellbauer (1980b, pp. 119-66).

First, the concept of separability arises from the assumption that the consumer is assumed to make budget allocations in two steps. First, total expenditure is allocated among different groups of consumption items (eg. meats, other food, shelter, entertainment, etc.). Second, the expenditure allocated to a particular group is allocated among individual products within that group. For example, within the meat group, expenditure is allocated among beef, pigmeat, lamb, and chicken. The concept of weak separability implies that the marginal rate of substitution between two commodities *i* and *j* from the same group is independent of the quantities of commodities from other groups.

Second, the aggregation problem arises because analysts usually use aggregate data in empirical works i.e. data derived by summing quantities consumed and expenditures across individual consumers. The problem is whether or not aggregate data reflect relationships which hold at the level of the individual consumer, or whether these relationships might become 'lost' or distorted in the aggregation process. Some economists have argued that to overcome the aggregation problem, divide aggregate data by population levels. Hence, individuals average out to negligible proportion in aggregate, leaving only the systematic effects of variations in prices and income (Deaton and Muellbauer 1980b).

3.2 The econometric model

3.2.1 General specification and variable choices

It was decided to estimate flexible functional form models in which the data are allowed to determine the form of the demand relationships. It was also considered desirable to use a demand system approach which could allow the restrictions from economic theory to be incorporated and cross-commodity effects to be captured. In addition, there are at least two advantages of estimating the system of equation on flexible functional forms, namely (i) approximate a wider range of underlying sets of preference; and (ii) has a smaller risk of specification bias (Piggott *et al.* 1995).

As Smallwood *et al.* (1989) and Alston and Chalfant (1991b, 1991c) point out, empirical results on structural change of meat demand depend on model choices. Thus a number of flexible demand system models should be estimated. This is intended to determine how sensitive results are to model choices.

This study employs the 'true' AIDS, the LA/AIDS, and the Rotterdam models to test the null hypothesis. The linear approximate version of AIDS and the Rotterdam model are the most popular models used by food demand analysts (Alston and Chalfant 1991a, 1991c; Piggott 1991; Brester and Wohlgenant 1991; and Barten 1993). Both models are similar in many respects. They have identical data requirements, are equally parsimonious with respect to parameters and both are linear in parameters. The first-differenced version of the LA/AIDS model is virtually identical to that of the Rotterdam model. However, their dependent variables differ substantially. This leads to difficulties in comparing both models using simple goodness-of-fit measures. In some applications, the two models lead to different results (Alston and Chalfant 1993). Thus, it is interesting to apply both systems to evaluate how different the results will be.

Although those models have some advantages, they have not been free from criticism. Deaton and Muellbauer (1980a), for example, obtained positive own-price elasticities for food when they applied the AIDS model to British data. Another important criticism of LA/AIDS centres around the use of Stone's price index (Buse 1994; Hahn 1994; and Moschini 1995). One criticism of the Rotterdam model is that it is too restrictive because it implies the demand elasticity for food increases as its expenditure share decreases (King 1979 as cited by Piggott 1991).

The choice of particular models and the assumption of weak separability determine the choice of variables. Since this study assumes weak separability, the meat group consists of beef, lamb, pigmeat and chicken and the relevant income variable is expenditure on meat (Alston and Chalfant 1987). Mutton and fish could have been in the group, but lack of data have prevented inclusion of those two meats in the models. Mutton is excluded in response to concerns about the quality of the mutton data (see Chalfant and Alston 1988; Beggs 1989; and Alston and Chalfant 1991). Data for fish are unavailable. Since some previous studies of meat demand (e.g. Alston and Chalfant 1991a) have found seasonality and time trends to be statistically significant in Australian meat demand, those variables will be included in the models. Advertising expenditure variables are excluded from this study since previous studies have found only small contributions of those variables in determining the quantity of meat demanded (Faruq 1988; Piggott 1991), although a later study has shown that advertising expenditure has a significant effect on Australian beef and chicken consumption but not in pork consumption (Piggott *et al.* 1995).

3.2.2 The Almost Ideal Demand System (AIDS)

The AIDS model is a flexible functional form model in which demand equations are derived from an expenditure function. A detailed description of the model can be found in Deaton and Muellbauer (1980a, 1980b). The AIDS model expresses w_i, the budget share of the *i-th* good, as:

$$w_{i,t} = \alpha_i + \sum_j \gamma_{ij,t} \log p_{j,t} + \beta_i \log(X/P)_t + \mu_{i,t} \qquad (3.6)$$

for $i,j = 1,2, \ldots, N$ and $t = 1, 2 \ldots, T$. Here, X is the total expenditure on all commodities in the system, $\mu_{i,t}$ are the residuals which are assumed to have zero mean and finite variance. The variable P is a price index defined as:

$$\log P = \alpha_0 + \sum_i \alpha_i \log p_i + \tfrac{1}{2} \sum_i \sum_j \gamma_{ij} \log p_i \log p_j \qquad (3.7)$$

The empirical estimation of the AIDS involves the estimation of equation (3.6) which is often referred to as the 'true' AIDS. However, to avoid the complexities and problems associated with non-linear estimation, equation (3.7) is often replaced by Stone's geometric price index *(P*)* defined as:

$$\log P^*_t = \sum_{i=1}^{N} w_i \log p_{it} \tag{3.8}$$

where w_i is the budget share. This is called the linear approximate version of the AIDS model (LA/AIDS), is given as:

$$w_{i,t} = \alpha_i + \sum_j \gamma_{ij,t} \log p_{j,t} + \beta_i \log(X/P^*)_t + \mu_{i,t} \tag{3.9}$$

The demand restrictions: adding up, homogeneity and symmetry can be imposed or tested on the system by the following relationships.

Adding up: $\sum \alpha_i = 1$; ; and $\sum \beta_i = 0$ (Engel aggregation) (3.10)

$\sum \gamma_{ij} = 0$ (Cournot aggregation) (3.11)

Homogeneity: $\sum \gamma_{ij} = 0$ (3.12)

Symmetry: $\gamma_{ij} = \gamma_{ji}$ (3.13)

The adding up restriction implies that the sum of constant terms for all meat expenditure share equations will add up to one and the coefficients for expenditure variables will add up to zero. The adding up restriction also implies that the coefficients for price variables in a meat expenditure share equation will add up to zero. This latter adding up restriction is also known as homogeneity restriction. The symmetry restriction implies that the coefficient for the lamb price variable in the beef equation is equal to the coefficient of the beef price variable in the lamb equation. The same relationships will also prevail for each of two other pair of meats.

The expenditure and price elasticities are given by:

$$\eta_i = 1 + \beta_i / w_i \tag{3.14}$$

$$\epsilon_{ii} = -1 + \left(\gamma_{ii} / w_i\right) - \beta_i \tag{3.15}$$

$$\delta_{ii} = -1 + \left(\gamma_{ii} \big/ w_i \right) + w_i \tag{3.16}$$

$$\in_{ij} = \gamma_{ij} \big/ w_i - \beta_i \left(w_j \big/ w_i \right) \tag{3.17}$$

$$\delta_{ij} = \left(\gamma_{ii} \big/ w_i \right) + w_j \tag{3.18}$$

where η denotes the expenditure elasticities, $\in$ denotes the Marshallian (uncompensated) price elasticities and δ denotes the Hicksian (compensated) price elasticities. The parameters γ_{ij} and β_i are derived as follows:

$$\begin{aligned} \gamma_{ij} &= \partial w_i \big/ \partial \log P_j ; \text{ and} \\ \beta_i &= \partial w_i \big/ \partial \log(X/P) \;. \end{aligned} \tag{3.19}$$

If the hypothesis of no structural changes is valid then the parameters in equation (3.9) i.e. α, β, and γ estimated over the full sample, would be adequate. Since structural change can be characterised by allowing this set of parameters to change over time, a common time path (denotes as h_t) can be introduced. Following Moschini and Meilke (1989), with some minor changes in notation, equation (3.20) was used to determine the effect of parameter change over time, where t and D_k are trend and seasonal dummy variables.

$$\begin{aligned} w_{i,t} &= \alpha_i + \theta_i h_t + \sum_j \left(\gamma_{ij} + \delta_{ij} h_t \right) \log p_{jt} + \left(\beta_i + \delta_i h_t \right) \log (X / P^*)_t \\ &+ \tau_i t + \phi_i t + \sum_k \left(\alpha_{ik} + \theta_{ik} h_t \right) D_k + \mu_{it} \end{aligned} \tag{3.20}$$

Additional parametric restrictions (Moschini and Meilke 1989) are shown below.

Adding up: $\Sigma_i \theta_i = 0$; $\Sigma_i \delta_{ij} = 0$; $\Sigma_i \delta_i = 0$; $\Sigma_i \theta_{ik} = 0$; $\Sigma_i \phi_i = 0$ (3.21)

Homogeneity: $\Sigma_i \delta_{ij} = 0$ (3.22)

Symmetry: $\delta_{ij} = \delta_{ji}$ (3.23)

The adding up restriction implies that the coefficients of the time path will add up to zero in all meat expenditure share equations. The coefficients of the time path for price variables will add up to zero for a meat equation and for seasonal dummy variables will add up to zero in an equation for all seasons .

To allow for estimation of dynamic behaviour, which is typical of time-series data, equation (3.20) is expressed in first difference form and the estimated model (Moschini and Meilke 1989) appears as:

$$\begin{aligned} \Delta w_{it} &= \theta_i \Delta h_t + \sum_j \left[\gamma_{ij} \Delta \log p_{jt} + \delta_{ij} \Delta(h_t p_{jt})\right] \\ &+ \beta_i \Delta \log(X / P^*)_t + \delta_i \Delta(h_t \log(X / P^*)_t \\ &+ \tau_i t + \phi_i \Delta t + \sum_k \left[\alpha_{ik} \Delta D_k + \theta_{ik} \Delta(h_t D_k)\right] + \mu_{it} \end{aligned} \tag{3.24}$$

The error terms μ_{it} in equation (3.24) are assumed to have a multinormal distribution but to be contemporaneously correlated across equations. Thus:

$$\begin{aligned} &E(\mu_{ij}) = 0; \\ &E(\mu_{it}\mu_{jt}) = \omega_{ij}; \\ &E(\mu_{it}\mu_{js}) = 0 \quad \text{for } t \neq s. \end{aligned} \tag{3.25}$$

3.2.3 The Rotterdam model

The Rotterdam model (Theil 1980) may be written as:

$$w_i d\,log(q_i) = \beta_i d\,log(Q) + \sum_{j=1}^{n} \gamma_{ij}\ d\,log(p_j) + \mu_{i,t} \tag{3.26}$$

where $d\,log(Q) = \sum_i w_i\ d\,log(q_i)$ is the Divisia volume index.

In this model, w_i corresponds to the expenditure share of meat item *i* in time period *t*, q_i denotes per capita consumption of meat item *i* in time period *t*, and p_i corresponds to the real price of meat item *i* in time period *t*. For empirical application which involves discrete observations, the logarithmic differentials (*dlog's*) of variables are replaced by their logarithmic first differences ($\Delta logp = logp_{i,t} - logp_{i,t-1}$) and the w_i are replaced by $\overline{w}_i = 0.5(w_{i,t} + w_{i,t-1})$. This results in the absolute price version of the Rotterdam model:

$$\overline{w}_i \Delta \log q_i = \beta_i \Delta \log(Q) + \sum_{j=1}^{n} \gamma_{ij} \Delta \log p_j \tag{3.27}$$

As a result of this approximation, the Rotterdam model cannot be considered as an exact representation of preferences unless restrictive conditions are imposed. Nonetheless, according to Bannett (1979) and Mountain (1988) the Rotterdam model is a flexible approximation to an unknown demand system. Alston and Chalfant (1993) have predicted that the model will gain popularity as the main alternative to the LA/AIDS model in the next few years.

This model necessitates the use of classical restrictions so that the estimates of demand parameters conform to theory. The restrictions for the Rotterdam model are as follows:

Adding up: $\Delta \log(Q) = \sum_{j=1}^{n} w_j \; \Delta \log(q_j) \quad \Sigma \gamma_{ij} = 0$; and $\Sigma \beta_i = 1$ (3.28)

Homogeneity: $\Sigma \gamma_{ij} = 0$; and (3.29)

Symmetry: $\gamma_{ij} = \gamma_{ji}$ (3.30)

The expenditure and price elasticities for the Rotterdam model are given by:

$$\eta_i = \beta_i / w_i \tag{3.31}$$

$$\epsilon_{ii} = \left(\gamma_{ii} / w_i \right) - \beta_i \tag{3.32}$$

$$\epsilon_{ij} = \gamma_{ij} / w_i - \beta_i \left(w_j / w_i \right) \tag{3.33}$$

where η denotes the expenditure elasticities, ϵ denotes the Marshallian (uncompensated) price elasticities.

3.3 Summary

This chapter was divided into two main sections: economic model and econometric model. The economic model commenced with a brief review of neoclassical demand theory that results in demand functions with prices and incomes as their main components. The theoretical restrictions among parameters and the concept of weak separability and the aggregation problem were then discussed because of their importance in empirical work. The econometric model commenced with a discussion of general specification and variable choices. Since empirical results on structural change in meat demand depend upon model choices then it is advisable to estimate a number of flexible demand systems. The choice of variables to be included in a model depends on the particular model, the assumption of weak separability and the decision to include time trends and seasonality as factors that influence demand. Finally, a detailed description of the Almost Ideal and the Rotterdam models were outlined.

4. Method of Analysis

4.1 Estimation issues

The analysis was undertaken using SHAZAM version 7.0 (White 1993) on the METZ computer at the University of New England. Before the structural shift analysis was carried out, a series of autocorrelation tests were conducted because autocorrelation is common in time series data. As noted by Kramer (1990) the Chow test, for example, cannot be trusted unless the disturbances are not autocorrelated. The significance of trend and seasonal dummy variables in the model were also evaluated. Based on these tests, autocorrelation was corrected using the **AUTO** command of SHAZAM. Trend and seasonal dummy variables were statistically significant in the models and therefore they were retained because exclusion of those variables might cause misspecification (see also Alston and Chalfant 1991a).

The LA/AIDS, the first differenced LA/AIDS and the Rotterdam models were estimated using both single equation and systems of equation methods. The 'true' AIDS model was estimated using the systems of equations method only. The homogeneity restriction was imposed in both the single equation and systems of equation, while adding-up and Slutsky symmetry were imposed in the system versions only.

The systems of equation were estimated by nonlinear seemingly unrelated regression (SUR). Each of equations in the system was estimated using the **NL** command of SHAZAM. To avoid the problem of a singular matrix, the share equations for chicken were not estimated. If the residuals are not serially correlated, the parameters of the excluded equation can be derived from the parameters of the included equations using the adding-up restriction. According to Barten (1969), the resultant estimates are invariant with respect to the equation deleted.

As was first pointed out by Deaton and Muelbauer (1980a) and later by Alston and Chalfant (1991a), the intercept in the AIDS price index (α_0 in equation (3.7)) often creates trouble during estimation. The values of the estimated coefficients for the 'true' AIDS model are very sensitive to the starting value of α_0. To ensure that a global maximum was reached instead of a local maximum, several sets of starting values of all the parameters were employed during the estimation.

Three tests were applied to the linear demand system to evaluate the stability of the demand parameters, namely: Chow, Farley-Hinich (F-H) and Ohtani-Katayama (O-K) tests. All of these tests were imposed in the unrestricted linear demand equations. The Chow test was applied by inserting a **DIAGNOS/CHOWTEST** command immediately after the OLS estimation command in each of equations. The command generates a sequential Chow tests. This is the only estimation where autocorrelation was not corrected because **DIAGNOS/CHOWTEST** cannot be applied after the **AUTO** command and **RESTRICT** option. Instead, the Chow test for the Almost Ideal was conducted in the first differenced LA/AIDS model because it was found that the LA/AIDS had an autocorrelation problem whereas its first differenced form did not. Application of the F-H test was undertaken by first generating a time path, $h = t/T$, and multiplying it by all the independent variables. Those new independent variables are tested for their joint significance in the model (F-test). The O-K test is almost the same as the F-H test except that there is an allowance for smooth changes between two breaks points. Procedures to incorporate the time path in the model can be seen in equations (3.20) to (3.25).

The Andrews-Fair (A-F) test was applied to the nonlinear systems of equation of the LA/AIDS and the Rotterdam model. The data were divided into two subsamples at observation 38. The first period consists of 1965:1 to 1974:1 and the second period from 1974:3 to 1992:4 (see Figure 1). A time path $t_1 = -37, \ldots, -1$ was assigned to the first period and $t_2 = 1, \ldots, 74$ to the second period. T was set equal to zero at observation 38 (1974:2) where it was assumed the structural change occurred.

4.2 Data sources

Data were obtained from a database constructed by NSW Agriculture. The raw quantity data were sourced from ABS and AMLC while the raw price data were sourced from ABARE. The data are composed of 112 quarterly observations beginning with the first quarter 1965 and ending with the fourth quarter 1992. Quarterly data were chosen as most appropriate in estimating the demand model. Annual data were considered too lengthy 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 same set of data with different time spans were used by Main *et al.* (1976), Reynolds (1978), Fisher (1979), Martin and Porter (1985), Piggott (1991), Goddard and Griffith (1992) and Piggott *et al.* (1995). Additional information concerning the data used in this study is included in Appendix 1.

4.3 Data characteristics

The data consist of four price variables: beef price, lamb price, pigmeat price and chicken price, and four quantity variables: beef consumption, lamb consumption, pigmeat consumption and chicken consumption. Graphical representations of the quantity variables can be seen in Figure 1 and of the price variables in Figure 3. Interpretation of the graphical representation of the quantity variables has been discussed in Chapter 1. The behaviour of nominal retail price variables is shown in the upper part of Figure 3 and the real retail prices in the lower part of the figure. As shown in the figure, the nominal price of the meats were almost the same in 1965, but all prices increased sharply to 1992. Beef and pigmeat prices increased by more than six times. The nominal price of chicken is relatively stable compared to the other meats. All the real prices have reduced with chicken and pigmeat experiencing the greatest reduction. The real prices of beef and lamb fluctuated over the period with only a small reduction in real prices to 1992 compared to their real prices in 1965. A mirror image is shown when the real price and quantity consumed of each meat were plotted in a graph

(Figure 4). When the real price of a meat reduced then the quantity consumed of the meat tended to increase and vice versa.

The summary statistics of the data can be seen in Table 1. In general, the coefficients of variation of the nominal price variables are higher than the quantity variables. The beef nominal price has the highest coefficient of variation (62.38 percent) followed by the lamb nominal price and pigmeat nominal price with coefficients of variation of 58.21 percent and 53.51 percent respectively. Pigmeat consumption has the lowest coefficient of variation (15.51 percent). When the price variables were deflated, the coefficients of variation of the real prices became low.

In Table 2 are shown the correlations among these variables. The correlation among nominal retail price and quantity variables can be seen in part a of the table and the correlation among real retail price and quantity variables can be seen in part b of the table. The correlations among the nominal price variables are very high, while the correlations among the quantity variables are low and negative except between pigmeat consumption and chicken consumption. The correlations among the nominal price variables and quantity variables are mixed. The correlation between pigmeat consumption and chicken consumption and the nominal price variables are high and positive, whereas the correlation of beef consumption and lamb consumption with the nominal price variables are low and negative.

The correlation among the real prices are low, except between pigmeat price and lamb price and between pigmeat price and chicken price. In general, the correlation among the real price variables and quantity variables are lower than when the prices were not deflated. However, the correlation among pigmeat and chicken consumption and pigmeat and chicken real prices are still high and become negative.

Figure 3: Nominal and real retail prices of meats, 1965 to 1992

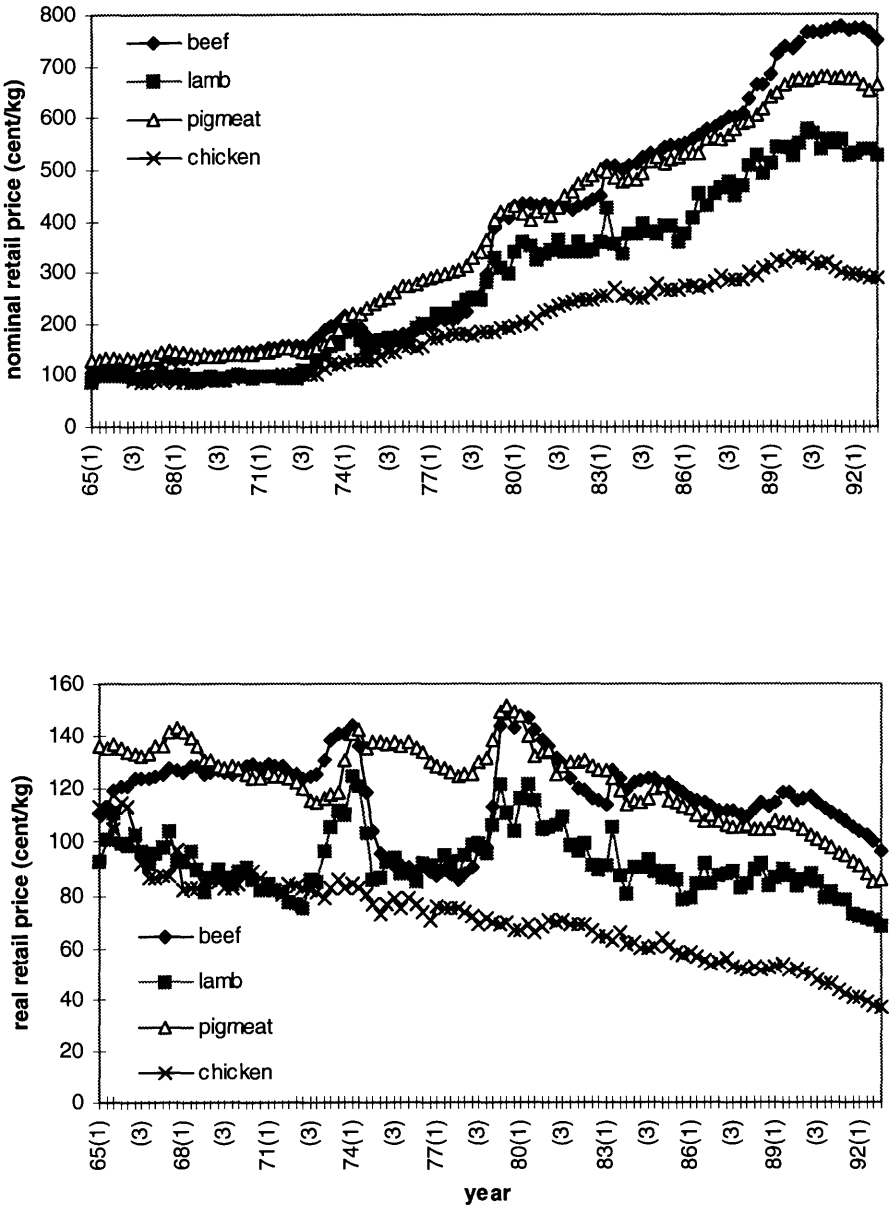
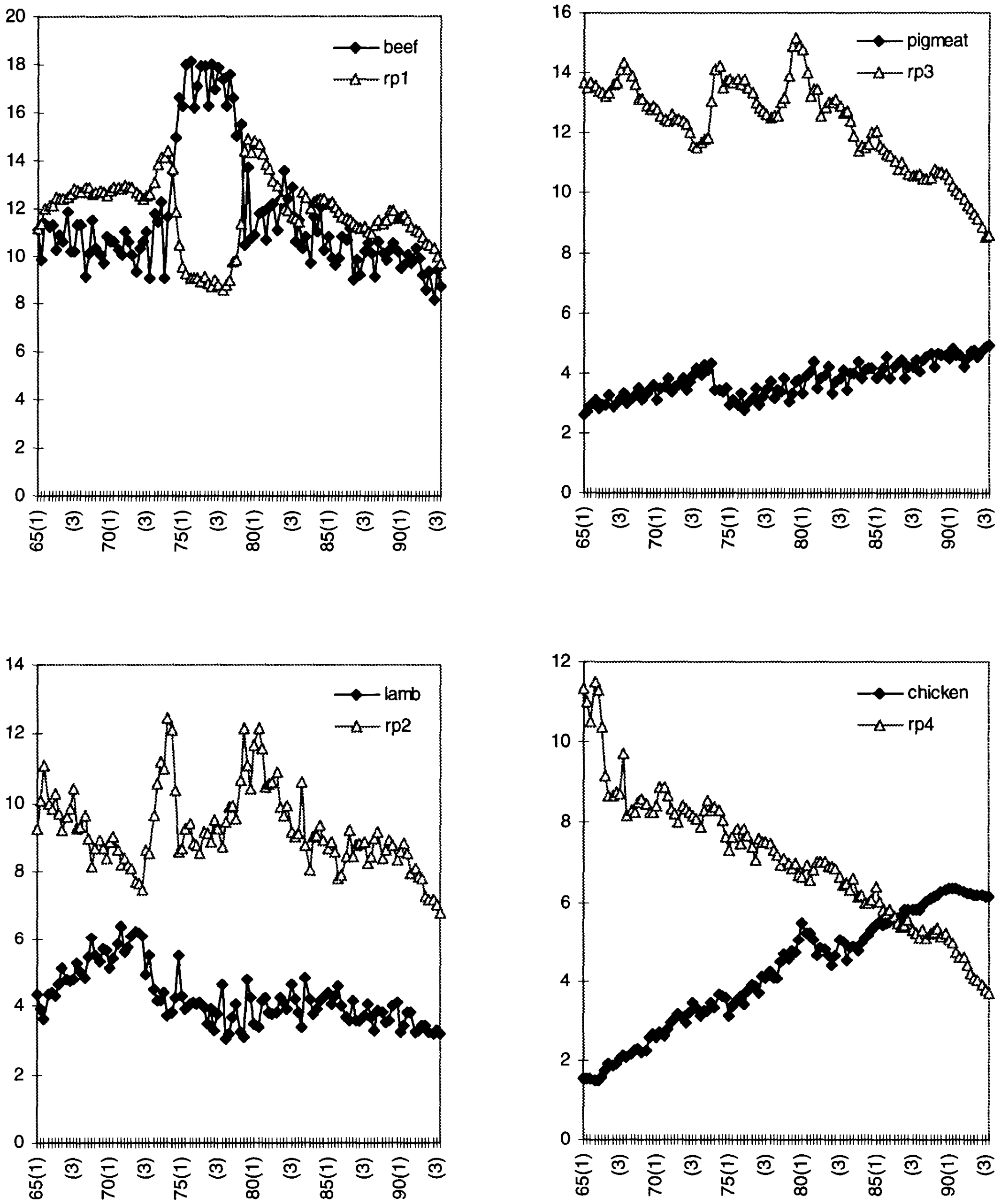


Figure 4: Real retail price and quantity consumed, 1965 to 1992



Note:		
	rp1	real retail beef price
	rp2	real retail lamb price
	rp3	real retail pigmeat price
	rp4	real retail chicken price

Table 1: Summary statistics of the data

Variable	N	Mean	Standard deviation	Variance	Min	Max	Coefficient of variation
Nominal retail price							
beef	112	367.49	229.22	52541.0	105.00	775.30	0.62375
lamb	112	282.31	164.35	27011.0	85.90	575.65	0.58216
pigmeat	112	365.93	195.83	38348.0	128.70	680.10	0.53514
chicken	112	192.79	82.88	6869.40	84.50	329.90	0.42990
Real retail price							
beef	112	117.99	14.98	224.39	86.10	148.51	0.12695
lamb	112	91.874	11.51	132.38	67.78	124.71	0.12523
pigmeat	112	122.96	14.85	220.59	85.34	151.63	0.12079
chicken	112	70.735	16.91	285.80	37.10	115.09	0.23900
Consumption							
beef	112	11.650	2.5996	6.75780	8.1366	18.165	0.22313
lamb	112	4.2681	0.8170	0.66749	3.0726	6.4176	0.19142
pigmeat	112	3.7553	0.5825	0.33940	2.6106	4.9003	0.15513
chicken	112	4.2265	1.4973	2.24180	1.5043	6.3468	0.35425

Table 2: The correlation matrix

a. Nominal retail price and quantity consumed

p1	1.00000							
p2	0.98722	1.00000						
p3	0.98317	0.99225	1.00000					
p4	0.96747	0.98231	0.99024	1.00000				
q1	-0.41355	-0.30381	-0.27087	-0.24938	1.00000			
q2	-0.60023	-0.68467	-0.66162	-0.66047	-0.14367	1.00000		
q3	0.83959	0.79906	0.78231	0.76948	-0.50742	-0.30875	1.00000	
q4	0.93612	0.95496	0.96094	0.95075	-0.18498	-0.62297	0.81139	1.00000
	p1	p2	p3	p4	q1	q2	q3	q4

b. Real retail price and quantity consumed

rp1	1.00000							
rp2	0.48273	1.00000						
rp3	0.28813	0.67525	1.00000					
rp4	0.24592	0.40306	0.74652	1.00000				
q1	-0.56124	0.23536	0.46084	0.22071	1.00000			
q2	0.35097	-0.20951	0.33027	0.55116	-0.14367	1.00000		
q3	0.04202	-0.37963	-0.81639	-0.81091	-0.50742	-0.30875	1.00000	
q4	-0.18053	-0.25022	-0.67945	-0.94740	-0.18498	-0.62297	0.81139	1.0000
	rp1	rp2	rp3	rp4	q1	q2	q3	q4

Note:

p1	nominal beef price	q1	beef consumption
p2	nominal lamb price	q2	lamb consumption
p3	nominal pigmeat price	q3	pigmeat consumption
p4	nominal chicken price	q4	chicken consumption

rp1	real beef price
rp2	real lamb price
rp3	real pigmeat price
rp4	real chicken price

The high correlation among these variables might cause multicollinearity problems during estimation. The main problem arising from multicollinearity is large standard errors. This causes insignificant t-tests for coefficient estimates despite high R^2 or F-values. Problems associated with multicollinearity in Australian meat consumption data have been documented (e.g. Fisher 1979; Martin and Porter 1985; Chalfant and Alston 1986) where the high correlation between quantity of chicken consumption and price variables caused problems in estimating poultry demand. One possible solution to this problem is to impose linear restrictions on the parameters (Griffiths *et al.* 1993), such as in a demand system. Another solution is to deflate the price variables (Tomek and Robinson 1981). As are shown in Table 2, the correlation among real price and quantity variables are lower.

In addition to the conventional data characteristics as described above, several tests were also conducted to evaluate whether or not the variables contain unit roots. The presence of a unit root is an indication of nonstationary series. In the presence of nonstationary variables there might be a spurious regression where R^2 is high and t-values are statistically significant but the results are without any economic meaning (Granger and Newbold 1974). Fortunately, most nonstationary series can be transformed to stationary series by differencing the original series once or twice.

Unit root tests developed by Dickey and Fuller (1979) and the associated improvement of the test developed by Phillips and Perron (1988), with allows milder assumptions concerning the distribution of errors, were applied to the data. The procedure for unit root testing is described by Enders (1995, pp. 256-8). The tests were evaluated both in linear and in logarithmic form. When the results of the tests are different between those two forms, the results of tests on the logarithmic form are preferable. Likewise, the results of the Phillips-Perron (PP) test are preferable compared to the Augmented Dickey-Fuller (ADF) test.

As can be seen in Table 3, the ADF test produced a greater number of variables which have a unit root, whereas the PP test produced a smaller number of variables which have a unit root. There are big differences in lag lengths among the variables. The differences are due to the true order of the autoregressive process. It seems that four variables have a unit root i.e. beef and lamb consumption, and lamb and chicken prices, whereas the other four variables do not have a unit root i.e. pork and chicken consumption, and beef and pork prices.

The results are different from those reported by Lee (1991). Employing monthly data from January 1973 to June 1990 on seven variables: prices and consumption of beef, lamb and pork plus commodity expenditure he found that all the seven variables contained a unit root. The difference can be rationalised by the fact that the presence of unit roots (stochastic trends) shows consistent evidence on variables sampled at high frequencies. In other words, the evidence is more clear in monthly data compared to low frequency (annual) data. One argument for this is a typically greater number of observations found on high frequency data (Myers 1994). To confirm that second unit roots are not present in the variables, subsequent tests were also applied to the same data both in linear and logarithmic form by taking the first difference of the series. The results show that none of the variables contains a second unit root.

Table 3: Testing for unit roots

Series	nlag	ADF	PP	AIC/SC
		Consumption		
Beef {ql}	1	I (1)	I (1)	lowest
Logarithmic form	1	I (1)	**I (1)**	lowest
Lamb {q2}	3	I (1)	not I (1)	lowest
Logarithmic form	3	I (1)	**I (1)**	lowest
Pork {q3}	12	I (1)	not I (1)	lowest
Logarithmic form	12	I (1)	**not I (1)**	lowest
Chicken {q4}	12	I (1)	not I (1)	lowest
Logarithmic form	12	I (1)	**not I (1)**	lowest
		Nominal retail price		
Beef {pl}	3	I (1)	not I (1)	lowest
Logarithmic form	3	I (1)	**not I (1)**	lowest
Lamb {p2}	6	I (1)	I (1)	lowest
Logarithmic form	6	I (1)	**I (1)**	lowest
Pork {p3}	3	not I(1)	not I (1)	lowest
Logarithmic form	3	I (1)	**not I (1)**	lowest
Chicken {p4}	12	I (1)	I (1)	lowest
Logarithmic form	12	not I (1)	**I (1)**	lowest

Note:

nlag	number of lags
ADF	augmented Dickey-Fuller test
PP	Phillips-Perron test
AIC	Akaike information criterion
SC	Schwarz criterion
I(1)	has a unit root