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Changing Pattern of Meat Consumption in Australia

by

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Abstract:

The objective of this paper is to present a systematic analysis of the Australian meat demand using data for the period 1962 to 2011 for 5 types of meat, namely beef, lamb, mutton, chicken and pork, under a system-wide framework using three demand system, Rotterdam, CBS and AIDS.

In 2011, Australians consumed around 111kg of meat per person divided into 33kg of beef, 9kg of lamb, 43kg of chicken and 25kg of pork. Australian consumers allocate about 4 percent of their budget to the purchase of meat. Within their expenditure on meat, they allocate about 44 percent on beef, 12 percent on lamb, 21 percent on chicken and 24 percent on pork with very little or none on mutton. In terms of market share, chicken and pork have increased their share by 3 and 2 times, respectively, in the last 50 years at the expense of beef, lamb and mutton. Mutton share was 13.8 percent in 1962 and has been almost wiped out in 2011. The retail prices of all five meat types has steadily increased over the last 50 years with beef, lamb and mutton prices increased at faster rate than the prices increase of chicken and pork.

The paper also found support four empirical regularities in consumer demand, namely, quantity variance exceeds price variance; demand curve slopes downwards; income flexibility tends towards -0.5; and, budget share of food declines with increasing income. In general, the two demand theory hypotheses, demand homogeneity and Slutsky symmetry were found to be acceptable for the meat data.

The implied income and price elasticities show that beef is a luxury while mutton, lamb, chicken and pork are necessities. The demand for mutton is price elastic and demand for beef, lamb, chicken and pork are price inelastic. We also found that chicken and pork are pairwise complements while all other pairs are pairwise substitutes.

1. Introduction

Meat consumption plays a major role in consumer's daily food intake. Australian consumers currently allocate about 40 percent of their food expenditure allocation on meat. This also accounts for about 4 percent of their total consumption expenditure on all goods and services. Within the meat group, Australian consumers currently allocate 44 percent of the meat expenditure on beef, 12 percent on lamb, 20 percent on chicken and 24 percent on pork. Furthermore, over the last 50 years, Australian meat consumption pattern has changed significantly between the meat types due to change in consumer taste as well as some supply side regulations such as trade restrictions, change in meat classifications etc. Australian consumers have increased their consumption of chicken and pork at the expense of beef, mutton and lamb. Consequently, an economic analysis on the demand for meat in Australia is crucial to the meat producers, meat sellers as well as meat consumers. This paper attempts to present an empirical analysis on the demand for the different types of meat, namely beef, lamb, mutton, chicken and pork, in Australia over the last five decades spanning over the period 1962 to 2011. This study adopts the well-known system-wide approach to achieve this purpose.

There are three basic reasons for the selection of system-wide approach in this study. Firstly, the implication of the consumer's budget constraint is that any increase in expenditure on one good can only arise from a decreased expenditure of at least one other good. This underlying interrelationship between the consumption of the different types of meat can only be studied when the demand equations for all meat types are considered simultaneously.

Secondly, there are certain constraints arising from consumption theories that necessitate the utilization of a system of demand equations. The first is that demand equations are homogeneous of degree zero in income and prices, termed *demand homogeneity*. This property stipulates that an equal proportional increase in a consumer's income and prices of the different meat types should have no effect on the quantities consumed; this translates to the assumption that the consumer is not subject to money illusion.

The next is that, if the consumer's real income is held constant, the quantity change in the consumption of a good, arising from a one-dollar increase in the price of a different good, will be exactly the same as the change in the consumption of the first good brought about by a one-dollar increase in the price of the latter good. This is termed *Slutsky symmetry* and when represented algebraically becomes a cross-equation constraint. As such, it is evident that only a system-wide approach will satisfy the constraints under Slutsky symmetry.

Besides, economic theories should not accept the taking of one good in isolation from the rest; thus, this study hopes to tell a common story for all the five meat types. It is only when we can paint a complete picture of the demand conditions for all the five meat types that we can hope to present a true picture.

This study's aim is to present a detailed scientific analysis of meat consumption patterns of Australian consumers considering specifically the five types of meat, beef, lamb, mutton, chicken and pork. We focus on the impact of two economic variables, income of the consumers and individual prices of beef, lamb, mutton, chicken and pork on the consumption of these five meat types. We also investigate the change in meat consumers' tastes, habits etc and the substitutability or complementarities between different types of meat. In addition, this study will also investigate whether the meat consumption data supports a number of empirical regularities found in other consumption studies, such as (1) quantity variance systematically exceeds price variance; (2) income flexibility is about -0.5; (3) the demand curve slopes downwards; and (4) budget share of meat declines with increasing income.

The paper is structured in the following manner. Section 2 presents a literature review of a number of past Australian meat studies and summarizes the reported demand model parameters – namely income, own-price and cross-price elasticities. This will be followed, in Section 3, by a brief overview of the basic concepts of consumer demand. Section 4 will present a preliminary analysis of the Australian meat data. In the next section we investigate a number of empirical regularities in consumer demand with Australian meat data. In Section 6, we present the demand systems, the Working's model, the Almost Ideal Demand System (AIDS) and the Rotterdam Model for estimation and in Section 7 select the preferred model using the goodness-of-fit measure, the information inaccuracy. In section 8 we tabulate the estimation results for the preferred model and present the implied income and price elasticities. Finally, Section 9 provides the concluding comments.

2. A Summary of Previous Studies

In this section, we present a summary of a number of Australian meat demand studies. These studies vary in terms of the data time period, functional forms, type of meats considered, and the method of estimation used. Consequently, the estimated income and price elasticities also vary depending on the data, time period and the method of estimation.

Table 1 presents the income elasticities and own-price elasticities of the five types of meat. Table 2 presents summary measures of all the income and own-price elasticities for the five meat types across all studies. As can be seen, the average income elasticities across the studies are 0.77 for beef, 0.24 for lamb, -0.65 for mutton, 0.47 for chicken and 0.48 for pork. Except for mutton, all the average income elasticities are positive. Although the average for mutton is negative, the value ranges between -3.59 and 1.52. The estimated income elasticities for the four meat types are mainly positive; indicating that, consumption of the beef, lamb, chicken and pork will increase commensurate with an increase in income.

With respect to the five meats' own-price elasticities, on average, all the elasticities are negative as they should be; that is the quantity demanded for these goods will fall in response to an increase in their prices. Most of the own-price elasticities for beef, lamb, mutton and pork are greater than 1 indicating that their demand is elastic. In other words, the change in quantity demanded of these goods will be more than proportionate to a change in their respective prices. Chicken, with most of the estimates less than 1, appears to have an inelastic demand; hence changes in the quantity demanded of chicken will be less than proportionate to changes in its price.

Table 3 presents the corresponding cross-price elasticities for the five meat groups from the Australian meat studies. As can be seen, a majority of the cross-price elasticities are positive indicating a high degree of substitutability between the five types of meat. There is also some degree of complementarity noticeable between the mutton, pork and chicken meat subgroup.

Table 1 Summary of previous studies and income and own-price elasticities of 5 meat types

Author	Data period	Model / Estimation	Income Elasticity					Own-price Elasticity				
			Beef	Lamb	Mutton	Chicken	Pork	Beef	Lamb	Mutton	Chicken	Pork
Taylor (1961)	1951-60 (A)	Double Log (OLS)						-0.96	0.02			
Van der Meulen (1961)	1948-60 (A)	Double Log (OLS)	0.40	0.23				-0.71	-1.18			
Taylor (1963)	1951-60 (A)	Double Log (OLS)						-1.03	-1.80	-1.20		
Marceau (1967)	1951-63 (Q)	Double Log (OLS)	-0.24	0.14	0.01			-1.33	-2.07	-1.09		
Hill (1967)	1948-62 (A)	Double Log (OLS)										-1.20
Gruen et al (1968)	1950-65 (A)	Double Log (OLS)	0.55	0.83	-1.73		2.81	-0.96	-1.55	-1.38		-2.19
Pender & Erwood (1970)	1953-69 (A)	ILS					1.50					-3.29
Paton (1970)	1954-69 (A)	Double Log (OLS)				0.42					-1.31	
Papadopoulos (1971)	1962-70 (Q)	Double Log (OLS)	0.98	-0.72	0.26		-0.26	-2.06	-1.33	-0.48		-3.99
Throsby (1972)	1962-70 (Q)	2SLS	0.59					-1.90				
Throsby (1975)	1962-72 (Q)	2SLS	0.22					-0.76				
Greenfield (1974)	1955-72 (A)	Double Log (OLS)	1.23	-0.51		0.66	0.80	-1.71	-0.61		-1.25	-1.05
Main et al (1976)	1962-75 (Q)	Double Log (OLS)	0.42	0.03	-0.86		-0.09	-1.46	-1.68	-2.22		-1.62
Main et al (1976)	1962-75 (Q)	SUR (Double Log)	0.38	-0.14	-0.96		-0.34	-1.41	-1.89	-2.02		-1.99
Reynolds (1976)	1962-76 (Q)	SUR (Double Log)	0.38	0.10	-1.45	1.84	0.15	-1.32	-1.71	-1.30	-0.89	-1.59
Reynolds (1976)	1962-76 (Q)	SUR	0.46	-0.16	-1.95	1.74	0.25	-1.27	-1.63	-1.30	-0.89	-1.91
Freebairn & Gruen (1977)	1962-75 (Q)	Double Log (OLS)	0.51					-1.39				
Fisher (1979)	1962-77 (Q)	Double Log (FIML)	0.48	0.03	-1.45	0.16	0.2	-1.32	-1.66	-1.17	-0.16	-1.40
Fisher (1979)	1962-77 (Q)	Modified Translog (FIML)	0.54	0.09	-0.81	0.20	0.04	-1.19	-1.58	-1.12	-0.23	-0.95
Griffith & Vere (1981)	1966-79 (Q)	Linear (OLS)		0.09					-1.33			
Murray (1984)	1950-79 (A)	AIDS (SUR)	1.16	0.84	1.09	1.32	1.06	-1.87	-1.32	-1.02	-1.10	-1.39
Murray (1984)	1950-79 (A)	Translog (SUR)	1.04	0.44	1.52	-0.02	1.97	-1.56	-1.43	-1.05	-0.44	-2.01
Murray (1984)	1950-79 (A)	Indirect Addilog (SUR)	1.36	0.75	0.63	-0.50	1.06	-1.63	-1.49	-1.41	-0.40	-1.85
Shaw et al (1983)	1966-81 (A)	Log Change (OLS)	0.20	0.20	0.20	0.20	0.20	-0.95	-1.41	-4.26	-0.75	-1.57
Dewbre et al (1985)	1965-83	Double Log (OLS)	0.37	0.21		0.29	0.31	-0.98	-1.43		-0.77	-1.34
Martin & Porter (1985)	1962-83 (Q)	Double Log (OLS)	0.68	-0.13	-3.59	2.13	0.25	-1.13	-1.88	1.39	-0.85	-1.09
Alston & Chalfant (1987)	1968-83 (Q)	Double Log (OLS)	1.61	0.85		0.17	0.26	-0.42	-1.33		-0.37	-1.12
Alston & Chalfant (1987)	1968-83 (Q)	AIDS (Modified Translog)	0.15	0.39		-0.93	-0.24	-1.11	-1.39		-0.31	-1.02
Vere & Griffith (1988)	1966-86 (Q)	Double Log (OLS)		-0.67					-0.82			
Cashin (1991)	1967-90 (Q)	LA-AIDS (SUR)	1.65	0.53		0.06	0.23	-1.24	-1.33		-0.47	-0.83
Cashin (1991)	1982-90 (Q)	LA-AIDS (SUR)	1.38	0.77		1.11	0.31	-0.82	-0.99		-0.23	-1.20
Harris & Shaw (1992)	1962-88 (A)	LA-AIDS (SUR)	0.26					-0.92				
Piggot et al (1996)	1978-88 (Q)	Double Log (OLS)	1.82	0.43		0.18	0.15	-0.42	-1.26		-0.46	-0.87
Vere et al (2000)	1970-96 (Q)	Linear (2LS)	0.33	0.22			0.12	-1.38	-1.54			-1.59
Ulubasoglu et al (2011)	1999-2004	LA-AIDS (OLS)	1.64	1.64		1.38	1.59	-1.35	-1.42		-1.39	-2.20
Nhung et al (2011)	1999-2004	AIDS (OLS)						-0.99	-0.67		-0.46	-0.79
Mounter et al (2012)	1965-2010(Q)	LA-AIDS	1.49	0.78		0.09	0.48	-0.99	-0.84		-0.27	-0.36
		AIDS	1.49	0.72		0.14	0.47	-2.18	-1.02		-1.38	-0.81
		Rotterdam	1.61	0.56		0.06	0.30	-1.14	-0.89		-0.30	-0.25

Table 2: Summary income and own-price elasticities across all studies

Summary statistic	Income elasticites					Own-price elasticities				
	Beef	Lamb	Mutton	Chicken	Pork	Beef	Lamb	Mutton	Chicken	Pork
Mean	0.77	0.24	-0.65	0.47	0.48	-1.23	-1.33	-1.31	-0.63	-1.48
Standard Error	0.10	0.08	0.37	0.17	0.14	0.07	0.08	0.29	0.08	0.15
Median	0.54	0.21	-0.84	0.19	0.26	-1.22	-1.40	-1.20	-0.46	-1.37
Minimum	-0.24	-0.72	-3.59	-0.93	-0.34	-2.18	-2.07	-4.26	-1.38	-3.99
Maximum	1.82	0.85	1.52	2.13	2.81	-0.42	0.02	1.39	-0.16	-0.25
Count	31	29	14	20	26	34	32	15	21	28

Table 3 Summary of previous studies and Cross-price elasticities of meat groups

Author	Data	Model / Estimation	Meat type	Cross-price Elasticity				
				Beef	Lamb	Mutton	Chicken	Pork
Van der Meulen (1961)	1948-60 (A)	Double Log (OLS)	Beef		0.49			
			Lamb	0.91				
Marceau (1967)	1951-63 (Q)	Double Log (OLS)	Beef		0.02			
			Lamb	0.48		-0.60		
			Mutton	1.24	0.79	-1.09		
Gruen et al (1968)	1950-65 (A)	Double Log (OLS)	Beef		0.29	0.20		
			Lamb	0.5		0.24		
			Mutton	1.20	0.28			
Papadopoulos (1971)	1962-70 (Q)	Double Log (OLS)	Beef		-2.03	0.13		1.42
			Lamb	0.86		-2.13		0.21
			Mutton	1.07	1.29			0.26
			Pork	5.36	0.65	-1.58		
Greenfield (1974)	1955-72 (A)	Double Log (OLS)	Beef					
			Lamb	0.95				0.34
			Pork	0.29	0.16			
			Chicken		0.41			-0.02
Main et al (1976)	1962-75 (Q)	Double Log (OLS)	Beef		0.03	0.34		0.34
			Lamb	0.71		0.25		0.86
			Mutton	0.63	1.06			1.12
			Pork	0.68	0.69	-0.46		
Main et al (1976)	1962-75 (Q)	SUR (Double Log)	Beef		0.09	0.34		
			Lamb	0.64		0.25		0.91
			Mutton	0.51	0.91			0.95
			Pork	0.51	0.73	-0.30		
Reynolds (1976)	1962-76 (Q)	SUR (Double Log)	Beef		-0.16	0.36	0.04	0.36
			Lamb	0.72		0.25	-0.01	0.53
			Mutton	1.22	0.06		0.55	1.05
			Chicken	-0.57	0.21	-0.31		-0.49
			Pork	0.72	-0.27	0.38	-0.43	
Reynolds (1976)	1962-76 (Q)	SUR	Beef		0.19	0.11	0.07	0.12
			Lamb	0.62		0.29	-0.05	0.23
			Mutton	0.75	0.57		0.08	-0.12
			Chicken	0.42	-0.13	0.06		-0.52
			Pork	0.82	0.49	-0.15	-0.51	
Fisher (1979)	1962-77 (Q)	Double Log (FIML)	Beef		0.72	0.96		1.13
			Lamb	0.21		0.46		0.78
			Mutton	0.14	0.23			-0.70
			Pork	0.16	0.37	-0.63		-1.40
Fisher (1979)	1962-77 (Q)	Modified Translog (FIML)	Beef		0.14		0.04	
			Lamb	0.47		0.25	-0.12	0.33
			Mutton		0.49		0.23	-0.48
			Chicken	0.28	-0.25	0.27		-0.27
			Pork	1.00	0.70	0.52	-0.27	
Murray (1984)	1950-79 (A)	AIDS (SUR)	Beef		0.30	0.16	0.09	0.17
			Lamb	0.54		0.06	-0.13	0.12
			Mutton	0.15	-0.09		-0.03	-0.09
			Chicken	-0.21	0.03	-0.04		0.01
			Pork	0.52	0.19	-0.32	-0.06	
Murray (1984)	1950-79 (A)	Translog (SUR)	Beef		0.15	0.22	0.01	0.15
			Lamb	0.87		-0.26	0.06	0.32
			Mutton	0.59	0.45		-0.25	-0.35
			Chicken	0.59	0.19	-0.25		-0.08
			Pork	0.60	0.45	-0.76	-0.24	

Author	Data	Model / Estimation	Meat type	Cross-price Elasticity				
				Beef	Lamb	Mutton	Chicken	Pork
Murray (1984)	1950-79 (A)	Indirect Addilog (SUR)	Beef		0.13	0.09	-0.03	0.08
			Lamb	0.60		0.09	-0.03	0.08
			Mutton	0.6	0.13		-0.03	0.08
			Chicken	0.60	0.13	0.09		0.08
			Pork	0.60	0.13	0.09	-0.03	
Shaw et al (1983)	1966-81 (A)	Log Change (OLS)	Beef		0.22	0.3	-0.06	0.08
			Lamb	0.46		0.04	0.21	0.20
			Mutton	1.7	0.59		-0.77	0.05
			Chicken	0.13	0.05	0.01		0.02
			Pork	0.48	0.17	0.04	0.22	
Dewbre et al (1985)	1965-83	Double Log (OLS)	Beef		0.23		-0.03	0.05
			Lamb	0.50			0.13	0.07
			Chicken	0.12	0.06			0.02
			Pork	0.36	0.18		0.16	
Martin & Porter (1985)	1962-83 (Q)	Double Log (OLS)	Beef		0.06	0.20	0.19	0.63
			Lamb	0.68		0.41	0.70	0.53
			Mutton	1.55	-3.64		0.35	1.35
			Chicken	-0.19	0.10	0.02		-0.63
			Pork	0.38	0.09	0.07	-0.28	
Alston & Chalfant (1987)	1968-83 (Q)	Double Log (OLS)	Beef		1.06		0.21	0.47
			Lamb	0.37			0.08	0.20
			Chicken	0.02	0.28			-0.31
			Pork	0.29	0.20		-0.14	
Alston & Chalfant (1987)	1968-83 (Q)	AIDS (Modified Translog)	Beef		0.70		0.12	0.36
			Lamb	0.26			0.08	0.18
			Chicken	0.46	0.51			-0.23
			Pork	0.75	0.42		-0.01	
Cashin (1991)	1967-90 (Q)	LA-AIDS (SUR)	Beef		0.51		0.03	0.24
			Lamb	-0.02			0.12	0.22
			Chicken	-0.19	0.05			0.14
			Pork	-0.20	0.25		0.26	
Cashin (1991)	1982-90 (Q)	LA-AIDS (SUR)	Beef		-0.02		1.07	0.42
			Lamb	-0.11			0.99	0.36
			Chicken	-0.36	0.26			-0.32
			Pork	-0.02	0.10		-0.11	
Piggot et al (1996)	1978-88 (Q)	Double Log (OLS)	Beef		0.68		0.34	0.43
			Lamb	0.43			-0.10	0.17
			Chicken	-0.14	0.47			0.27
			Pork	0.13	0.11		0.23	
Ulubasoglu et al (2011)	1999/2004	LA-AIDS (OLS)	Beef		0.08		0.21	0.13
			Lamb	0.19			0.13	0.22
			Pork	0.44	0.32		0.47	
Nhung et al (2011)	1999/2004	AIDS (OLS)	Beef		0.03		0.06	0.08
			Lamb	0.10			-0.01	0.01
			Chicken	0.26	-0.01			-0.50
			Pork	0.08	0.01		-0.47	
Mounter et al (2012)	1965-2010 (Q)	LA-AIDS	Beef		-0.11		-0.20	-0.20
			Lamb				0.13	0.01
			Chicken					
			Pork				-0.12	
		AIDS	Beef		0.70		0.40	0.22
			Lamb				-0.18	-0.22
			Pork				-7.40	

3. Basics of Consumer Demand Systems

We begin this section by defining basic concepts in consumer demand such as income, budget shares, marginal shares, elasticities, etc.

Let p_i and q_i be the price and per capita consumption of commodity i. Then the total expenditure on all n goods (or income for short), M, and on a group of goods S_g, M_g, are given by

$$M = \sum_{i=1}^{n} p_i q_i ; \qquad M_g = \sum_{i \in S_g} p_i q_i \tag{1}$$

The unconditional (conditional) budget shares of good i, the proportion of income (group expenditure) allocated to a commodity, i, can be defined as:

$$w_i = \frac{p_i q_i}{M}, \quad i = 1,\ldots,n, \qquad w_i' = \frac{p_i q_i}{M_g}, \quad i \in S_g. \tag{2}$$

Budget shares are obviously positive; and following from (1) and (2), they have a unit sum, where

$$\sum_{i=1}^{n} w_i = 1, \qquad \sum_{i \in S_g} w_i' = 1 \tag{3}$$

When income increases by $1, the additional amount spent on commodity i can be measured as

$$\theta_i = \frac{\partial(p_i q_i)}{\partial M} \qquad i = 1,\ldots,n \tag{4a}$$

which is referred to as the *i-th (unconditional) marginal share*. Similarly, when the group expenditure increases by $1, the additional amount spent on commodity i in group S_g can be measured as

$$\theta_i' = \frac{\partial(p_i q_i)}{\partial M_g}, \qquad i \in S_g \tag{4b}$$

which is referred to as the *i-th conditional marginal share*.

From (1) and (4), one can easily see that the marginal shares also add up to 1. That is

$$\sum_{i=1}^{n} \theta_i = 1, \qquad \sum_{i \in S_g} \theta_i' = 1 \tag{5}$$

Unlike the budget shares, marginal shares need not always be positive; if *i* is an inferior good, then θ_i (or $\theta_i^{'}$) will be negative. In other words, for an inferior good, as income (or group expenditure) rises, demand for that good will decrease.

The unconditional (conditional) income elasticity of commodity i, η_i or $\eta_i^{'}$, is the percentage change in consumption of commodity *i* when income (or group expenditure) increases by 1 percent. That is

$$\eta_i = \frac{\partial q_i / q_i}{\partial M / M} = \frac{\partial(\log q_i)}{\partial(\log M)}, \quad i = 1,\ldots,n, \qquad \eta_i^{'} = \frac{\partial q_i / q_i}{\partial M_g / M_g} = \frac{\partial(\log q_i)}{\partial(\log M_g)}, \quad i \in S_g. \tag{6}$$

From (2), (4) and (6), it follows that unconditional and conditional elasticities can be written as

$$\eta_i = \frac{\theta_i}{w_i}, \qquad i = 1,\ldots,n \qquad \eta_i^{'} = \frac{\theta_i^{'}}{w_i^{'}}, \qquad i \in S_g \tag{7}$$

If the income elasticity is greater than zero, the good is classified as a normal good; implying that as income (or group expenditure) rises, quantity demanded of the good rises. Goods with income elasticities greater than unity are called *luxuries*; where quantity demanded of these goods increases by a greater proportion than the increase in income (or group expenditure). Goods with negative income elasticity are *inferior* goods because income (or group expenditure) increases lead to decreasing consumption of said good. On the other hand, the goods with income elasticity less than one are called necessities, where the quantity demanded of these goods increase by a lesser proportion than the increase in income (or group expenditure). Food is a good example of a necessity.

The price elasticity, η_{ij}, is the percentage change in the consumption of good i when the price of good j increases by 1 per cent. That is

$$\eta_{ij} = \frac{\partial(\log q_i)}{\partial(\log p_j)} \qquad i, j = 1,\ldots,n \tag{8}$$

According to the 'Law of Demand' for i = j, the own-price elasticity should be negative. If the absolute value of the own-price elasticities of good *i* (η_{ii}) is less than one, that is the consumption of good *i* increases less than proportionate to its price increase, the demand for good *i* is price inelastic. On the other hand, if the absolute value of η_{ii} is greater than one ($|\eta_{ii}| > 1$), then the demand for good *i* is price elastic.

For i ≠ j, the coefficient η_{ij} in (8) is the cross-price elasticity of commodity *i* in regards to commodity *j*; or the elasticity of demand for *i* with respect to the price of *j*. If η_{ij} is positive, goods *i* and *j* are called gross substitutes; that is the demand for good *i* rises with increases in the price of good *j*. Accordingly, if η_{ij} is negative, then the two goods are gross complementary; that is any increases in the price of good *j* will lead to decreases in the demand for good *i*.

4. Preliminary Data Analysis

In this section, we present the Australian meat consumption data and use them to present a preliminary data analysis on the demand for meat in Australia. We also investigate a number of empirical regularities in consumption patterns with Australian meat data.

The Data

We consider five types of meat, namely, beef, lamb, mutton, chicken and pork. The per capita consumption and price data for the period 1962-1977 are from Roberts (1990) and for 1978-2011 are from various issues of publications of the *Meat and Livestock Australia* and the *Australian Bureau of Agricultural and Resource Economics and Sciences* (ABARES). The consumer price index data (6401.0 - *Consumer Price Index*, Australia), the total private final consumption expenditure data (5206.0 - *Australian National Accounts: National Income, Expenditure and Product*) and Australian population data (3101.0 *Australian Demographic Statistics*) are all from various issues of Australian Bureau of Statistics publications.

Consumption and Prices

Table 4 presents the basic data for consumption and prices for five meat types for selected years. Figure 1 displays the per capita consumption of the five types of meat during 1962 and 2011. As can be seen, in general, consumption of pork and chicken have increased steadily and that of beef,

Table 4 Consumption, prices, expenditure and budget shares for five types of meat, selected years, 1962-2011

Year	Beef (1)	Lamb (2)	Mutton (3)	Chicken (4)	Pork (5)	Total meat (6)
Per capita consumption (kg)						
1962	45.30	19.30	25.21	4.44	8.80	103
1971	40.30	23.14	15.95	11.10	13.80	104
1981	47.60	16.49	2.71	20.20	15.30	102
1991	39.50	13.20	9.60	23.10	18.40	104
2001	34.50	11.75	5.12	30.90	18.80	101
2011	32.80	9.20	0.30	43.30	25.00	111
Prices ($/kg)						
1962	0.94	0.76	0.46	1.19	1.09	
1971	1.52	0.96	0.64	0.98	1.48	
1981	5.42	3.68	2.29	2.63	4.39	
1991	9.73	5.28	3.54	4.80	6.51	
2001	12.25	7.95	5.33	4.97	8.35	
2011	15.46	14.62	9.45	5.49	10.91	
Price index (1962=100)						
1962	100	100	100	100	100	
1971	162	126	139	82	136	
1981	578	482	499	221	403	
1991	1038	691	773	403	598	
2001	1307	1040	1164	418	766	
2011	1649	1914	2063	462	1001	
Expenditure on meat ($/person)						
1962	42.47	14.75	11.55	5.28	9.59	83.64
1971	61.28	22.21	10.15	10.86	20.43	124.93
1981	257.98	60.69	6.19	53.04	67.22	445.12
1991	384.30	69.71	33.98	110.81	119.78	718.58
2001	422.73	93.35	27.29	153.48	156.90	853.75
2011	507.02	134.52	2.84	237.80	272.78	1154.96
Unconditional budget shares (w_{it})						
1962	4.27	1.48	1.16	0.53	0.96	8.41
1971	3.51	1.27	0.58	0.62	1.17	7.16
1981	4.23	0.99	0.10	0.87	1.10	7.29
1991	2.73	0.49	0.24	0.79	0.85	5.10
2001	1.92	0.42	0.12	0.70	0.71	3.87
2011	1.47	0.39	0.01	0.69	0.79	3.35
Conditional budget shares (w'_{it})						
1962	50.78	17.63	13.81	6.32	11.46	
1971	49.05	17.78	8.13	8.69	16.35	
1981	57.96	13.64	1.39	11.92	15.10	
1991	53.48	9.70	4.73	15.42	16.67	
2001	49.51	10.93	3.20	17.98	18.38	
2011	43.90	11.65	0.25	20.59	23.62	

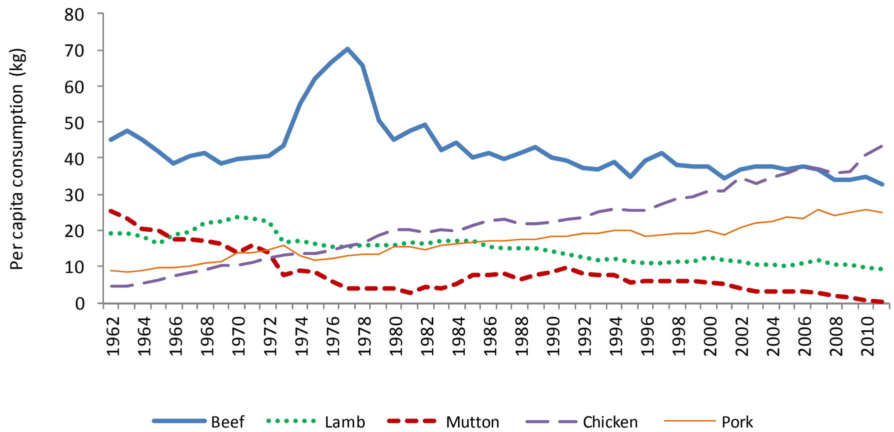

Figure 1 Per capita consumption of meat in Australia, Five meat types, 1962-2011

lamb and mutton have fallen steadily. Australian per capita consumption of beef has fallen from 45.3 kg in 1962 to 38.6 kg in 1969 and then steadily increased to 70.4kgs in 1977 and then has again fallen steadily to 32.8kg in 2011. This fall in local consumption in the early seventies was due to strong world demand. High world price for beef has lead to lower supply of beef to the local Australian market. This situation has changed in the mid to late seventies due to the increased trade restrictions placed on the Australian major export markets resulting in increased supply of beef in the local Australian market.

In the early seventies, improvement in wool prices and the introduction of guaranteed floor price of wool has lead to reduced supply of lamb and mutton to the local Australian meat market as lamb stocks were withheld from slaughter. Lamb consumption has increased from 19.3kg in 1962 to 23.6kg in 1970 and then steadily fell to less than half of what it was in 1960's to 9.2kg in 2011. Australians consumed more mutton than lamb in the 60's, but have reduced mutton intake over the years, with 25.2kgs per person in 1962 to a very low level of 0.3kg per person in 2011. In 2011, the per capita consumption of mutton and lamb combined has fallen to almost one-fifth of what they were in the early 60's. The fall in beef, lamb and mutton consumption have been mostly captured by the increase in the consumption of chicken and pork. Per capita chicken consumption has increased 7 times, increasing from 4.4kg in 1962 to 43.3kgs in 2011. Pork consumption has also increased 3 times, where it has increased from 8.8kgs in 1962 to 25.0kgs in 2011. While chicken consumption has increased steadily over the years, pork consumption has fallen slightly in the mid 1980's and increased steadily from then onwards.

Part of Table 4 presents the retail prices and their indices for selected years and Figure 2 displays the retail prices in index form with base 1962=100 during 1962 to 2011. Considering the prices for the five types of meat for selected years presented in Table 4, we can see that the retail price of beef has increased steadily over the years from $0.94/kg in 1962 to $15.46/kg in 2011. Over the same period, lamb price has increased from $0.76 to $14.62/kg, mutton price from $0.46 to $9.45/kg and pork price from $1.09/kg to $10.91/kg. The chicken price has increased from $1.19/kg in 1962 to $3.02/kg in 1987. Before 1987, only frozen chicken were supplied for consumption and from 1987 it was mostly replaced by fresh chicken. The price of fresh chicken has increased steadily from $1.51 in 1988 to $5.49 in 2011. As can be seen from Figure 2, prices of beef, lamb and mutton have increased at a faster rate than the prices of chicken and pork.

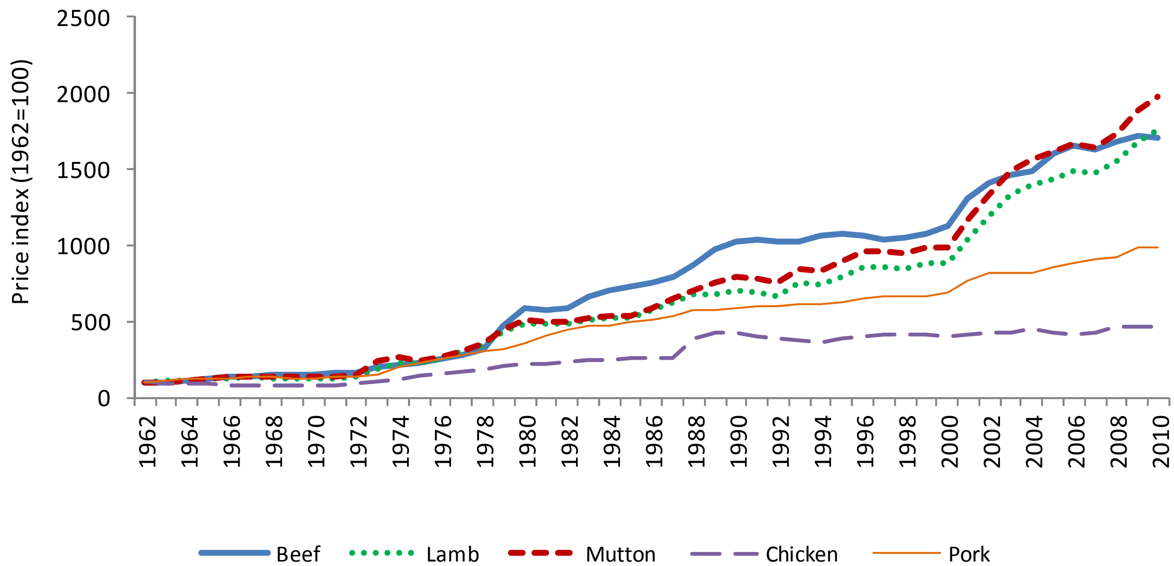

Figure 2 Price indices (1962=100) of meat in Australia, Five meat types, 1962-2011

The retail price indices (with base 1962=100) together with per capita consumption data for each meat type during 1962 to 2011 is presented in Figure 3. As can be seen prices and consumption has moved in the opposite direction for beef, lamb and mutton; while they have moved in the same direction for chicken and pork. Prices of beef, lamb and mutton have increased at a much faster rate than chicken and pork. This may have moved consumption from beef, lamb and mutton towards chicken and pork.

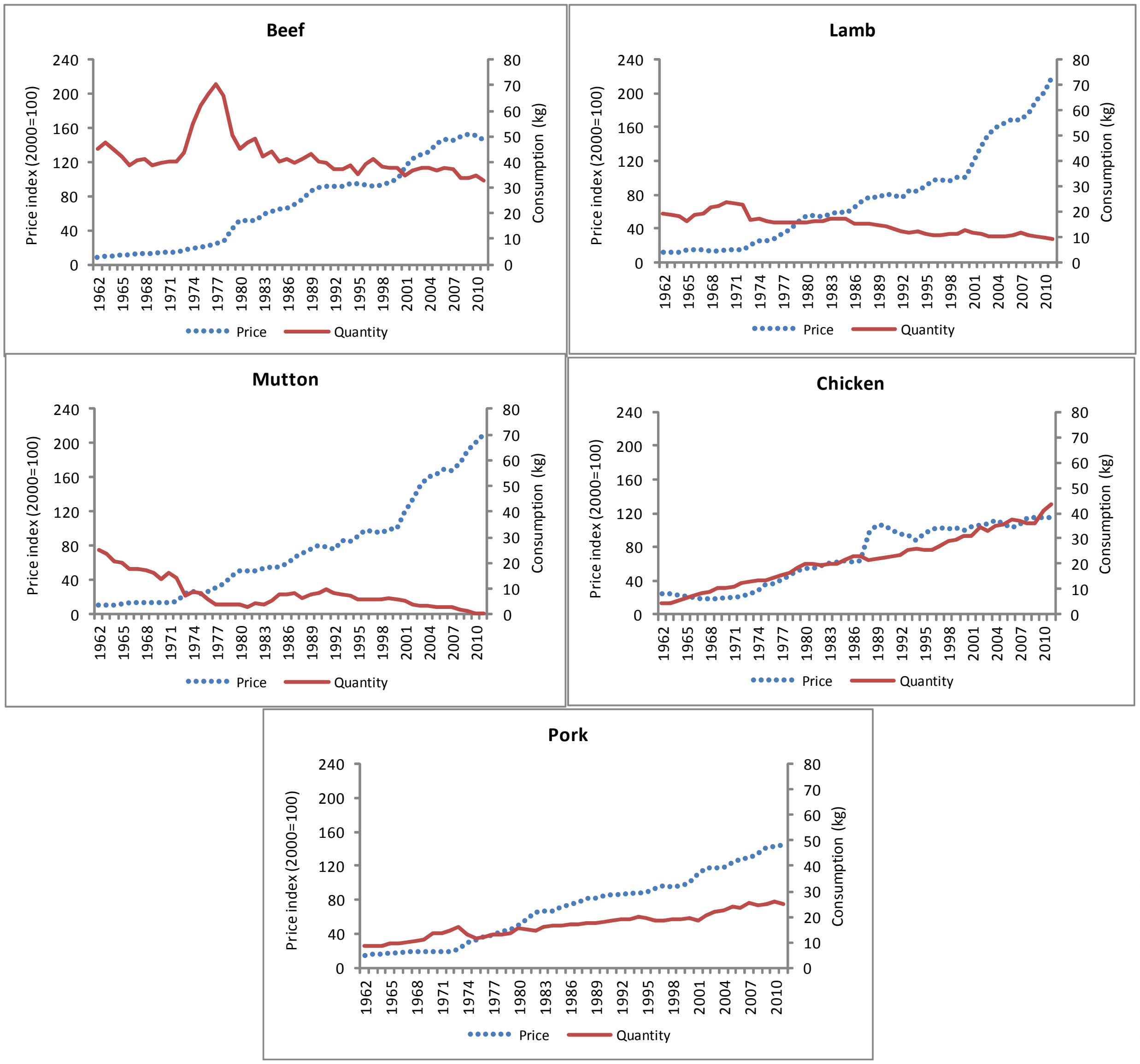

Figure 3 Price indices and per capita consumption in Australia, Five meat types, 1962-2011

It would be rational, according to economic theories, to conclude that the consumption for beef will fall commensurate with the increase in the price of beef; and that the highest fall in consumption for lamb would result from lamb having the highest percentage increase in price. Also in the initial period the consumption of chicken and pork decreases as their price increase, however, in the later years their consumption increase while their price also increase due to the substitution of chicken and pork in place of beef and lamb due to their price increase.

Budget shares

The lower section of Table 4 presents, for selected years, the expenditure on each meat type, the unconditional and conditional budget shares for the five meat types and the budget share for meat as a whole. Figures 4 and 5 present these budget share series in graphical form. In general, the proportion of total income spent on beef, lamb, mutton and pork have been declining and that of chicken has increased slightly during the sample period. Within the meat group, clearly, chicken and pork have captured the falling market shares of beef, lamb and mutton.

As can be seen, for example in 2011, Australians allocate about 1.5% of their income on beef, 0.4% on lamb, 0.01% on mutton, 0.7% on chicken, 0.8% on pork, giving a total of 3.4% of their income on meat. Within the meat group, Australian consumers allocate 44 percent of their meat expenditure on beef, 12 percent on lamb, 0.3 percent on mutton, 20% on chicken and the remaining 24% of their meat expenditure on pork. Over the years, the consumer's income allocation on beef has fallen from 4.3% in 1962 to 1.5% in 2011, on lamb has fallen from 1.5% to 0.4%, mutton from 1.2% to 0.01%, pork from 1.0% to 0.8% and chicken has increased from 0.5% to 0.7%. For meat as a whole, the allocation of income has more than halved from 8.5 percent in 1962 to 3.7 percent in 2011. Clearly, in recent years there is not much demand for mutton and demand for beef and lamb are competing against chicken and pork.

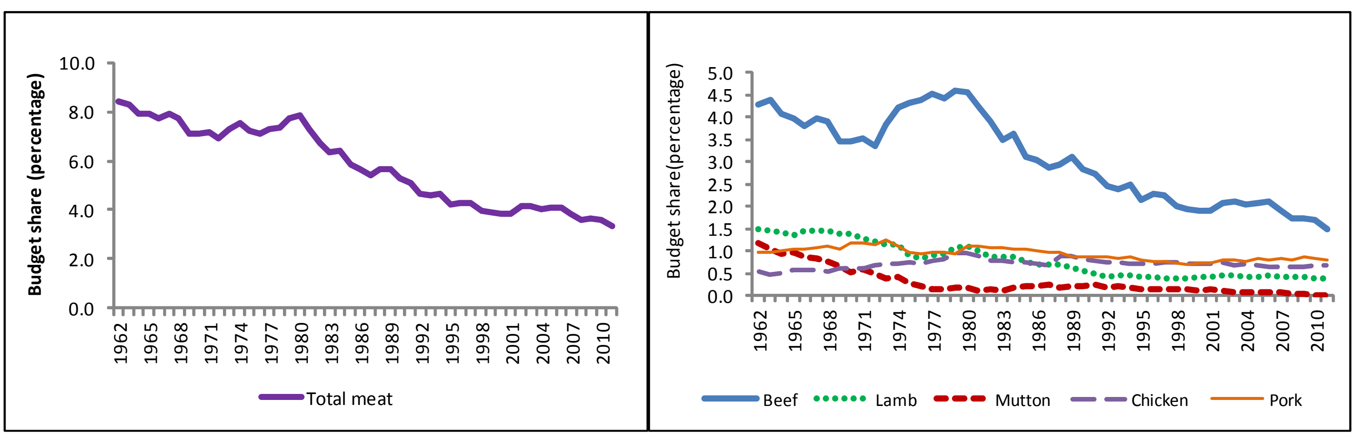

Figure 4 Expenditure share of total meat and the unconditional budget shares of five meat types, 1962-2011

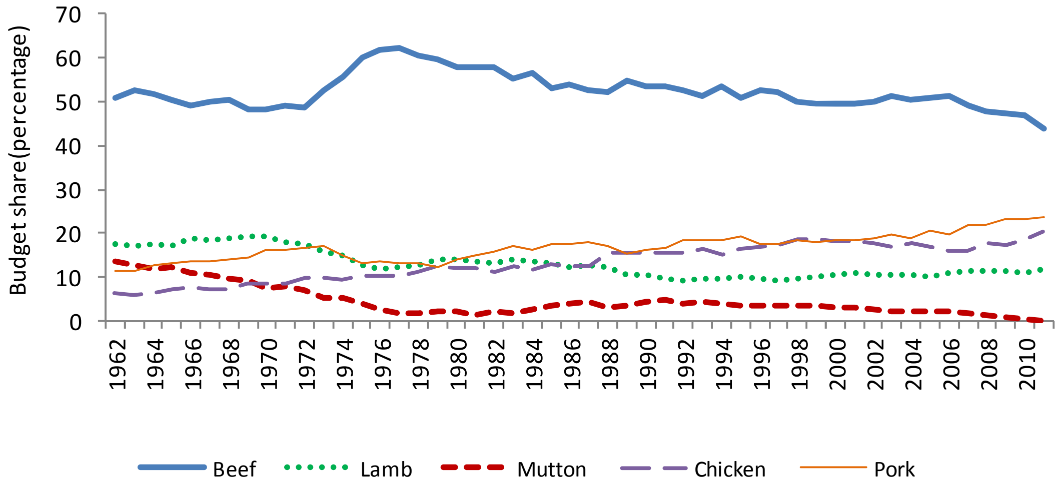

Figure 5 Conditional budget shares of the five meat types, 1962-2011

Divisia Moments

Now we summarize the data in the form of Divisia index numbers. We define the price and quantity log-changes, respectively, as

$$Dp_{it} = ln(p_{it}) - ln(p_{it-1}) \quad \text{and} \quad Dq_{it} = ln(q_{it}) - ln(q_{it-1})$$

where p_{it} and q_{it} are the price and consumption of good i at time t. When these log-changes are multiplied by 100, they can be interpreted as percentage changes or percentage growth rates from year t-1 to year t. Here and elsewhere, *ln* refers to the natural logarithm.

The overall growth in prices and consumption of the meat group can be measured by the Divisia price and quantity indices which are defined as

$$DP_{gt} = \sum_{i=1}^{5} \overline{w}_{it}^{'} Dp_{it} \quad \text{and} \quad DQ_{gt} = \sum_{i=1}^{5} \overline{w}_{it}^{'} Dq_{it} \tag{9}$$

where $\overline{w}_{it}^{'} = ½(w_{it}^{'} + w_{it-1}^{'})$ is the arithmetic average of the conditional budget shares in periods t and t-1.

Columns 2 and 3 of Table 5 presents the average absolute ($D\overline{p}_i$ and $D\overline{q}_i$) and columns 4 and 5 present the relative price and consumption growth rates ($D\overline{p}_i - D\overline{P}$ and $D\overline{q}_i - D\overline{Q}$) for the five meat types, averaged over the sample period. As can be seen, on average, consumption of beef, lamb and mutton has fallen at a rate of 0.7, 1.5 and 9.0 per cent per annum while chicken and pork consumption have increased at a rate of 4.7% and 2.1% per annum, respectively. On average, the prices have all increased at a rate of 5.7%, 6.0%, 6.2%, 3.1% and 4.7%, per annum, respectively. While growth rates in consumption of beef, lamb and mutton relative to the meat group are negative, their relative growth rates in prices are positive. The relative growth in the consumption of chicken and pork are positive while their relative price growth rates are negative.

Table 5 Average growth rates in consumption and prices (1962-2011)

Meat type	Growth rate		Relative	
	Consumption	Price	Consumption	Price
(1)	(2)	(3)	(4)	(5)
Beef	-0.66	5.72	-0.70	0.40
Lamb	-1.51	6.02	-1.55	0.70
Mutton	-9.04	6.18	-9.08	0.86
Chicken	4.65	3.12	4.61	-2.20
Pork	2.13	4.70	2.09	-0.62

5. Empirical Regularities in Consumption Patterns

Various consumption studies have observed a number of empirical regularities in the consumption patterns of consumers in a number of countries (see, for example, Selvanathan, S., 1993; Selvanathan and Clements, 1995; Chen, 2001). The four such important empirical regularities we investigate in this paper are, namely:

Empirical Regularity 1: Quantity variance exceeds price variance;

Empirical Regularity 2: Demand curve slopes downwards;

Empirical Regularity 3: Income flexibility tends towards -0.5; and,

Empirical Regularity 4: Budget share of food declines with increasing income.

Below, we investigate whether these regularities are supported by the Australian meat data.

Empirical Regularity 1: Quantity Variances Exceeds Price Variances

To measure the variation in prices and consumption, we use the second-order Divisia moments. The corresponding Divisia second-order moments, Divisia price and quantity variances defined as

$$\Pi_{gt} = \sum_{i=1}^{5} \bar{w}_{it}^{'}[Dp_{it} - DP_{gt}]^2 \quad \text{and} \quad K_{gt} = \sum_{i=1}^{5} \bar{w}_{it}^{'}[Dq_{it} - DQ_{gt}]^2$$

The co-movement of prices and quantities is measured by the Divisia price-quantity correlation

$$\rho_{gt} = \frac{\Gamma_{gt}}{\sqrt{\Pi_{gt} K_{gt}}},$$

where

$$\Gamma_{gt} = \sum_{i=1}^{5} \bar{w}_{it}^{'}[Dp_{it} - DP_{gt}][Dq_{it} - DQ_{gt}]$$

is the price-quantity covariance.

Table 6 presents the Divisia quantity and price indices, for the meat data for the period 1962-2011. As can be seen from the mean row of the first two columns, on average, meat as a whole its consumption hasn't grown that much , whilst meat prices have grown at a much larger rate of 5.8 percent per annum over the same study period.

A comparison of the quantity variances (K_{gt}) in column (5) with the corresponding price variances (Π_{gt}) in column (4) reveals that, in most years, quantity variance systematically exceeds the price variance. In Figure 6, we plot the standard deviations, $\sqrt{K_{gt}}$ against $\sqrt{\Pi_{gt}}$, for t=1,….., T, together with the 45^{o} line, which shows that most of the points lie above the 45^{o} line; indicating that, on average, the quantity variance does exceed the price variance. The above findings agrees well with the results of Clements (1982, 1983), Meisner (1979), Selvanathan, S. (1993), Selvanathan and Selvanathan (1993, 1994), Selvanathan and Clements (1995), Theil and Suhm (1981), and Suhm (1979), Selvanathan and Selvanathan (2003).

Table 6 Divisia Moments for meat: Australia 1962-2011

Year	Price index DP_{gt}	Quantity index DQ_{gt}	Price variance Π_{gt}	Quantity variance K_{gt}	Price-quantity covariance Γ_{gt}	Price-quantity correlation ρ_{gt}
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1963	3.12	0.73	6.00	20.55	-1.76	-0.16
1964	5.39	-3.46	7.33	42.88	-12.87	-0.73
1965	8.58	-3.73	20.11	66.76	-35.14	-0.96
1966	4.46	-1.74	28.25	113.37	-52.21	-0.92
1967	4.41	4.75	11.19	7.72	-6.71	-0.72
1968	0.10	4.18	14.11	19.74	-11.27	-0.68
1969	0.73	-1.48	4.35	46.68	-3.45	-0.24
1970	4.23	3.54	3.52	70.65	-5.25	-0.33
1971	3.83	2.48	7.80	17.40	-0.20	-0.02
1972	3.29	0.60	2.42	28.46	-3.05	-0.37
1973	21.78	-2.77	109.34	421.32	-205.83	-0.96
1974	11.00	10.78	73.88	253.37	-136.61	-1.00
1975	7.66	4.39	48.96	86.38	-0.77	-0.01
1976	9.89	3.56	2.52	66.26	-5.95	-0.46
1977	9.93	4.47	9.38	49.69	-12.07	-0.56
1978	12.89	-2.94	3.51	23.17	-6.28	-0.70
1979	28.98	-14.43	191.70	236.38	-199.79	-0.94
1980	17.17	-3.49	34.03	87.30	-46.92	-0.86
1981	1.64	2.58	24.25	29.71	-8.49	-0.32
1982	2.49	1.79	14.75	44.64	-10.81	-0.42
1983	9.14	-6.68	16.78	104.45	-40.14	-0.96
1984	3.84	3.67	3.90	24.85	2.47	0.25
1985	3.66	-3.07	3.92	97.30	-7.45	-0.38
1986	3.78	1.49	8.70	25.02	-11.64	-0.79
1987	5.56	-1.48	7.58	7.31	0.14	0.02
1988	12.79	0.06	149.17	32.03	-32.06	-0.46
1989	7.27	3.35	23.91	12.21	8.59	0.50
1990	4.19	-3.25	4.74	27.32	-7.99	-0.70
1991	-0.17	-0.51	5.17	16.35	-2.71	-0.29
1992	-1.63	-3.41	3.56	28.01	1.48	0.15
1993	1.57	-0.15	17.15	13.55	-11.10	-0.73
1994	0.72	4.02	11.27	3.30	3.53	0.58
1995	2.83	-7.35	7.19	30.01	2.10	0.14
1996	2.06	4.43	15.75	62.11	-27.87	-0.89
1997	0.18	3.98	3.30	2.45	-0.91	-0.32
1998	-0.58	-1.85	1.10	36.16	-6.26	-0.99
1999	2.39	-0.16	0.87	1.27	-0.33	-0.31
2000	2.62	2.08	8.44	13.66	-7.25	-0.68
2001	12.08	-6.57	19.32	9.93	-13.07	-0.94
2002	7.03	5.96	11.84	42.75	-17.53	-0.78
2003	3.39	0.29	10.73	33.04	-13.45	-0.71
2004	2.62	0.82	3.23	3.93	1.11	0.31
2005	4.26	0.06	18.64	14.03	-5.67	-0.35
2006	1.83	2.68	6.57	7.54	-2.00	-0.28
2007	0.21	1.15	3.28	29.16	4.10	0.42
2008	4.09	-7.59	4.63	19.18	2.74	0.29
2009	3.32	0.37	7.68	15.07	-1.82	-0.17
2010	0.29	2.80	2.80	77.65	-9.32	-0.63
2011	-0.23	-3.14	13.83	34.16	3.73	0.17
Mean	5.32	0.04	20.66	52.17	-19.47	-0.41

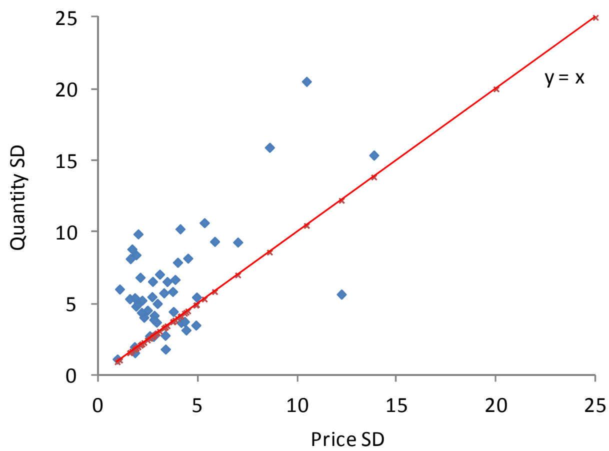

Figure 6 Quantity vs Price standard deviation, meat group, 1962-2011

A point also worth noting is the unusually high values of both the price and quantity variances during the years 1973, 1974, 1979 and 1988. As stated before, the high variances could be due to (i) the high export demand resulting in higher prices and lower local consumption of beef in the Australian meat market; (ii) reduced supply of lamb and mutton due to better wool prices resulting in shortage of lamb and mutton for local consumption; (iii) increased trade restrictions in the Australian major export markets during the 1970s; (iv) events such as the introduction of 'fresh' chicken instead of 'frozen' chicken into the Australian meat market; and (v) the introduction of pig-meat imports into the Australian meat market during the late 1980s. We shall revisit this later the paper.

Empirical Regularity 2: Demand Curves Slope Downwards

Last column of Table 6 presents the Divisia price-quantity correlations. As can be seen, almost all the price-quantity correlations presented in Table 6 are negative, with an average value of -0.4, indicating that there is a negative relationship between price and consumption supporting the 'Law of Demand'. To investigate this further, In Figure 7, we plot the relative consumption ($Dq_{it} - DQ_{gt}$) against the relative price ($Dp_{it} - DP_{gt}$), t = 1,…,T, for each meat type for Australia. As can be seen, in all scatter plots, most points are scattered around a negatively sloped line. This again gives supports to the law of demand that the demand curve slopes downwards.

Empirical Regularity 3: Income flexibility is about -0.5

Figure 7 plots the relative consumption ($Dq_{it} - DQ_t$) against the relative price ($Dp_{it} - DP_t$), t = 1,…,T, for the five meat types and for total meat for the period 1962 to 2011. The slope of the estimated trend line can be interpreted as an estimate of the reciprocal of the income flexibility (the income elasticity of the marginal utility of income) for each of the meat type. Table 7 collects the slope estimates of each plot, which are estimates of income flexibility. The last row of the tables, gives the average of the 6 estimates, which is ϕ = -0.54. These finding give support to a number of previous econometric findings that income flexibility is an international constant and is about -0.5 (e.g., see Theil and Suhm, 1981; Theil and Clements, 1987; Selvanathan, 1993; and Selvanathan and Selvanathan, 2005).

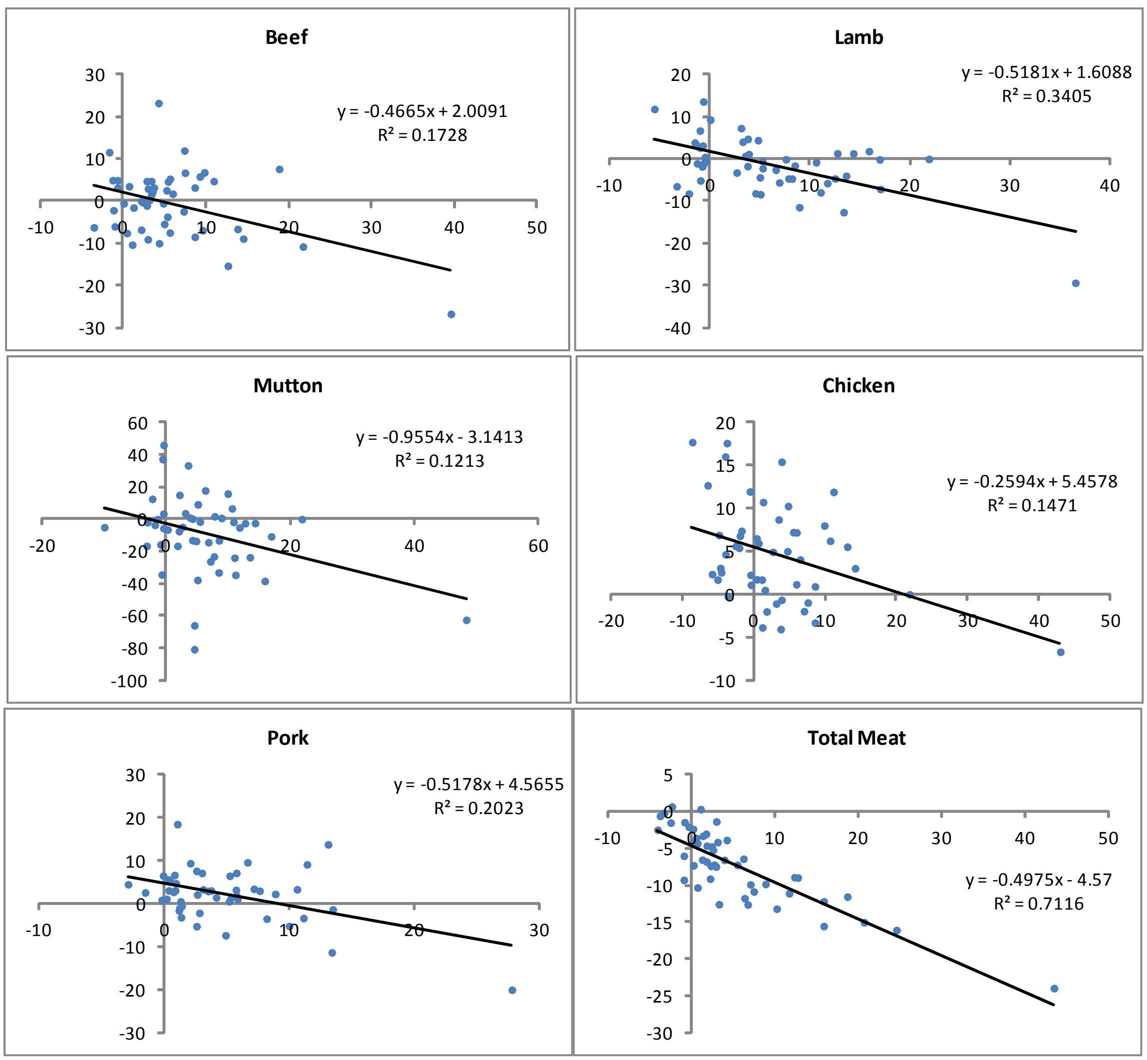

Figure 7 Relative quantity vs relative price, five meat types and total meat, 1963-2011

Table 7 Estimates of income flexibility*

Meat type	Income flexibility
Beef	-0.47
Lamb	-0.52
Mutton	-0.96
Chicken	-0.26
Pork	-0.52
Total meat	-0.50
Mean	-0.54

* Based on Figure 7.

Empirical Regularity 4: Budget share of food declines with increasing income.

An average Australian's budget share of meat, in relation to total private expenditure as evidenced in Table 4, shows a continuous decline except for 2005 and 2006, from about 8.4 percent to 3.4 percent for the period 1962 to 2011. One of the most important empirical regularity in consumption economics, Engel's Law, states that the budget share of food falls with increasing income. We investigate whether Engel's Law holds for different types of food items individually as well, in particular for the five meat types. Figure 8 presents the plot of budget share of the five meat types and total meat against the logarithmic of the per capita expenditure for Australia. As can be seen, the points are scattered around a negatively sloping straight line. In other words, when income increases, the share of expenditure on the various meat types falls.

6 The Demand Models

In terms of differential demand systems, the three most popularly utilised in applied demand analysis have been the Rotterdam demand system (Barten, 1964; Theil, 1965); the Working's (1943) parameterisation of the Rotterdam model, also termed the CBS demand system (Keller and van Driel, 1985) and the Almost Ideal Demand System, AIDS (Deaton and Muelbauer, 1980).

In this section, we introduce the three demand systems to be used for estimation and then test the demand theory hypotheses. We then select the preferred model among the three and present the estimation results and implied income and price elasticities for the five meat types based on the preferred model.

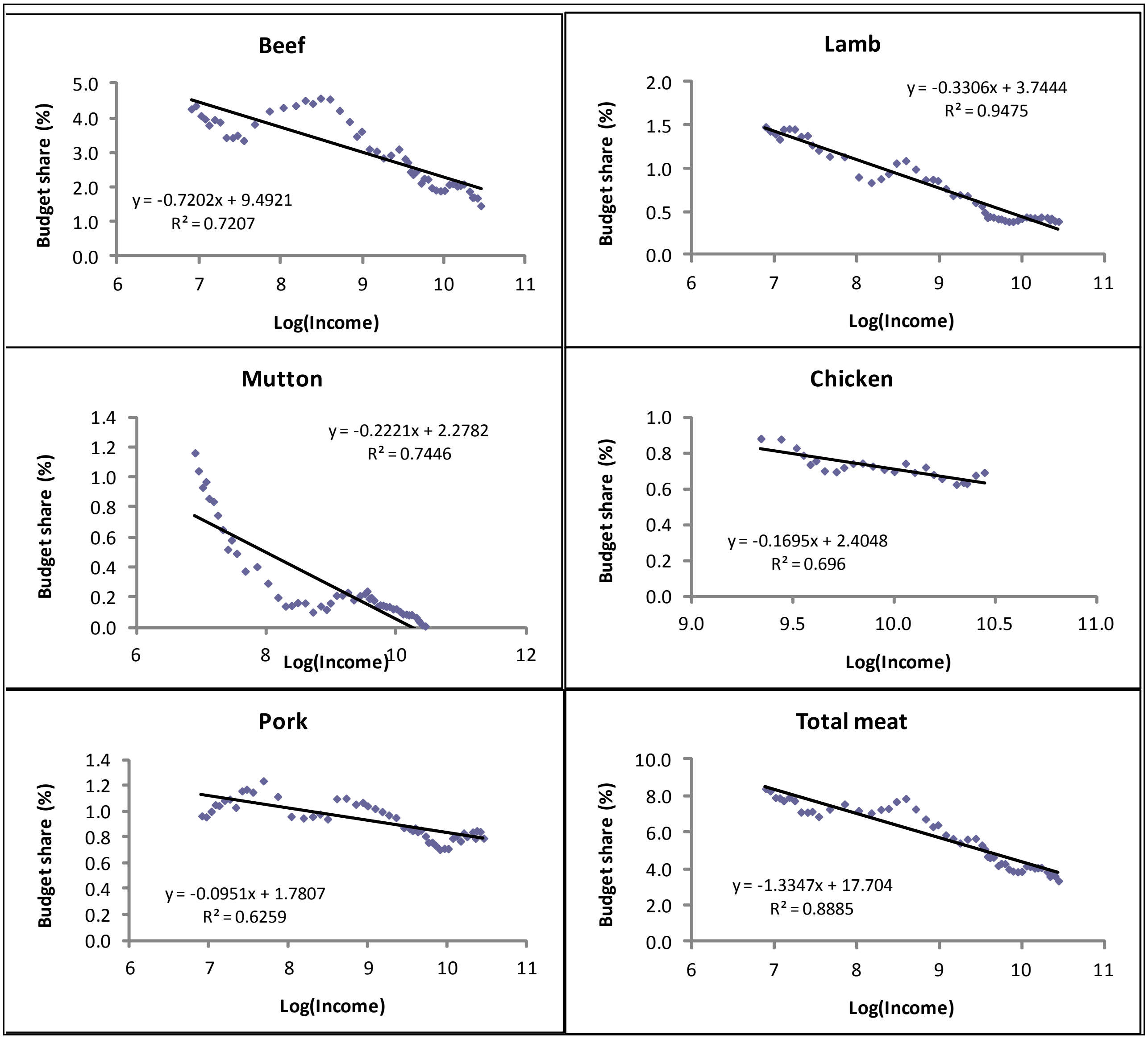

Figure 8 Budget shares of meat groups vs log of income, five meat types and total meat, 1962-2011

Rotterdam Model

The basic specification of the Rotterdam model for good $i \in S_g$, in differentials, takes the form (see, for example, Theil, 1980; Selvanathan, 1993; Selvanathan and Clements, 1995)

$$\bar{w}'_{it} Dq_{it} = \alpha_i + \theta'_i DQ_t + \sum_{j \in S_g} \pi^g_{ij} Dp_{jt} + \varepsilon_{it}, \qquad i \in S_g \qquad (10)$$

where $\bar{w}_{it}^{'}$, Dq_{it}, Dp_{it} and DQ_{gt} are defined as before; and α_i is the constant term of the i^{th} demand equation satisfying $\sum_{i\in S_g} \alpha_i = 0.$ The use of the constant terms in the demand equations is to take into account any trend-like changes in tastes etc. The marginal share, $\theta_i^{'}$, answers the question 'if group expenditure increases by one dollar, how much of this increase will be allocated to commodity i?' and also satisfies $\sum_{i\in S_g} \theta_i^{'} = 1.$ If $\theta_i^{'} < \bar{w}_{it}^{'}$, then the commodity *i* is classified as a necessity; if it is otherwise, then it will be classified as a luxury. The coefficient π_{ij}^{g} is the $(i,j)^{th}$ Slutsky price coefficient which satisfies

$$\sum_{i\in S_g} \pi_{ij}^{g} = 0.$$

These coefficients also satisfy

$$\sum_{j\in S_g} \pi_{ij}^{g} = 0. \qquad (11)$$

Constraint (11) reflects the homogeneity property of the demand system that postulates that a proportionate change in all prices has no effect on the demand for any good under the condition that real income is constant. Accordingly, it is known as *demand homogeneity*.

The Slutsky coefficients are symmetric in i and j, that is

$$\pi_{ij}^{g} = \pi_{ji}^{g}, \qquad i,j \in S_g, \qquad (12)$$

which is known as *Slutsky symmetry*. In other words, when real income is held constant, the effect of an increase in the price of commodity *j* on the demand for commodity *i* is equal to the effect of a price increase of *i* on the demand for *j*. In other words, as the commodity subscripts can be interchanged, the substitution effects are symmetric in *i* and *j*. As well, the Slutsky matrix, $\left[\pi_{ij}^{g}\right]$, is symmetric negative semi-definite with rank (n_g -1), where n_g is the number of goods in group S_g.

The term ε_{it} is the disturbance term of the i^{th} equation. It is assumed that the disturbance terms, ε_{it}, i=1,…,n_g, are serially independent and normally distributed with zero means with a contemporaneous covariance matrix.

Equation (10) for i=1,…,n_g, is a fairly general demand system in the sense that it can be considered as a first-order approximation of the true demand equations. If we sum both sides of (10) over i=1,…,n_g, we obtain $\sum_i \varepsilon_{it}$ = 0, for t=1,…T. Therefore, the ε_{it}'s are linearly dependent and one of the equations becomes redundant and can be deleted (Barten, 1969). We delete the n_g-*th* equation. It can be shown that the best linear unbiased estimators of the parameters for the system of equations (10) for i=1,…,n_g will be the same as those obtained by estimating each equation separately by least squares (LS). See Theil (1971) for details.

CBS Model

The basic specification of the second differential demand system, the CBS model, for good *i* in differentials takes the form (see, for example, Barten et al, 1989; Selvanathan, 1993; Selvanathan and Clements, 1995)

$$\bar{w}'_{it}(Dq_{it} - DQ_{gt}) = \alpha_i + \beta'_i DQ_{gt} + \sum_{j \in S_g} \pi^g_{ij} Dp_{jt} + \varepsilon_{it}, \tag{13}$$

where α_i is the constant term of the i^{th} demand equation satisfying $\sum_{i \in S_g} \alpha_i = 0.$ As above, the use of the constant terms in the demand equations is to take into account any trend-like changes in tastes and the like. The income coefficient β'_i satisfies $\sum_{i \in S_g} \beta'_i = 0.$. If β'_i is negative (positive), then the commodity is classified as a necessity (luxury). As before, the coefficient π^g_{ij} is the $(i,j)^{\text{th}}$ Slutsky price coefficient; here as well, these coefficients satisfy the demand homogeneity and Slutsky symmetry properties.

AIDS

In differential form, Deaton and Muellbauer's (1980) AIDS takes the form

$$dw_{it}^{'} = \alpha_i + \beta_i^{'} DQ_{gt} + \sum_{j \in S_g} \gamma_{ij} Dp_{jt} + v_{it}, \qquad i \in S_g \tag{14}$$

where $dw_{it}^{'} = w_{it}^{'} - w_{it-1}^{'}$. The right-hand side of the AIDS is very similar to the CBS model, but the left-hand side dependent variable is not $\bar{w}_{it}^{'}(Dq_{it} - DQ_{gt})$, but the change in budget share, $dw_{it}^{'}$. The properties of the α_i and $\gamma_{ij}^{'}$ are similar to those of the CBS model.

Testing Demand theory hypotheses

We use the Demand Analysis Package, DAP2000 (Yang et al, 2000) and DEMMOD-3 (Barten et al, 1989) program to estimate the three demand systems given by (10), (13) and (14). In the models, we have included two dummy variables, one to take into account of the change in the type of chicken meat from 'frozen' to 'fresh' as well as the introduction of pig-meat imports (from 1988 onwards); and the other is to cater for the changes in trade restrictions as well as the high price of wool during the 1970s.

Testing Demand Homogeneity

As discussed above, demand homogeneity postulates that a proportionate change in all prices has no effect on the demand for any good when real income is held constant. We now test the demand homogeneity based on the estimation results of the three demand systems using the Australian meat data. For testing homogeneity, there are two tests available. The Wald test which is an asymptotic χ^2 test with n_g -1 degrees of freedom and the other is a finite-sample test introduced by Laitinen (1978) based on Hotelling's T^2 distribution which is also a constant $[(n_g-1)(T-n_g-1)/(T-2n_g+1)]$ multiple of the F distribution with n_g -1 and T-2n_g -1 degrees of freedom. The results for the Australian meat data with n_g=5 meat types (and T=50) are presented in Table 8.

Table 8 Testing for demand homogeneity, Australian meat data, 1962-2011

Model	Wald Test					Laitinen's Test				
	Test statistic	Critical value		Decision		Test statistic	Critical value		Decision	
		$\chi^2_{(0.05,4)}$	$\chi^2_{(0.01,4)}$	5% level	1% level		$F_{(0.05,4,37)}$	$F_{(0.01,4,37)}$	5% level	1% level
Rotterdam	13.23	9.49	13.28	Reject	Do not reject	3.06	2.63	3.87	Reject	Do not reject
CBS	14.29	9.49	13.28	Reject	Reject	3.30	2.63	3.87	Reject	Do not reject
AIDS	12.64	9.49	13.28	Reject	Do not reject	2.92	2.63	3.87	Reject	Do not reject

As can be seen from Table 8, the homogeneity hypothesis is rejected for all three models at the 5 percent level and not rejected for two models at the 1 percent level by the Wald test. This result is not surprising as the asymptotic test has been found to be biased towards rejection of the null hypothesis (see, for example, Barten, 1977). When we apply Laitinen's finite sample test, while homogeneity is rejected at the 5 percent level, it is acceptable at the 1 percent level for all three models.

Slutsky Symmetry

For testing symmetry, we use asymptotic χ^2 test with $q = ½(n_g -1)(n_g -2)$ degrees of freedom (see Theil, 1971, for details). The results for the Australian meat data are presented in Table 9. As can be seen, symmetry is acceptable for all three models at the 1 percent level of significance. Taking homogeneity as given, the symmetry hypothesis is acceptable for all three models at the 5 percent level.

Thus, overall, we conclude that homogeneity and symmetry hypotheses are generally acceptable by all the three models; and, in the remaining sections of the paper, we consider models with homogeneity and symmetry imposed.

Table 9 Testing for Slutsky symmetry, Australian meat data, 1962-2011

	Symmetry					Symmetry given Homogeneity		
Model	Test statistic	Critical value		Decision		Test statistic	Critical value	Decision
		$\chi^2_{(0.05,10)}$	$\chi^2_{(0.01,10)}$	5% level	1% level		$\chi^2_{(0.05,6)}$	
Rotterdam	18.47	18.3	23.2	Reject	Do not reject	4.39	12.6	Do not reject
CBS	19.68	18.3	23.2	Reject	Do not reject	4.52	12.6	Do not reject
AIDS	17.39	18.3	23.2	Do not eject	Do not reject	3.96	12.6	Do not reject

6. The preferred demand model

We select the preferred model among the three demand systems, Rotterdam, CBS and AIDS, by calculating the predicted budget shares from each model and then use them to calculate the goodness-of-fit measure, *information inaccuracy*, for each meat type and for meat as a whole.

Let $w'_{1t}, \ldots, w'_{n_g t}$ be the observed budget shares of n_g commodities in period t, and $\hat{w}'_{1t}, \ldots, \hat{w}'_{n_g t}$ be the predicted budget shares implied by the demand model. The information inaccuracies for the predictions by meat type (i) is given by

$$I_{it} = w'_{it} \log\left(\frac{w'_{it}}{\hat{w}'_{it}}\right) + (1 - \bar{w}'_{it}) \log\left(\frac{1 - w'_{it}}{1 - \hat{w}'_{it}}\right), \qquad i \in S_g, \tag{15}$$

and the overall information inaccuracy for the predictions is given by

$$I_t = \sum_{i \in S_g} w'_{it} \log\left(\frac{w'_{it}}{\hat{w}'_{it}}\right). \tag{16}$$

The information inaccuracies measure the extent to which the predicted budget shares ($\hat{w}'_{it}$) differ from the corresponding observed budget shares (w'_{it}). Both I_{it} and I_t are non-negative and the larger their observed value, the poorer is the quality of the predicted budget shares $\hat{w}'_{1t}, \ldots, \hat{w}'_{nt}$.

A naïve model of no-change extrapolation is one in which the current period prediction of w'_{it} is specified as w'_{it-1}. That is, $\hat{w}'_{it} = w'_{it-1}$. Table 10 presents the information inaccuracies for the three models and for the no-change model, for the five meat types and for the total meat group. As can be seen, at the individual meat type level as well as the total meat, in most cases AIDS model performs better than the other two. Based on the goodness-of-fit measure, information inaccuracy, we conclude that the preferred model for modelling meat demand is AIDS.

Table 10 Information Inaccuracies I_{it} and I_t (x 10^2)

	Demand model				
Meat type	Rotterdam	CBS	AIDS	No-Change	Best-fit
Beef	370	356	342	563	AIDS
Lamb	254	247	207	266	AIDS
Mutton	554	557	548	614	AIDS
Chicken	123	108	139	379	CBS
Pork	245	250	240	332	AIDS
Total meat	1225	1211	1186	1684	AIDS

Estimates and implied elasticities

Next we present the estimation results using the Australian meat data for the preferred model, AIDS with homogeneity and symmetry imposed, and then use the estimates to obtain the implied income and price elasticities.

Table 11 presents the estimation results for AIDS with homogeneity and symmetry imposed using the Australian meat data. As can be seen, a majority of the coefficient estimates are statistically significant at the 5 percent level of significance. The estimated constant terms for beef, lamb and mutton are negative and for chicken and pork are positive, indicating that there is an autonomous trend out of beef, lamb and mutton into pork. The income coefficient for beef is positive, indicating that it is a luxury, while for lamb, mutton, chicken and pork are negative, indicating that they are necessities.

Table 11 Parameter estimates AIDS, Australian meat data, 1962-2011*

	Constant	Income	Beef	Lamb	Mutton	Chicken	Pork	I_1	I_2
Beef	-0.0035	0.2965	-0.0073	0.0145	0.0167	-0.0399	0.0161	0.0126	0.0362
	(0.0020)	(0.0523)	(0.0018)	(0.0035)	(0.0041)	(0.0097)	(0.0040)	(0.0133)	(0.0147)
Lamb	-0.0014	-0.0604	0.0145	0.0137	-0.0051	-0.0069	-0.0162	-0.0032	-0.0037
	(0.0011)	(0.0295)	(0.0035)	(0.0051)	(0.0023)	(0.0071)	(0.0040)	(0.0077)	(0.0083)
Mutton	-0.0025	-0.0199	0.0167	-0.0051	-0.0167	-0.0010	0.0061	-0.0078	-0.0009
	(0.0010)	(0.0265)	(0.0041)	(0.0023)	(0.0046)	(0.0074)	(0.0056)	(0.0071)	(0.0075)
Chicken	0.0047	-0.1014	-0.0399	-0.0069	-0.0010	0.0777	-0.0299	0.0005	0.0009
	(0.0009)	(0.0239)	(0.0097)	(0.0071)	(0.0074)	(0.0140)	(0.0129)	(0.0078)	(0.0068)
Pork	0.0027	-0.1147	0.0161	-0.0162	0.0061	-0.0299	0.0239	-0.0020	-0.0325
	(0.0012)	(0.0305)	(0.0040)	(0.0040)	(0.0056)	(0.0129)	(0.0130)	(0.0089)	(0.0085)

* Standard error are in parentheses.

Based on AIDS, the income elasticity for good i will be given by

$$\eta_i^{'} = 1 + \frac{\beta_i^{'}}{w_i^{'}}$$

and the own and cross price elasticites are given by

$$\eta_{ii}^{'} = -1 + \frac{\gamma_{ii}^{'}}{w_i^{'}} - \beta_i^{'}$$

and

$$\eta_{ij}^{'} = \frac{\gamma_{ij}^{'}}{w_j^{'}} - \frac{\beta_i^{'} / w_i^{'}}{w_j^{'}}.$$

Table 12 presents the implied income and price elasticities calculated at sample means together with the estimates presented in Table 11.

Table 11 Implied income and price elasticities

	Income	Price elasticities				
Meat type	elasticity	Beef	Lamb	Mutton	Chicken	Pork
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Beef	1.536	-0.407	0.152	0.069	0.064	0.122
Lamb	0.556	0.611	-0.710	-0.042	0.084	0.057
Mutton	0.454	0.800	-0.122	-1.187	-0.026	0.534
Chicken	0.221	0.253	0.082	-0.019	-0.276	-0.051
Pork	0.435	0.381	0.044	0.143	-0.040	-0.528

As can be seen from Table 12, the income elasticity for beef is 1.54 (> 1), lamb 0.56 (< 1), mutton 0.45 (< 1), chicken 0.22 (< 1) and pork 0.44 (< 1). This means that among the 5 meat types, beef is a luxury and lamb, mutton, chicken and pork are necessities.

All the own-price elasticities are negative as they should be. The values are beef (-0.41), lamb (-0.71), mutton (-1.19), chicken (-0.28) and pork (-0.53). As the magnitude of mutton's own price elasticity is larger than one, demand for mutton is price inelastic and the absolute vales of the own-price elasticity of all other four meats are less than one indicating that the demand for beef, lamb, chicken and pork are price inelastic.

Among the cross-price elasticities (except for pork-chicken), all are positive indicating that pork and chicken are complements and all other combinations are pairwise substitutes.

7. Concluding Comments

In this paper, we have presented a systematic analysis of Australian meat demand using data from 1962 to 2011 for the 5 meat types, namely beef, lamb, mutton, chicken and pork.

According to the statistics published for 2011, Australians consume about 111 kgs of meat per person divided into 33kg of beef, 9kg of lamb, 43kg of chicken and 25kg of pork. In recent years, Australian consumers allocate about 4 percent of their budget to the purchase of meat. Within their expenditure on meat, they allocate about 44 percent on beef, 12 percent on lamb, 21 percent on chicken and 24 percent on pork with very little or none on mutton. In terms of market share, chicken and pork have increased their share by 3 and 2 times, respectively, in the last 50 years at the expense of beef, lamb and mutton. Mutton share was 13.8 percent in 1962 and has been almost wiped out in 2011. The retail prices of all five meat types has steadily increased over the last 50 years with beef, lamb and mutton prices increased at faster rate than the prices increase of chicken and pork.

In this paper, we also investigated the following four empirical regularities in consumer demand and find strong support for all of them using the Australian meat data, (1) the quantity variance exceeds the price variance; (2) demand curve slopes downwards; (3) income flexibility tends towards -0.5; and, budget share of food declines with increasing income.

To model the data, we used three well-known and popular demand systems, namely, Rotterdam, CBS and AIDS and tested the two demand theory hypotheses, demand homogeneity and Sltusky symmetry. In genereal, both hypotheses were acceptable for all three models using the meat data. We then used the goodness of fit measure, information inaccuracy to select the preferred model among the three and found that AIDS performed better than Rotterdam and CBS for the Australian meat data.

We also presented the implied income and price elasticities based on the preferred model. The results showed that beef is a luxury while mutton, lamb, chicken and pork are necessities. The demand for mutton is price elastic and demand for beef, lamb, chicken and pork are price inelastic. We also found that chicken and pork are pairwise complements while all other pairs are pairwise substitutes.

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