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WEAK SEPARABILITY AND A TEST FOR THE SPECIFICATION OF INCOME IN DEMAND MODELS WITH AN APPLICATION TO THE DEMAND FOR MEAT IN AUSTRALIA*

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Most studies of the demand for meat in Australia have used some measure of total income or expenditure, but two recent studies have assumed weak separability of a meat group and used expenditure on the meat group instead. These specification differences are of interest to the extent that they affect the economic interpretation, goodness-of-fit, elasticity estimates, predictive performance or hypothesis tests in empirical demand equations. In this paper, non-nested hypothesis testing procedures are used to test the alternative specifications of the income variable and the hypothesis of separability. The results favour the use of the expenditure variable implied by separability but are mixed concerning whether separability holds.

Empirical demand models commonly are specified in budget-share or quantity-dependent form with the prices of a few closely related goods and some measure of income as explanatory variables.[1] Most often, the income variable is a measure of total disposable income or total expenditure on all goods. Such specifications may be *ad hoc* or derived from rigorous theoretical argument, but in either case the prices excluded from the model must be assumed to be either (a) uncorrelated with the explanatory variables in the model or (b) irrelevant in the demand equation of interest if parameter estimates are to be consistent and unbiased.

Data limitations prevent explicitly including all prices in a demand model, so the assumption of weak separability is often used to reduce the number of prices which must be included in empirical analysis.

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[1] We use the terms income and expenditure interchangeably. Nearly all studies use expenditure rather than income, possibly to omit savings from the analysis or to avoid using a regressor with measurement error likely (for example, Martin and Porter 1985). Thus, we consider *which* expenditure variable should play the role of 'income'.

Generally, researchers have in mind a multistage budgeting process in which consumer expenditures are allocated first across large groups of goods such as 'housing', 'entertainment', 'non-meat food', 'meat' etc. The allocation of meat expenditure to individual meat items then depends only on total meat expenditure and the relative prices of items in the group. Weak separability thus justifies the exclusion of other prices and is both necessary and sufficient for characterising the *second stage* of the budgeting process in this fashion.[2]

When separability is assumed, the theoretically correct income measure in the demand model is total expenditure on the items in the group rather than total expenditure on all goods (Deaton and Muellbauer 1980). Whether or not it is appropriate to assume separability is strictly an empirical question. It is theoretically inconsistent to assume separability and then to use total expenditure on all goods as the income variable in a demand model. On the other hand, the resulting specification may be empirically superior to the specification using expenditure on the group as the income variable if separability does not hold. In at least one case, the two alternatives for the income variable are equally good: that is, in a double-log specification when the elasticity of expenditure on meat with respect to total expenditure on all goods is a constant.

The assumption of separability in the context of the retail demand for meat in Australia is examined here. There have been many studies of the demand for meat in Australia, including several reviewed by Richardson (1976) and more recent work including Main, Reynolds, and White (1976), Fisher (1979), Murray (1984), Martin and Porter (1985) and Chalfant and Alston (1986). Of these studies, two (Murray 1984; Chalfant and Alston 1986) assumed weak separability between a meat group and all other goods and thus used expenditure on meat as the relevant income variable. The other studies used some measure of total income (Main, Reynolds, and White 1976; Fisher 1979) or total expenditure (Martin and Porter 1985) as the income variable.

The separability assumption was used by Murray (1984) and Chalfant and Alston (1986) to exclude all non-meat prices from their models. Both Main, Reynolds and White (1976) and Martin and Porter (1985) incorporated non-meat prices by deflating using the consumer price index for all goods. Fisher (1979) included an index of the prices of other food items (excluding non-food prices) as a separate explanatory variable.

The other major specification differences have been among alternative functional forms and between single equations and systems approaches. The most common functional forms used either logarithms of quantities or expenditure shares as functions of logarithms of prices and incomes.

A variety of elasticity estimates has resulted from these studies. The

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[2] The first stage of the budgeting process requires some additional assumptions in order for allocations to the broad categories defined by each group to depend only on price indexes for each group and total expenditure. Hereafter, weak separability is referred to as separability and the other possible definitions are not considered. The stronger restriction of strong or additive separability places restrictions on demand elasticities which are generally deemed to be too severe. See Deaton and Muellbauer (1980) for an extended discussion of all of these points including the requirements for the first stage of the budgeting process.

range of results presumably may be attributed largely to the differences in specifications, differences in estimation methods, different periods analysed or differences resulting from the use of quarterly rather than annual data. Many issues about appropriate specification of meat demand equations related to these differences remain unresolved. This paper deals with a small subset of these issues. The aim is to answer two distinct but closely related questions: first, what is the appropriate income variable to include in Australia's meat demand equations; and second, is the meat group weakly separable from other consumption goods?

To address these questions, demand equations for four types of meat are estimated using two alternative income variables: expenditure on the meat group alone and expenditure on all goods. A hierarchical testing procedure is then applied to the models. First, non-nested hypothesis testing procedures are applied to test each specification of the income variable against the alternative in order to determine which (if either) income variable is the appropriate one. This is a test of a necessary but not a sufficient condition for weak separability. Consistency with weak separability requires both that expenditure on meat is the appropriate income variable and that other (non-meat) prices are irrelevant. In the models, this implies an additional parametric restriction which can be tested conventionally. Thus, the order of testing is first to test the alternative income variables in the unrestricted model and, second, to test the parametric restriction in the model that includes expenditure on meat as the income variable. A third step directly compares the original, non-separable model with the one which embodies the separability restrictions.[3] This is done with a second round of non-nested testing since neither model includes the other as a special case.

The Demand Models

Two commonly used functional forms are applied to estimate both of two alternative models of meat demand. The two alternative demand models are identical in all respects except for the specification of the income variable. In both of these models, consumption of beef, chicken, lamb, and pork per person are assumed to depend only on prices of those four types of meat (deflated by the consumer price index for all groups), quarterly intercept dummies, a time trend variable, and an income variable.[4] Thus, the models already are restricted compared with the most general non-separable demands — all non-meat prices are assumed to enter only through the consumer price index. The income variable is either per person expenditure on all goods deflated by the consumer price index or per person expenditure on the four meat types deflated by a meat price index.

[3] An alternative (nested) test for separability is to include prices of non-meat items as explanatory variables and test their significance. The disadvantage of this approach is that the range of possible prices to be tried is endless. With sufficient experimentation, it seems certain that a price may be found that appears to contribute to the regression.

[4] Time trends are included because results from previous studies have indicated shifts over time in per person demands for meat in Australia when these functional forms are estimated. Quarterly intercept dummies are also significant (Chalfant and Alston 1986). Mutton was not included in the study due to its relatively low budget share and some concerns about the data and the behaviour of mutton demand (Martin and Porter 1985; Chalfant and Alston 1986).

Deflating by the consumer price index (or some other price index) is conventional and doing so allows comparisons with other studies. It is a convenient way of imposing homogeneity of degree zero in income (either expenditure on all goods or on the meat group) and prices (all meat prices and the consumer price index). This restriction stops short of imposing separability. The demand equation will be consistent with separability only if the parameters are such that the partial effect of the consumer price index on consumption of meat is zero. In the following models, this additional requirement can be met by imposing a further restriction that the parameters on the logarithms of prices sum to zero. Conveniently, this restricts the demands to be homogeneous of degree zero in meat prices and income and is equivalent to the restriction that only relative prices of meat matter.

The two alternative functional forms used below are identical in all respects except the dependent variable. In the first, it is the logarithm of per person consumption for each type of meat; in the second, it is per person expenditure on each type of meat as a share of per person expenditure on the four meat types. The first is probably the most common functional form in all of the empirical demand literature, although Beggs (1987) found that the second appears to perform well. In both cases, the regression models are linear. The independent variables are quarterly intercept dummies and the logarithms of prices, income and the time trend. Thus, the first specification corresponds broadly to the double-log specification of Main, Reynolds and White (1976), Fisher (1979) and Martin and Porter (1985). The second specification corresponds to Fisher's (1979) modified translog and the almost-ideal demand models used by Murray (1984) and Chalfant and Alston (1986). Excluding quarterly intercept dummies, the alternative models may be summarised as follows:

Model 1: Including expenditure on meat

$$\text{(1)}\quad \ln Q_i = a_i + \sum_j b_{ij} \ln\left(\frac{P_j}{CPI}\right) + c_i \ln\left(\frac{X_1}{P}\right) + d_i \ln T$$

Model 2: Including expenditure on all goods

$$\text{(2)}\quad \ln Q_i = a_i + \sum_j b_{ij} \ln\left(\frac{P_j}{CPI}\right) + c_i \ln\left(\frac{X_2}{CPI}\right) + d_i \ln T$$

where:

Q_i = retail quantity per person of meat i (beef, chicken, lamb or pork);
P_i = price of meat;
X_1 = expenditure on the four meat types;
P = Stone's (1953) geometric index of the four meat prices;
X_2 = expenditure on all goods;
CPI = the consumer price index (all groups); and
T = a quarterly time trend variable with 1962(1) = 1.

To fit the alternative functional form specification, the logarithms of quantities (ln Q_i) in equations (1) and (2) are replaced with the shares of each meat in total meat expenditure (S_i). The equations are as follows:

Model 3: Including expenditure on meat

$$(3) \quad S_i = a_i + \sum_j b_{ij} \ln\left(\frac{P_j}{CPI}\right) + c_i \ln\left(\frac{X_1}{P}\right) + d_i \ln T$$

Model 4: Including expenditure on all goods

$$(4) \quad S_i = a_i + \sum_j b_{ij} \ln\left(\frac{P_j}{CPI}\right) + c_i \ln\left(\frac{X_2}{CPI}\right) + d_i \ln T$$

where S_i is the share of meat i (beef, chicken, lamb or pork) in total meat expenditure, and the other variables are as previously defined.[5]

It is a maintained hypothesis in all of the models that the demands are homogeneous of degree zero in the relevant prices and income. Models 1-4 are homogeneous of degree zero in the prices of the four meats, the consumer price index and expenditure (either expenditure on all goods or expenditure on meat). This is easily verified; the monetary variables all enter in ratio form.

Under an assumption of separability, the consumer price index ought to be irrelevant. If this is so, the consumer price index in Models 1 and 3 represents an irrelevant variable, and the demands will not be restricted to be homogeneous of degree zero in the meat prices and expenditure terms. To eliminate the consumer price index and impose homogeneity in Models 1 and 3 requires the additional restriction:

$$(5) \quad \sum_j b_{ij} = 0$$

Models with this restriction imposed are referred to as Models 5 and 6, respectively. This, plus the use of expenditure on meat as the income variable in these models, is consistent with weak separability. In practice, this restriction is easily imposed by excluding the consumer price index from the models and deflating the other prices by the price of pork. Then an F test is used to test the restriction.

These six sets of demand equations are estimated using ordinary least squares, without imposing any of the cross-equation restrictions implied by theory, and using quarterly data for the period 1968(1) to 1983(1) specified in Chalfant and Alston (1986). The estimates of the first four models are reported in Table 1 (quantities) and Table 2 (shares). Models 5 and 6 are estimated only to test hypotheses and the estimates are not reported.

Comparing the estimates for each meat type between Model 1 and Model 2 and between Model 3 and Model 4 gives some indication of the relative merits of the alternative income measures. These comparisons may be made in terms of statistical properties of estimates or more

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[5] In Model 3, which includes expenditure on the meat group as the income variable, the specification conforms to a single equation version of the almost-ideal demand system (Deaton and Muellbauer 1980) assuming the four meat types comprise a separable group. More detail about this specification and the results from estimating the sytem using restricted seemingly unrelated regressions are provided by Chalfant and Alston (1986).

TABLE 1

Single Equation Estimates of Demand for Meat Using Models 1 and 2[a]

Independent variable	Dependent variables: logarithms of quantities of							
	Beef		Chicken		Lamb		Pork	
	1	2	1	2	1	2	1	2
ln P_b	−0.42*	−1.11*	0.21*	0.12*	1.06*	0.70*	0.47*	0.36*
	(0.04)	(0.07)	(0.09)	(0.05)	(0.07)	(0.05)	(0.04)	(0.03)
ln P_c	0.02	0.46	−0.37*	−0.31	0.28	0.51*	−0.31*	−0.23*
	(0.08)	(0.25)	(0.18)	(0.18)	(0.15)	(0.19)	(0.09)	(0.09)
ln P_l	0.37*	0.26*	0.08	0.08	−1.33*	−1.39*	0.20*	0.18*
	(0.04)	(0.13)	(0.09)	(0.09)	(0.08)	(0.10)	(0.05)	(0.05)
ln P_p	0.29*	0.75*	−0.14	−0.01	0.20	0.42*	−1.12*	−1.02*
	(0.07)	(0.21)	(0.15)	(0.15)	(0.12)	(0.16)	(0.07)	(0.08)
ln T	−0.11*	0.19	0.63*	0.91*	−0.18*	−0.11	−0.004	0.11
	(0.03)	(0.22)	(0.06)	(0.16)	(0.05)	(0.17)	(0.03)	(0.09)
ln X_1	1.61*		0.17		0.85*		0.26*	
	(0.08)		(0.17)		(0.14)		(0.08)	
ln X_2		0.15		−0.93		0.39		−0.24
		(0.78)		(0.56)		(0.60)		(0.30)
R^2	0.99	0.91	0.97	0.97	0.96	0.94	0.95	0.95
RMSE	0.023	0.071	0.052	0.051	0.041	0.054	0.025	0.027
DW	1.85	2.09	0.72	0.77	2.11	2.19	2.37	2.33

[a] Models labelled '1' include expenditure on the four meats as the income variable, while models labelled '2' include expenditure on all goods. Figures in parentheses are standard errors of parameter estimates.

* Statistically significant at the 5 per cent level.

TABLE 2

Single Equation Estimates of Demand for Meat Using Models 3 and 4[a]

Independent variable	Dependent variables: share of							
	Beef		Chicken		Lamb		Pork	
	3	4	3	4	3	4	3	4
ln P_b	−0.005 (0.019)	−0.128* (0.016)	−0.041* (0.010)	−0.002 (0.007)	0.069* (0.012)	0.089* (0.007)	−0.022* (0.008)	0.041* (0.008)
ln P_c	−0.010 (0.038)	0.067 (0.056)	0.037 (0.020)	0.013 (0.023)	0.030 (0.024)	0.017 (0.024)	−0.057* (0.016)	−0.097* (0.026)
ln P_l	0.094* (0.020)	0.074* (0.029)	−0.009 (0.010)	−0.001 (0.012)	−0.086* (0.012)	−0.083* (0.012)	−0.0002 (0.008)	0.010 (0.014)
ln P_p	0.074* (0.032)	0.152* (0.048)	−0.033* (0.016)	−0.051* (0.020)	0.004 (0.020)	−0.014 (0.020)	−0.045* (0.013)	−0.086* (0.022)
ln T	−0.041* (0.013)	−0.005 (0.051)	0.061* (0.007)	0.074* (0.021)	−0.027* (0.008)	−0.054* (0.022)	0.007 (0.005)	−0.015 (0.024)
ln X_1	0.291* (0.036)		−0.098* (0.019)		−0.044 (0.022)		−0.149* (0.015)	
ln X_2		0.090 (0.178)		−0.122 (0.074)		0.064 (0.076)		−0.032 (0.084)
R^2	0.92	0.81	0.88	0.83	0.95	0.94	0.93	0.80
RMSE	0.011	0.016	0.006	0.007	0.007	0.007	0.004	0.008
DW	1.80	2.05	0.75	1.57	2.16	2.12	2.41	2.16

[a] Models labelled '3' include expenditure on the four meats as the income variable, while models labelled '4' include total expenditure on all goods. Figures in parentheses are standard errors.

* Statistically significant at the 5 per cent level.

qualitative criteria. On the basis of R^2, the models using expenditure on meat explain a higher proportion of the variation in meat consumption than the models using total expenditure on all goods. For each meat type, the R^2 value for Model 1 is at least as large as that for Model 2. The R^2 values for Model 3 are generally greater than for Model 4. Changing the income measure has relatively little effect on the R^2 in the chicken equations. The chicken equations stand out, also, in having low Durbin-Watson statistics (an indication of significant autocorrelation). When these were re-estimated with an autocorrelation correction, there was a slight preference for Models 2 and 3.

There are some significant effects of changing the income specification on parameter estimates. The most striking of these is the significance of trend in the models. Trends are highly significant in six of the eight models using expenditure on meat compared with only three of the eight models using expenditure on all goods. Once again, chicken is outstanding, having significant positive trends regardless of the specification of the dependent variable and regardless of which income measure is used. Excluding chicken, trends are significant in four of six models using expenditure on meat but only one of six models using expenditure on all goods. This is possibly due to higher correlation between time and total expenditure than between time and the group expenditure.

The price elasticity estimates are generally similar between the models and are plausible. However, given the conditional nature of the models including only meat expenditure, the elasticities are not directly comparable between models. Additional information is needed on the first-stage allocation of total expenditure between meat and other goods to make exact comparisons possible. The one striking difference is in the own-price elasticity of demand for beef; but neither specification is clearly superior in terms of the conformation of estimated elasticities with priors.

On the whole, it may be said that the results indicate a general specification problem with the chicken equations, a problem noted by Martin and Porter (1985). Thus, the results for chicken should be discounted somewhat in further analysis of the effects of using alternative income measures.

On the basis of R^2 values, expenditure on the meat group performs better than total expenditure on all goods. On the other hand, significant trends in demand models are not highly desirable and trends are less important in the models using total expenditure as an income measure. As argued in Chalfant and Alston (1987), the significance of trend effects could be taken to be evidence of structural change or of model misspecification. Since the results of these informal comparisons are mixed, the next step is to compare the models more formally. To do so, non-nested testing procedures are used to test each income measure against the other for each meat. This is done for both specifications of the dependent variable. Then, out-of-sample mean-square prediction errors are used to compare the models both within and across specifications.

Non-Nested Tests

Some examples of using non-nested test procedures can be found in the literature on the demand for money (McAleer, Fisher and Volker

1982; Gregory and McAleer 1983; Milbourne 1985) and elsewhere in the demand literature (such as Chalfant 1987, for selecting between almost-ideal and translog models of US meat demand). The tests proposed by Davidson and MacKinnon (1981) are used in this study. They proposed three tests that work as follows. Consider two non-nested regression models, H_1 and H_2 for some variable y:

$$(6) \quad H_1: y = f_1(x_1, \theta_1) + u_1$$

and

$$(7) \quad H_2: y = f_2(x_2, \theta_2) + u_2$$

where x_1 and x_2 are matrixes of explanatory variables (which cannot be written as linear combinations of one another), θ_1 and θ_2 are corresponding parameter vectors, and u_1 and u_2 are random errors assumed to have zero means and constant variances.

Each of the three tests is based on a compound regression model formed from (6) and (7):

$$(8) \quad y = (1 - \alpha) f_1(x_1, \theta_1) + \alpha f_2(x_2, \theta_2) + v$$

The test of the validity of H_1 is the test of the hypothesis that $\alpha = 0$ in equation (8), while H_2 is tested by testing the hypothesis that $\alpha = 1$. All three tests can be used to test each hypothesis against the alternative. It is quite possible to reject both specifications, to choose one over the other, or to find that neither can be distinguished as a preferred specification.

When the objective is to test both specifications, the first step in all three testing procedures is to obtain separate estimates of the parameters of the alternative models (H_1 and H_2). These first-stage estimates ($\hat{\theta}_1$ and $\hat{\theta}_2$) are then used to estimate α in a second-stage regression. This two-stage approach has several advantages over attempting to estimate the compound model directly (Davidson and MacKinnon 1981). To perform the J test of H_1, α and θ_1 are estimated jointly, conditional on $\hat{\theta}_2$ from the first stage. To test H_2, $(1 - \alpha)$ and θ_2 are estimated jointly, conditional on $\hat{\theta}_1$. In contrast, the C test estimates α conditional on both $\hat{\theta}_1$ and $\hat{\theta}_2$ for either hypothesis.

The J test is well-behaved asymptotically but may be difficult to perform if f_1 is non-linear. The C test is easier to use but is less reliable. Thus, Davidson and MacKinnon (1981) modified the C test by obtaining $\hat{\alpha}$ from:

$$(9) \quad y - f_1(x_1, \hat{\theta}_1) = \alpha[f_2(x_2, \hat{\theta}_2) - f_1(x_1, \hat{\theta}_1)] + F_1 b + w$$

where F_1 represents the elements from the Jacobian matrix:

$$\frac{\partial f_1(x_1, \hat{\theta}_1)}{\partial \hat{\theta}_1}$$

and b is a vector of parameters. This they termed the P test. As in the J test, the procedure is reversed to test H_2. The t-tests for $\hat{\alpha}$ in the J and P tests were shown to be asymptotically valid by Davidson and

TABLE 3

Test Statistics for Non-Nested Tests of Each Income Variable Against the Other Without Imposing Separability Restrictions[a]

Dependent variable	Meat type (i)	*t*-statistics			
		H_1: Expenditure on meat is correct		H_2: Total expenditure on all goods is correct	
		P test	*C* test	*P* test	*C* test
$\ln Q_i$	Beef	0.298	0.009	20.614*	22.56*
	Chicken	1.680	1.559	1.018	0.564
	Lamb	0.763	0.115	6.081*	6.572*
	Pork	0.897	0.264	3.043*	3.173*
S_i	Beef	0.649	0.067	8.017*	8.717*
	Chicken	1.996*	0.756	5.406*	5.375*
	Lamb	0.896	0.392	1.978*	1.958
	Pork	0.518	0.037	9.934*	10.839*

[a] A significant *t*-statistic indicates that the null hypothesis (H_1 or H_2) should be rejected.

* Statistically significant at the 5 per cent level.

MacKinnon (1981). They suggested that the *J* test be used for linear H_1, the *P* test for non-linear H_1, and the *C* test as a simple approximation. Of course, when H_1 is linear, as is the case with the models presented here, the *J* and *P* tests are identical.

The *C* and *P* tests may be used to test each income variable against the other in the demand equations above. To do so, let H_1 conform to using expenditure on meats as the income measure and H_2 conform to using total expenditure on all goods. Tests are then performed using each of the two functional forms. The *t*-statistics for these tests are shown in Table 3. Since the asymptotic behaviour of the *P* test is preferred, only those results are discussed in detail.

In seven of the eight cases, the *P* statistics for H_1 are not significant. The single exception is in the almost-ideal specification of the demand for chicken (Model 3). In contrast, seven of the eight *P* statistics for H_2 are significant. Again, the one exception is in the demand for chicken, but this time it is when the logarithm of quantity per person is used as the dependent variable (Model 2). Thus, with chicken as the one exception, expenditure on meats is the preferred income variable (H_1), while the hypothesis that expenditure on all goods is the correct income variable (H_2) is rejected.[6]

For chicken, using the logarithms of quantities per person as the dependent variable, neither income measure is rejected; and, in the almost-ideal demand specification, both income measures are rejected. That is, the results for chicken are inconclusive and neither income measure is clearly superior. This could be a consequence of some other

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[6] The *C* test results differ only slightly from those for the *P* tests. None of the models (including chicken) using expenditure on meat is rejected. Six of the eight models using total expenditures are rejected. The *t*-value for lamb in share-dependent form is fractionally below the critical value. Aside from lamb, as with the *P* test, only for chicken is total expenditure not rejected as the income measure.

specification problem with the chicken equations, a problem noted in previous studies.

One possibility would be to use results corrected for the autocorrelation present in the chicken equations. While tests may be misleading if this is not done, it is also the case that correcting for autocorrelation caused by some other specification error would cloud the interpretation of non-nested tests (Milbourne 1985).

On the whole, the weight of the evidence from these tests is in favour of the use of expenditure on the meat group rather than expenditure on all goods as the income measure in Australian meat demand equations. Also, these results provide some support for the assumption of separability of the meat group. However, further restrictions are required to test this assumption formally.

Out-of-Sample Prediction Performance

The final piece of evidence to be presented about the relative performance of the four alternative models above is predictive performance, measured by mean-square prediction errors. Data are available for seven quarters beyond the sample data. For each meat type, the estimated parameters for each of the four models are used to predict either logarithms of quantities per person or expenditure shares for each of the seven quarters beyond 1983(1). Prediction errors are computed by subtracting these estimates from actual values. The mean squares of these prediction errors for each model and each meat type are reported in Table 4. For three of the four meat types, Model 1 (including meat expenditure) provides better predictions than Model 2 (incuding total expenditure on all goods). The exception is chicken. When expenditure shares are used as dependent variables, the model including meat expenditure (Model 3) results in better predictions for only two types of meat. With this specification of the dependent variable, the model including total expenditures provides better predictions for beef as well as chicken. On the basis of out-of-sample mean-square prediction errors, it is difficult to discriminate between the alternative income variables. Discounting the chicken equations, due to the other

TABLE 4

Out-of-Sample Mean-Square Prediction Errors for the Four Models[a]

	Mean-square prediction errors			
Meat type	Model 1	Model 2	Model 3	Model 4
Beef	0.00176	0.00906	0.00043	0.00025
Chicken	0.01974	0.01822	0.00024	0.00007
Lamb	0.00396	0.00739	0.00011	0.00012
Pork	0.00040	0.00105	0.00001	0.00011

[a] Mean-square errors were computed from predicting seven quarters beyond the last observation in the sample data used to estimate the models. Models 1 and 3 use expenditure on meat as the income variable; Models 2 and 4 use total expenditure; Models 1 and 2 use the logarithms of quantities as dependent variables; and Models 3 and 4 use expenditure shares. The prediction errors are comparable between the first pair of models and between the second pair of models but *not* between models that use different dependent variables.

problems noted above, the results slightly favour the use of expenditure on meat.

Tests for Separability

In the above analysis, models including expenditure on the meat group have been compared with models including total expenditure on all goods. The results favour the use of expenditure on the meat group. This outcome satisfies one of two necessary conditions for weak separability. The second necessary condition in the models used above is that the parameters on the logarithms of prices (b_{ij}) sum to zero.

Two additional sets of tests are therefore indicated. The first is a nested test of the restriction on parameters with the assumption that expenditure on meat is the correct income variable as a maintained hypothesis (that is, testing Model 5 against Model 1 and Model 6 against Model 3). The results from these tests are summarised in Table 5. The second test is a non-nested test of the joint hypothesis that expenditure on meat is the correct income measure and that the price coefficients sum to zero (that is, testing Model 5 against Model 2 and Model 6 against Model 4). The results from these non-nested tests are summarised in Table 6.

In Table 5, it can be seen that the restriction that the b_{ij}'s sum to zero is rejected in four of the eight cases. The restriction is strongly rejected for both beef and pork using either specification of the dependent variable. The restriction is not rejected for either chicken or lamb in either specification. That is, maintaining the hypothesis that expenditure on meat is the correct income variable, it is inappropriate to restrict the parameters according to the second necessary condition for two of the four meat types. This may be taken as evidence that the meat group, as defined, is not weakly separable from other goods. However, it could

TABLE 5

Tests of the Parametric Restriction Implied by Separability on Models that Include Expenditure on Meat[a]

Dependent variable	Meat type (i)	Error sum of squares: Restricted model (SSE_r)	Error sum of squares: Unrestricted model (SSE_u)	Pr(F)
ln Q_i	Beef	0.030243	0.027401	0.03
	Chicken	0.137694	0.135647	0.38
	Lamb	0.089367	0.087610	0.32
	Pork	0.056239	0.032614	0.00
S_i	Beef	0.006883	0.005912	0.01
	Chicken	0.001651	0.001562	0.09
	Lamb	0.002311	0.002298	0.59
	Pork	0.001647	0.001006	0.00

[a] The restriction imposed in Models 1 and 3 is that the parameters on the logarithms of prices sum to zero (that is, $\Sigma_j b_{ij} = 0$). Imposing the restriction increases the error degrees of freedom from 51 to 52. The standard F test for a parametric restriction is applied and the test statistic is computed as $F = \frac{SSE_r - SSE_u}{SSE_u/51} \sim F_{1,51}$.

TABLE 6

Non-Nested Tests of the Joint Hypothesis that Both Necessary Conditions for Weak Separability Hold[a]

		t-statistics for tests of the null hypotheses			
		H_1: Restricted model using meat expenditure is correct		H_2: Unrestricted model using total expenditure is correct	
Dependent variable	Meat type (i)	*P* test	*C* test	*P* test	*C* test
ln Q_i	Beef	2.32*	0.38	20.61*	21.37*
	Chicken	1.92	1.82	1.02	0.49
	Lamb	1.27	0.34	6.08*	6.43*
	Pork	6.19*	5.57*	3.04*	1.26
S_i	Beef	2.98*	1.17	8.02*	7.71*
	Chicken	2.68*	1.31	5.41*	5.06*
	Lamb	1.05	0.50	1.98*	1.89
	Pork	5.74*	2.72*	9.93*	7.86*
Number of rejections		5	2	7	6

[a] A significant *t*-statistic indicates that the null hypothesis (H_1 or H_2) should be rejected.

* Statistically significant at the 5 per cent level.

also be the result of some other specification problem such as the use of an incorrect functional form.

An alternative test of the assumption of separability is to test the two necessary conditions jointly. This requires a non-nested test, so the *P* tests and *C* tests described above are applied to test the joint hypothesis. In Table 6, it can be seen that the results from these tests are mixed. The joint hypothesis is rejected in five of the eight cases using the *P* test and in two of eight cases using the *C* test. The alternative hypothesis — that the unrestricted model using total expenditure on all goods is the correct model — is rejected more often. The *P* test rejects this alternative model in seven out of eight cases, while the *C* test rejects it in five out of eight cases. Combining the results of the two tests, the joint hypothesis is rejected in 7 out of 16 cases while the alternative hypothesis is rejected in 13 of the 16 cases.

Implications of the Study

Most previous studies of the demand for meat in Australia have used a measure of total income or total expenditure on all goods. Usually the prices of only a few closely related goods are included as explanatory variables. There is some theoretical support for using only the expenditure on those goods, rather than total expenditure, as the income variable under an assumption of weak separability.

Non-nested hypothesis tests provide empirical support in this instance for the use of expenditure on the meat group alone as the income variable. However, a second necessary condition for separability is rejected for two of the four meat types under the maintained hypothesis that expenditure on meat is the correct income variable. The results are less favourable for separability when the joint hypothesis is tested, although the model with the assumption of separability imposed is still rejected less often than the alternative model which uses total income.

The results do favour the use of expenditure on meat as the income variable but this specification is not logically connected with economic theory unless separability is assumed. To maintain contact with economic theory, it is necessary either to reject the separability assumptions — and use an income variable that the tests have strongly rejected — or to accept the separability assumption in spite of it having been rejected in half of the models. The latter course of action would seem to be favoured although neither is completely satisfactory.

A clear choice would require additional information, and some is available. First, all of the tests for separability are conditioned on the functional forms for demand equations that were used in the analysis. That is, separability was tested in double-log or almost-ideal demand equations. As is always the case, the use of an inappropriate functional form might have caused false rejections of separability. While separability was rejected using either functional form, the detailed test results differed significantly between the two forms tried, suggesting that the tests are indeed sensitive to the chosen form.[7]

An alternative approach to this problem would be to use a non-parametric analysis, thus avoiding the problem of selecting a functional form. In an application of non-parametric demand analysis using the same data set (Chalfant and Alston 1987), the existence of a stable system of weakly separable per person demands was not rejected. Because the rejection probability of such tests is not known, it is difficult to gauge the strength of support this gives to the separability assumption. However, it is consistent with a specification error interpretation of the various cases in this paper in which separability was rejected. Further tests of these functional forms using other specification tests will be of interest in this regard.

The different specifications used in previous studies have yielded a variety of elasticity estimates using this data set. Our results indicate that the estimates using expenditure in the meat group alone are likely to be more reliable. Whether the additional restrictions implied by separability should be imposed as well remains an open question.

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[7] By the same token, the tests of the alternative income variables are conditional tests too, but here the results were relatively clear-cut and relatively insensitive to the functional forms specified.

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