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Food demand elasticities for Australia*

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There is renewed interest in robust estimates of food demand elasticities at a disaggregated level not only to analyse the impact of changing food preferences on the agricultural sector, but also to establish the likely impact of pricing incentives on households. Using data drawn from two national Household Expenditure Surveys covering the periods 1998/1999 and 2003/2004, and adopting an Almost Ideal Demand System approach that addresses the zero observations problem, this paper estimates a food demand system for 15 food categories for Australia. The categories cover the standard food items that Australian households demand routinely. Own-price, cross-price and expenditure elasticity estimates of the Marshallian and Hicksian types have been derived for all categories. The parameter estimates obtained in this study represent the first integrated set of food demand elasticities based on a highly disaggregated food demand system for Australia, and all accord with economic intuition.

Key words: Almost Identical Demand Systems model, Australia, food demand.

1. Introduction

Despite their central importance, robust estimates of food demand elasticities are not available for many developed economies. Reliable estimates of such elasticities are critical for the formulation of various public policies and many strategic decisions undertaken at the industry level. Important examples of these policy decisions include, setting R&D priorities, forecasting future market conditions, evaluating promotional campaigns and assessing proposals for industry or commodity-based taxes and levies. The worldwide debate

* We would like to thank Editor John Rolfe, an associate editor, and three anonymous referees for their highly encouraging and constructive comments on earlier versions of this paper. We also thank the Rural Industries Research and Development Corporation for funding the project (Project No. PRJ-00296) that gave rise to this article. We are also indebted to Margaret Dinan and Clinton Mahar from ABS, and Terry Shields, David Barrett, Helal Ahammad and Edwina Heyhoe from ABARES for providing us with valuable information during the data collection stage, John Freebairn, Keith McLaren and George Veryikios for very useful input into this paper, and Rejaul Bakshi and Habibur Rahman for excellent research assistance.

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on policy responses to the increasing rate of noncommunicable diseases linked to obesity is also a policy evaluation process that rests on a sound understanding of food demand elasticities. Consider, in this vein, the debate on 'fat taxes' and 'thin subsidies' (see, among others, Nordstrom and Thunstromb 2009; Yaniv *et al.* 2009 and Allais *et al.* 2010). A tax on fatty foods could change household food-purchasing decisions towards the consumption of low-fat food. What impact any tax will have on household behaviour and household well-being will depend, in part, on the responsiveness of households to the rise in price of fatty foods. How large will the reduction in purchases of fatty foods be, and what foods will be purchased as substitutes? Similarly, consider 'thin subsidies'. How much rise will be observed in the production and the sales of fresh vegetables and fruit if their retail prices are subsidised? Availability of sound food demand elasticity estimates can thus strongly add to policy debates and assist in informed decision-making (see Edwards and Freebairn 1981; Dixon *et al.* 1982; Hill *et al.* 2001). Policy research without knowing the values of the relevant elasticities is analogous to calculating the expansion due to heating of a substance without knowing whether the substance is steel, concrete or paper. Under such conditions, neither economists nor physicists can possibly get their answers right.

This paper contributes to the public policy literature by estimating a comprehensive and integrated set of food demand elasticities for 15 disaggregated food categories in Australia. Although export demand is a key component of the demand for traded goods such as grains, meats and dairy products, domestic food demand is still of considerable importance to the food supply sector and the Australian economy as a whole. Domestic food demand has been exhibiting changes in food preferences that are likely to be driven by ageing, health concerns, advertising and a changing ethnic mix due to international migration (see Worsley 2002 and Kearney 2010), all of which could influence the responsiveness of food demand to price changes. Therefore, the evaluation of current food demand elasticities is a key consideration in the formulation of efficient policy settings for Australia.

Given this background, this paper makes three important contributions to the literature. First, own-price, cross-price and expenditure elasticities of Marshallian and Hicksian type are estimated using biweekly food expenditure data for 15 food categories in Australia. The food categories analysed in this study cover most of the standard food items in household shopping lists in Australia. This allows us to take into consideration the households' budgeting decisions in accord with substitution and complementarity issues. We use the Almost Ideal Demand System model as a base to estimate our elasticity estimates and address the zero observations problem in the first stage of the estimation through parametric and semi-nonparametric methods. Second, the level of disaggregation in food items that we cover in this paper is unique for Australia. Third, we provide separate estimates of the elasticities for households with Australian-born household heads. Comparing

the food demand behaviour of these households with the full sample case, we attempt to derive some inferences about how food demand might vary across households with Australian-born and foreign-born household heads.¹

Section 2 reviews the extant literature on Australian food demand elasticities and highlights how this study differs from prior work. The data are described in Section 3, while in Section 4, we discuss the patterns in food demand and food prices in Australia. Econometric methodology is discussed in Section 5, estimation results are reported in Section 6, and conclusions and possible implications are outlined in Section 7.

2. Previous food demand estimates for Australia

Table 1 provides the list of studies that have estimated Australian food demand elasticities since the 1970s, revealing five important facts. First, little is known about the values of *disaggregated* food demand elasticities for Australia. A great majority of previous studies focused on aggregate food categories, such as ‘food’ or ‘meat’, or specialised in only a few disaggregated items within one category, such as beef, lamb, chicken and pork within meat. Comprehensive elasticity estimates for many of the food items that are usually seen in households’ shopping lists in Australia were not made available. Second, a great majority of the studies used data from several decades ago, and as a result almost none of the studies employed data from the 1990s and the 2000s. The nature of demand relationships could well have changed over time as evidenced by several studies. Third, almost all studies estimating Australian elasticities utilised time series data at the national level. Estimates based on survey data and capturing food demand behaviour at the household level are very limited. Fourth, almost all of the studies focused on own-price elasticities. Cross-price elasticities are necessary to be able to account for possible substitution effects in evaluating the effects policies, such as a tax levy or a subsidy. Finally, past studies did not explore the implications of a changing ethnic mix on food demand, a phenomenon that is observed in many developed countries due to international migration. These contributions make our scope and contributions significantly different from those of existing studies.

Past studies have drawn data from various sources including the Australian Bureau of Statistics (ABS), the Australian Bureau of Agricultural and Resource Economics (ABARE) and the Australian Meat and Livestock Corporation (see Table 1). Tulpulé and Powell (1978) estimated expenditure elasticities using the TELES/Frisch approach, with estimates ranging between 0.1 and 0.5. Selvanathan (1991) estimated the own-price elasticity of ‘food’ for different states and obtained estimates that lie between 0 and -0.53 .

¹ This article builds on Ulubasoglu *et al.* (2011), a report prepared for the Rural Industries Research and Development Corporation that estimated the Australian domestic demand elasticities for rural marketing and policy analysis.

Table 1 Previous estimates of Australian food demand elasticities

Authors	Data	Model and estimation	Estimates
Tulpulé and Powell (1978)†	1964/1965–1975/1976	TELES, Expenditure, Frisch	Expenditure elasticities:
			Bread, cakes 0.1
			Confectionary 0.4
			Flour, cereals 0.2
Selvanathan (1991)	1975–1989 states	Working, ML	Food nec 0.5
			Spatial food demand elasticities:
			AU –0.26
			NSW –0.4
Hyde and Perloff (1998)	1970(1)–1988(1)	LA/AIDS	QLD –0.26
			SA –0.29
			TAS –0.53
			VIC 0.0
Piggott <i>et al.</i> (1996)	1978(3)–1988(4)	Single equation, OLS	WA –0.45
			Food demand elasticities:
			Beef –1.41
			Lamb –1.71
Alston and Chalfant (1987)	1968(1)–1983(1)	Single equation, OLS	Pork –1.04
			Beef –0.42
			Chicken –0.46
			Lamb –1.26
Martin and Porter (1985)	1962(1)–1983(1)	Single equation, OLS	Pork –0.87
			Beef –1.33
			Chicken –1.12
			Mutton 1.39
Bhati (1987)	1971(1)–1986(4)	Supply and Demand, 2SLS	Pork –1.09
			Chicken –0.85
			Lamb –1.88
			Poultry meat –0.36
Bewley (1987)	1984 Household Expenditure Survey	GADS, GLS	Chicken meat –0.35
			Delivered milk –14.77
			Nondelivered milk –3.62

Table 1 (Continued)

Authors	Data	Model and estimation	Estimates	
Seale <i>et al.</i> (2003)	1996 Cross-country data	Florida–Slutsky, ML, Frisch	Beverages and Tobacco Bread and cereals Dairy Fats and oils Fresh fruit Nuts	–0.314 –0.115 –0.275 –0.136 –0.66 –0.96
HAL (2008)	Weekly, 2001–2007	OLS	Aggregated Bacon Beef Chicken Fresh Pork Ham Lamb Pork	–0.283 –0.202 –0.257 –0.256 –0.58
Cashin (1991)	1967(1)–1990(1)	LA/AIDS, ML SUR	Disaggregated –0.95 –0.82 – –1.2 –1.19 –0.99 –	–0.283 –0.202 –0.257 –0.256 –0.58

†Reported by Dixon *et al.* (1982, p. 185).

Studies by Alston and Chalfant (1987), Martin and Porter (1985) and Piggott *et al.* (1996) used a single-equation OLS approach and estimated own-price elasticities for beef, chicken, pork and lamb. Alston and Chalfant (1987) and Piggott *et al.* (1996) obtained roughly similar own-price elasticities in the range of -0.42 and -1.26 , Martin and Porter's (1985) estimates were on the higher side, ranging between -0.85 and -1.88 . Bhati's (1987) estimates for chicken, using a 2SLS approach, were similar to Alston and Chalfant's. These studies covered the period from the 1960s to the 1980s.

Cashin (1991), and Hyde and Perloff (1998), also estimated own-price elasticities for disaggregated meat items using data that span the 1970s and 1980s, and adopted the Almost Identical Demand Systems (AIDS) methodology. Hyde and Perloff's estimates were in the range of -1.04 and -1.71 , while Cashin's estimates were relatively lower and varied between -0.83 and -1.33 .

Using a generalised addilog demand system and the 1984 Household Survey, Bewley (1987) estimated the demand elasticity for milk and finds highly elastic estimates, -14.77 for delivered milk and -3.62 for nondelivered milk. Horticulture Australia Limited (2008), using weekly retail sales data from 2001 to 2007, estimated a demand system for horticultural products and obtained the own-price, cross-price and expenditure elasticities for nuts, fresh fruit and vegetables, including some varieties within each category. These commodities form <20 per cent of household food purchases in Australia.

In an uncommon approach, using the 1996 cross-country data on international price comparisons and a Florida-Slutsky-based demand model, Seale *et al.* (2003) provided own-price, income and expenditure elasticities for Australia along with 113 countries for eight food items classified as follows: beverages and tobacco, bread and cereals, dairy, fats and oils, fish, fruit and vegetables, meat, and other foods. While in terms of product coverage and disaggregation, Seale *et al.* (2003) come close to ours, the implications associated with cross-country demand analysis are very unclear. For instance, widely different consumer food preferences across countries may result in elasticities that are based on strong assumptions, or measurement errors might traverse across the system and contaminate the estimates.

3. Data

We use diary data reported by households on food purchases over a 2-week period, available in the Household Expenditure Surveys (HESs) of the ABS (Australian Bureau of Statistics 2006). The data come from the 1998/1999 and 2003/2004 HESs, which contain, respectively, 6859 and 6957 households that are surveyed in different quarters during the year. The most recent HES data cover the period 2009/2010.² Not incorporating the 2009/2010 survey data in this study is unlikely to change our results meaningfully, because the

² This information became available after the completion of the project that gave rise to this study.

relationships are likely to be stable across time. Nevertheless, the 2009/2010 information would be useful to validate our elasticity estimates in future studies.

Food price data for our period are available for capital cities of each state in Australian Bureau of Statistics (1998 and 2003). Monthly prices are averaged into quarterly prices for concordance. Thus, variation in the price data comes from price differences across capital cities and different quarters in a year. Available information on food purchases and food prices feasibly yields 16 food categories for estimation: milk, dairy products (butter and cheese), bread, rice, beef and veal, mutton and lamb, pork, other meat, poultry, fresh fruit, fresh vegetables, preserved fruit, preserved vegetables, sugar and jam, margarine and other foods. Detailed information on the construction of the data set is provided in Appendix S1 in the working paper version of this article (Ulubasoglu *et al.* 2014).

4. Food demand and food prices in Australia

This section discusses food demand and food prices in Australia for the 15 product categories analysed in this study. The objective is to provide a background for the elasticities to be estimated in the next section.

4.1. Food expenditure shares

Appendix S2 in the working paper version of this study presents the expenditure shares of each food category (i.e. shares within the 15 food categories covered in this study) for the households surveyed in 1998/1999 and 2003/2004. The shares are reported by ethnicity, state, households' children status and the age of the household head. Focusing on the 1998/1999 survey, milk constitutes a significant food item with an expenditure share of around 13 per cent, not varying much across the demographic groups. Dairy products constitute approximately 9 per cent, while margarine occupies around a 4 per cent share. Bread has a mean expenditure share of 12 per cent, varying little across the demographic groups. Rice exhibits some important variability, however. Households whose heads were born in Australia spend 3 per cent on rice, whereas households with overseas-born heads spend 6 per cent. Given that rice is a staple food for ethnicities like Indians and other Asian communities, these differences seem to be unsurprising. Meat categories exhibit important characteristics. The average beef and veal expenditure share in Australian food budgets is 13 per cent. The mean expenditure share for mutton and lamb, poultry, and other meat is 10, 11 and 6 per cent, respectively, with relatively little variability across the demographics. However, pork does exhibit some variation across different demographic cohorts. The mean Australian expenditure share for pork is 9 per cent, with households whose heads were born in Australia consuming 8 per cent and households with overseas-born heads spending 11 per cent on pork. All other

food categories exhibit limited variability across the demographic groups, with mean expenditure shares reported as follows: fresh fruit 7 per cent, fresh vegetables 9 per cent, preserved fruit 4 per cent, preserved vegetables 5 per cent and sugar and jam 4 per cent.

The 2003/2004 survey does not exhibit any significant changes in expenditure shares compared to the 1998/1999 survey.

4.2. Food prices

Table 2 in this article presents the average prices for 15 food categories, standard deviations of prices (in the estimation sample) and total weekly household food expenditure on the 15 categories for 1998/1999 and 2003/2004. Considering all 15 categories, average food prices rose by 26 per cent between the two survey periods. This is above the 17 per cent increase in the CPI over the same period in Australia. The largest increase in food prices was observed for mutton and lamb (64 per cent), and the lowest increase was for sugar and jam (3.6 per cent). Meat categories generally exhibited large rises (except poultry); average prices for the five meat categories increased by 38 per cent over the 5 years. Milk, bread, fresh vegetables, preserved vegetables and margarine prices registered rises of more than 20 per cent, while dairy products, fresh fruit, and sugar and jam had price increases of 10 per cent or less. All these point to changes in the absolute and relative food prices over time. Total weekly household food expenditure for the 15 food categories covered in this study increased by 24 per cent (from \$41.39 to \$51.22) over the 5 years.

Table 2 Average prices for each food category

Food category	Unit (per)	1998/1999 A\$	2003/2004 A\$
Milk	2 L	2.533 (0.17)	3.171 (0.10)
Dairy products	500 g	2.791 (0.13)	3.090 (0.15)
Bread	700 g	2.157 (0.17)	2.736 (0.17)
Rice	1 kg	1.556 (0.09)	2.027 (0.09)
Beef and veal	1 kg	8.536 (0.50)	12.355 (0.41)
Mutton and lamb	1 kg	6.442 (0.29)	10.563 (0.27)
Pork	1 kg	6.989 (0.32)	9.209 (0.45)
Other meat	625 g	3.426 (0.21)	4.724 (0.13)
Poultry	1 kg	3.509 (0.19)	3.927 (0.21)
Fresh fruit	1 kg	2.202 (0.42)	2.405 (0.36)
Fresh vegetables	1 kg	1.967 (0.24)	2.386 (0.20)
Preserved fruit	625 g	1.602 (0.08)	1.914 (0.08)
Preserved vegetables	500 g	1.303 (0.13)	1.587 (0.08)
Sugar and jam	1250 g	2.372 (0.14)	2.458 (0.15)
Margarine	500 g	1.761 (0.13)	2.344 (0.06)
Total weekly food expenditure		41.390 (24.97)	51.217 (34.14)
Sample size		6850	6957

Note: Figures in parentheses refer to standard deviations. Prices in Australian dollars (A\$).

5. Estimation of food demand elasticities

There are many possible ways of estimating demand relationships – from using the simplest single-commodity models, which are adequate for small expenditure items, to whole demand systems. In this paper, a systems approach is adopted because it best represents the decisions that consumers make regarding food and other purchase decisions, and recognises the need to simultaneously meet a whole range of expenses.

Specifically, we adopt the linearised version of Deaton and Muellbauer's (1980) AIDS methodology, which is the workhorse of many household demand systems' studies. The AIDS model is based on a price index that is nonlinear in parameters, so following standard practice, a linear approximation has been applied to the AIDS model (see Buse 1994 and Moschini 1995). Among all the demand systems, AIDS is particularly attractive because its properties in relation to the consumers' preferences are well known (Barnett and Seck 2008). Accordingly, we estimate expenditure share equations for a system of 16 food categories and derive the elasticities for 15 categories. Our expenditure share equations look like the following:

$$W_i = \alpha_i + \sum_k \eta_{i,k} d_{i,k} + \sum_j \gamma_{i,j} \log p_j + \beta_i \log(X/P) + \mu_i S_i + u_i,$$

for $i = 1, 2, \dots, 16$, where W is the expenditure share of commodity i , p is the unit price of the commodity, X is the total food expenditure, P is aggregate price level, $d_{i,k}$ is k -th demographic characteristic (including the country of birth of the household head, age of the household head, household size and the number of children under 15), and S stands for state of residence.

Next, we derive the own-price, cross-price and expenditure elasticities of 15 food categories. We compute the Marshallian own-price elasticities following Equation (A12) in Appendix S3 in the working paper version of this study and derive the Hicksian cross-price elasticities following Okrent and Alston (2011, p. 8). We compute the standard errors of the elasticities using the delta method. Description of the AIDS model including the theoretical constraints, and the procedural details of other derivations used in this study, is provided in Appendix S3.

Zero expenditures for some food categories are the foremost estimation issue in our estimation. The problem is one of nonrandom sampling, which results in sample selection bias leading to inconsistent OLS estimates due to skewedness of the observations towards a certain number (in this case, zero). What causes people not to buy a product which they would otherwise have bought? An important reason for zero purchases is the 2-week-long survey period. During a short survey horizon, household expenditures for certain items are more likely to be zero than over a longer term. The survey horizon problem is mentioned in, among others, Heien and Wessells (1990). Zero

purchases could also be preference and demographics-driven and can thus be explained by variables such as ethnicity, the number of children and proportion of meals eaten outside the home.

As a solution, we adopt the two-stage Heckman selection method. In the first stage, we estimate a probit model where the dependent variable takes 1 for positive purchases and 0 for zero purchases. The independent variables are all of the explanatory variables of the expenditure share equation, plus a distinct variable that is to be excluded from the second stage (described below). Mills ratios calculated from the first stage for each of the food categories are then included in the respective expenditure share equations in the second stage, which are estimated jointly using Seemingly Unrelated Regressions methodology.

Regarding the distinct variable to be excluded from the second stage, most variables that would explain the zero food purchases, such as ethnicity, number of children and household size, are already included in the expenditure share equations. We are also unable to use other desired variables, such as the proportion of meals eaten outside or the presence of a pregnant woman, because this information was not available in our data set. We follow the reasoning of Heien and Wessells (1990), who argue that if the interview period were longer, more items would be observed entering the consumer's market basket. One can reasonably say that once households go shopping, they buy not only food, but also other items such as detergent, toilet paper, cling wrap and toothpaste. In other words, if nonfood expenditure is positive in the survey period, then there is a chance that food expenditure is positive too. If nonfood expenditure is zero, then food expenditure can also be zero. Hence, we use nonfood expenditure as the variable to be excluded from the second stage. We do not expect nonfood expenditure to explain the expenditure shares of food items; therefore, we assume it is excludable from the second stage.

Although the two-step Heckman procedure provides an elegant solution to the censoring problem, the estimator is derived under the assumption that the disturbance in the censoring equation follows a normal distribution. This assumption may be untenable in microdata. In a robustness check, we relax the normality assumption by employing a two-step semi-nonparametric approach used by Gallant and Nychka (1987) instead of a probit model. This estimator yields elasticity estimates that are, to a great extent, similar to our benchmark Heckman approach. See Appendix S3 in the working paper version of this study for more details on the Gallant and Nychka's (1987) estimator.

In an unreported analysis, we also conduct our estimations without correcting the sample selection problem. We expect that, given the elasticity formula for own-price elasticities for instance, the OLS estimate should be downwardly biased if the demand is inelastic in reality, and upwardly biased if elastic. Ten out of the 15 OLS estimates are in line with this expectation. For the remaining five food categories, which have mostly unit-elastic

demand, the difference between the OLS estimates and corrected estimates is small. Of the 10 categories, the OLS-based elasticities are, on average, 10 per cent biased compared to those obtained with correction.³

Another issue related to zero observations is the price data for the relevant product category. It is plausible to assume that consumers with zero consumption face the same prices as those paid by people who purchased the product in the same state and quarter. This is an assumption made in this paper.

Finally, the two surveys are pooled in the estimation process as this approach has significant advantages over utilising them separately. This practice provides a larger degree of freedom and a greater variation in the price data, thus resulting in more meaningful measurement of consumer responses.⁴ The question that may arise here is whether the 2003/2004 prices should be deflated by a price index. Importantly, the AIDS model allows for explicitly imposing the homogeneity condition through a simple constraint on the coefficients. This takes care of the issue of 'real' prices.⁵

6. Results

Table 3 provides the summary statistics for the explanatory variables included in the expenditure share equations. Our discussion will mainly focus on Marshallian-based own-price and expenditure elasticities and Hicksian-based cross-price elasticities, both drawn from the benchmark Heckman procedure. Note that Hicksian elasticities measure the substitution effect that is due to price changes only and exclude the income effect.

6.1. Marshallian own-price elasticities for all households

The Heckman estimation results for the Marshallian own-price and expenditure elasticities are reported in Table 4. As expected, almost all of the own-price elasticities are negative. A great majority of the estimates are statistically significant at 5 per cent or above.

³ The magnitude of the bias reported here is the weighted mean percentage deviation (in absolute values) from the 'corrected' estimates. Weights are the expenditure shares of the relevant categories. However, the reasoning concerning the bias here is based on single-equation estimation, not the system estimation.

⁴ We have tested for the price stability of each commodity in the system using a Chow-type test. The results show that the change was significant at 10 per cent level for three categories (preserved fruits, preserved vegetables, sugar and jam), significant at 5 per cent level for one category (pork) and significant at 1 per cent level for two categories (milk and bread). The remaining 10 categories saw no changes in the parameters between the two samples. This suggests that the parameters are, to a large extent, stable over time.

⁵ We would like to thank Keith McLaren for pointing this out to us.

Table 3 Summary statistics for ethnicity, household characteristics and states, 1998/1999 and 2003/2004

Demographic characteristics	1998/1999	2003/2004
Households with children aged between 0 and 15	0.591 (0.95)	0.551 (0.95)
Family size	2.620 (1.35)	2.524 (1.32)
Household head Australian-born	72.20%	72.82%
Household head foreign-born	27.80%	27.18%
New South Wales	29.54%	25.08%
Victoria	19.96%	22.01%
Queensland	15.88%	12.75%
South Australia	8.18%	12.42%
Western Australia	9.42%	10.48%
Tasmania	6.95%	7.98%
Northern Territory and ACT	9.94%	9.29%
Sample size	6859	6957

Note: Figures in parentheses refer to standard deviations.

Table 4 Marshallian own-price and expenditure elasticities for all Australian households (Heckman method)

Food category	Own-price elasticity	Expenditure elasticity
Milk	-0.233 (-1.47)	0.371*** (24.36)
Dairy products	-0.999*** (-3.23)	1.004*** (36.68)
Bread	-0.733*** (-7.43)	0.449*** (33.74)
Rice	-2.657*** (-4.28)	1.196*** (16.55)
Beef and veal	-1.353*** (-9.15)	1.636*** (57.87)
Mutton and lamb	-1.420*** (-8.38)	1.637*** (44.18)
Pork	-2.203*** (-5.03)	1.592*** (31.78)
Other meat	-0.846*** (-3.57)	1.259*** (30.49)
Poultry	-1.388*** (-4.26)	1.381*** (43.50)
Fresh fruit	-1.049*** (-9.16)	0.755*** (29.92)
Fresh vegetables	-0.526*** (-5.34)	0.888*** (42.94)
Preserved fruit	-0.439 (-0.89)	1.516*** (18.70)
Preserved vegetables	-1.383*** (-4.86)	1.230*** (21.46)
Sugar and jam	1.018** (2.03)	1.187*** (20.40)
Margarine	-1.696*** (-7.51)	0.938*** (18.82)

Note: ***, ** and * refer to statistical significance at 1%, 5% and 10% levels, respectively. Figures in parentheses refer to the z-statistics.

6.1.1. Milk, dairy products and margarine

While the own-price elasticity of milk is estimated to be -0.23 , the elasticity falls short of being statistically significant. The own-price elasticity for dairy products is estimated to be unit elastic, while margarine is estimated to have an elastic demand, with the own-price elasticity standing at -1.70 .

6.1.2. Bread and rice

Not surprisingly, bread's own-price elasticity is estimated to be low, standing at -0.73 . Rice, on the other hand, is estimated to have an elastic demand with an own-price elasticity of -2.66 . While rice is a staple item for some ethnicities,

its elasticity estimate seems to be dominated by the households with an Australian-born head for whom it does not occupy a large space in total food expenditure and hence the strong response to price changes (see below).

6.1.3. Beef and veal, mutton and lamb, pork, poultry, and other meat

The estimation results offer significant insights regarding own-price elasticities for different meat products. Own-price elasticities for beef and veal, mutton and lamb, and poultry are estimated to be almost the same, with estimates being roughly around -1.4 . On the other hand, pork is estimated to have much higher own-demand elasticity, with an estimate of -2.20 . Finally, the demand for the other meats category (which includes sausages, bacon, ham and canned meat) is about unit elastic, with an estimate of -0.85 .

Comparatively speaking, own-price elasticity estimates for meat products are intuitive in that 'white meat' (chicken) is positioned next to the main Australian staples of beef and lamb, with pork demand being much more responsive to price changes. The fact that Australian households consider pork substitutable might explain its high elasticity estimate.

6.1.4. Fruits and vegetables

We estimate the elasticities for fruit and vegetables for both fresh and preserved products. Once again, the estimates appear plausible and are consistent with anecdotal evidence about consumer behaviour in food stores. Fresh fruit is estimated to have unit-elastic demand with an elasticity estimate of -1.05 , while the demand for fresh vegetables is inelastic with an elasticity standing at -0.53 . Thus, consumers seem to be relatively less responsive to changes in fresh vegetable prices. Conversely, preserved fruit is estimated to have an insignificant own-price elasticity, while preserved vegetables have an elastic demand with an estimate of -1.38 .

6.1.5. Sugar and jam

The own-price elasticity for sugar and jam is estimated to be positive. A close analysis of the data suggested that this counter-intuitive result is largely driven by sugar and, importantly, by some outliers in sugar purchases – households are unlikely to purchase sugar on a weekly basis and they are likely to store this item. Modelling any dynamic influences on sugar consumption is beyond the scope of this study, given our data set; however, eliminating from the sample 87 households whose sugar and jam purchases constitute 10 per cent or more of their food budget in 2003/2004, the elasticity estimate becomes insignificant.

6.2. Marshallian own-price elasticities for households with Australian-born heads

So far, the results cover all households in the two surveys. However, ethnicity is a potentially important factor in food demand in Australia. Preferences for

Table 5 Marshallian own-price and expenditure elasticities for households with Australian-born heads (Heckman method)

Food category	Own-price elasticity	Expenditure elasticity
Milk	-0.093 (-0.55)	0.393*** (25.20)
Dairy products	-1.178*** (-3.64)	0.946*** (35.62)
Bread	-0.622*** (-6.05)	0.496*** (35.71)
Rice	-4.358*** (-6.23)	1.116*** (13.13)
Beef and veal	-1.344*** (-8.62)	1.551*** (54.56)
Mutton and lamb	-1.505*** (-8.87)	1.555*** (42.20)
Pork	-2.494*** (-5.02)	1.595*** (28.63)
Other meat	-0.805*** (-3.32)	1.207*** (27.80)
Poultry	-1.425*** (-4.05)	1.358*** (37.36)
Fresh fruit	-1.004*** (-8.08)	0.726*** (28.89)
Fresh vegetables	-0.627*** (-6.12)	0.849*** (41.10)
Preserved fruit	-0.049 (-0.10)	1.421*** (18.64)
Preserved vegetables	-1.023*** (-3.57)	1.167*** (20.86)
Sugar and jam	1.561*** (2.67)	1.189*** (16.35)
Margarine	-1.774*** (-7.68)	0.943*** (20.21)

See the notes to Table 4.

commodities such as milk, rice and meat can differ widely across ethnicities. While elasticities for different ethnicities are difficult to estimate due to sample size considerations, estimation for households with Australian-born heads is possible. Table 5 demonstrates that a great majority of these elasticities mimic the full sample case, although there are some important differences.

Focusing on the estimates that are different, the first notable difference is related to rice. Its own-price elasticity is -4.36 , which is strikingly higher than -2.66 obtained in the full sample case. This suggests that for households with Australian-born heads, rice demand is much more price responsive than for households with overseas-born heads. Rice is less of a staple food for households with Australian-born heads and has probably more substitutes for this group in the sample. A few other food categories also register some noteworthy variations, including dairy products, pork, sugar and jam (all with higher estimates for households with Australian-born heads), and preserved vegetables (with a lower estimate for households with Australian-born heads).

6.3. Marshallian expenditure elasticities for all households and households with Australian-born heads

Expenditure elasticities are key behavioural parameters in policy models. Tables 4 and 5 present the expenditure elasticity estimates for all households and households with Australian-born heads, respectively. There does not appear to be any significant difference between the two samples, and therefore, our discussion will focus on the full sample.

Our expenditure elasticity estimates accord with economic intuition. All the food items are estimated to have positive and statistically significant expenditure elasticities. The demand for milk, bread, fresh fruit, fresh vegetables and margarine are estimated to be expenditure inelastic, with the estimates ranging from 0.37 to 0.94. The demand for dairy products is in the neighbourhood of unit elasticity. On the other hand, all the meat items, rice, sugar and jam, and preserved fruit/vegetables are estimated to have expenditure-elastic demand, with estimates in the range of 1.19 and 1.64. It is worth-noting that milk and bread have the lowest expenditure elasticities, and beef and veal, mutton and lamb, and pork possess the highest elasticities among our estimates.

6.4. Semi-nonparametric estimation results for Marshallian elasticities

Appendix S4 in the working paper version of this article presents the estimates computed using the semi-nonparametric method of Gallant and Nychka (1987). We calculate these elasticities for the full sample. The concordance between most of the elasticities obtained through parametric and semi-nonparametric methods is noteworthy. However, the semi-nonparametric method reinforces the fact that the sugar and jam elasticity estimate is insignificant (even without removing the outliers), suggesting that non-normality in the residuals might have affected the previous result. Also, we find the own-elasticity of rice and mutton and lamb are much higher than before, suggesting that the normality assumption in addressing the zero observations may not be so tenable for these goods.

6.5. Hicksian cross-price elasticities

Table 6 presents Hicksian cross-price elasticities derived from the Marshallian cross-price elasticities for the full sample. The key feature of Hicksian elasticities is that they facilitate predictions about the substitutability of the food categories. Most results are robust to the semi-parametric treatment as displayed in Appendix S4 in the working paper version. Note that negative cross-price elasticities imply that the relevant items are complementary, while positive elasticities imply that they are substitutes.

We estimate the response of the demand for dairy products to a change in margarine prices to be positive and significant. The response of margarine demand to price changes in dairy products is insignificant. However, both responses are insignificant with the semi-nonparametric approach; hence, we find no robust evidence for substitutability between dairy products and margarine based on their prices.

Conversely, milk, dairy products and margarine are estimated to have statistically significant cross-price elasticities of varying signs with other food items, such as mutton and lamb, poultry or fresh vegetables. The data might be picking up some common bundling choices across households here,

Table 6 Hicksian cross-price elasticities for all Australian households (Heckman method)

Food category	Milk	Dairy products	Bread	Rice	Beef and veal	Mutton and lamb	Pork	Other meat	Poultry	Fresh fruit	Fresh vegetables	Preserved fruit	Preserved vegetables	Sugar and jam	Margarine
Milk		0.35*** (2.07)	0.36*** (3.84)	-0.80 (-1.30)	0.26* (1.76)	0.23 (1.07)	-0.27 (-0.64)	0.06 (-0.23)	0.83*** (3.80)	-1.04*** (-6.84)	-0.67*** (-5.91)	-1.23*** (-3.05)	0.07 (0.23)	-1.85*** (-5.73)	-1.25*** (-3.95)
Dairy products	0.25*** (2.73)		0.05 (0.80)	-0.22 (-0.26)	0.09 (0.82)	0.49*** (3.01)	1.04*** (2.15)	0.07 (0.26)	-0.68*** (-2.88)	0.09 (0.72)	0.03 (0.35)	0.15 (0.26)	-0.29 (-0.74)	0.75 (1.47)	0.70* (1.81)
Bread	0.367*** (3.78)	-0.04 (-0.29)		1.567*** (3.37)	0.12 (0.98)	-0.27 (-1.57)	-0.35 (-1.08)	0.56*** (3.06)	0.02 (0.14)	-0.80*** (-6.59)	-0.44*** (-4.93)	-0.01 (-0.03)	0.76*** (3.35)	-1.05*** (-4.45)	-0.31 (-1.36)
Rice	-0.03 (-0.75)	-0.08 (-0.67)	0.15*** (4.46)		0.21*** (4.02)	0.42*** (5.32)	0.24 (0.99)	0.34*** (2.61)	0.09 (0.85)	0.08 (1.34)	-0.01 (-0.22)	-0.11 (-0.35)	0.41*** (2.03)	0.47* (1.75)	0.43*** (2.16)
Beef and veal	0.18** (2.25)	-0.08 (-0.77)	0.11* (1.83)	0.17 (0.45)	0.40*** (3.70)	0.36*** (2.34)	0.59*** (2.25)	0.22 (1.46)	0.41*** (2.89)	0.30*** (2.85)	0.04 (0.50)	-0.12 (-0.48)	-0.25 (-1.36)	-0.14 (-0.74)	0.09 (0.49)
Mutton and lamb	0.11* (1.78)	0.14* (1.71)	-0.01 (-0.31)	0.79*** (2.63)	0.30*** (3.70)	0.47*** (2.25)	-0.05 (-0.44)	0.22* (1.95)	0.22* (1.95)	0.23*** (2.76)	0.04 (0.67)	0.24 (1.27)	-0.13 (-0.87)	-0.06 (-0.39)	0.20 (1.34)
Pork	0.02 (0.25)	0.23* (1.73)	0.02 (0.49)	0.14 (0.27)	0.35*** (4.63)	0.40*** (3.48)	0.07 (0.41)	0.32*** (2.08)	0.32*** (2.08)	0.03 (0.31)	0.05 (0.71)	0.57* (1.69)	-0.25 (-1.02)	0.09 (0.34)	0.49*** (2.06)
Other meat	0.01 (0.17)	-0.03 (-0.27)	0.19*** (3.95)	1.02*** (2.11)	0.26*** (3.39)	0.08 (0.68)	0.15 (0.50)	0.07 (0.34)	-0.07 (-0.44)	0.01 (0.12)	-0.05 (-0.74)	0.36 (1.13)	0.27 (1.17)	0.24 (0.93)	-0.02 (-0.7)
Poultry	0.41*** (4.03)	-0.71*** (-3.54)	0.05 (0.65)	-0.26 (-0.35)	0.40*** (3.29)	0.28 (1.51)	0.60 (1.29)	-0.29 (-1.13)		0.31*** (2.24)	0.24*** (2.26)	0.32 (0.67)	-0.44 (-1.24)	-0.07 (-0.17)	0.83*** (2.35)
Fresh fruit	-0.40*** (-6.59)	0.04 (0.46)	-0.28*** (-5.97)	0.84*** (2.49)	0.38*** (4.92)	0.55*** (4.76)	0.33 (1.48)	0.15 (1.19)	0.41*** (3.41)		-0.14*** (-2.27)	-0.16 (-0.75)	0.52*** (3.21)	-0.06 (-0.31)	-0.52*** (-3.16)
Fresh vegetables	-0.36*** (-5.03)	0.05 (0.45)	-0.19*** (-3.55)	0.39 (0.97)	0.21 (0.73)	0.31*** (2.36)	0.44 (1.62)	0.05 (0.34)	0.49*** (3.38)	-0.16* (-1.66)		0.98*** (3.79)	0.24 (1.24)	-0.21 (-1.01)	-0.39*** (-1.99)
Preserved fruit	-0.08* (-1.70)	0.00 (0.03)	0.08** (2.25)	-0.24 (-0.49)	0.19*** (3.65)	0.32*** (4.05)	0.59*** (2.30)	0.22 (1.59)	0.24*** (2.00)	-0.11* (-1.73)	0.14*** (2.99)	-0.02 (-0.11)	-0.02 (-0.11)	0.09 (0.27)	-0.03 (-0.13)
Preserved vegetables	0.04 (0.74)	-0.14 (-1.22)	0.16*** (4.45)	0.78* (1.80)	0.10* (1.80)	0.11 (1.33)	-0.14 (-0.55)	0.19 (1.45)	-0.02 (-0.18)	0.13* (1.94)	-0.00 (-0.04)	-0.06 (-0.21)		0.30 (1.16)	0.55*** (2.79)
Sugar and jam	-0.20*** (-5.00)	0.12 (0.99)	0.48*** (2.82)	0.81* (1.81)	0.15*** (3.50)	0.19*** (2.84)	0.25 (1.52)	0.18 (1.32)	0.12 (1.13)	-0.08 (-1.43)	-0.10*** (-2.32)	0.15 (0.43)	0.29 (1.44)		0.19 (0.95)
Margarine	-0.17*** (-4.16)	0.09 (1.01)	-0.03 (-1.09)	0.71*** (2.05)	0.17*** (3.74)	0.26*** (3.91)	0.54*** (2.71)	0.03 (0.29)	0.33*** (3.44)	-0.26*** (-4.87)	-0.16*** (-3.99)	-0.02 (-0.08)	0.47*** (2.92)	0.16 (0.76)	

Note: ***, ** and * refer to statistical significance at 1%, 5% and 10% levels, respectively. Row headings refer to the price of the respective product, and column headings refer to the quantity demanded of the respective product. Figures in parentheses refer to the *t*-statistics.

perhaps in association with two-stage budgeting decisions made during the purchase, or the amount or the timing of purchase of the food items.

Demand for bread seems to increase significantly upon an increase in the price of rice, as shown by a significant cross-price elasticity of 1.57. However, using both methods, the demand for rice does not seem to be responsive to a change in the price of bread.

We also estimate cross-price elasticities among five meat categories. The estimates are generally positive and generally significant for all groups except other meat. This suggests that, in Australia, the demand for different meat categories responds to changes in prices in other categories, and hence, they are substitutes.

Fresh fruit and fresh vegetables have small, negative and significant cross-price elasticities. This is probably reflective of most households' behaviour of purchasing these goods jointly from stores. On the other hand, the demand for preserved fruit and preserved vegetables seems to respond to price changes in fresh fruit and fresh vegetables, respectively, but not vice versa.

7. Conclusions

This paper computes the price responsiveness of demand for 15 food categories in Australia using HESs for the periods 1998/1999 and 2003/2004. Adopting an Almost Ideal Demand System approach and addressing the frequent zero observations in the first stage through parametric and semi-nonparametric methods, we estimate the Marshallian and Hicksian own-price, cross-price and expenditure elasticities for all categories. To our knowledge, such levels of disaggregation for food elasticities are unique to our study. The food categories analysed in this study cover standard food items in household shopping lists in Australia, allowing us to account for households' budgeting decisions in accord with substitution and complementarity issues. We also estimate the elasticities for households with Australian-born heads. Comparing these estimates with the full sample case, we derive some inferences about how food demand varies across households headed by individuals with Australian and foreign origin. The underlying food demand elasticities obtained in this study generally accord with economic intuition.

Our estimates convey relevant information central to the formulation of various public policies and to strategic industry planning in the agricultural sector in Australia. Notably, the marked differences in the estimated own-price elasticities of demand suggest that an inclusion of all food items in the Goods and Services Tax (GST) regime could have markedly different impacts on different food items. Our estimates indicate that any increase in food prices that resulted from a tax on all food would tend to have the largest impacts on the demand for rice and meat and would probably have little impact on the demand for milk and preserved fruit. For fresh fruit, a 10 per cent increase in consumer prices would depress final consumer demand by

around 10 per cent. We note that there is potential to further update the analysis with more recent HES data for 2009/2010.

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Supporting Information

Additional Supporting Information may be found in the working paper version of this article:

Appendix S1. Data.

Appendix S2. Expenditure shares.

Appendix S3. Econometric methodology.

Appendix S4. Results with semi-nonparametric Method.