



Australian Government
Rural Industries Research and
Development Corporation

How Price Affects the Demand for Food in Australia

— *An analysis of domestic demand elasticities for rural marketing and policy* —

RIRDC Publication No. 11/062



RIRDC Innovation for rural Australia



Australian Government

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Development Corporation**

How Price Affects the Demand for Food in Australia

**Australian Domestic Demand Elasticities for Rural
Marketing and Policy**

by Mehmet Ulubasoglu, Debdulal Mallick, Mokhtarul Wadud, Phillip Hone and Henry Haszler

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Foreword

An understanding of the relationships between price and quantity demanded is important in many aspects of economic analysis.

The degree to which demand or supply reacts to a change in price is known as its 'elasticity'. Normally, sales increase with a drop in prices and decrease with a rise in prices. Elasticity varies among products because some products may be more essential to the consumer. If a small change in price leads to a sharp change in the quantity demanded or supplied a good or service is considered to be highly elastic. Usually these kinds of products are readily available in the market and are not necessarily deemed as 'essential' items.

A good or service is deemed 'inelastic' when changes in its price result in only modest changes in the quantity demanded or supplied. These goods tend to be things that are more of a necessity to consumers.

In the case of the Australian food sector there has been a distinct lack of up-to-date estimates of these relationships to guide policy makers and analysts. This project fills that gap by providing a set of demand elasticity estimates drawn from an analysis of the most recent Household Expenditure Surveys conducted by the Australian Bureau of Statistics. These elasticity estimates, based on an integrated systems approach, offer modellers and policy analysts a point of reference for their market analyses. As such, they provide the potential to improve the quality of information going into the Australian food policy arena.

The results from this project show that the longer term response of Australian consumers to price changes is generally higher than the existing literature would suggest. While the demand for bread and fresh vegetables was shown to have low responsiveness to prices changes, the demand for beef and veal, mutton and lamb, poultry, pork, rice, margarine, and preserved vegetables were all shown to be characterised by comparatively responsive demand in the long run. The demand for milk, preserved fruits, and sugar and jam was found to be unresponsive to price variations observed in the sample.

This work was undertaken by staff from the School of Accounting, Economics and Finance at Deakin University and was financially supported by a grant from the RIRDC. This project was funded from RIRDC Core Funds which are provided by the Australian Government.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our Global Challenges R&D program, which aims to address emerging and current issues through R&D, including global competitiveness, market access and trade barriers, productivity and climate change, which will lead to a globally competitive Australian agricultural sector.

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Craig Burns
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Abbreviations

AIDS	Almost Ideal Demand System
HES	Household Expenditure Survey
ABS	Australian Bureau of Statistics
CURF	Confidentialised Unit Record Files
SIH	Survey of Income and Housing
CPI	Consumer Price Index
OLS	Ordinary Least Squares
CGE	Computable General Equilibrium
R&D	Research and Development

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Executive Summary

What the report is about

This report provides estimates of the responsiveness of the quantity of food demanded to changes in food prices in Australia. The parameters reported measure longer run responsiveness at the household level and represent the first integrated set of food demand elasticities based on a highly disaggregated food demand system published in Australia.

Who is the report targeted at?

The elasticity estimates presented in this report are of particular relevance to the analysis of food demand issues in Australia. As such the findings from this report will be of strategic significance to all those involved in the management and analysis of the Australian food and agricultural sectors including industry analysts, R&D bodies and policy analysts.

Where are the relevant industries located in Australia?

As this report is focused on a wide and disaggregated definition of household food demand, it has implications for all the major food and agricultural industries in Australia. However, because the report focuses on Australian household demand it will be of most importance to those industries that sell a significant proportion of their total output into the domestic Australian market.

Background

Both strategic industry planning in the agri-food sector and many aspects of economic policy formulation in general require an understanding of food demand. Despite this central place in economic policy, there is a dearth of recent estimates of the basic parameters in Australian food demand. This is a major policy problem because the use of dated parameter estimates in policy analysis could lead to misleading results. Not only is it possible that these parameters have changed over time, but the estimation techniques used in demand estimation have evolved as well, providing the potential for more reliable empirical results

Aims/objectives

The aim of this project is produce an integrated set of demand elasticities from the most recent data set available for Australia using contemporary estimation techniques. In so doing we will provide an accessible basic reference source for market and policy analysts.

Methods used

Data from the two latest Household Expenditure Surveys conducted by the ABS have been used to estimate an integrated food demand system for Australia. A system of equations has been estimated econometrically using an Almost Ideal Demand System (AIDS), as a result of which elasticities for 15 food categories have been derived.

Results/key findings

The underlying food demand elasticities obtained in this study all accord with economic intuition and theory. Specifically, we find that, in terms of own-price elasticities, bread and fresh vegetables face an inelastic demand, while beef & veal, mutton & lamb, poultry, pork, rice, margarine, and preserved vegetables possess elastic demand. Dairy products, fresh fruits, and Other Meat categories are estimated to have unit elastic demand. On the other hand, the demand for milk, preserved fruits, and sugar & jam does not respond to price variations observed in the sample as their elasticity estimates

are statistically insignificant. The insignificance of the own-price elasticity of milk is noteworthy in this context. Cross-price elasticities also offer several intuitive results. Our estimates indicate a one-way responsiveness from rice to bread, meaning that when the rice prices rise, consumers demand more bread. We also find that in Australia demand for different meat types is taste-driven, rather than price-driven, as seen through generally insignificant cross-price elasticities across the meat categories. Also, fresh vegetables and fresh fruits seem to be complements indicating that they are generally purchased jointly from the food stores. The cross-price elasticities between fresh fruits/vegetables and preserved fruits/vegetables suggest that they may also be purchased together for different reasons. Finally, expenditure elasticity estimates suggest that milk, bread, fresh vegetables and fresh fruits are expenditure-inelastic, suggesting that they are necessary items in the shopping lists at the lowest levels of expenditure, while all meat categories, rice, sugar & jam, and preserved fruits are expenditure-elastic.

Households with Australian-born heads exhibit important differences in food demand. Notably, the own-price elasticity of milk is still insignificant among this group of consumers. These households also have much higher own-price elasticity for rice, indicating that they are much responsive to price changes compared to ethnicities like Indians and other Asian communities. Finally, the demand for pork is more elastic among the consumers with Australian-born heads compared to households whose heads were born overseas. This is probably because pork is more of a staple item for some Asian households.

International comparisons also reveal important features in food demand. Our own-price elasticity estimates for rice, bread, milk, and especially fresh vegetables are reasonably close to the USA, Canadian, and Japanese elasticities. However, Australian meat demand seems to be uniformly more elastic than that in the other countries.

It must be noted that, although there are important similarities, our own-price elasticity estimates are higher than previous Australian estimates. This is most likely due to our use of cross-sectional household data, and thereby, capturing of long-run elasticities. Previous studies for Australia have generally used time-series data, in which case they derived short-run elasticities. Arguably, long-run elasticities are more meaningful than short-run elasticities for many policy studies. So with these elasticities we provide an accessible basic reference source for academics, policymakers, modellers, and market and policy analysts.

Implications for relevant stakeholders for:

The results from this report provide policy makers and analysts with information central to many complex decisions they face. For example, cost benefit analysis by R&D organisations and researchers can now be undertaken with more confidence in the basic parameters of the analysis and CGE modellers have estimated parameters to compare with the historical estimates that have been driving their models.

Recommendations

Industry analysts and modellers are encouraged to note the parameter estimates presented in this report and consider their relevance for their models and industry studies.

Research bodies should consider the potential value of commissioning a further food demand study when the next HES becomes available. This is required to validate the estimates reported here and to monitor changes in the Australian food sector.

1. Introduction

Good decision-making requires an understanding of the underlying relationships of the system being considered. In the case of decisions that impact on the food sector, an important aspect of the underlying relationships is reflected in consumer responses to changes in food prices and household expenditure. These responses, measured in terms of price and expenditure elasticities, play a significant part in determining the nature and the extent of the impact of system changes on farmers, processors, and consumers overall.

A good understanding of food elasticities is important in many strategic decisions undertaken at the industry level. Important examples include setting R&D priorities and evaluating research proposals, forecasting future market conditions, evaluating promotional campaigns and assessing proposals for industry or commodity based taxes and levies. For example, Edwards and Freebairn (1981) highlight the importance of having reliable estimates of the magnitudes of the market elasticities in evaluating the returns from agricultural research. Similarly, Hill et al. (2001) rely on an equilibrium displacement model based on elasticity parameters to evaluate dairy product promotion.

In a general policy context, an understanding of food demand is critical in evaluating proposals to tax food items. Evaluating household response to policies that impact on the financial well-being of households is also important, because food expenditure is a crucial part of total household expenditure.

The current debate on policy responses to the increasing rate of non-communicable diseases linked to obesity is a good example of a policy evaluation process that rests on a sound understanding of food demand elasticities (see, for example, Chouinard et al 2007, Staley 2008, and Moodie et al. 2006). If policymakers wish to change consumers' food purchasing behaviour they need to understand the factors that are driving current purchasing patterns and the options that are available to influence these patterns in the future. A tax on fatty foods (or Fat Tax) 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?

A wide range of policy proposals in Australia are evaluated through the application of policy models (Powell and Snape 1993). These models, typically, have a household sector where food demand is an important component. Food demand elasticities, whether they are own-price or expenditure, are either the basic parameters in these models, or are used to derive other parameters (see, for example, Dixon and Rimmer 2002). In either case, parameter values for elasticities are generally assumed. However, asking economists to “do” policy research without knowing the values of the relevant elasticities is analogous to asking a physicist to calculate the expansion due to heating of a substance without telling them whether the substance is steel, concrete, or paper. Under such conditions, neither the economist nor the physicist can possibly get the answer right.

Unfortunately, little is known about the current value of the food demand elasticities in Australia. There have been few recent studies of Australian food demand, and those that have been undertaken are at a degree of high aggregation or a limited coverage. For example, Selvanathan (1991) reports demand elasticities for food as a single group, and Hyde and Perloff (1998) analyse meat demand abstracting from all other food categories. The dearth of information on disaggregated food elasticities is surprising given the importance of the food

sector to the Australian economy and the strong interest and influence the economics profession has had in this sector.

Leaving the aggregation issues aside, the use of dated estimates of demand relationships is potentially misleading because the nature of these relationships could well have evolved over time to an economically significant extent. In addition, the Australian economy and society is constantly in transition. The population, ethnic mix, age structure, and income levels have changed markedly over the last two decades. Coupled with this, Australians have adopted new tastes in food, driven by information on health concerns and changes in the range of foods available. There have also been adjustments in the relative prices of different food groups. All these factors are consistent with the hypothesis that food demand elasticities have changed over time.¹

¹ Studies carried out in Canada, Japan, Switzerland, South Africa and the UK all found evidence that food demand elasticities had changed in an economically important way in recent years (see Pomboza and Mbaga 2007; Chern et al. 2003; Awudu 2002; Dunne and Edkins 2005; Tiffin and Tiffin 1999).

2. Objectives

The aim of the project is to estimate a full systems-based set of Australian domestic demand elasticities for foods. The research updates and refines existing information and – very importantly – provides a significantly increased range of disaggregated individual commodity or product level elasticities.

Specifically we provide estimates of the following parameters for 15 different food categories:

- Own price elasticity of demand
- Cross price elasticities of demand
- Expenditure elasticities.

3. Methodology

This paper presents a comprehensive and integrated set of food demand elasticities for 15 food categories in Australia using the most recent data available. We deviate dramatically from the extant literature. First, own-price, cross-price and expenditure elasticities for 15 food categories are provided and their reliability is assessed using several checks. These parameter values are estimated in an integrated demand system. The model we have used is based on the Almost Ideal Demand System popularised by Deaton and Muellbauer (1980). This model has been applied in a number of similar studies overseas and has been found to be flexible, conceptually sound and capable of being applied to large models like the one here. To our knowledge, such levels of disaggregation for food elasticities are unique to this Australian case. The food categories analyzed in this study exhaust almost all of the possible food items in household shopping lists, allowing us to take into consideration the households' budgeting decisions in accord with substitution and complementarity issues. This approach would prove superior over, among other things, picking elasticities from different studies where the estimates would not capture such decisions. Second, we draw data from the two most recent household surveys of 1998/99 and 2003/2004, and capture the contemporary consumer behaviour in food demand in Australia. Third, we compute the elasticities for only households whose heads were born in Australia. Comparing the food demand behaviour of these households with the full sample case, we attempt to derive some inferences about the demand pattern associated with households whose heads were born overseas. Last but not least, we compare our elasticities with the Canadian, US, and Japanese elasticities that are derived from comparable studies

In addition to a detailed break down of household expenditure the HES also provides information on household characteristics such as income, ethnic background and age. These socio-economic variables are potentially important in accounting for differences in food consumption patterns between households and are explicitly incorporated in our food demand model.

4. Previous Food Demand Estimates for Australia

Several studies have provided food demand elasticity estimates for Australia. However, a great majority of those studies have focused on aggregate food categories, such as “food” or “meat”, or have specialized in only a few disaggregated items within one category, such as beef, lamb, chicken, and pork within meat. To date, comprehensive elasticity estimates for many of the food items that are usually seen in households’ shopping lists in Australia have not been made available. Further, a great majority of the studies have used data from several decades ago, and almost none of the studies have employed data from the 1990s and the 2000s. Finally, almost all of the studies have focused on own-price elasticities. Expenditure elasticities, and especially cross-price elasticities for various food categories, have not been widely reported.

Previous studies have drawn data from sources like the Australian Bureau of Statistics (ABS), the Australian Bureau of Agricultural and Resource Economics (ABARE), and the Australian Meat and Livestock Corporation. Table 1 in Appendix A provides the list of studies that have estimated Australian food demand elasticities since the 1970s. Tulpule and Powell (1978) estimate the expenditure elasticities using the TELES/Frisch approach, with estimates ranging between 0.1 and 0.5. Selvanathan (1991) estimates the own-price elasticity of “food” for different states, and obtained estimates that lie between 0 and -0.53. Studies by Alston and Chalfant (1987), Martin and Porter (1985), and Piggot et al. (1996) use a single equation OLS approach and estimate the own-price elasticities for beef, chicken, pork, and lamb. While Alston and Chalfant (1987) and Piggot et al. (1996) obtain roughly similar own-price elasticities for each category (in the range of -0.42 and -1.26), Martin and Porter’s (1985) estimates are on the higher side, ranging between -0.85 and -1.88. Bhati’s (1987) estimates for chicken, using the 2SLS approach, are similar to Alston and Chalfant’s. These studies cover the period from the 1960s through to the 1980s.

Cashin (1991) and Hyde and Perloff (1998) also estimate the own-price elasticities for disaggregated meat items using data that span the 1970s and 1980s, but adopting the Almost Ideal Demand Systems (AIDS) methodology. Hyde and Perloff’s estimates are in the range of -1.04 and -1.71, while Cashin’s estimates are relatively lower and vary between -0.83 and -1.33.

Using a generalised Addilog demand system and the 1984 Household Survey, Bewley (1987) estimates the demand elasticity for milk, and finds highly elastic estimates, -14.77 for delivered milk and -3.62 for non-delivered milk. Horticulture Australia Limited (2008), using weekly retail sales data from 2001 to 2007, estimates a demand system for horticultural products and obtains the own-price, cross-price and expenditure elasticities for nuts, fresh fruit, and vegetables, including some varieties within each category. They estimate the own-price elasticity for fresh fruit to be -0.66 and for vegetables -0.58. The expenditure elasticities for these products are 1.12 and 0.84, respectively.²

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) provide own-price, income, and expenditure elasticities for Australia along with 113 countries for eight food items including beverages & tobacco, bread & cereals, dairy, fats & oils, fish, fruits & vegetables, meat, and other foods. Their own-price and expenditure elasticity estimates are,

² Note that these commodities represent less than 20% of household food purchases in Australia.

generally, on the lower side of the reported estimates, ranging between -0.12 and -0.58, and 0.14 and 0.39, respectively. While in terms of product coverage and disaggregation this study comes close to ours, the consequences and 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 problems related to exchange rates or PPP estimation may make the elasticity estimates rely on other estimated variables, where any measurement error would traverse across the system and contaminate the results.

5. Data on Food Demand

For the estimation of food demand elasticities, we use data on household expenditure and food prices. The Household Expenditure Surveys (HES) conducted by the ABS provide most of the necessary data. We use the latest two surveys, 1998/99 and 2003/04, primarily because of the compatibility between the surveys and the range of data they offer. Although prior surveys also include data on expenditure and other household characteristics, there are serious concordance issues with the two recent surveys, requiring strong assumptions to construct a larger dataset.

The Household Expenditure Surveys (HES)

The ABS conducted HESs in 1984, 1988/89, 1993/94, 1998/99 and 2003/04. The detailed data from these surveys are provided in the form of HES Confidentialised Unit Record Files (CURF). The 1998/99 HES CURF contains detailed information on expenditure, income and demographic characteristics for a sample of 6,892 households in Australia, excluding special dwellings such as hospitals, institutions, nursing homes, hotels and hostels, and dwellings in remote and sparsely-settled parts of the country. Information was collected through personal interviews equally spread over the period July 1998 to June 1999 from all persons aged 15 years and over in the selected households.

The HES conducted in 2003/04 was also integrated with a Survey of Income and Housing (SIH). Prior to 2003/04, the HES and SIH were conducted independently. The SIH included 11,361 households, and collected information on household characteristics, assets and liabilities and detailed income by source. In the HES, 6,957 households were included from the SIH sample and were asked to supply detailed information on household expenditure, loans and financial stress. The surveys were conducted throughout Australia from July 2003 to June 2004 on a sample of dwellings not recently included in an ABS household survey. The sample excluded non-private dwellings such as hospitals, nursing homes, hotels, hostels, and dwellings defined as very remote or indigenous communities.

Information on household characteristics and the detailed weekly expenditure for various household items are recorded in the household and expenditure level data files. In both 1998/99 and 2003/04, the data include information on state or territory and area of residence, type of dwelling, tenure type, landlord type, household type and composition, household reference person, household income, costs, demography, and expenditures. The 1998/99 and 2003/04 HES samples were independent of each other. Respondents from the earlier sample were not part of the 2003/04 sample.

Price data

Despite a wide range of information collected by the ABS on households' expenditure, income, and demographic characteristics, data on prices that households pay are not available from the HES databases. Price data are integral components for estimation on demand elasticities, and, hence, these had to be collected from other source(s). The ABS collects price data for about 100,000 items for compiling the CPI but they are not released, even for generic items. Hence, although prices and price indexes are available for aggregate sectors or subsectors, data on prices at the disaggregated level for various household items are limited. The most detailed data on prices are available for capital cities from the ABS publication entitled Average Retail Prices of Selected Items, Eight Capital Cities (ABS Catalogue No. 6403). These average prices are obtained as geometric means of prices for specified grades,

qualities, brands etc. charged by a number of retailers in each city. These prices are collected for about 55 categories of goods used by Australian households, including food and beverages.

The process of obtaining the price information changed over the two surveys for some food items. In 1998/99, prices for fresh fruit and vegetables were collected weekly, while those for milk, fresh meat, bread, fish, petrol and alcohol were collected monthly. Prices for all other items were collected during the mid-month of each quarter. In 2003/04, prices for milk, butter, bread, fresh meat, fresh fruit and vegetables, margarine, petrol and alcohol were obtained each month at regular intervals and were averaged to obtain quarterly prices. Prices for all other items were collected during the mid-month of each quarter. All these prices were averaged to obtain quarterly prices.

Database for Estimation

In the HES databases of 1998/99 and 2003/04, expenditure on more than 600 items is listed including expenditures on housing, fuel, food, clothing, furnishings, health, transport, personal care and recreation. Information on households' expenditure is reported for about 127 food items. Of these, we identified about 50 food expenditure items with the corresponding price data available. Then, we aggregated these items into 16 categories for a feasible elasticity estimation. These categories are: milk, dairy products (butter & cheese), bread, rice, beef & veal, mutton & lamb, pork, other meat, poultry, fresh fruit, fresh vegetables, preserved fruit, preserved vegetables, sugar & jam, margarine, and other foods. The unit price for each food item was defined as per the publication on average retail prices (ABS Catalogue No. 6403). Several additional household level demographic variables that are likely to affect households' spending behavior were also included in our database. These include the number of family members aged between 0 to 15 years, the age of the head of the household, family size, and ethnic background. To control for the effects of the ethnic background of the household head, we use three categories: whether the household heads were born in Australia, in other English speaking countries, or in other countries. Total food expenditure of each household, to be used at the first stage of our model estimation (see below), was obtained through aggregating the expenditure on all the 16 categories. Note that the 16th category is "Other Foods", which is not analysed.

Data Concordance

Developing an appropriate set of price data to match the expenditure categories of the households is generally difficult, mainly due to lack of exact concordance among the expenditure categories and the items classified in the price data catalogues. Fortunately, the same 10-digit commodity codes were used in both the 1998/99 and 2003/04 HES expenditure databases, which precludes any need for concordance of commodity categories between these databases. We match the expenditure items with the classifications used in the price data using the description of each commodity. The prices were matched with expenditures according to the time period (i.e., quarter), the state and the territory of the surveyed households. As per information available on location in the HES CURFs, households residing in ACT and NT were assigned the average prices of their capital cities.

Data Limitations

Acquiring information on prices can be a problem because they are mostly available as averages over multiple products, depending on the level of aggregation of commodities and locations within a city or state. Thus, they may not accurately portray the actual prices paid

by the households for a given food item. Also, the ABS considers average retail prices in major Australian cities as representative for measuring price changes over time (ABS Catalogue no. 6403) and regards such prices as approximate indicators of the price levels. Therefore, the prices may not precisely reflect the price differences within a region, state, or commodity group. Moreover, at the data compilation stage, prices for generic categories of food were obtained by taking simple averages of the disaggregated items, which may potentially have led to imprecision in the prices. Further, in the HES CURFs, the ABS reduced the level of detail for many data items for the sake of maintaining confidentiality. Finally, in the basic CURF, which is used in this study, households residing in ACT and NT have been assigned a combined location, ACT/NT.

6. Trends in Food Demand and Food Prices in Australia

This section discusses trends in food demand and food prices in Australia for the 15 product categories analyzed in this study. The objective is to provide a background for the elasticities to be estimated in the next section and an understanding for a meaningful interpretation of the findings.

Trends in Food Demand

Tables 2a and 2b present the mean expenditure shares of 15 food categories in total food expenditure in the 1998/99 and 2003/04 surveys, respectively, by demographic groups, namely, ethnicity, state, households' children status, and the age of the head of the household. Also presented are the standard deviations of the means, and the number of households that purchased the product. We first focus on the 1998/99 survey.

Milk constitutes a significant food item in households' shopping lists in Australia. Unsurprisingly, its mean share in food budgets is around 13%, not varying much across the demographic groups. One important feature, however, is that households with younger heads tend to buy more milk (15.4%) than those with older heads (11.2%). Dairy products constitute approximately 9% of the food budgets, while margarine occupies around a 4% share, both with little variation across the demographic groups.

Bread is a daily food item for Australian households. Accordingly, it has a mean expenditure share of 12% in total food expenditure, almost unvarying across the demographic groups. Rice exhibits some important variability, however households whose heads were born in Australia spend 3% of their food budgets on rice, whereas households with overseas-born heads spend 6%. Given that rice is a staple food for ethnicities like Indians and other Asian communities, these differences seem to be unsurprising. On the other hand, Tasmania and NSW have the lowest and the highest expenditure shares for rice, 2.9% and 6.1%, respectively. The difference probably arises as a result of differences in the immigration patterns in those states. The other states spend roughly around 4% on rice, which is the Australian average. Further, young-headed households spend 5.1% and households with heads who are 55 and above spend 3.2% on rice.

Meat categories exhibit important characteristics. The average beef & veal expenditure share in Australian food budgets appears to be 13%. While variability across demographic groups for this category is relatively limited, it is worth noting that households with no children under 15 tend to buy more beef & veal than households with children under 15 (14.4% vs 11.3%). The mean expenditure share for mutton & lamb, poultry, and Other Meat seems to revolve around 10%, 11%, and 6%, respectively, with relatively little variability across the demographics. However, pork does exhibit some variation across different demographic cohorts. Mean Australian expenditure share for pork is 9%, with households whose heads were born in Australia consuming 8% and households with overseas-born heads spending 11% of their budgets on pork. Further, Tasmania and NSW again feature the lowest and the highest expenditure shares, 6.8% and 11.1%, respectively. This can again be explained with differences in immigrant populations in the respective states. For some Asians, pork is a traditional staple meat so it is likely to represent a larger share of their total food budget than is the case for the sample overall.

All other food categories in this study exhibit limited variability across the demographics, with mean expenditure shares reported as follows: Fresh fruits 7%, fresh vegetables 9%, preserved fruits 4%, preserved vegetables 5%, and sugar & jam 4%.

Looking at the 2003/04 survey, there does not seem to be any dramatic changes in food demand pattern over the five year period. Nevertheless, some differences are noteworthy. Households seem to have increased their expenditure shares in milk, bread, beef & veal, mutton & lamb, and poultry by about 1%-2%. The only notable decrease in expenditure shares is in fresh fruits by 1%. These changes may very well be about sampling in the surveys. All other food categories appear to have very similar expenditure shares to those in 1998/99. Features related to variability across demographic groups are largely preserved, although some changes are also observed. For instance, the milk consumption gaps between households with Australian-born heads vs households with overseas-born heads, and households with young vs elderly heads seem to have widened. On the other hand, the rice and the pork consumption gaps between NSW and Tasmania seem to have decreased, which appears to be due to reduced consumption in NSW. In fact, states in general look to have experienced some notable variations in the consumptions of food categories like bread and mutton & lamb, with the moves being generally upwards.

Trends in Food Prices

Tables 3a and 3b present the average prices for 15 food categories, the standard deviations of the mean prices, and total weekly household food expenditure for 1998/99 and 2003/04, respectively, for all of Australia as well as for different states. A great deal of variability is observed across the states in the prices of nearly every food category. For a particular food category, one standard deviation difference from the Australian mean generally leaves the average price of at least one state out of the range.

There has been a major increase in food prices in Australia over the five year period. Considering all 15 categories, average food prices rose by 26% between the two survey periods.³ This is above the 17% increase in the CPI over the same period in Australia.⁴ The largest increase in food prices is observed in mutton & lamb (64%) and the lowest increase is in sugar & jam (3.6%). Meat categories generally exhibited large rises (except poultry); average prices of the five meat categories increased by 38% over the five years. While milk, bread, fresh vegetables, preserved vegetables and margarine prices registered rises of more than 20%, dairy products, fresh fruits, and sugar & jam had price increases of 10% or less. All these point out to changes in the absolute and relative food prices over time. On the other hand, total weekly household food expenditure increased by 24% (from \$41.39 to \$51.22) over the five year period of study.⁵

State-wise decomposition of the prices reveals important variations as well. Milk prices rose by around 30% in NSW, Queensland, and Northern Territory & ACT, while increasing by around 15% in Victoria and Tasmania. Compared to the Australian average, the prices of beef & veal and mutton & lamb have increased relatively uniformly across the states, while poultry registered very low increases in NSW and Tasmania, and Other Meat in Western

³ Note that average prices in Australia for this study are the weighted averages of the states' prices where the weights are the population shares of each state in the sample (which reasonably approximates the population shares of the states in Australia overall).

⁴ Increases in food prices contribute significantly to the rises in CPI, so these figures indicate a relatively higher increase in food prices compared to (at least some of) the other items in the CPI basket, as well as a real rise in food prices.

⁵ The maximum total household weekly expenditure in the sample increased by 19% (from \$199 to \$235), while the minimum stayed at zero in both surveys.

Australia and Tasmania. Pork prices exhibited a relatively higher increase in Western Australia. Prices increased relatively highly compared to the Australian average for the following food categories and states: bread in South Australia, fresh vegetables in Queensland, and margarine in Victoria. On the other hand, the following food categories and states experienced relatively low increases in prices compared to the Australian average: dairy products in Tasmania, fresh fruits in South Australia and Northern Territory & ACT, preserved vegetables in Tasmania, and sugar & jam in NSW and Western Australia. Finally, total weekly food expenditures increased relatively uniformly across the states.

7. Estimation of Food Demand Elasticities

There are many possible ways of estimating demand relationships - from using the simplest single commodity models to whole demand systems. In this paper a systems approach is adopted because it best represents the fact that consumers make food and other purchase decisions while recognising the need to simultaneously meet a whole range of expenses.

Specifically, we adopt the linearized version of Deaton and Muelbauer's (1980) Almost Ideal Demand System (LA/AIDS) methodology, which has become over the years, the workhorse of household demand systems estimation of various expenditure items. The AIDS model is based on a price index that is not linear in parameters; so following the standard practice a linear approximation has been applied to the AIDS model. 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 groups. Our expenditure share equations are of the following type:

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

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 characteristics (including the country origin of birth of the household head, age of the household head, household size, and the number of children under 15), and S stands for states.

Next, we derive the own-price, cross-price and expenditure elasticities of each food category, and then compute the standard errors of the estimates through the delta method. A description of the complete AIDS model including the theoretical constraints, and the procedural details of other derivations used in this study, are provided in Appendix B.

It is worth mentioning some problems faced during the estimation phase, and the solutions that were adopted. Zero expenditures for some food categories were the foremost issue. Frequent zero observations for many expenditure items have attracted significant theoretical and empirical interest in the literature on demand estimations. The problem is one of non-random 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 two-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), who estimate food demand elasticities for the US using the AIDS approach and the 1977/78 household food consumption survey. Zero purchases could also be preference and demographics driven, thus, variables like ethnicity, household characteristics (the number of children), proportion of meals eaten outside the home, etc. can explain them.

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, and the independent variables are all of the explanatory variables of the expenditure share equation, as well as a distinct 'identifier' variable (described below). Mills

ratios calculated from this stage for each of the food categories are then included in the respective expenditure share equations in the second stage, which are all estimated jointly using Seemingly Unrelated Regressions methodology.

A distinct ‘identifier’ variable for the first stage, to be excluded from the second stage, is needed to distinguish the zero purchases from positive purchases. Most variables that would explain the zero purchases for food items, 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 presence of a pregnant woman because such data do not exist in the HES database. We follow Heien and Wessells’s (1990) reasoning, who argue that if the interview period were longer, more items would be observed entering the consumer’s market basket. Hence, we use non-food expenditure as the ‘identifier’. One can reasonably say that households go to shopping to buy not only food, but also other items like detergent, toilet paper, cling wrap, toothpaste, etc. In other words, if non-food expenditure is positive, then there is a chance that food expenditure is positive. If zero, then food expenditure can be zero. Our objective with this identifier is to capture the households’ joint expenditure behavior that includes food and non-food purchases during the survey period. Non-food expenditure is not expected to explain the expenditure shares of food items, therefore, it is excludable from the second stage.^{6, 7}

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 ignorable. Of the 10 categories, the OLS-based elasticities are, on average, 10% biased compared to those obtained with correction.⁸ However, the general pattern of elasticities across all the food categories (i.e., inelasticity-unit elasticity-elasticity) remained categorically unchanged with this exercise, indicating a steadiness in the estimates.

Another issue related to zero observations are 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, which is an assumption made in this paper.

Finally, the two surveys are pooled in the estimation process as this approach has significant advantages over utilizing 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. The question that may arise here is whether the 2003/04 prices should be deflated by a price index. Note that the AIDS model allows for explicitly imposing the homogeneity condition through a simple constraint on the coefficients. This takes care of the

⁶ We find the non-food expenditure by subtracting the total food expenditure from income. The latter is widely used as a proxy for total expenditure. See Heien and Wessells (1990).

⁷ Some studies suggest the size of households’ cities (i.e., small, medium-sized, big cities) as an identifier variable, but this is likely to be relevant only for developing countries. People in small cities (especially rural areas) make their own bread, grow their own vegetables, breed their own chicken, etc., a notion generally not applicable to Australia.

⁸ The magnitude of the bias reported here is the weighted mean percentage deviation (in absolute values) from the “corrected” estimates. Expenditure shares of the relevant products are the weights. All these results are available upon request.

issue of “real” prices. In fact, if it is done properly, any deflator would fall out of the consumer optimization problem in the AIDS model.⁹

⁹ In the more ad hoc demand equations that characterize the food demand literature, dividing the prices by a deflator to obtain the ‘real’ prices is appropriate. We would like to thank Keith McLaren for pointing this out to us.

8. Results

Summary statistics of the explanatory variables used in the expenditure share equations are provided in Table 4 for each survey.

Own-Price and Cross-Price Elasticities for All Australian Households

Estimation results for own-price and cross-price elasticities are reported in Table 5. The diagonal entries in Table 5 represent the own-price elasticities, and the non-diagonal entries represent the cross-price elasticities. Note that cross-price elasticities are not symmetric, meaning that the consumer response for a commodity to a change in the price of another good is not necessarily the same as the consumer response for the other good to a change in the price of the commodity in question.

As expected, almost all of own-price elasticities are negative, and a great majority of them are statistically significant at 5% or stronger levels. On the other hand, some cross-price elasticities are negative and some are positive. Negative cross-price elasticities imply that the relevant items tend to be complementary, while positive elasticities imply that they tend to be substitutes. The significance of cross-price elasticities varies across product categories. Statistically insignificant elasticities imply that the quantity demanded for a food category does not respond to price changes, suggesting that the purchase (or budgeting) decision is not affected by a change in the price of own or another commodity observed in the sample.

An important point to note is that because we use cross-sectional household data, we are likely to capture the long-run elasticities. Previous studies in Australia have generally used time-series data, which tend to capture short-run elasticities.

Comparative discussion is provided below for broad categories of food items. We focus on elasticities that are statistically significant at 5% or stronger levels.

Milk, Dairy Products, Margarine

Own-price elasticity of milk is estimated to be -0.23. However, the estimate falls short of being statistically significant, implying that the milk demand is invariant to price changes observed in this sample. Own-price elasticity for dairy products is estimated to be unit elastic with an estimate of -1.00, while margarine is estimated to have an elastic demand, with own-price elasticity standing at -1.70.

Doctors, nutritionists, and health specialists are parties to an ongoing significant debate regarding the merits and demerits of margarine and butter for obesity and a healthy diet. They differ in views about the impact of saturated and unsaturated fats on cholesterol levels, arterial health, and associated cancer risks. Our dairy products category includes butter. We estimate the response of the demand for dairy products to a change in margarine prices to be positive. The response of margarine demand to price changes in dairy products is, however, insignificant.

On the other hand, milk, dairy products, and margarine are estimated to have statistically significant cross-price elasticities of varying signs with other food items, such as mutton & lamb, poultry, or fresh vegetables. The data might be picking up some common bundling choices across households here, perhaps in association with two-stage budgeting decisions made during the purchase, or the amount or the timing of purchase of the food items.

Bread, 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 Australian-born head for whom it does not occupy a large space in total food expenditure, and hence the strong response to price changes.

On the other hand, demand for bread seems to increase significantly upon an increase in the price of rice, as shown by a significant cross-price elasticity of 1.55 . However, the demand for rice does not seem to be responsive to a change in the price of bread.

It must be noted that rice demand from some ethnic groups like Indians and other Asians may be driving the estimated elasticities. Casual empiricism suggests that for these groups rice is more often than not associated with a bulk purchasing behavior. Although this issue will be re-visited in Section 6.2, we checked the robustness of our own-price estimate to outliers in rice purchases in this sample. Removing around 85 households whose rice purchases are higher than 20% of the food budgets, we re-estimate the own-price elasticity of rice to be -3.60 (with a t-statistic of 7.15). Thus, as expected, heavy purchasers of rice drive the elasticity down.

Beef & Veal, Mutton & Lamb, Pork, Poultry, Other Meat

Estimation results offer significant insights regarding own-price elasticities for different meat products. Own-price elasticities for beef & veal, mutton & 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 very 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. Highly elastic demand for pork does not seem surprising, because, as noted above, red meat has a relatively higher share than pork in meat purchases.

Our estimates can be compared with other Australian elasticities, namely those of Hyde and Perloff (1988) and Cashin (1991), given the similarities in estimation methodologies. Our elasticity estimate for beef generally matches their estimates. Likewise, the estimate for lamb is again reasonably close to theirs. Their pork elasticity estimates are, however, lower than ours. While their estimates indicate about a unit-elastic demand, our estimate points to an elastic demand. Further, Cashin estimates chicken meat elasticity to be very low at -0.47 , while ours is comparable to beef and lamb.

Very importantly, we also estimate cross-price elasticities among five meat categories. The estimates are generally positive but almost categorically insignificant. This can suggest that, in Australia, the demand for different meat categories is taste-driven, rather than driven by responsiveness to changes in prices.

Fruits, Vegetables

We estimate the elasticities for fruit and vegetables for both fresh and preserved products. Once again, the estimates appear plausible and reflective of Australian consumer behavior in food stores. Fresh fruits are estimated to have unit elastic demand with an elasticity estimate

of -1.05, while the demand for fresh vegetables is estimated to be inelastic with an elasticity estimate standing at -0.53. Consumers seem to be relatively less responsive to changes in fresh vegetable prices than to those in fresh fruit prices, reflecting probably that vegetables are essential for cooking meals. On the other hand, preserved fruits are estimated to have insignificant own-price elasticity, while preserved vegetables have an elastic demand as seen through an estimate of -1.38. This suggests that the purchase of canned fruits is choice-driven, rather than price-driven, while consumers' preference for preserved vegetables is important but relatively responsive to price changes.

Cross-price elasticities also suggest interesting behaviors. First, fresh fruits and fresh vegetables have small, negative and significant cross-price elasticities of -0.20 and -0.22. This is probably reflective of most households' behaviour of purchasing these goods jointly from grocery stores. Second, the demand for preserved fruits and preserved vegetables seems to respond to price changes in fresh fruits and fresh vegetables, respectively, not vice versa.

Our estimates can be compared with those of HAL (2008). Their own-price elasticity estimate for fresh fruits (-0.66) is lower than our unit elastic estimate, but their estimate for vegetables (-0.58) is very close to our -0.53. On the other hand, they estimate the cross-price elasticity for the demand for fruits as a response to change in vegetable prices to be -0.28, which is again close to our -0.20. Further, their cross-price elasticity estimate for the demand for vegetables upon a price change fresh fruits is -0.17, while our estimate stands at -0.22. Finally, their expenditure elasticity estimate for fresh fruits and fresh vegetables are 1.12 and 0.84, respectively, while our estimates are 0.76 and 0.89, all indicating important similarities between our estimates, especially for vegetables.

Sugar & Jam

The own-price elasticity for sugar & jam is estimated to be counter-intuitively positive. We determine that this sign is largely driven by sugar, and importantly, by some outliers in sugar purchases. When we eliminate from the sample 87 households whose sugar & jam purchases constitute 10% or more of their food budget in 2003/04, the elasticity estimate becomes insignificant. Given that this product category does not pass the outlier test, we conclude that, considering the majority of the households, consumption of sugar & jam in Australia is generally unresponsive to price changes.

Own-Price and Cross-Price Elasticities for Households with Australian-born Heads

So far, the results cover all the households in the two surveys. However, ethnicity is a crucial factor in food demand in Australia. Preferences for commodities like milk, rice and meat differ widely across ethnicities. While elasticities for non-Australians and/or different ethnicities are difficult to estimate due to sample size considerations, obtaining elasticities for households with Australian-born heads is possible.¹⁰ These elasticities are presented in Tables 6. A great majority of these elasticities mimic the full sample case, although there are some important and interesting differences. The discussion here will focus only on 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

¹⁰ Note that while utilizing this sample for estimation, the dummies relating to origin of the birth of the household head are removed from the estimating equation.

households with Australian-born heads, rice demand is much more price-responsive than for households with overseas-born heads. On the other hand, the significant change in the demand for bread as a result of a variation in rice price is not found in the Australians-only case. This suggests that the effect found above is probably driven by households with overseas-born heads.

A few other food categories register some noteworthy variations in own-price elasticity estimates. Those with such variations include dairy products, pork, sugar & jam (with higher estimates for households with Australian-born heads), and preserved vegetables (with a lower estimate for households with Australian-born heads). Further, there is evidence of a significant two-way responsiveness between the demand for mutton & lamb and pork among households with Australian-born heads, given that their cross-price elasticities are positive and significant. In other words, whenever there is an increase in the price of one of the categories, households with Australian-born heads respond by changing the demand for the other meat category (with the response for the demand for mutton & lamb being relatively higher than that for pork).

In an unreported analysis, we include only those households whose heads are of English-speaking origin.¹¹ Households with heads who were born in English-speaking countries such as the UK or New Zealand might exhibit similar food demand patterns as those with Australian-born heads. This sample generally produces elasticities very close to the Australians-only case. Notable differences are, the own-price elasticity of rice is -5.67, which is more elastic than the Australians-only case, and -2.29 for pork and -1.33 for preserved vegetables, which are relatively closer to the full sample case (all these estimates are significant at 1% level).

Expenditure Elasticities for All and Households with Australian-born Heads

Expenditure elasticities are key behavioral parameters in policy models such as GTAP, or country-specific Computable General Equilibrium (CGE) models. Table 5 and 6 comprise the expenditure elasticity estimates in the last columns 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 case.

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 and 0.94. The demand for dairy products is in the neighborhood of unit elasticity. On the other hand, all the meat items, rice, sugar & jam, and preserved fruits/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 & veal, mutton & lamb, and pork possess the highest elasticities among our estimates. All these suggest that, as expected, staple food products are necessary items in the shopping lists at the lowest levels of expenditure, while all the meat categories and preserved food are purchased together with many items that will increase the expenditure levels.

¹¹ We do this analysis for only own-price elasticities.

9. International Comparisons

Studies estimating a comprehensive set of disaggregated food demand elasticities have been recently undertaken in a number of other developed countries including Canada, the US, and Japan. Thus, these countries can be a reference point for us to compare elasticities. We compare our results with studies that adopt cross-sectional household-level data, the AIDS methodology, and time periods that are as close as possible to ours.

Canada

Pomboza and Mbagwa (2007) use household level data from the Canadian Food Expenditure Survey of 2001 to estimate the own-price and cross-price elasticities for 14 food categories in Canada, which is considered a contemporary economy with a similar structure to Australia's.

Their estimate for bread is -0.40, which is lower than ours but still comparable in terms of being inelastic. Their elasticity for dairy products, -0.77, is not far from our unit-elastic estimate. However, their dairy products also include milk, so if we take the averages of our milk and dairy elasticities, we obtain -0.69, indicating a greater similarity. They estimate the fruit elasticity to be -0.73, while our estimate (for fresh fruit) is unit elastic. Their estimate for vegetables, -0.55, is very close to ours at -0.60. On the other hand, their estimates for meat categories are overall lower than our estimates. Their elasticity for beef is -0.40, for poultry -0.77, and for pork -0.65. However, their elasticity for the Other Meat category, -0.81, is reasonably close to ours. Thus, except for main meat items, Canadian households important exhibit similarities to Australian households in terms of own-price elasticities. In addition, Pomboza and Mbagwa estimate all the cross-price elasticities for meat categories to be insignificant, which is another finding very similar to ours.

However, the expenditure elasticities determined by Pomboza and Mbagwa exhibit significant differences compared to the Australian case. More often than not, their expenditure elasticity estimates are in the neighbourhood of unit elasticity, with the exceptions being fruit and vegetables which have elasticities around 1.3. These two estimates are much higher than ours. Other important differences are for meat categories, with much lower estimates of around 0.8, and bread with a higher estimate of 0.94.

USA

Huang and Lin (2000) estimate own-price and expenditure elasticities for 13 food groups in the USA using the 1987-88 Nationwide Food Consumption Survey data. Their estimates are generally very close to the Canadian case.¹² It must be noted that Pomboza and Mbagwa (2007) generally follow Huang and Lin (2000) in estimation issues, including the categorization of the food products, for the Canadian case discussed above. In terms of own-price elasticities, therefore, Huang and Lin's estimates for dairy (including milk) and vegetables are close to ours, while the elasticities of other categories feature the differences mentioned above.

In terms of expenditure elasticities, too, the USA and the Canadian cases mimic each other. A notable difference is in relation to bread, with Huang and Lin's estimate of 0.7 being closer to our estimate of 0.6.

¹² Huang and Lin (2000) by-pass the zero observations issue. They use a unit-values approach (not expenditure shares) within the AIDS context. We use unadjusted expenditure elasticities for comparison.

Japan

Using Japanese household-level data for 1997, Chern et al. (2003) present own-price and expenditure elasticities. They estimate the own-price elasticity of rice to be around -1.7, for bread around -0.7, for milk around -0.1, and for fresh vegetables around -0.7. These are reasonably similar to our estimates. However, their own-price estimate for fresh fruit, -0.6, is lower than our unit elastic estimate.

Likewise, expenditure elasticities are also reasonably comparable. Their elasticities for milk, bread, and fresh vegetables are approximately 0.5 and 0.6, and for rice and fresh fruit approximately 1.1.

However, meat demand in Japan exhibits differences compared to Australian demand. Chern et al.'s own-price elasticity for beef is around -0.6, for pork -0.7, and for poultry -0.8. These are lower than our estimates, indicating different responsiveness for meat across the two countries. However, the own-price elasticity of the Other Meat category (i.e., average elasticities of ham, sausage, bacon) is about -0.9, which is again close to our unit elastic estimate. Finally, their expenditure elasticity estimates for all meat products are overall lower than ours, ranging between 0.8 and 1.3.

The Japanese daily diet exhibits important differences to the Australian diet. However, the range of elasticity values reported for Japan is broadly comparable to those reported in this study. This suggests that the elasticity values reported in this study are plausible long run responses.

10. Implications

Average food prices rose in Australia by 26% between 1998 and 2003, an increase that surpassed the rise in the average level of prices by 9%. Of the food categories, mutton & lamb prices recorded the highest rise, 64%, with average meat prices rising overall by 38%. While milk, bread, fresh vegetables, preserved vegetables and margarine prices registered rises of more than 20%, dairy products, fresh fruits, and sugar & jam had price increases of 10% or less. On the other hand, average total weekly household food expenditure increased by 24% (from \$41.39 to \$51.22) over the same period. State-wise decomposition of prices also reveals important variations in food prices. How did the Australian consumers respond to such changes in absolute as well as the relative prices?

This paper estimates the price responsiveness of food demand for 15 food categories using the latest two household expenditure surveys available, covering the period 1998/99 and 2003/04. Adopting an Almost Ideal Demand System approach, we deviate dramatically from the extant literature in terms of objectives and the scope. We estimate the own-price, cross-price and expenditure elasticities for all categories. To our knowledge, such levels of disaggregation for food elasticities are unique to this Australian case. The food categories analyzed in this study exhaust almost all of the possible food items in household shopping lists, allowing us to take into consideration the 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 attempt to derive some inferences regarding the food demand behavior of households with Australian-born vs overseas-born heads. We also compare our elasticities with the Canadian, US, and Japanese elasticities that are derived from comparable studies. The underlying food demand elasticities obtained in this study all accord with economic intuition and theory. Importantly, but not surprisingly, some of these elasticities differ, in a policy relevant sense, from the estimates found in earlier studies.

Specifically, we find that, in terms of own-price elasticities, bread, and fresh vegetables face an inelastic demand, while beef & veal, mutton & lamb, poultry, pork, rice, margarine, and preserved vegetables possess elastic demand. Dairy products, fresh fruits, and Other Meat categories are estimated to have unit elastic demand. On the other hand, demands for milk and preserved fruits do not respond to price variations observed in the sample as their elasticity estimates are statistically insignificant. When outliers are removed, sugar & jam is also found to be unresponsive to price changes. Cross-price elasticities also offer several intuitive results. Our estimates indicate a one-way response from rice to bread, meaning that when the rice prices rise, consumers demand more bread. We also find that in Australia demand for different meat types is taste-driven, rather than price-driven, as seen through generally insignificant cross-price elasticities across the meat categories. Also, fresh vegetables and fresh fruits seem to be purchased jointly from the food stores. Finally, expenditure elasticity estimates suggest that milk, bread, fresh vegetables and fresh fruits are expenditure-inelastic, suggesting that they are necessary items in the shopping lists at the lowest levels of expenditure, while all meat categories, rice, sugar & jam, and preserved fruits are expenditure-elastic, indicating that they are purchased together with many items.

Households with Australian-born heads exhibit some important differences in food demand. Notably, these households have much higher own-price elasticity for rice, indicating that they are more responsive to price changes in rice compared to ethnicities from Asia and the subcontinent, for whom rice is a staple diet. Also, the demand for pork, and to some extent dairy products (cheese and butter) is relatively more elastic among the households with Australian-born heads vs households whose heads were born overseas. On the other hand,

demand for preserved vegetables is relatively less elastic among the former group. Further, there is evidence of a significant two-way responsiveness between the demand for mutton & lamb and pork among these households. Whenever there is an increase in the price of one of the meat types, households respond by changing the demand for the other type.

International comparisons also reveal important features in food demand. Our own-price elasticity estimates for rice, bread, milk, and especially fresh vegetables are reasonably close to the Canadian, US, and Japanese elasticities. However, Australian meat demand seems to be uniformly more elastic than that in the other countries.

It must be noted that, although there are important similarities, our own-price elasticity estimates are higher than previous Australian estimates. This is most likely due to our use of cross-sectional household data, and thereby, capturing of long-run elasticities. Previous studies in Australia have generally used time-series data, which tend to capture short-run elasticities. Arguably, long-run elasticities are more meaningful than short-run elasticities for many policy studies. Further, the relatively comparable elasticity values with international studies using cross-sectional data seem to point out to the plausible long-run responses to food that we have obtained in the Australian case. Therefore, with these elasticities, we provide an accessible basic reference source for academics, policymakers, modelers, and market and policy analysts.

11. Recommendations

Industry analysts and modellers are encouraged to note the parameter estimates presented in this report and consider their relevance for their models and industry studies.

Research bodies should consider the potential value of commissioning a further food demand study when the next HES becomes available. This is required to validate the estimates reported here and to monitor changes in the Australian food sector.

Appendix A

Table 1 Previous Estimates of Australian Food Demand Elasticities

Authors	Data	Model and Estimation	Estimates			
Tulpule & Powell (1978) a	1964/5 -1975/6	TELES, Expenditure, Frisch	Expenditure Elasticities:			
			Bread, cakes	0.1	Fruit &Veg	0.5
			Confectionary	0.4	Marg, oil, fats	0.5
			Flour, cereals	0.2	Meat products	0.5
			Food nec	0.5	Milk products	0.1
Selvanathan (1991)	1975 -1989 States	Working, ML	Spatial Food Demand Elasticities:			
			AU	-0.26		
			NSW	-0.4	TAS	-0.53
			QLD	-0.26	VIC	0.0
			SA	-0.29	WA	-0.45
Hyde & Perloff (1998)	1970(1) - 1988(1)	LA/AIDS	Food Demand Elasticities:			
			Beef	-1.41	Pork	-1.04
			Lamb	-1.71		
Piggot et al (1996)	1978(3) – 1988(4)	Single equation, OLS	Beef	-0.42	Lamb	-1.26
			Chicken	-0.46	Pork	-0.87
Alston & Chalfant (1987)	1968(1) – 1983(1)	Single equation, OLS	Beef	-0.42	Lamb	-1.33
			Chicken	-0.37	Pork	-1.12
Martin &Porter (1985)	1962(1) - 1983(1)	Single equation, OLS	Beef	-1.13	Mutton	1.39
			Chicken	-0.85	Pork	-1.09
			Lamb	-1.88		
Bhati (1987)	1971(1) - 1986(4)	Supply and Demand, 2SLS	Chicken meat	-0.36	Poultry meat	-0.35
Bewley (1987)	1984 Household Expenditure Survey	GADS, GLS	Delivered Milk	-14.77	Non-delivered Milk	-3.62
Seale et al (2003)	1996 Cross country data	Florida Slutsky, ML, Frisch	Beverages &Tobacco	-0.314	Fish	-0.283
			Bread &Cereals	-0.115	Fruits & Veg	-0.202
			Dairy	-0.275	Meat	-0.257
			Fats& Oils	-0.136	Other Foods	-0.256
HAL (2008)	Weekly, 2001-2007	OLS	Fresh Fruit	-0.66	Vegetables	-0.58
			Nuts	-0.96		
Cashin (1991)	1967(1) - 1990(1)	LA/AIDS, ML SUR	Aggregated		Disaggregated	
			Bacon	-	-0.95	
			Beef	-1.24	-0.82	
			Chicken	-0.47	-	

Authors	Data	Model and Estimation	Estimates	
			Fresh Pork	- -1.2
			Ham	- -1.19
			Lamb	-1.33 -0.99
			Pork	-0.83 -

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

Table 2a Expenditure Shares for Each Food Category by Demographics (1998/99)

Food Category	By Ethnicity			By State							By Children under 15		By Age of Household's Head		
	All	Australians	Non-Australians	NSW	VIC	QLD	WA	SA	TAS	NT & ACT	Hhs w kids under 15	Hh w/o kids under 15	Below 35	Between 35-55	Above 55
Milk	0.126 (0.12) [6324]	0.127 (0.12) [4589]	0.122 (0.12) [1735]	0.122 (0.12) [1735]	0.124 (0.11) [1279]	0.133 (0.13) [1001]	0.133 (0.12) [594]	0.139 (0.13) [515]	0.134 (0.13) [449]	0.129 (0.14) [631]	0.131 (0.12) [2221]	0.123 (0.12) [4103]	0.154 (0.15) [1609]	0.118 (0.11) [2898]	0.112 (0.09) [1817]
Dairy products	0.086 (0.06) [5141]	0.083 (0.06) [3757]	0.092 (0.07) [1384]	0.092 (0.07) [1384]	0.087 (0.06) [1065]	0.082 (0.05) [834]	0.085 (0.06) [479]	0.089 (0.07) [415]	0.091 (0.07) [366]	0.083 (0.06) [510]	0.080 (0.05) [1880]	0.089 (0.06) [3261]	0.092 (0.06) [1229]	0.084 (0.06) [2450]	0.083 (0.06) [1462]
Bread	0.122 (0.10) [6428]	0.122 (0.10) [4661]	0.122 (0.10) [1767]	0.122 (0.10) [1767]	0.124 (0.09) [1297]	0.123 (0.11) [1016]	0.114 (0.09) [598]	0.130 (0.11) [520]	0.136 (0.10) [458]	0.108 (0.09) [640]	0.114 (0.09) [2200]	0.126 (0.11) [4228]	0.130 (0.12) [1588]	0.120 (0.10) [2934]	0.119 (0.09) [1906]
Rice	0.041 (0.06) [1554]	0.029 (0.04) [997]	0.061 (0.08) [557]	0.061 (0.08) [557]	0.041 (0.06) [323]	0.037 (0.05) [231]	0.037 (0.04) [158]	0.037 (0.06) [116]	0.029 (0.02) [88]	0.042 (0.06) [184]	0.040 (0.06) [625]	0.041 (0.06) [929]	0.051 (0.08) [368]	0.040 (0.06) [793]	0.032 (0.04) [393]
Beef and veal	0.133 (0.10) [3350]	0.133 (0.10) [2455]	0.135 (0.10) [895]	0.135 (0.10) [895]	0.127 (0.09) [680]	0.143 (0.10) [547]	0.123 (0.10) [317]	0.137 (0.11) [258]	0.120 (0.09) [222]	0.137 (0.09) [370]	0.113 (0.08) [1174]	0.144 (0.11) [2176]	0.132 (0.10) [746]	0.129 (0.10) [1589]	0.142 (0.10) [1015]
Mutton and lamb	0.103 (0.08) [2209]	0.105 (0.08) [1706]	0.098 (0.08) [503]	0.098 (0.08) [503]	0.104 (0.08) [482]	0.100 (0.07) [302]	0.093 (0.07) [219]	0.120 (0.10) [170]	0.087 (0.06) [160]	0.099 (0.06) [208]	0.090 (0.06) [750]	0.110 (0.08) [1459]	0.110 (0.09) [417]	0.097 (0.07) [1043]	0.108 (0.08) [749]
Pork	0.091 (0.07) [1384]	0.081 (0.05) [901]	0.111 (0.09) [483]	0.111 (0.09) [483]	0.086 (0.06) [279]	0.085 (0.06) [245]	0.085 (0.06) [132]	0.088 (0.06) [106]	0.068 (0.05) [78]	0.098 (0.08) [139]	0.092 (0.08) [472]	0.091 (0.07) [912]	0.094 (0.07) [267]	0.094 (0.08) [660]	0.085 (0.06) [457]
Other meat	0.064 (0.05) [3323]	0.065 (0.05) [2492]	0.062 (0.05) [831]	0.062 (0.05) [831]	0.059 (0.04) [678]	0.072 (0.05) [563]	0.069 (0.05) [345]	0.065 (0.07) [259]	0.062 (0.06) [240]	0.062 (0.05) [319]	0.058 (0.04) [1320]	0.069 (0.06) [2003]	0.072 (0.06) [780]	0.062 (0.05) [1628]	0.062 (0.05) [915]
Poultry	0.110 (0.08) [3403]	0.108 (0.08) [2386]	0.115 (0.09) [1017]	0.115 (0.09) [1017]	0.108 (0.07) [707]	0.100 (0.07) [498]	0.112 (0.08) [358]	0.121 (0.09) [277]	0.100 (0.07) [216]	0.115 (0.09) [367]	0.101 (0.07) [1330]	0.117 (0.09) [2073]	0.123 (0.09) [825]	0.107 (0.07) [1690]	0.105 (0.08) [888]
Fresh fruits	0.070 (0.07) [4990]	0.069 (0.07) [3580]	0.074 (0.07) [1410]	0.074 (0.07) [1410]	0.068 (0.07) [1032]	0.068 (0.07) [823]	0.072 (0.07) [459]	0.059 (0.04) [373]	0.064 (0.05) [327]	0.076 (0.08) [504]	0.060 (0.05) [1776]	0.076 (0.07) [3214]	0.071 (0.07) [1106]	0.066 (0.06) [2325]	0.076 (0.07) [1559]
Fresh vegetable	0.089 (0.07) [5909]	0.088 (0.07) [4264]	0.092 (0.07) [1645]	0.092 (0.07) [1645]	0.081 (0.05) [1195]	0.089 (0.07) [954]	0.087 (0.07) [564]	0.081 (0.06) [460]	0.088 (0.06) [400]	0.101 (0.07) [594]	0.078 (0.05) [2030]	0.095 (0.07) [3879]	0.090 (0.07) [1384]	0.085 (0.06) [2729]	0.096 (0.07) [1796]
Preserved fruits	0.042 (0.04) [2268]	0.042 (0.04) [1737]	0.041 (0.04) [531]	0.041 (0.04) [531]	0.041 (0.04) [450]	0.041 (0.05) [391]	0.041 (0.04) [215]	0.041 (0.04) [150]	0.043 (0.03) [161]	0.045 (0.05) [226]	0.035 (0.03) [899]	0.046 (0.05) [1369]	0.045 (0.04) [491]	0.038 (0.04) [1099]	0.045 (0.04) [678]
Preserved vegetables	0.046 (0.04) [2788]	0.047 (0.03) [2109]	0.045 (0.04) [679]	0.045 (0.04) [679]	0.044 (0.03) [545]	0.045 (0.04) [433]	0.045 (0.03) [291]	0.048 (0.04) [228]	0.049 (0.03) [187]	0.050 (0.04) [271]	0.041 (0.03) [1148]	0.050 (0.04) [1640]	0.053 (0.04) [654]	0.043 (0.03) [1381]	0.047 (0.04) [753]
Sugar and jam	0.036 (0.03) [3141]	0.036 (0.03) [2254]	0.036 (0.03) [887]	0.036 (0.03) [887]	0.036 (0.03) [648]	0.034 (0.03) [524]	0.036 (0.03) [287]	0.034 (0.03) [255]	0.044 (0.03) [226]	0.032 (0.02) [277]	0.028 (0.02) [1156]	0.040 (0.03) [1985]	0.034 (0.03) [618]	0.031 (0.02) [1472]	0.043 (0.03) [1051]

Margarine	0.039 (0.03) [2960]	0.040 (0.03) [2276]	0.037 (0.03) [684]	0.037 (0.03) [684]	0.036 (0.02) [601]	0.037 (0.03) [425]	0.037 (0.03) [266]	0.043 (0.05) [251]	0.050 (0.03) [225]	0.035 (0.03) [281]	0.033 (0.03) [1110]	0.043 (0.04) [1850]	0.040 (0.04) [605]	0.035 (0.02) [1422]	0.045 (0.04) [933]
Sample Size	6859	4952	1907	2026	1369	1089	646	561	477	682	2296	4563	1746	3095	2018

Footnotes: Figures with no parenthesis refer to mean, within the first parentheses to the standard deviation, and the second parentheses to total number of observations.

Table 2b Expenditure Shares for Each Food Category by Demographics in 2003-04

Food Category	By Ethnicity			By State							By Children under 15		By Age of Household's Head		
	All	Australians	Non-Australians	NSW	VIC	QLD	WA	SA	TAS	NT & ACT	Hh w kids under 15	Hh w/o kd under 15	Below 35	Between 35-55	Above 55
Milk	0.136 (0.12) [6201]	0.140 (0.13) [4540]	0.124 (0.11) [1661]	0.130 (0.12) [1524]	0.130 (0.11) [1357]	0.143 (0.12) [794]	0.137 (0.14) [661]	0.153 (0.14) [774]	0.133 (0.11) [514]	0.135 (0.13) [577]	0.146 (0.12) [1971]	0.131 (0.13) [4230]	0.164 (0.15) [1289]	0.136 (0.12) [2039]	0.115 (0.10) [2050]
Dairy products	0.091 (0.07) [5050]	0.090 (0.07) [3711]	0.093 (0.07) [1339]	0.089 (0.06) [1231]	0.095 (0.08) [1101]	0.088 (0.07) [656]	0.090 (0.07) [520]	0.094 (0.06) [651]	0.088 (0.06) [415]	0.092 (0.07) [476]	0.080 (0.05) [1659]	0.096 (0.08) [3391]	0.101 (0.08) [991]	0.087 (0.07) [1724]	0.089 (0.07) [1657]
Bread	0.142 (0.11) [6356]	0.143 (0.11) [4628]	0.137 (0.11) [1728]	0.151 (0.12) [1608]	0.144 (0.11) [1390]	0.132 (0.10) [807]	0.130 (0.09) [668]	0.141 (0.10) [784]	0.148 (0.11) [519]	0.132 (0.10) [580]	0.142 (0.10) [2004]	0.141 (0.11) [4352]	0.158 (0.13) [1308]	0.136 (0.09) [2099]	0.132 (0.10) [2116]
Rice	0.041 (0.06) [1350]	0.027 (0.03) [878]	0.067 (0.09) [472]	0.050 (0.08) [363]	0.043 (0.06) [307]	0.038 (0.06) [177]	0.034 (0.04) [124]	0.037 (0.06) [135]	0.027 (0.02) [92]	0.039 (0.04) [152]	0.041 (0.07) [534]	0.041 (0.06) [816]	0.048 (0.07) [264]	0.041 (0.06) [503]	0.035 (0.05) [390]
Beef and veal	0.141 (0.10) [3085]	0.139 (0.10) [2244]	0.146 (0.11) [841]	0.147 (0.11) [758]	0.132 (0.10) [670]	0.149 (0.11) [401]	0.142 (0.10) [355]	0.136 (0.10) [367]	0.127 (0.08) [252]	0.151 (0.10) [282]	0.118 (0.09) [969]	0.151 (0.11) [2116]	0.146 (0.12) [509]	0.133 (0.09) [1105]	0.151 (0.11) [1095]
Mutton and lamb	0.116 (0.09) [2013]	0.115 (0.09) [1545]	0.117 (0.09) [468]	0.123 (0.09) [494]	0.124 (0.10) [442]	0.095 (0.07) [241]	0.110 (0.08) [234]	0.114 (0.09) [218]	0.102 (0.08) [188]	0.124 (0.10) [196]	0.099 (0.08) [636]	0.123 (0.10) [1377]	0.130 (0.11) [291]	0.107 (0.08) [686]	0.120 (0.09) [769]
Pork	0.094 (0.08) [1326]	0.084 (0.06) [898]	0.114 (0.09) [428]	0.103 (0.08) [312]	0.094 (0.08) [274]	0.096 (0.08) [197]	0.091 (0.07) [167]	0.086 (0.07) [134]	0.079 (0.06) [108]	0.093 (0.06) [134]	0.084 (0.06) [408]	0.098 (0.08) [918]	0.091 (0.08) [158]	0.095 (0.08) [466]	0.095 (0.07) [535]
Other meat	0.070 (0.06) [3280]	0.071 (0.06) [2478]	0.068 (0.05) [802]	0.068 (0.05) [792]	0.069 (0.06) [696]	0.079 (0.07) [427]	0.074 (0.06) [383]	0.068 (0.05) [400]	0.070 (0.06) [281]	0.063 (0.05) [301]	0.063 (0.05) [1177]	0.074 (0.06) [2103]	0.073 (0.06) [590]	0.069 (0.06) [1154]	0.069 (0.05) [1064]
Poultry	0.117 (0.09) [3329]	0.114 (0.09) [2345]	0.125 (0.10) [984]	0.116 (0.09) [794]	0.122 (0.10) [751]	0.106 (0.07) [403]	0.125 (0.09) [394]	0.117 (0.09) [388]	0.108 (0.08) [261]	0.120 (0.09) [338]	0.110 (0.09) [1181]	0.121 (0.09) [2148]	0.138 (0.11) [663]	0.114 (0.09) [1142]	0.110 (0.08) [1035]
Fresh fruits	0.061 (0.06) [4863]	0.059 (0.06) [3539]	0.068 (0.06) [1324]	0.070 (0.08) [1229]	0.058 (0.05) [1049]	0.062 (0.06) [620]	0.061 (0.06) [515]	0.054 (0.05) [573]	0.052 (0.07) [397]	0.061 (0.05) [480]	0.051 (0.05) [1562]	0.066 (0.07) [3301]	0.062 (0.06) [862]	0.055 (0.05) [1631]	0.068 (0.07) [1746]
Fresh vegetable	0.087 (0.07) [5726]	0.086 (0.06) [4190]	0.089 (0.07) [1536]	0.088 (0.07) [1413]	0.085 (0.07) [1229]	0.086 (0.06) [748]	0.086 (0.07) [632]	0.084 (0.06) [705]	0.086 (0.06) [471]	0.091 (0.06) [528]	0.072 (0.05) [1799]	0.093 (0.07) [3927]	0.084 (0.07) [1111]	0.084 (0.07) [1905]	0.094 (0.07) [1968]

Preserved fruits	0.045 (0.05) [2104]	0.046 (0.05) [1607]	0.043 (0.04) [497]	0.044 (0.04) [528]	0.048 (0.05) [461]	0.046 (0.04) [301]	0.039 (0.04) [198]	0.047 (0.06) [239]	0.044 (0.04) [189]	0.044 (0.04) [188]	0.034 (0.03) [711]	0.051 (0.05) [1393]	0.050 (0.05) [348]	0.040 (0.04) [714]	0.050 (0.05) [772]
Preserved vegetables	0.047 (0.04) [2748]	0.047 (0.04) [2063]	0.046 (0.04) [685]	0.046 (0.04) [663]	0.046 (0.04) [594]	0.045 (0.04) [363]	0.044 (0.04) [336]	0.053 (0.05) [349]	0.047 (0.04) [222]	0.047 (0.05) [221]	0.041 (0.03) [1017]	0.050 (0.05) [1731]	0.053 (0.05) [510]	0.045 (0.04) [963]	0.046 (0.04) [882]
Sugar and jam	0.032 (0.04) [2736]	0.032 (0.04) [1958]	0.033 (0.03) [778]	0.031 (0.03) [686]	0.031 (0.03) [618]	0.032 (0.03) [354]	0.029 (0.02) [254]	0.036 (0.06) [368]	0.040 (0.04) [240]	0.026 (0.03) [216]	0.023 (0.02) [906]	0.037 (0.04) [1830]	0.029 (0.03) [409]	0.027 (0.03) [932]	0.040 (0.05) [1045]
Margarine	0.037 (0.03) [2499]	0.037 (0.03) [1909]	0.037 (0.03) [590]	0.039 (0.04) [621]	0.037 (0.04) [565]	0.035 (0.03) [292]	0.037 (0.03) [251]	0.037 (0.03) [344]	0.034 (0.02) [224]	0.038 (0.04) [202]	0.027 (0.02) [824]	0.042 (0.04) [1675]	0.034 (0.03) [400]	0.032 (0.03) [838]	0.043 (0.03) [947]
Sample Size	6957	5066	1891	1745	1531	887	729	864	555	646	2096	4861	1483	2249	2302

Footnotes: Figures with no parenthesis refer to mean, within the first parentheses to the standard deviation, and the second parentheses to total number of observations.

Table 3a Average Prices for Each Food Category in 1998-99

Food Category	Australia	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Northern Territory & ACT
Milk	2.533 (0.17)	2.383 (0.06)	2.743 (0.05)	2.416 (0.06)	2.647 (0.08)	2.758 (0.06)	2.552 (0.05)	2.422 (0.05)
Dairy products	2.791 (0.13)	2.836 (0.06)	2.845 (0.02)	2.729 (0.08)	2.489 (0.03)	2.673 (0.05)	3.015 (0.06)	2.853 (0.04)
Bread	2.157 (0.17)	2.250 (0.07)	2.225 (0.18)	2.066 (0.05)	1.737 (0.01)	2.143 (0.08)	2.156 (0.04)	2.248 (0.07)
Rice	1.556 (0.09)	1.505 (0.03)	1.526 (0.02)	1.544 (0.02)	1.403 (0.01)	1.711 (0.02)	1.746 (0.02)	1.636 (0.02)
Beef and veal	8.536 (0.50)	8.917 (0.21)	8.252 (0.20)	7.846 (0.05)	8.777 (0.20)	8.757 (0.22)	7.831 (0.26)	9.158 (0.12)
Mutton and lamb	6.442 (0.29)	6.245 (0.18)	6.479 (0.28)	6.523 (0.21)	6.604 (0.24)	6.824 (0.11)	6.000 (0.07)	6.636 (0.14)
Pork	6.989 (0.32)	7.056 (0.17)	6.690 (0.15)	6.636 (0.10)	6.999 (0.17)	7.176 (0.13)	7.238 (0.07)	7.595 (0.12)
Other meat	3.426 (0.21)	3.302 (0.08)	3.355 (0.12)	3.303 (0.08)	3.320 (0.06)	3.849 (0.04)	3.830 (0.05)	3.536 (0.06)
Poultry	3.509 (0.19)	3.550 (0.14)	3.484 (0.07)	3.242 (0.21)	3.558 (0.14)	3.481 (0.09)	3.728 (0.13)	3.692 (0.12)
Fresh fruits	2.202 (0.42)	2.426 (0.24)	2.012 (0.27)	1.895 (0.31)	1.773 (0.19)	2.674 (0.47)	1.773 (0.13)	2.610 (0.21)
Fresh vegetable	1.967 (0.24)	2.115 (0.14)	1.834 (0.17)	1.748 (0.12)	2.019 (0.20)	1.843 (0.15)	1.811 (0.13)	2.330 (0.21)
Preserved fruits	1.602 (0.08)	1.591 (0.01)	1.526 (0.06)	1.567 (0.06)	1.555 (0.05)	1.669 (0.04)	1.752 (0.05)	1.715 (0.05)
Preserved vegetables	1.303 (0.13)	1.283 (0.05)	1.218 (0.10)	1.246 (0.05)	1.217 (0.11)	1.329 (0.08)	1.572 (0.04)	1.479 (0.02)
Sugar and jam	2.372 (0.14)	2.402 (0.03)	2.283 (0.04)	2.279 (0.06)	2.154 (0.07)	2.565 (0.05)	2.683 (0.07)	2.391 (0.05)
Margarine	1.761 (0.13)	1.807 (0.04)	1.594 (0.07)	1.793 (0.05)	1.604 (0.07)	1.745 (0.07)	2.008 (0.10)	1.880 (0.08)
Total Weekly Food Expenditure	41.390 (24.97)	41.796 (25.86)	42.822 (24.67)	40.092 (23.40)	37.964 (23.72)	41.816 (25.55)	41.091 (25.26)	42.552 (25.03)
Sample Size	6850	2026	1369	1089	561	646	477	682

Footnotes: Figures with no parenthesis refer to mean, within the first parentheses to the standard deviation, and the second parentheses to total number of observations. Prices in A\$.

Table 3b Average Prices for Each Food Category in 2003-04

Food Category	Australia	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Northern Territory & ACT
Milk	3.171 (0.10)	3.123 (0.01)	3.157 (0.02)	3.170 (0.01)	3.217 (0.04)	3.381 (0.06)	2.959 (0.01)	3.217 (0.03)
Dairy products	3.090 (0.15)	3.184 (0.13)	3.142 (0.12)	2.966 (0.05)	2.880 (0.07)	3.037 (0.08)	3.050 (0.08)	3.256 (0.08)
Bread	2.736 (0.17)	2.699 (0.10)	2.759 (0.15)	2.700 (0.09)	2.665 (0.11)	2.617 (0.10)	2.945 (0.33)	2.878 (0.06)
Rice	2.027 (0.09)	1.944 (0.04)	2.110 (0.02)	1.925 (0.05)	1.962 (0.01)	2.105 (0.02)	2.151 (0.05)	2.082 (0.03)
Beef and veal	12.355 (0.41)	12.387 (0.10)	12.293 (0.07)	11.937 (0.15)	12.557 (0.08)	12.910 (0.21)	11.445 (0.25)	12.880 (0.18)
Mutton and lamb	10.563 (0.27)	10.539 (0.10)	10.411 (0.12)	10.522 (0.13)	10.736 (0.17)	10.874 (0.11)	10.015 (0.15)	10.935 (0.14)
Pork	9.209 (0.45)	9.023 (0.24)	8.989 (0.18)	8.649 (0.23)	9.316 (0.16)	10.098 (0.14)	9.595 (0.15)	9.530 (0.18)
Other meat	4.724 (0.13)	4.844 (0.07)	4.599 (0.04)	4.661 (0.04)	4.651 (0.11)	4.825 (0.15)	4.658 (0.06)	4.823 (0.05)
Poultry	3.927 (0.21)	3.684 (0.07)	4.012 (0.09)	3.815 (0.17)	4.132 (0.10)	3.961 (0.12)	3.915 (0.09)	4.235 (0.02)
Fresh fruits	2.405 (0.36)	2.595 (0.19)	2.378 (0.18)	2.129 (0.08)	1.817 (0.19)	2.838 (0.30)	2.291 (0.18)	2.731 (0.18)
Fresh vegetable	2.386 (0.20)	2.426 (0.16)	2.338 (0.16)	2.372 (0.16)	2.366 (0.12)	2.188 (0.09)	2.278 (0.19)	2.751 (0.16)
Preserved fruits	1.914 (0.08)	1.879 (0.08)	1.929 (0.01)	1.922 (0.03)	1.827 (0.01)	1.895 (0.07)	2.079 (0.03)	1.958 (0.06)
Preserved vegetables	1.587 (0.08)	1.590 (0.05)	1.588 (0.05)	1.645 (0.04)	1.457 (0.08)	1.563 (0.07)	1.624 (0.04)	1.663 (0.08)
Sugar and jam	2.458 (0.15)	2.421 (0.03)	2.409 (0.05)	2.426 (0.06)	2.272 (0.04)	2.548 (0.04)	2.879 (0.03)	2.498 (0.04)
Margarine	2.344 (0.06)	2.330 (0.01)	2.376 (0.03)	2.363 (0.02)	2.222 (0.02)	2.317 (0.02)	2.425 (0.03)	2.403 (0.02)
Total Weekly Food Expenditure	51.217 (34.14)	51.348 (35.01)	52.102 (34.88)	50.199 (33.96)	47.082 (31.65)	52.105 (33.61)	52.739 (32.18)	53.387 (35.31)
Sample Size	6957	1745	1531	887	864	729	555	646

Footnotes: Figures with no parenthesis refer to mean, within the first parentheses to the standard deviation, and the second parentheses to total number of observations. Prices in A\$.

Table 4 Summary statistics for ethnicity variables, household characteristics and states in 1998-99 and 2003-04

	1998-99	2003-04
Households with Children Aged between 0-15	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 & ACT	9.94%	9.29%
Sample Size	6859	6957

Footnote: Figures within first parentheses refer to the associated standard deviation;

Table 5 Own-Price, Cross-Price and Expenditure Elasticities for All Australian Households

Food Category	Milk	Dairy products	Bread	Rice	Beef and veal	Mutton & lamb	Pork	Other meat	Poultry	Fresh fruits	Fresh vegetable	Preserved fruits	Preserved vegetables	Sugar and jam	Margarine	Expenditure Elasticity
Milk	-0.233 (-1.47)	0.121 (1.31)	0.308*** (3.18)	-0.191*** (-4.29)	-0.037 (-0.48)	-0.105* (-1.73)	-0.192*** (-3.02)	-0.153** (-2.36)	0.230** (2.26)	-0.496*** (-8.24)	-0.472*** (-6.67)	-0.280*** (-5.99)	-0.126*** (-2.66)	-0.356*** (-9.03)	-0.293*** (-7.26)	0.371*** (24.36)
Dairy products	0.313* (1.87)	-0.999*** (-3.23)	-0.077 (-0.60)	-0.181 (-1.62)	-0.225** (-2.16)	-0.002 (-0.03)	0.093 (0.69)	-0.145 (-1.13)	-0.828*** (-4.15)	-0.024 (-0.25)	-0.0287 (-0.26)	-0.130 (-1.07)	-0.246** (-2.20)	0.019 (0.17)	0.008 (0.09)	1.004*** (36.68)
Bread	0.313*** (3.32)	-0.077 (-1.14)	-0.733*** (-7.43)	-0.005 (-0.15)	-0.102 (-1.64)	-0.230*** (-4.83)	-0.186*** (-3.91)	0.026 (0.55)	-0.132* (-1.72)	-0.379*** (-8.11)	-0.309*** (-5.73)	-0.121*** (-3.66)	-0.003 (-0.10)	-0.239*** (-8.48)	-0.155*** (-5.47)	0.449*** (33.74)
Rice	-0.811 (-1.33)	-0.265 (-0.31)	1.551*** (3.33)	-2.657*** (-4.28)	0.106 (0.28)	0.727** (2.41)	0.077 (0.15)	0.968** (2.01)	-0.315 (-0.42)	0.809** (2.40)	0.357 (0.89)	-0.301 (-0.62)	0.729* (1.69)	0.769* (1.70)	0.674* (1.94)	1.196*** (16.55)
Beef and veal	0.206 (1.41)	-0.050 (-0.47)	0.055 (0.46)	0.0449 (0.88)	-1.353*** (-9.15)	0.075 (0.93)	0.130* (1.74)	0.089 (1.16)	0.211* (1.74)	0.279*** (3.59)	0.091 (1.01)	-0.016 (-0.32)	-0.070 (-1.28)	-0.008 (-0.20)	0.038 (0.86)	1.636*** (57.87)
Mutton and lamb	0.193 (0.89)	0.380** (2.34)	-0.324* (-1.86)	0.287*** (3.68)	0.185 (1.19)	-1.420*** (-8.38)	0.224** (1.96)	-0.057 (-0.48)	0.130 (0.70)	0.470*** (4.05)	0.217* (1.64)	0.154** (1.97)	-0.024 (-0.28)	0.059 (0.90)	0.162** (2.41)	1.637*** (44.18)
Pork	-0.302 (-0.73)	0.951** (1.96)	-0.388 (-1.21)	0.129 (0.53)	0.442* (1.68)	0.322 (1.54)	-2.203*** (-5.03)	0.033 (0.11)	0.470 (1.01)	0.261 (1.17)	0.355 (1.32)	0.448* (1.76)	-0.250 (-1.02)	0.145 (0.64)	0.452** (2.28)	1.592*** (31.78)
Other meat	-0.081 (-0.34)	-0.000 (-0.00)	0.534*** (2.91)	0.257** (1.99)	0.114 (0.74)	-0.164 (-1.35)	-0.036 (-0.21)	-0.846*** (-3.57)	-0.383 (-1.49)	0.102 (0.80)	-0.007 (-0.05)	0.114 (0.85)	0.111 (0.83)	0.099 (0.84)	-0.031 (-0.29)	1.259*** (30.49)
Poultry	0.785*** (3.61)	-0.790*** (-3.36)	-0.026 (-0.16)	-0.037 (-0.32)	0.220 (1.57)	0.031 (0.28)	0.136 (0.89)	-0.209 (-1.41)	-1.388*** (-4.26)	0.322*** (2.72)	0.385*** (2.68)	0.070 (0.58)	-0.162 (-1.36)	-0.012 (-0.11)	0.223** (2.33)	1.381*** (43.50)
Fresh fruits	-1.065*** (-7.00)	0.027 (0.21)	-0.831*** (-6.84)	0.005 (0.08)	0.194* (1.84)	0.120 (1.45)	-0.078 (-0.90)	-0.072 (-0.82)	0.222 (1.60)	-1.049*** (-9.16)	-0.215** (-2.27)	-0.210*** (-3.31)	0.045 (0.70)	-0.162*** (-2.76)	-0.319*** (-6.04)	0.755*** (29.92)
Fresh vegetable	-0.703*** (-6.20)	-0.054 (-0.56)	-0.478*** (-5.38)	-0.116** (-2.48)	-0.106 (-1.37)	-0.104* (-1.74)	-0.093 (-1.41)	-0.160** (-2.41)	0.122 (1.13)	-0.202*** (-3.38)	-0.526*** (-5.34)	0.012 (0.24)	-0.110** (-2.24)	-0.200*** (-4.91)	-0.244*** (-6.07)	0.888*** (42.94)
Preserved fruits	-1.250*** (-3.09)	0.109 (0.19)	-0.028 (-0.10)	-0.158 (-0.52)	-0.187 (-0.78)	0.166 (0.87)	0.502 (1.49)	0.304 (0.96)	0.265 (0.54)	-0.197 (-0.91)	0.944*** (3.65)	-0.439 (-0.89)	-0.116 (-0.39)	0.097 (0.28)	-0.061 (-0.26)	1.516*** (18.70)
Preserved vegetables	0.054 (0.18)	-0.335 (-0.86)	0.742*** (3.26)	0.351* (1.76)	-0.329* (-1.77)	-0.205 (-1.38)	-0.319 (-1.33)	0.209 (0.91)	-0.502 (-1.42)	0.490*** (3.00)	0.201 (1.03)	-0.094 (-0.43)	-1.383*** (-4.86)	0.232 (1.17)	0.426*** (2.65)	1.230*** (21.46)
Sugar and jam	-1.865*** (-5.77)	0.720 (1.41)	-1.071*** (-4.52)	0.433 (1.61)	-0.198 (-1.03)	-0.116 (-0.77)	0.042 (0.15)	0.199 (0.76)	-0.117 (-0.28)	-0.086 (-0.45)	-0.243 (-1.16)	0.037 (0.12)	0.256 (1.00)	1.018** (2.03)	0.124 (0.60)	1.187*** (20.40)
Margarine	-1.266*** (-4.00)	0.666* (1.71)	-0.331 (-1.44)	0.383* (1.93)	0.030 (0.16)	0.137 (0.92)	0.431* (1.81)	-0.063 (-0.28)	0.776** (2.21)	-0.548*** (-3.33)	-0.427** (-2.17)	-0.085 (-0.40)	0.507** (2.55)	0.141 (0.72)	-1.696*** (-7.51)	0.938*** (18.82)

Notes: 1. Diagonal elements are own-price elasticities and off-diagonal elements are cross-price elasticities; 2. Row headings refer to the price of the respective product, and column headings to the quantity demanded of the respective product; 3. ***, **, and * refer to statistical significance at 1%, 5% and 10% levels, respectively; 4. Figures in parentheses refer to the z-statistics.

Table 6 Own-Price, Cross-Price and Expenditure Elasticities for Households with Australian-Born Heads

Food Category	Milk	Dairy products	Bread	Rice	Beef and veal	Mutton & lamb	Pork	Other meat	Poultry	Fresh fruits	Fresh vegetable	Preserved fruits	Preserved vegetables	Sugar and jam	Margarine	Expenditure Elasticity
Milk	-0.093 (-0.55)	0.135 (1.44)	0.155 (1.53)	-0.162*** (-5.45)	-0.088 (-1.07)	-0.152** (-2.38)	-0.141** (-2.45)	-0.118* (-1.70)	0.164 (1.58)	-0.560*** (-8.93)	-0.436*** (-5.96)	-0.268*** (-5.40)	-0.180*** (-3.63)	-0.311*** (-7.36)	-0.335*** (-7.76)	0.393*** (25.20)
Dairy products	0.346** (1.96)	-1.178*** (-3.64)	-0.034 (-0.26)	-0.245*** (-2.80)	-0.211* (-1.93)	0.000 (0.00)	0.025 (0.18)	-0.237* (-1.77)	-0.999*** (-4.83)	-0.049 (-0.50)	0.084 (0.74)	-0.142 (-1.07)	-0.125 (-1.06)	-0.071 (-0.57)	-0.011 (-0.12)	0.946*** (35.62)
Bread	0.176* (1.75)	-0.044 (-0.63)	-0.622*** (-6.05)	-0.091*** (-4.19)	-0.126* (-1.94)	-0.203*** (-4.04)	-0.194*** (-4.54)	-0.002 (-0.04)	-0.103 (-1.32)	-0.382*** (-7.86)	-0.293*** (-5.27)	-0.139*** (-9.29)	0.034 (0.93)	-0.283*** (-9.29)	-0.156*** (-5.14)	0.496*** (35.71)
Rice	-0.544 (-0.80)	-0.927 (-0.87)	0.533 (1.06)	-4.358*** (-6.23)	0.696* (1.68)	0.250 (0.77)	0.563 (0.92)	0.747 (1.35)	1.028 (1.19)	0.495 (1.27)	0.423 (0.95)	-0.439 (-0.66)	0.516 (0.95)	-0.252 (-0.35)	1.302*** (2.97)	1.116*** (13.13)
Beef and veal	0.105 (0.67)	-0.033 (-0.30)	-0.012 (-0.10)	0.068** (1.96)	-1.344*** (-8.62)	0.020 (0.24)	0.101 (1.48)	0.059 (0.70)	0.139 (1.10)	0.271*** (3.32)	0.022 (0.23)	-0.037 (-0.65)	-0.087 (-1.50)	-0.040 (-0.85)	0.020 (0.42)	1.551*** (54.56)
Mutton and lamb	0.042 (0.19)	0.397** (2.55)	-0.216 (-1.24)	0.127** (2.62)	0.109 (0.70)	-1.505*** (-8.87)	0.239** (2.48)	-0.047 (-0.40)	0.125 (0.70)	0.344*** (3.00)	0.238* (1.83)	0.164** (2.07)	-0.069 (-0.85)	0.049 (0.74)	0.168** (2.47)	1.555*** (42.20)
Pork	0.079 (0.17)	0.948 (1.60)	-0.561 (-1.58)	0.304 (1.39)	0.497* (1.69)	0.460** (1.99)	-2.494*** (-5.02)	-0.343 (-0.97)	0.314 (0.58)	0.596** (2.32)	0.222 (0.73)	0.612* (1.83)	-0.196 (-0.64)	0.297 (0.97)	0.306 (1.23)	1.595*** (28.63)
Other meat	0.051 (0.20)	-0.154 (-0.60)	0.388** (2.06)	0.095 (1.09)	0.070 (0.44)	-0.168 (-1.35)	-0.219 (-1.40)	-0.805*** (-3.32)	-0.357 (-1.39)	0.145 (1.10)	-0.140 (-0.90)	0.047 (0.34)	-0.062 (-0.46)	0.000 (0.00)	-0.029 (-0.26)	1.207*** (27.80)
Poultry	0.705*** (2.93)	-1.018*** (-4.00)	0.032 (0.17)	0.108 (1.23)	0.161 (1.05)	0.028 (0.23)	0.064 (0.42)	-0.210 (-1.28)	-1.425*** (-4.05)	0.469*** (3.62)	0.369** (2.37)	0.092 (0.67)	-0.263** (-2.00)	-0.018 (-0.15)	0.180* (1.67)	1.358*** (37.36)
Fresh fruits	-1.29*** (-7.68)	0.011 (0.08)	-0.886*** (-6.72)	-0.102** (-2.24)	0.207* (1.80)	0.039 (0.44)	0.001 (0.01)	-0.036 (-0.37)	0.378** (2.52)	-1.004*** (-8.08)	-0.265** (-2.60)	-0.299*** (-4.14)	-0.066 (-0.93)	-0.171** (-2.53)	-0.371*** (-6.22)	0.726*** (28.89)
Fresh vegetable	-0.662*** (-5.46)	0.054 (0.54)	-0.467*** (-5.02)	-0.138*** (-4.26)	-0.158* (-1.94)	-0.097 (-1.54)	-0.144** (-2.36)	-0.222*** (-3.11)	0.092 (0.83)	-0.233*** (-3.70)	-0.627*** (-6.12)	-0.014 (-0.27)	-0.126** (-2.41)	-0.182*** (-4.12)	-0.239*** (-5.50)	0.849*** (41.10)
Preserved fruits	-1.028** (-2.49)	0.172 (0.30)	-0.157 (-0.53)	-0.109 (-0.45)	-0.150 (-0.61)	0.233 (1.21)	0.567* (1.68)	0.212 (0.66)	0.367 (0.75)	-0.376* (-1.68)	0.827*** (3.14)	-0.049 (-0.10)	-0.267 (-0.89)	-0.010 (-0.03)	-0.289 (-1.19)	1.421*** (18.64)
Preserved vegetables	-0.247 (-0.80)	0.160 (0.41)	0.949*** (4.13)	0.155 (1.05)	-0.302 (-1.59)	-0.275* (-1.85)	-0.211 (-0.91)	-0.052 (-0.22)	-0.704** (-1.99)	0.233 (1.40)	0.176 (0.89)	-0.224 (-1.00)	-1.023*** (-3.57)	0.085 (0.41)	0.442*** (2.67)	1.167*** (20.86)
Sugar and jam	-1.479*** (-4.10)	0.440 (0.79)	-1.457*** (-5.55)	-0.099 (-0.37)	-0.229 (-1.08)	-0.106 (-0.64)	0.198 (0.62)	0.051 (0.18)	-0.086 (-0.19)	-0.038 (-0.18)	-0.077 (-0.34)	-0.067 (-0.19)	0.092 (0.33)	1.561*** (2.67)	0.090 (0.40)	1.189*** (16.35)
Margarine	-1.479*** (-4.54)	0.635* (1.64)	-0.312 (-1.35)	0.434*** (3.00)	0.046 (0.24)	0.176 (1.18)	0.191 (0.84)	-0.008 (-0.03)	0.577* (1.64)	-0.587*** (-3.50)	-0.319 (-1.61)	-0.305 (-1.39)	0.521** (2.60)	0.089 (0.44)	-1.774*** (-7.68)	0.943*** (20.21)

Notes: 1. Diagonal elements are own-price elasticities and off-diagonal elements are cross-price elasticities; 2. Row headings refer to the price of the respective product, and column headings to the quantity demanded of the respective product; 3. ***, **, and * refer to statistical significance at 1%, 5% and 10% levels, respectively; 4. Figures in parentheses refer to the z-statistics.

Appendix B

Methodology of the Almost Ideal Demand System

Let W_i be the expenditure share of commodity i in total food expenditure, and is given by $W_i = \frac{P_i q_i}{X}$, where p_i and q_i are, respectively, the unit price and the quantity of commodity i purchased, and X is the total food expenditure. Therefore, $q_i = \frac{W_i X}{P_i}$. The own-price elasticity of commodity i is then given by

$$\varepsilon_{i,i} = \frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i} = -1 + \frac{\partial W_i}{\partial \log p_i} \frac{1}{W_i} \quad \text{----(1)}$$

In what follows, we derive expressions for $\frac{\partial W_i}{\partial \log p_i}$.

One-stage estimation

Let us first ignore the sample selection problem due to frequent zero observations on expenditure items. The expenditure share equation is given by

$$W_i = \alpha_i + \sum_j \gamma_{i,j} \log p_j + \beta_i \log(X / P) + u_i, \text{ for } i = 1, 2, \dots, 16,$$

where P is aggregate price level (which is the weighted average of the prices of 16 food categories constructed as a Laspeyres index, using the mean budget share of each commodity as weights), and j is all other commodities except i .

The above equation is augmented by household characteristics (standard in the literature) as

$$W_i = \alpha_i + \sum_k \eta_{i,k} d_{i,k} + \sum_j \gamma_{i,j} \log p_j + \beta_i \log(X / P) + u_i, \quad \text{---(2)}$$

for $i = 1, 2, \dots, 16$, where $d_{i,k}$ is k -th demographic characteristic. In our estimation, $d_{i,k}$ includes household size, age of the household head, number of dependents aged between 0-15 years, and two dummies for the origin of birth of the household head (Australian, and other English-speaking

countries, with the rest of the world as the base category). In addition, state dummies are also included to account for regional variation in consumption patterns.

In a system, the restriction that the expenditure shares add up to unity ($\sum_i W_i = 1$) requires that $\sum_i \alpha_i = 1$, $\sum_i \beta_i = 0$, $\sum_i \eta_{i,k} = 0$ and $\sum_k \gamma_{k,j} = 0$. The homogeneity restriction is satisfied by the condition $\sum_k \gamma_{j,k} = 0$, while the symmetry is satisfied by $\gamma_{i,j} = \gamma_{j,i}$.

From equation (2), it can be shown that $\frac{\partial W_i}{\partial \log p_i} = \gamma_{i,i}$. Therefore, the elasticity in equation

(1) is derived as

$$\varepsilon_{i,i} = \frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i} = -1 + \frac{\gamma_{i,i}}{W_i}, \quad \text{---(3)}$$

where W_i is evaluated at its mean value. The standard error of ε_i is derived by the delta method, which is commonly described in econometrics textbooks.

Two-stage estimation

To overcome the sample selection problem due to frequent zero observations on food expenditure items, the two-stage Heckman estimation is employed. In the first stage, the following equation is estimated

$$\begin{aligned} I_i &= \alpha_i + \sum_k \eta_{i,k} d_{i,k} + \sum_j \gamma_{i,j} \log p_j + \beta_i \log(X/P) + \delta_n NFE_n + e_i \\ &= \omega_i \Gamma_i + e_i, \end{aligned} \quad \text{---(4)}$$

where I_i is a binary variable indicating whether or not a consumer purchased the commodity i , and NFE_n is the total food expenditure of the n -th household. From the first-stage, inverse-Mills ratio is calculated as

$$\lambda_i = \frac{\phi(\omega_i \Gamma_i)}{\Phi(\omega_i \Gamma_i)} = \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \quad \text{-----(5)}$$

for $W_i > 0$ (or $I_i = 1$), and

$$\lambda_i = \frac{\phi_i(\cdot)}{1 - \Phi_i(\cdot)} \quad \text{----(6)}$$

for $W_i = 0$ (or $I_i = 0$). Here $\phi_i(\cdot)$ is the normal density function and $\Phi_i(\cdot)$ is the cumulative normal distribution. In the second-stage of the Heckman method, λ_i is included in equation (2):

$$W_i = \alpha_i + \sum_k \eta_{i,k} d_{i,k} + \sum_j \gamma_{i,j} \log p_j + \beta_i \log(X/P) + \varphi_i \lambda_i + u_i. \quad \text{---(7)}$$

Observe that NFE is not included in this model. Thus, we estimate a system of 16 equations (as in equation (7)) and calculate $\frac{\partial W_i}{\partial \log p_i}$, which is given by

$$\frac{\partial W_i}{\partial \log p_i} = \gamma_{i,i} + \varphi_i \frac{\partial \lambda_i}{\partial \log p_i} \quad \text{---(8)}$$

Suppose, θ_i is the proportion of consumers for which $W_i > 0$. Therefore, for $1 - \theta_i$, $W_i = 0$. Then we have

$$\frac{\partial \lambda_i}{\partial \log p_i} = \theta_i \left. \frac{\partial \lambda_i}{\partial \log p_i} \right|_{W_i > 0} + (1 - \theta_i) \left. \frac{\partial \lambda_i}{\partial \log p_i} \right|_{W_i = 0} \quad \text{----(9)}$$

$$\left. \frac{\partial \lambda_i}{\partial \log p_i} \right|_{W_i > 0} = -\gamma_{i,i} \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} + \left(\frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \right)^2 \right] \quad \text{---(10a)}$$

$$\left. \frac{\partial \lambda_i}{\partial \log p_i} \right|_{W_i = 0} = -\gamma_{i,i} \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{1 - \Phi_i(\cdot)} - \left(\frac{\phi_i(\cdot)}{1 - \Phi_i(\cdot)} \right)^2 \right]. \quad \text{---(10b)}$$

Substituting equations (8), (9), (10a) and (10b) into equation (1) and after some manipulation, we obtain the own-price elasticity as:

$$\varepsilon_{i,i} = -1 + \frac{\gamma_{i,i} \varphi_i}{W_i} \left\{ \frac{1}{\varphi_i} - \theta_i \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} + \left(\frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \right)^2 \right] - (1 - \theta_i) \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{1 - \Phi_i(\cdot)} - \left(\frac{\phi_i(\cdot)}{1 - \Phi_i(\cdot)} \right)^2 \right] \right\}. \quad \text{-----(11)}$$

Here, $\phi_i(\cdot)$, $\Phi_i(\cdot)$ and $\omega_i\Gamma_i$ are evaluated at the mean value of $\omega_i\Gamma_i$, and W_i is evaluated at its own mean value. Standard error of $\varepsilon_{i,i}$ is derived by the delta method. Comparing equations (3) and (11), it can be seen that the two-step estimation corrects the bias in the elasticity by the term

$$\varphi_i \left\{ \frac{1}{\varphi_i} - \theta_i \left[\omega_i\Gamma_i \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} + \left(\frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \right)^2 \right] - (1-\theta_i) \left[\omega_i\Gamma_i \frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} - \left(\frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} \right)^2 \right] \right\}.$$

It is important to mention that the elasticity formula in equation (11) includes all observations in the second stage regression. Therefore, we estimate unconditional elasticities. For conditional elasticity, ($\theta_i = 1$), the second stage regressions include only those sample households who purchased that particular commodity. Calculation of conditional elasticity in a system of equations may result in serious loss of degrees of freedom (even estimation may not be feasible) because of loss of observations, and therefore, we do not calculate those elasticities in this paper.

Cross-price elasticity

It is given by

$$\varepsilon_{i,j} = \frac{\partial q_i}{\partial p_j} \frac{p_j}{q_i} = \frac{\partial W_i}{\partial \log p_j} \frac{1}{W_i}, \quad \text{----(12)}$$

where

$$\frac{\partial W_i}{\partial \log p_j} = \gamma_{i,j} + \varphi_i \frac{\partial \lambda_i}{\partial \log p_j}. \quad \text{---(13)}$$

As before, we have

$$\frac{\partial \lambda_i}{\partial \log p_j} = \theta_i \frac{\partial \lambda_i}{\partial \log p_j} \Big|_{W_i > 0} + (1-\theta_i) \frac{\partial \lambda_i}{\partial \log p_j} \Big|_{W_i = 0}, \quad \text{----(14)}$$

$$\frac{\partial \lambda_i}{\partial \log p_i} \Big|_{W_i > 0} = -\gamma_{i,j} \left[\omega_i\Gamma_i \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} + \left(\frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \right)^2 \right], \quad \text{and} \quad \text{---(15a)}$$

$$\frac{\partial \lambda_i}{\partial \log p_i} \Big|_{W_i = 0} = -\gamma_{i,j} \left[\omega_i\Gamma_i \frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} - \left(\frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} \right)^2 \right]. \quad \text{---(16b)}$$

Substituting equations (13) to 15(b) into equation (12), we obtain the cross-price elasticity as:

$$\varepsilon_{i,i} = \frac{\gamma_{i,j}\varphi_i}{W_i} \left\{ \frac{1}{\varphi_i} - \theta_i \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} + \left(\frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \right)^2 \right] - (1-\theta_i) \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} - \left(\frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} \right)^2 \right] \right\}. \quad \text{-----(17)}$$

If Heckman correction is not made in the first-stage, then $\frac{\partial W_i}{\partial \log p_i} = \gamma_{i,j}$, and the (biased) cross-price elasticity will be given by

$$\varepsilon_{i,j} = \frac{\gamma_{i,j}}{W_i} \quad \text{---- (18)}$$

Expenditure elasticity

It is given by

$$\varepsilon_{e,i} = \frac{\partial q_i}{\partial X} \frac{X}{q_i} = 1 + \frac{\partial W_i}{\partial \log X} \frac{1}{W_i}, \quad \text{----(19)}$$

where

$$\frac{\partial W_i}{\partial \log X} = \beta_i + \varphi_i \frac{\partial \lambda_i}{\partial \log X}, \quad \text{----(20)}$$

$$\left. \frac{\partial \lambda_i}{\partial \log X} \right|_{W_i > 0} = \beta_i \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} + \left(\frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \right)^2 \right], \text{ and} \quad \text{---(21a)}$$

$$\left. \frac{\partial \lambda_i}{\partial \log X} \right|_{W_i = 0} = \beta_i \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} - \left(\frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} \right)^2 \right]. \quad \text{---(22b)}$$

Combining equations (19)-(22b), expenditure elasticity can be written as

$$\varepsilon_{e,i} = 1 + \frac{\beta_i \varphi_i}{W_i} \left\{ \frac{1}{\varphi_i} - \theta_i \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{\Phi_i(\cdot)} + \left(\frac{\phi_i(\cdot)}{\Phi_i(\cdot)} \right)^2 \right] - (1-\theta_i) \left[\omega_i \Gamma_i \frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} - \left(\frac{\phi_i(\cdot)}{1-\Phi_i(\cdot)} \right)^2 \right] \right\}. \quad \text{---(23)}$$

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How Price Affects the Demand for Food in Australia

— *An analysis of domestic demand elasticities for rural marketing and policy* —

by Mehmet Ulubasoglu, Debdulal Mallick, Mokhtarul Wadud, Phillip Hone and Henry Haszler

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This report provides estimates of the responsiveness of the quantity of food demanded to changes in food prices in Australia. The parameters reported measure longer run responsiveness at the household level and represent the first integrated set of food demand elasticities based on a highly disaggregated food demand system published in Australia.

The findings from this report will be of strategic significance to all those involved in the management and analysis of the Australian food and agricultural sectors including industry analysts, R&D bodies and policy analysts.

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