Public Health Monograph Series
No. 21
ISSN 1178-7139

PRICE ELASTICITIES FOR HEALTH ECONOMIC MODELLING OF FOOD PRICING INTERVENTIONS IN AUSTRALIA AND NEW ZEALAND

Burden of Disease Epidemiology, Equity and Cost-Effectiveness Programme (BODE[3])

Technical Report: Number 9

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November 2011

A technical report published by the Department of Public Health,
University of Otago, Wellington, New Zealand

ISBN 978-0-473-20292-7

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Acknowledgements

The authors thank their colleagues on the SPEND Project for helpful comments on the draft (Cliona Ni Mhurchu, Helen Eyles and Murat Genç) and also Steve Stillman (University of Otago, Dunedin). However, this acknowledgement does not imply agreement with all of the final text. This work receives funding support from the Health Research Council of New Zealand (the BODE^3 Programme, project number 10/248).

Statement of No Competing Interests

The authors declare that they have no competing interests.

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1. Abstract

Background: There is increasing international and national research and policy interest on the health impacts of changes in food prices. Such changes are occurring via the global food commodity market and such factors as agricultural impacts of climate change. But there is also increasing interest in the use of taxes on "unhealthy foods" and subsidies on "healthy foods". Quantitative modelling of these impacts requires both own-price elasticities (PEs; how consumption of a good changes with change in its own price) and cross-PEs (how consumption of a good changes with change in the price of another good).

Ideally, robust data would be present in NZ to generate PEs. Parallel work to BODE^3 is being undertaken by the SPEND project (Strategic Pricing: Effects on Nutrition and Disease, University of Auckland and University of Otago) to empirically estimate PEs using Household Economic Survey and Food Price Index data. However, these data are not yet available and will have various limitations (eg, by being prone to random error). Thus, the guiding principle of this Report is that by careful review and analysis of existing overseas studies, it should be possible to construct a plausible matrix of own- and cross-PEs (including guidance about their uncertainty) for initial use in BODE^3 modelling. It may also be possible to conceptualise the estimates arrived at in this report as 'priors' (in a Bayesian sense) for the empiric estimations of the SPEND project, or to revise the estimates provided in this report once the empiric estimates from SPEND are available.

Aims: This Technical Report aims to describe the more detailed methodology on how food own-PEs and cross-PEs were selected for health economic modelling analyses as part of NZACE-Prevention work (part of the BODE^3 Programme). This work considers pricing interventions in both NZ and Australia.

Methods: A total of 22 food categories of relevance to NZACE-Prevention modelling were specified. A literature review was performed and data sources covering PEs were prioritised according to: relevance to long-term elasticities; methodological clarity and quality; and inclusion of at least some cross-PE data. After identifying the best study, additional data from three other studies were utilised to estimate PEs for additional food categories of interest (with various systematic adjustments made). Cross-PEs were also obtained from the literature

(where available). Adjustments were made when there was good evidence that source data were likely to be over or under-estimates (eg, when datasets included multiple estimates for many countries, allowing a determination of systematic differences by country), or where there was incoherence between estimates. To all the results we applied a budgetary constraint (Cournot aggregation conditions) so that total weekly household food expenditure would remain unchanged in both the NZ and Australian settings (based on Household Economic Survey data).

Results: Existing appropriate Australia and NZ data were not identified and so a range of international data was considered. From 16 studies and datasets identified, we prioritised five studies. Additional selection (based on also having data on standard errors and income elasticities) resulted in the selection of a single UK study as a starting point for our estimations,[Ministry of Agriculture 2000] with other studies drawn upon as secondary sources.

Own-PEs: Focusing here on the NZ results, we were able to estimate own-PEs for 22 food categories of interest. These ranged from -0.14 to -1.09, for "potatoes and kumara" and "breakfast cereals", respectively. The own-PE for "fruit and vegetables" was: -0.69, and for soft drinks was: -0.78. PE estimations for items within the dairy group were from: -0.32 to -0.52; and for items within the meat group from: -0.39 to -1.06. All own-PEs for Australia were estimated to be 7% lower in absolute values than the NZ estimates.

Cross-PEs: These were also estimated and ranged from -0.72 for "poultry processed" and "pork processed" (ie, the consumption of processed poultry reduces by 0.72% for each 1% increase in price of processed pork); to 0.55 for "beef processed" and "pork fresh and unprocessed" (ie, conversely, the consumption beef processed goes up for 0.55% for each 1% increase in price of fresh pork. Cross-PEs values within the fresh and unprocessed meat group were between -0.72 and 0.40. Cross-PEs between butter and margarine, and between low fat and high fat milk, were all estimated as positive, ranging from 0.08 to 0.32, and from 0.23 to 0.41, respectively. All cross-PEs for Australia were estimated as 3% higher in absolute values than the NZ estimates.

Uncertainty: The PEs included in this report will be used for disease modelling, and are prone to uncertainty about their true values. This report does not provide definitive uncertainty intervals for every PE, not does it provide definitive instructions on how to model uncertainty in PEs. Rather, we provide options for later consideration, case-by-case, for intervention modelling.

Conclusions: It was possible to estimate plausible own- and cross-PEs using a combination of extracts from the international studies, combined with careful appraisal of the quality of studies and applicability to NZ and Australia and for our modelling requirements. Nevertheless, there are many limitations and assumptions with using such data and estimations, meaning that our best estimates may still be suboptimal. Hence the need for careful sensitivity analyses in later disease and economic decision modelling (and also for further research in both settings to derive more precise country-specific data). In addition to direct use in early BODE^3 modelling, the estimates in this report will be useful 'priors' for current direct empirical estimation being conducted by the SPEND study, using household economic survey and food price index data. BODE^3 modelling work may switch to, or incorporate, the updated SPEND estimates in due course.

2. Introduction

There is increasing international and national research and policy interest on the health impacts of changes in food prices. Such changes are occurring via the global food commodity market and such factors as agricultural impacts of climate change. But there is also increasing interest in the use of taxes on “unhealthy foods” and subsidies of “healthy foods”. Quantitative modelling of these impacts requires both own (how consumption of a good changes with change in its own price) and cross-price elasticities (PEs; how consumption of a good changes with change in the price of another good). Theoretically, the magnitude and direction of cross-PEs will vary depending on whether the two goods are complementary (eg, buying more bread might result in buying more butter) or substitutes (eg, buying more poultry might mean buying less beef). There are many existing international empiric estimates of own- and cross-PEs, but their applicability to NZ can be limited in many ways: PEs vary by time and place due to cultural trends in taste, what is considered essential, the presence or absence of substitute goods, etc; existing estimates use a range of methods (eg, cross-sectional data versus repeated time series data), different groupings of foods, and different mathematical or econometric models and assumptions; and existing estimates will have greater accuracy for predicting changes in consumption for small changes in price and in the short-run – changes in consumption arising from large changes in price and over the long-run are less easily predicted (but still of intense academic and policy interest) due to adaptive changes in society at ‘tipping points’ (eg, large increases in red meat price may precipitate large infrastructure investment and eventual cheaper production by the poultry industry). Nevertheless, an academic and policy priority remains to try and simulate the effects on human health of price changes in food.

Ideally, robust data (eg, data reflect actual prices paid by households for a disaggregated food items, and there are sufficient variations in prices) would be present in NZ to generate PEs. Parallel work to BODE[3] is being undertaken by the SPEND project (Strategic Pricing: Effects on Nutrition and Disease, University of Auckland and University of Otago) to empirically estimate PEs using Household Economic Survey (HES) and Food Price Index data. However, the data are not ideal (eg, need to aggregate two different types of data set and match them in terms of price and consumption for a given food item), and will be prone to random error (as with any study). Thus, the guiding principle of this Report is that by careful review and analysis of existing overseas studies, it should be possible to construct a matrix of own- and cross-PEs (including guidance about their uncertainty) for initial use in BODE^3 modelling. It may also be possible to conceptualise the estimates arrived at in this report as 'priors' (in a Bayesian sense) for the empiric estimations of the SPEND project, or to revise the estimates provided in this report once the empiric estimates from SPEND are available (for comparable food categories).

As part of NZACE-Prevention work (part of the BODE^3 Programme) we are exploring a range of food price interventions to protect population health. These may include such interventions as:

- applying a saturated fat tax (modelled on that used in Denmark)
- applying greenhouse gas taxes to meat and dairy products
- removing GST from fruit and vegetables (or a wider selection of healthy and/or staple foods)
- providing vouchers for healthy and/or staple foods
- applying a soft drink tax or sugary beverage tax (eg, at levels used in other OECD jurisdictions).

BODE^3 has a strong interest in modelling equity impacts (eg, differential cost-effectiveness by level of deprivation). In the domain of tobacco epidemiology and control, there is reasonably strong evidence that the change in consumption of cigarettes responds more strongly to tax increases among the young and low socio-economic groups, ie, the own price elasticity is differential by personal socioeconomic position.[Main et al. 2008] The accuracy and precision to measure such differential PEs (especially cross-PEs) across a range of food categories is very limited. Nevertheless, theory would reasonably suggest that PEs do vary by social group. We do not present such variation in this report, but do note the need to model this possibility in sensitivity analyses in subsequent disease and economic decision models using PEs.

All these interventions are likely to be modelled in the NZ setting, but some also in the Australian setting. To perform such modelling work it is necessary to include food PEs. Such information may also be of potential value for other research involving University of

Auckland and University of Otago researchers (the SPEND[1] Project), who are currently using direct empirical methods to estimate own- and cross-PEs for NZ using household economic survey and food price index data.

[1] Strategic Pricing: Effects on Nutrition and Disease, University of Auckland and University of Otago

3. Methods and Results

Methods on all aspects of the proposed food price interventions and modelling are detailed in separate BODE[3] Technical Reports (to be added to the BODE[3] website in early 2012). Here we focus on just the issues involved in estimating food own- and cross-PEs for use in modelling.

Food category selection: This was primarily driven by our interest in studying pricing interventions to reduce population level dietary salt and saturated fat consumption. Hence the food categories had to align with nutrition data from NZ's national nutrition survey, which will be used for estimating change in consumption/intake. Indeed, the 22 food categories shown in Table 4 (top to bottom) reflect the descending importance in terms of sources of salt intake to the NZ diet, albeit with some additional food categories added to the last few rows to enable modelling of other pricing interventions. These supplementary food categories were: cheese (as a source of saturated fat); "fruit and vegetables" (as a potential target for subsidies or GST removal); and "soft drinks" (as a potential target for specific excise taxes).

Literature review: Searches for publications and data on food PEs were performed using Medline and Google Scholar in May 2011. We also examined bibliographies of all those documents identified. We also searched OECD, FAO, and US Department of Agriculture (USDA) websites.

Prioritising data to use in the model: Limited data on food PEs in NZ were identified in two data sets (which are detailed further below).[Seale et al. 2005; Hansen and Brooks 2009a] An Australian study was identified but the authors of this work considered the results to be "preliminary" and the variances of the elasticity estimates were large.[Ulubasoglu et al. 2010] For these reasons we decided to consider the results of other international data for modelling work for both the Australian and NZ settings.

Studies on food PEs of relevance to OECD countries that we identified are shown in Table 1. Additional details about discussion in methods of bias of these studies are presented in Table 2. Additional details about elasticity database by Food and Agriculture Policy Research Institute (FAPRI) at Iowa State University[FAPRI 2011] are shown in Table 3.

To select the best single international study upon which to base the price intervention modelling work, we required it to: (i) involve long-run data (5+ years) since our interest was in long-term elasticities; (ii) involve a single method for calculating PEs (ie, we excluded datasets including multiple studies with varying methods); (iii) to include at least some cross-price elasticity data; and (iv) include many food categories.

From the studies detailed in Table 1 this resulted in the selection of just the following: two USA studies [Dharmasena and Capps 2011] [Reed et al. 2005], a UK one [Ministry of Agriculture 2000], one covering selected EU countries [Wirsenius et al. 2010], and another EU one [Bouamra-Mechemache et al. 2008].

We then applied additional selection criteria: (i) the study preferably had to include standard error estimates (2/5 studies); and (ii) the study had to have data on income elasticities (ie, how consumption varies with income, rather than just with price; 3/5 studies). Data about standard error estimates and income elasticities may be used in our later uncertainty and sensitivity analysis. This selection process just left the UK study [Ministry of Agriculture 2000].

This UK study employed the AIDS (Almost Ideal Demand System) demand model to estimate unconditional own- and cross-PEs for 20 food categories, using household data from 1988 to 2000 (Table 1; not updated since 2000 to our knowledge). “The AIDS demand system is derived from a utility function specified as a second-order approximation to any utility function. Demand is expressed in budget shares and uses the Stone geometric price index. Theoretical restrictions are applied directly to the parameters. This model allows testing of homogeneity and symmetry in estimating demand”.

“Unconditional PE” is a PE estimated from the demand system that uses the consumer's entire budget for all consumables – not just food. As this study employed long-term data (ie, data were obtained from the National Food Survey data for the period 1988– 2000 and were aggregated to the monthly level based on information from around 600 households with 92,930 households over the whole period) and the whole consumer’s budget, that would be suitable to our purposes of obtaining long-run PEs and modelling based on the total household budget. Moreover, this study broadly covered the particular food categories which were relevant to the price interventions of interest for our proposed modelling work.

Also of note with this particular study is that it included discussion around study limitations (which applied to only 2 out of the 5 studies in the final group) (Table 2). In particular, for own-PEs, estimations in this UK study were different compared to an earlier version of this UK work because of the inclusion of: cross-PEs, sampling variation, changes in consumers' tastes, relative prices and real incomes, food categories, and home food preparation technology. For cross-PEs, these UK estimates were, on the whole, small in magnitude because the study considered broad food categories (ie, the smaller the food categories, the more likely substitutes exist (eg, lamb for beef, rather that meat for cereals) with higher cross-PEs).

Furthermore, this UK study may have the most relevance to Australia and NZ, since the dietary pattern in these countries is probably more similar to that of the UK than the other countries (given the immigration history of Australia and NZ). Finally we note that other cost effectiveness modelling projects (for which we have some interest in comparability) have also used PE estimates from this same UK study [Sacks et al. 2010] [Nnoaham et al. 2009].

Table 1: Descriptions of studies identified with data on food PEs (OECD countries, with data covering at least five food categories)

	UK data	Systematic review	USDA median for USA[c]	Australian data	US dairy Report	UK data for meat	UK data for meat	US Report	USDA median for OECD[c]	USA	OECD from USDA - 144 countries	Selected EU	US	EU	UK	FAPRI
Reference	[Ministry of Agriculture 2000]	[Andreyeva et al. 2010]	[Hansen and Brooks 2009a]	[Ulubasoglu, Mallick et al. 2010]	[Davis et al. 2010]	[Tiffin and Tiffin 1999]	[Burton and Young 1992]	[Smith et al. July 2010]	[Hansen and Brooks 2009a]	[Dharmasena and Capps 2011]	[Seale, Jr. et al. 2005]	[Wirsenius, Hedenus et al. 2010]	[Reed, Levedahl et al. 2005]	[Bouamra-Mechemache, Réquillart et al. 2008]	[Tiffin and Arnoult 2008]	[FAPRI 2011]
Date of data collection/publication	2000	2007	2000-2006	2010[a]	2007	1999	1991	2010	2000-2006	2011[a]	2005	2010[a]	2005[a]	2008[a]	2008[a]	Unknown
Data available on at least some cross-PEs?	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Were any cross-PEs imputed?	No	No	No	No	No	No	No	No	No	No	No	Yes	No	Yes	No	No
Time frame for calculating PEs?	1988-2000	1938-2007[b]	many studies	1998/99 and 2003/04	2007	1972-1994	1961-1987	1998-2007	many studies	1998-2003	2005	1991-2002, 1958-93, 1989-98, 1960-94	1982 to 2000	1959-1997	2003/2004	Unknown
Data on income elasticities?	Yes	No	Yes	No	No	No	No	No	Yes	No	No	No	Yes	Yes	No	Yes
Data on overall food expenditure elasticities?	No	No	No	Yes	Yes	Yes	Yes	Yes	No		Yes	No	No	No	Yes	No
Demand models	AIDS[2]	Mixed[3]	Mixed[4]	LA/AIDS[5]	AIDS	AIDS	AIDS	AIDS	Mixed[6]	LA/QUAIDS[7]	The Florida[8] model[9]	AIDS	SAI[10]	Mixed[11]	LA/AID	Unknown

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[2] "The AIDS (An Almost Ideal Demand System) demand system is derived from a utility function specified as a second-order approximation to any utility function. Demand is expressed in budget shares and uses the Stone geometric price index. Theoretical restrictions are applied directly to the parameters. This model allows testing of homogeneity and symmetry in estimating demand. For reference, see Deaton and Muellbauer, "An Almost Ideal Demand System," *Econometrica*, Vol. 70, 1980, pp. 312-336." Hansen J, Brooks N. (2009b). "Commodity and Food Elasticities: Glossary." Retrieved 14/07, 2011, from http://www.ers.usda.gov/Data/Elasticities/glossary.htm.

[3] There are 160 studies were used and their demand models are not reported in this review.

[4] Demand models used in the USDA data set include AIDS, Translog, Rotterdam Model, LES (Linear Expenditure System), and Florida Model.

Translog is "known as a flexible functional form. The indirect translog model approximates the indirect utility function by quadratic form in the logarithms of the price-to-expenditure ratios. These demand equations are homogenous of degree zero. A limitation in this model is the large number of parameters to be estimated. For reference, see Christensen, Jorgenson, and Lau, "Transcendental Logarithmic Utility Function," *American Economic Review*, Vol. 70, 1975, pp. 422-432." Hansen J, Brooks N. (2009b). "Commodity and Food Elasticities: Glossary." Retrieved 14/07, 2011, from http://www.ers.usda.gov/Data/Elasticities/glossary.htm.

Rotterdam Model "was developed by Theil and Barten and has been used frequently to test economic theory. The model is not in logarithms but works in differentials. Theoretical restrictions are applied directly to the parameters. For references, see A.P. Barten, Theorie en empirie van een volledig stelsel van fraagvergelijkingen, doctoral dissertation, 1966, University of Rotterdam, Rotterdam, the Netherlands; and Theil, "The Information Approach to Demand Analysis," *Econometrica*, Vol. 33, 1965, pp. 67-87."

LES (Linear Expenditure System) "The LES demand system is derived from the Stone-Geary utility function and is a general linear formulation of demand and algebraically imposed theoretical restrictions of additivity, homogeneity, and symmetry. The LES is best used to estimate demand for goods with independent marginal utilities such as large baskets of goods or large categories of expenditures such as clothing, housing, food, and durables. For reference, see J.R.N. Stone, "Linear Expenditure System and Demand Analysis: An Application to the Pattern of British Demand," *Economic Journal*, Vol. 64, 1954, pp. 511-527."

[5] A linear approximation of the AIDS demand system.

[6] Types of demand models are similar to (but may be less than) the ones explained for the USDA for USA (in the previous footnote).

[7] This is a linear approximation to the QUAIDS (the Quadratic Almost Ideal Demand System) model developed by Banks et al. Banks J, Blundell R, Lewbel A, (1997). Quadratic Engel curves and consumer demand. Review of Economics and Statistics. 79:527-539.. The QUAIDS is "a new class of demand systems that have log income as the leading term in an expenditures hare model and additional higher order income terms .This preserves the flexibility of the empirical Engel curve findings while permitting consistency with utility theory and is shown to provide a practical specification for demands across many commodities, allowing flexible relative price effects." Banks J, Blundell R, Lewbel A, (1997).

	UK data	Systematic review	USDA median for USA[c]	Australian data	US dairy Report	UK data for meat	UK data for meat	US Report	USDA median for OECD[c]	USA	OECD from USDA - 144 countries	Selected EU	US	EU	UK	FAPRI
															S IPM	
Type of elasticities[12]	Unconditional	Uncompensated[13]	Mixed	Conditional	Uncompensated	Conditional & Uncompensated/compensated	Long- & short run, uncompensated /compensated	Conditional and uncompensated	Mixed	Uncompensated	Unconditional	Not specified	Unconditional	Mixed	Not specified	
Includes Australian or NZ data?	No	No	No	Australian	No	No	No	No	Both	No	Both	No	No	No	No	Yes
Data on standard error (ie, random error) or systematic error (eg, as an uncertainty interval)	Yes	Yes	No	Yes (the z-statistics)	No	No	Yes	Yes	No	No	No	No	No	Yes	Yes (2.5%: 97.5%)	No
Example SE/SD range for least elastic product	Fresh potatoes (-0.17 to -0.07)	Eggs (-1.5 to 0.96); Cheese (-1.67 to 0.79)	No	Not in SE/SD form	No	No	Pork (-0.85 to -1.3)	Low-fat milk (-0.44 to -0.98)	No	No	No	No	No	Drinking milk (-0.96 to -0.1)	Dairy (-0.136:-0.315)	-
Discusses bias (in *Methods*)	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	No	No	No	No	No	No

[a] This is the date of publication since date of data collection is not available. [b] This time frame is the published time of the studies used in this systematic review. [c] This dataset includes 14 studies with 33 countries with different demand systems employed and different types of elasticities estimated.

Quadratic Engel curves and consumer demand. Review of Economics and Statistics. 79:527-539. This model keeps all the desirable properties of the AIDS models, while allows good to be luxuries or necessities depending on income levels Dharmasena S, Capps J, (2011). Intended and unintended consequences of a proposed national tax on sugar sweetened beverages to combat the US obesity problem. Health Economics. Banks J, Blundell R, Lewbel A, (1997). Quadratic Engel curves and consumer demand. Review of Economics and Statistics. 79:527-539..

[8] The demand model that employed a differential approach and assumed weak separability.

[9] This model combines the core of the AIDS model with the differential approach and separability attributes of the Rotterdam model. This model overcomes several disadvantages of the AIDS models, ie, parameters in the AIDS model are non-linear and are difficult to estimate, negativity is not satisfied at all data points, and separability is not nested in the general specification. It also has fewer parameters to be estimated than in the AIDS model Theil H, Chung CF, Seale JL (1989). International evidence on consumption patterns, Jai Press..

[10] "The SAI demand system is a re-parameterization of the Almost Ideal (AI) demand system (Deaton and Muellbauer). Thus, it describes nonlinear Engle curves, defines community income and exact nonlinear aggregation over consumers, and defines budget shares and income elasticities for income inelastic goods, such as food, that decline as incomes rise. Moreover, the SAI demand system saves degrees of freedom while maintaining curvature at a point in the data" Reed AJ, Levedahl JW, Hallahan C, (2005). The generalized composite commodity theorem and food demand estimation. American Journal of Agricultural Economics. 87:28-37.

[11] This study summarizes the literature about PEs for dairy products in EU. There are different demand models are employed, eg, LA/AIDS, QUAIDS, and Double-log. "The double-log demand equation is obtained by taking logs of both sides of a multiplicative demand equation. The convenient property of double-log demand is that the parameters directly measure the price elasticity of demand." Hansen J, Brooks N. (2009b). "Commodity and Food Elasticities: Glossary." Retrieved 14/07, 2011, from http://www.ers.usda.gov/Data/Elasticities/glossary.htm.

1. [12] Hicksian or Compensated Demand "The Hicksian demand function (after British economist Sir John R. Hicks) shows the relationship between the price of a good, P1, and the quantity purchased on the assumption that other prices, P2, and utility, U0, are held constant. This consumer demand function is obtained by minimizing the consumer's expenditures subject to the constraint that his/her utility (the satisfaction a consumer derives from a particular market basket) is fixed at level U0." Ibid. Marshallian, Ordinary, or Uncompensated Demand "The Marshallian demand function (after British economist Alfred Marshall) shows the relationship between the price of a good, P1, and the quantity purchased, Q1, on the assumption that other prices, P2, and the consumer's budget (or income), Y0, is held constant. The demand function is obtained by maximizing the consumer's utility subject to the constraint that the customer's budget is fixed at the level Y0 and so are other prices."
2. Conditional Demand: "Conditional demand is derived from using a subset of the consumer's total budget. An example would be estimating food demand using the budget only for food. The demand is conditional upon the food budget and not the entire budget."

Unconditional Demand: "Unconditional demand is a demand system that uses the consumer's entire budget."

Note that other cost effectiveness modelling projects have used unconditional price elasticities Sacks G, Veerman JL, Moodie M, Swinburn B, (2010). 'Traffic-light' nutrition labelling and 'junk-food' tax: a modelled comparison of cost-effectiveness for obesity prevention. Int J Obes (Lond). [E-publication 17 November].

[13] The difference between the compensated (Hicksian) and uncompensated (Marshallian) demand is that the compensated demand is about "pure" substitution effects. That is, the income effects caused by price changes are eliminated.

Table 2: Additional details of discussion of bias (in the methods) for those studies in Table 1 that had some consideration of bias[14]

Sources	**Reference**	**Discussion of bias (*Methods Sections*)**
UK data	[Ministry of Agriculture 2000]	For own-PEs, estimations in this report are different compared to its earlier version because: no cross-PEs were considered in the earlier report, sampling variation; and changes in consumers' tastes, relative prices and real incomes, food categories, and home food preparation technology. For cross-PEs, these estimates are generally small in magnitude because the study considered broad food categories, rather than more disaggregated groups with greater substitutability (eg, whole with low-fat milk, as opposed to dairy with cereals).
Systematic review data	[Andreyeva, Long et al. 2010]	For example, the authors found "type of demand model, data, peer review status (ie, peer review versus no peer review), study size (multiple versus single categories of foods), and time of data analysis were not significantly related to the estimates in beef analyses". There was no significant variation in the PE estimations for pork, cheese, and vegetables among different study methodologies.
Australian data	[Ulubasoglu, Mallick et al. 2010]	For example, they used cross-sectional data and so their PE estimations are likely to capture long-run elasticities and are higher than previous Australia ones which used time series household data. Their PEs estimations for rice, bread, milk, and fresh vegetable are reasonably close to other studies in US, Canada, and Japan which adopted AIDS and household cross-sectional data. However, their estimations for meat are higher in absolute values than these studies (possibly due to diet differences).
UK data for meat	[Burton and Young 1992]	These authors mainly discuss about changing consumer tastes. Long-term PEs are normally more elastic than short-term ones.
USA	[Dharmasena and Capps 2011]	For example, their data set included a richer delineation of non-alcoholic beverages, thus own-PEs are larger in magnitude than those using an aggregation beverage category. This is because aggregated PEs cannot show the substitutability and complementarity among beverage sub-categories. Additionally, they used monthly data set over a 6-year span, of which they argued that is "more immune to effects from structural change compared to the studies employing annual time-series over a 30-year period".
OECD from USDA for 144 countries	[Seale, Jr. et al. 2005]	While these authors discuss the advantages of their model over others, there is actually no specific discussion of how their methods may bias their results.

[14] Methods of bias refer how the chosen methods impact the estimated price elasticities.

Table 3: Additional details of food PEs from FAPRI (Food and Agriculture Policy Research Institute) database[15]

Country	Butter	Cheese	Beef and veal	Pork	Poultry
EU[16]	-0.29	-0.18	No data	No data	No data
Australia	-0.1	-0.36	-0.22	-0.25	-0.26
NZ	-0.11	-0.79	-0.22	-0.39	-0.31
UK for NZACE[17]	*-0.45*	*-0.35*	*-0.91 (fresh)*	*-0.73 (fresh)*	*-0.42 (fresh)*

Additions to the baseline UK data: Since the selected UK study did not cover all food categories of interest to us, we used data from other studies to fill in the gaps. Table 4 shows food own-PEs identified for potential use in modelling work with studies in declining priority moving from left to right (and ordered by food categories of particular relevance to dietary salt intake and saturated fat intake for Australia and NZ). Own-PEs show how quantity purchased (%) of a food item changes as its price increases 1%. We used those studies with data in the missing food categories and selected data from these studies (prioritised according to study quality and relevance): a systematic review[Andreyeva, Long et al. 2010], USDA data for the USA[Hansen and Brooks 2009a], and Australian data (for one data point) [Ulubasoglu, Mallick et al. 2010]. Data points that were used in our modelling are shown in bold and larger font size. Furthermore, for the USDA data which involved multiple studies, we calculated median values.

As shown in Table 4, own-PEs for around half (11/22) of the food categories were taken from the key UK study (eg, breads, cheese, and fruit and vegetables). For the meat group, since the key UK study only reported PE estimations of -0.69 for carcase meats, and of -0.52 for other meats, we used data from the USDA median for USA [Hansen and Brooks 2009a]. This dataset showed different patterns of PEs for processed meats and fresh meats as expected. We also used PE values by the USDA median for USA for the dairy group since they reported a

[15] This is a different database from the USDA one. The USDA compiles their PE values from different studies outside their projects, while this database uses PE values generated from the FAPRI model estimates. This database reports own price (from both demand and supply sides) and income elasticities. Sometimes short-term and long-term PEs are reported. PEs values in the FAPRI database are much lower than our estimated UK values.

[16] No information could be found about how many EU countries were in this category.

[17] These are PE values after adjustments were made for the UK from the systematic review, the USDA data, and the Australia study. See Table 5 and its associated text for more details.

complete set of PEs values for the dairy group (ie, whole milk, low-fat milk, dairy products, butter, and margarine), and covered broad food categories (eg, breads, meats, and cheese). However, since the own-PE for dairy products (-0.05) was very low compared to that of other studies reported, we used instead the more credible own-PE (of -0.65) identified in the systematic review [Andreyeva, Long et al. 2010]. Finally, we used the own-PE for lamb reported by the Australian study [Hansen and Brooks 2009a]. One exception to the above was that for the soft drink category. The UK data (-0.37) was not specific enough as it covered “non-alcoholic beverages”, which included both soft drinks and other drinks, eg, fruit juices. Thus we used the own-PEs from the US systematic review [Andreyeva, Long et al. 2010] which was -0.79 for soft drinks (though we may consider using other values from more recent work in the sensitivity analysis as per Appendix 1).

Another exception to the above was that the single positive own-PE value obtained for “sauces” in the USDA data[Hansen and Brooks 2009a] (at +0.22). This was considered to be implausibly high, given that it is fairly unusual for robust food PEs of demand to be positive. The exceptions are rare (eg, Veblen goods and also Giffen goods in the economic literature), both of which are highly unlikely to apply to sauces. So we substituted the value calculated for all “Other” foods in the UK data set (ie, -0.39).

Table 4: Food PEs identified for potential use in modelling work with studies in declining priority moving from left to right (and ordered by food categories of particular relevance to dietary salt intake and saturated fat intake for NZ and Australia)[18]

Food categories	UK data [Ministry of Agriculture 2000]	Systematic review data [Andreyeva, Long et al. 2010]	USDA median for USA [Hansen and Brooks 2009a]	Australian data [Ulubasoglu, Mallick et al. 2010]	USDA median for OECD [Hansen and Brooks 2009a]	USA [Dharmasena and Capps 2011]	OECD from USDA for 144 countries [Seale, Jr. et al. 2005]	US Report [Davis, Dong et al. 2010]	Selected EU [Wirsenius, Hedenus et al. 2010]	US [Reed, Levedahl et al. 2005]	UK [Tiffin and Arnoult 2008]	EU [Bouamra-Mechemache, Réquillart et al. 2008]
1) Breads	***-0.4***		-0.25	-0.733	-0.16						-0.524 bread, cereals, pots	
Processed meats and sausages												
2) Pork	-0.52 other meat	-0.72	***-0.69***						-0.8			
3) Poultry		-0.68	***-0.40***						-1			
4) Beef		-0.75	***-0.78***						- 1.3 ruminant meat			
Other												
5) Potatoes & kumara	***-0.12***		-0.99									
6) Sauces	***-0.39***				0.22							
7) Breakfast cereals	***-0.94*** other cereal		-0.54				-0.042 cereals			-0.606 cereal & bakery		
Meat and poultry (fresh & unprocessed)												
8) Beef & veal	-0.69 carcase meat	-0.75	***-0.86***	-1.353			-0.369 meats			-0.605 meats	-0.859 meats, fish	
9) Poultry		-0.68	***-0.40***	-1.388								
10) Pork		-0.72	***-0.69***	-2.203								
11) Lamb/ mutton				***-1.420***								
Other												
12) Cakes, muffins and biscuits	***-0.94*** other cereal	-0.81 take-aways	0.35									
13) Bread-based dishes	***-0.94*** other	-0.81 take-aways										

[18] Data points that were used in our modelling works are shown in bold, italics and yellow highlight. There are various limitations with the selection of these food categories (which are discussed in another BODE[3] Technical Report – to be published on the BODE[3] website - www.uow.otago.ac.nz/BODE3-info.html).

Food categories	UK data [Ministry of Agriculture 2000]	Systematic review data [Andreyeva, Long et al. 2010]	USDA median for USA [Hansen and Brooks 2009a]	Aust-ralian data [Ulubasoglu, Mallick et al. 2010]	USDA median for OECD [Hansen and Brooks 2009a]	USA [Dharmasena and Capps 2011]	OECD from USDA for 144 countries [Seale, Jr. et al. 2005]	US Report [Davis, Dong et al. 2010]	Selected EU [Wirsenius, Hedenus et al. 2010]	US [Reed, Levedahl et al. 2005]	UK [Tiffin and Arnoult 2008]	EU [Bouamra-Mechemache, Réquillart et al. 2008]
	cereal											
Milk and dairy												
14) Milk-whole	-0.36	-0.59	***-0.73***	-0.233		-0.7591		-1.51				-0.53
15) Milk-low fat/trim/skim			***-0.78***			-0.9237		-1.57				
16) Dairy products	-	***-0.65***	-0.05	-0.999	-0.30		-0.382	-1.21	-0.5	-0.861	-0.202 milk & dairy	-0.57
Butter & margarine												
17) Butter	-	-0.65	***-1.15***				-0.09 oils & fats	-1.87			-0.525 fats	-0.47
18) Margarine	-		***-0.71***	-1.696				-0.95				
Other												
19) Pies and pasties	***-0.94*** other cereal	-0.81 take-aways										
20) Cheese	***-0.35***	-0.44	-0.88					*-1.68*				-0.6
21) Fruit & vegetables	***-0.60***[19]	-0.64	-0.52	-0.7875	-0.66		-0.241			-0.979	-0.71	
22) Soft drinks	-0.37	***-0.79***	0.07			-1.763	-0.462 Beverages & Tobacco					
23) Other	***-0.39***[20]		0.11		-0.33		-0.480					

[19] This is the median value for five categories of fruit and vegetables (excluding potatoes).

[20] This is the median own-price elasticity value for all food categories in the UK data.

Scaling factors for own-PEs: When adapting own-PEs taken from other studies (ie, the US systematic review, the USDA data for the USA, and the Australian study), adjustments were made for the differences in methodologies applied with respect to those of the UK study. That is, we treated the UK estimates as broadly accurate (ie, our expectation was that the UK estimates were likely to be too high 50% of the time, and too low 50% of the time, and therefore on average broadly 'correct'). We also assumed that even if other studies' data are not accurate for each point estimate, they are reasonable at giving relative differences between food categories in their PEs. We assumed that PE values in different studies share a systematic expectation to be higher or lower than other studies, and hence we developed scaling factors.

Table 5 shows the PE data points, their scaling factor, and the final own-PEs adjusted to the UK context (far right column). In the UK data column, PE values with yellow colour (light grey cell shading) were used directly in the final PE estimations, and values with orange colour (dark grey cell shading) were used as indicator points to adjust PE values from other studies. In the columns in Table 5 that report PEs for the non-UK studies, PE values with blue colour (light grey cell shading) were adjusted to the UK context by multiplying with a scaling factor. These were PEs values for processed meats and sausages, fresh and unprocessed meats and poultry, milk and dairy, and butter and margarine.

A scaling factor of a food category was calculated by dividing the mean of the key UK PEs for this food category by that of the PEs of the other study (ie, the study from which data is to be adjusted relative to the UK data). For example, a calculated scaling factor for processed meats and sausages was 0.83 and with this scaling factor, we still preserved the PE value for other meats by the UK data (that is, the average of adjusted PEs equals -0.52), while borrowing the pattern of price responsiveness for the processed meat group by the USDA data. Similarly, scaling factors ranged from 0.39 to 1.06 for lamb, fresh and unprocessed meats, milk and dairy, and butter and margarine. One exception to this approach was that for the soft drink category. As mentioned in the previous section, we used the own-PEs from the US systematic review [Andreyeva, Long et al. 2010], which was -0.79 for soft drinks, and adjusted it using a scaling factor of 0.85. This factor was the ratio of the mean of the UK data over that of the US systematic review data. Only food items that appeared in both the UK and the US data were included in the calculation of the means.

Table 5: Food PEs adjusted from various other studies to the UK context[21]

Food categories	*Price elasticity category from UK data (Table 11)*	*UK data*	*Systematic review data*	*Median for USDA*	*Australian data*	Scaling factors for PEs taken from studies other than [Ministry of Agriculture 2000]	*Final UK estimations* (Adjusted value in bold and italics)
Reference:	[Ministry of Agriculture 2000]	[Ministry of Agriculture 2000]	[Andreyeva, Long et al. 2010]	[Hansen and Brooks 2009a]	[Ulubasoglu, Mallick et al. 2010]		
1) Breads	"18 Bread"	-0.4		-0.25	-0.733		-0.4
Processed meats and sausages							
2) Pork	"4 Other meat…"	-0.52	-0.72	-0.69		0.83	***-0.58***
3) Poultry	"4 Other meat…"	-0.52	-0.68	-0.4		0.83	***-0.33***
4) Beef	"4 Other meat…"	-0.52	-0.75	-0.78		0.83	***-0.65***
Other							
5) Potatoes & kumara	"12 Fresh potatoes"	-0.12		-0.99			-0.12
6) Sauces	Median of all results in Table 6.2 of UK report	-0.39					-0.39
7) Breakfast cereals	"19 Other cereals…."	-0.94		-0.54			-0.94
Meat and poultry (fresh & unprocessed							
8) Beef & veal	"3 Carcase meat"	-0.69	-0.75	-0.86	-1.353	1.06	***-0.91***
9) Poultry	"3 Carcase meat"	-0.69	-0.68	-0.4	-1.388	1.06	***-0.42***
10) Pork	"3 Carcase meat"	-0.69	-0.72	-0.69	-2.203	1.06	***-0.73***
11) Lamb/mutton	"3 Carcase meat"	-0.69			-1.42	0.43	***-0.62***
Other							
12) Cakes, muffins and biscuits	"19 Other cereals…."	-0.94	-0.81	0.35			-0.94
13) Bread-based dishes	"19 Other cereals…."	-0.94	-0.81				-0.94
Milk and dairy							
14) Milk-whole	"1 Milk & cream"	-0.36	-0.59	-0.73	-0.233	0.48	***-0.35***
15) Milk-low fat/trim/skim	"1 Milk & cream"	-0.36		-0.78		0.48	***-0.37***
16) Dairy products	"1 Milk & cream"	-0.36	-0.65	-0.05	-0.999	0.58	***-0.38***
Butter and margarine							
17) Butter	"1 Milk & cream"	-0.36	-0.65	-1.15		0.39	***-0.45***
18) Margarine	"1 Milk & cream"	-0.36		-0.71	-1.696	0.39	***-0.27***
Other							
19) Pies and pasties	"19 Other cereals…."	-0.94	-0.81				-0.94

[21] In the UK data column, PE values with yellow colour (light grey cell shading) were used directly in the final table of PEs for use in the modelling, and values with orange colour (dark grey cell shading) were used as indicator points to adjust PE values from other studies. In the columns that reported PEs for other studies, PE values with blue colour (light grey cell shading) were adjusted to the UK context by multiplying with a scaling factor.

Food categories	Price elasticity category from UK data (Table 11)	UK data	Systematic review data	Median for USDA	Australian data	Scaling factors for PEs taken from studies other than [Ministry of Agriculture 2000]	Final UK estimations (Adjusted value in bold and italics)
Reference:	[Ministry of Agriculture 2000]	[Ministry of Agriculture 2000]	[Andreyeva, Long et al. 2010]	[Hansen and Brooks 2009a]	[Ulubasoglu, Mallick et al. 2010]		
20) Cheese	"2 Cheese"	-0.35	-0.44	-0.88			-0.35
21) Fruit & vegetables	Median value from items 13-17 in Table 6.2 of UK report	-0.6	-0.64	-0.52	-0.7875		-0.60
22) Soft drinks	"20 Beverages"	-0.37	-0.79	0.07		0.85[22]	***-0.67***
23) Other	Median of all results in Table 6.2 of UK report	-0.39		0.11			-0.39

Cross-PEs: Table 6 reports own- and cross-PEs, which were either taken from the key UK study [Ministry of Agriculture 2000] (cells without shading), or adjusted/assumed (cells with shading). Own-PEs, which show how quantity purchased (%) of a food item changes as its price increases 1%, are shown in cells with larger font size, dark bordered, and no shading. Cross-PEs show how quantity of a food item (name shown in the far left column) changes (%) with respect to a 1% increase in price of another food item (name shown in the top row). Cross-PEs that are positive indicate that two food items are substitute goods, that is when price of one food item rises, purchased quantity of the other food item also increases. Positive cross-PEs are presented in bold cells. Negative cross-PEs, on the other hand, indicate that two foods are complementary, that is when price of one food items goes up, the purchased quantity of the other food item goes down. Examples of substitute foods from our results were butter and margarine, and of complementary foods were bread and butter.

[22] This factor (0.85) was the ratio of the mean of the UK data over that of the US systematic review data. Only food items that appeared in both the UK and the US data were included in the calculation of the means.

Table 6: Own- and cross-PEs adjusted for the UK setting

Food items	PRICE:	Bread	Pork processed	Poultry processed	Beef processed	Potatoes & kumara	Sauces	Breakfast cereals	Beef & veal fresh*	Poultry*	Pork*	Lamb/mutton*	Cakes, muffins etc	Bread-based dishes	Milk-whole	Milk-low fat	Dairy products	Butter	Margarine	Pies & pasties	Cheese	Fruit & vegetables	Soft drinks	Other
QUANTITY	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bread	1	-0.40	0.03	0.03	0.03	0.00	-0.03	0.07	-0.07	-0.07	-0.07	-0.07	0.07	0.07	-0.07	-0.07	-0.07	-0.07	-0.07	0.07	0.36	-0.04	0.22	-0.03
Pork processed	2	0.11	-0.58	-0.24	0.24	-0.11	-0.01	0.27	0.53	0.53	0.53	0.53	0.27	0.27	-0.14	-0.14	-0.14	-0.14	-0.14	0.27	0.10	-0.04	0.02	-0.01
Poultry processed	3	0.11	-0.37	-0.33	0.75	-0.11	-0.01	0.27	0.53	0.53	0.53	0.53	0.27	0.27	-0.14	-0.14	-0.14	-0.14	-0.14	0.27	0.10	-0.04	0.02	-0.01
Beef processed	4	0.11	0.09	0.25	-0.65	-0.11	-0.01	0.27	0.53	0.53	0.53	0.53	0.27	0.27	-0.14	-0.14	-0.14	-0.14	-0.14	0.27	0.10	-0.04	0.02	-0.01
Potatoes & kumara	5	0.00	-0.01	-0.01	-0.01	-0.12	-0.01	-0.02	0.04	0.04	0.04	0.04	-0.02	-0.02	-0.05	-0.05	-0.05	-0.05	-0.05	-0.02	-0.08	-0.02	0.13	-0.01
Sauces	6	-0.02	0.00	0.00	0.00	-0.01	-0.39	-0.02	0.02	0.02	0.02	0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.01	0.00	0.01	0.00
Breakfast cereals	7	0.15	0.18	0.18	0.18	-0.09	-0.05	-0.94	-0.05	-0.05	-0.05	-0.05	0.10	0.10	-0.05	-0.05	-0.05	-0.05	-0.05	0.10	0.07	-0.13	-0.54	-0.05
Beef & veal*	8	-0.12	0.26	0.26	0.26	0.19	0.08	-0.03	-0.91	0.25	0.09	0.06	-0.03	-0.03	0.05	0.05	0.05	0.05	0.05	-0.03	-0.02	-0.09	0.34	0.08
Poultry*	9	-0.12	0.26	0.26	0.26	0.19	0.08	-0.03	0.75	-0.42	-0.37	0.00	-0.03	-0.03	0.05	0.05	0.05	0.05	0.05	-0.03	-0.02	-0.09	0.34	0.08
Pork*	10	-0.12	0.26	0.26	0.26	0.19	0.08	-0.03	0.24	-0.24	-0.73	0.03	-0.03	-0.03	0.05	0.05	0.05	0.05	0.05	-0.03	-0.02	-0.09	0.34	0.08
Lamb/mutton*	11	-0.12	0.26	0.26	0.26	0.19	0.08	-0.03	0.28	0.19	0.19	-0.62	-0.03	-0.03	0.05	0.05	0.05	0.05	0.05	-0.03	-0.02	-0.09	0.34	0.08
Cakes, muffins etc	12	0.15	0.18	0.18	0.18	-0.09	-0.05	0.10	-0.05	-0.05	-0.05	-0.05	-0.94	0.10	-0.05	-0.05	-0.05	-0.05	-0.05	0.10	0.07	-0.13	-0.54	-0.05

Food items	PRICE:	Bread	Pork processed	Poultry processed	Beef processed	Potatoes & kumara	Sauces	Breakfast cereals	Beef & veal fresh*	Poultry*	Pork*	Lamb/mutton*	Cakes, muffins etc	Bread-based dishes	Milk-whole	Milk-low fat	Dairy products	Butter	Margarine	Pies & pasties	Cheese	Fruit & vegetables	Soft drinks	Other
QUANTITY	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bread-based dishes	13	0.15	0.18	0.18	0.18	-0.09	-0.05	0.10	-0.05	-0.05	-0.05	-0.05	0.10	-0.94	-0.05	-0.05	-0.05	-0.05	-0.05	0.10	0.07	-0.13	-0.54	-0.05
Milk-whole	14	-0.14	-0.09	-0.09	-0.09	-0.24	-0.07	-0.05	0.04	0.04	0.04	0.04	-0.05	-0.05	-0.35	0.70	0.01	0.09	-0.08	-0.05	0.34	-0.02	-0.07	-0.07
Milk-low fat	15	-0.14	-0.09	-0.09	-0.09	-0.24	-0.07	-0.05	0.04	0.04	0.04	0.04	-0.05	-0.05	0.26	-0.37	0.00	0.08	-0.03	-0.05	0.34	-0.02	-0.07	-0.07
Dairy products	16	-0.14	-0.09	-0.09	-0.09	-0.24	-0.07	-0.05	0.04	0.04	0.04	0.04	-0.05	-0.05	0.05	0.23	-0.38	-0.01	0.12	-0.05	0.34	-0.02	-0.07	-0.07
Butter	17	-0.14	-0.09	-0.09	-0.09	-0.24	-0.07	-0.05	0.04	0.04	0.04	0.04	-0.05	-0.05	0.23	0.46	-0.01	-0.45	0.31	-0.05	0.34	-0.02	-0.07	-0.07
Margarine	18	-0.14	-0.09	-0.09	-0.09	-0.24	-0.07	-0.05	0.04	0.04	0.04	0.04	-0.05	-0.05	-0.11	0.07	0.00	0.08	-0.27	-0.05	0.34	-0.02	-0.07	-0.07
Pies & pasties	19	0.15	0.18	0.18	0.18	-0.09	-0.05	0.10	-0.05	-0.05	-0.05	-0.05	0.10	0.10	-0.05	-0.05	-0.05	-0.05	-0.05	-0.94	0.07	-0.13	-0.54	-0.05
Cheese	20	0.24	0.02	0.02	0.02	-0.13	0.02	0.02	-0.01	-0.01	-0.01	-0.01	0.02	0.02	0.12	0.12	0.12	0.12	0.12	0.02	-0.35	-0.04	-0.04	0.02
Fruit & vegetables	21	-0.02	-0.01	-0.01	-0.01	-0.05	0.00	-0.03	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	0.00	0.00	0.00	0.00	0.00	-0.03	-0.07	-0.60	0.16	0.00
Soft drinks	22	0.14	0.00	0.00	0.00	0.20	0.00	-0.14	0.13	0.13	0.13	0.13	-0.14	-0.14	-0.02	-0.02	-0.02	-0.02	-0.02	-0.14	-0.04	0.11	-0.67	0.00
Other	23	-0.02	0.00	0.00	0.00	-0.01	0.00	-0.02	0.02	0.02	0.02	0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.01	0.00	0.01	-0.39

Notes: PEs show how quantity of a food item (name shown in the far left column) changes (%) with respect to a 1% increase in price of another food item (name shown in the top row). Own PEs are shown in cells with larger font size, dark bordered, and no shading. Cross-PEs, which are taken from the key UK study,[Ministry of Agriculture 2000] are presented in cells without shading, and adjusted/assumed values are reported in cells with shading. Positive cross-PEs are presented in bold cells. * Fresh and unprocessed meat.

Similar to the approach with own-PEs, since the selected UK study did not cover all food categories, we used data from other studies to fill in the gaps for cross-PEs. We considered three sources of cross-PEs in the final PE estimations for the UK-based dataset: the key UK study [Ministry of Agriculture 2000] for most food categories, two other UK studies [Burton and Young 1992; Tiffin and Tiffin 1999] for the meat group, and the US study [Davis, Dong et al. 2010] for the dairy group.

Firstly, we used all the cross-PEs of the food items that are available in the key UK study[Ministry of Agriculture 2000], eg, bread and cheese (Appendix 1, Table 11). We applied the same cross-PEs for food items that are in the same group eg, for fresh beef, lamb, and chicken which were classified as carcase meats. That is, we assumed that cross-PEs for the aggregated good also applied to the disaggregated groups equally. For example, cross-PEs for bread and fresh beef were the same as those for bread and fresh chicken, and equalled: -0.07 (which is the cross-PE for bread and carcase meats in the UK data). This approach has been used elsewhere (ie, by Mytton et al [Mytton et al. 2007]). (However, it must be noted that cross-PEs may be higher for more disaggregated groups – a point to keep in mind for future sensitivity analyses). These values filled most (479/529 PEs; cells without shading) in the food PEs table adjusted for the UK context (Table 6).

Secondly, for cross-PEs within the meat group, we used *mean* cross-PEs (Table 7) taken from two other UK studies [Burton and Young 1992; Tiffin and Tiffin 1999]. Both studies used similar the demand system (AIDS) and dataset (National Food Survey) to the key UK study. (Note that the estimates of -0.24 and -0.37, for pork-chicken and chicken-pork, seem unlikely on the face of it. It is likely we will subject these to particular sensitivity analyses in future modelling). The calculated PEs values are shown in the blue area (dark grey cell shading) in the final PEs table (Table 6).

Table 7: Cross-PEs from other UK studies for the meat group

Quantity	Price	UK 1999[Tiffin and Tiffin 1999]	UK 1992[Burton and Young 1992]	Mean cross-PEs of the two studies (unless stated otherwise)
Beef	Beef	-1.64	-1.76	*Own-PE = -1.70*
Beef	Pork	0.04	0.14	0.09
Beef	Chicken	0.20	0.30	0.25
Beef	Lamb	-0.18	0.29	0.06
Pork	Beef	0.35	0.14	0.24
Pork	Pork	-1.87	-1.07	*Own-PE = -1.47*
Pork	Chicken	-0.33	-0.16	-0.24
Pork	Lamb	-0.08	0.14	0.03
Chicken	Beef	0.70	0.81	0.75
Chicken	Pork	-0.41	-0.34	-0.37*
Chicken	Chicken	-1.37	-1.14	*Own-PE = -1.26*
Chicken	Lamb	0.20	-0.21	0.00
Lamb	Beef	-0.06	0.62	0.28
Lamb	Pork	0.08	0.30	0.19
Lamb	Chicken	0.56	-0.17	0.19
Lamb	Lamb	-0.53	-1.62	*Own-PE = -1.07*

Notes: We don't use the own-PEs (values in italics and red) from these studies.

* This appears to be an unusual result in our view and would be in the NZ setting which pork is substantially more expensive than chicken.

Thirdly, for cross-PEs among the dairy group, we used the US study.[Davis, Dong et al. 2010] This study was different from the key UK study in the demand system, method, and data source, but covered all PEs within the dairy group.

Finally, the cereal grouping (derived from the NZ National Nutrition Survey) included the categories of: "breakfast cereals", "cakes, muffins, and biscuits", "bread-based dishes", and "pies and pasties". For this group, we were unable to identify any study that disaggregates PEs amongst such groups. Furthermore, we suspected that there will probably be a modest tendency for these food categories to act as substitutes for each other. Therefore, we purposefully set the cross-PEs at 0.10 for all possible pair-wise comparisons of these groups. These assumed PEs values filled the yellow area (light grey cell shading with dark border) in the final table (Table 6).

Scaling factors for cross-PEs: As detailed above, we adjusted own-PEs in the UK study for soft drinks (categorised as "beverages" in this study), from -0.37 to -0.67. We therefore developed a scaling factor of cross-PEs for soft drinks as a ratio of adjusted own-PE and UK own-PEs. We then multiplied cross-PEs of "beverages" with other food items, eg, beverages and carcase meats, in the UK data by that scaling factor.

For the dairy group, it was very hard to develop a scaling factor for this group since the US study [Davis, Dong et al. 2010] (from which we used the cross-PEs) only considered a partial demand system (ie, only the dairy group). We therefore scaled these data (see method below) to match the UK data based on comparison data for the same set of food categories in a 144-country study [Seale, Jr. et al. 2005]. That is, the PEs from this multi-country study (Appendix 1, Table 12) were adjusted to the UK study using a scaling factor of 1.34. This scaling factor was calculated using the median of own- PEs for UK over that for US reported in the multi-country study [Seale, Jr. et al. 2005] for those food items common to both studies. This allows the comparison of PEs values within OECD countries (Table 8 – far right column). The adjusted PEs filled the pink area (light grey cell shading without dark border) in the final PEs table (Table 6).

Whilst we have attempted to derive best estimates using scaling factors, we cannot ascribe great confidence to these estimations. Therefore if some of these "scaled" cross-PEs are important drivers of future models, it will be critical to include sensitivity analyses – and updated reviews of the literature for estimates.

Contextualising the PEs data: To help understand how Australian and NZ data compared with that from other OECD countries, we analysed selected data from the large multi-country study [Seale, Jr. et al. 2005] and which included all OECD countries and used the same type of data and methods (Table 8). Expenditure and price data for this research were obtained from the International Comparison Project (ICP) in 1996. The ICP coordinates the collection of price data for a basket of goods and services in many countries in five regions - Africa, Asia, the Commonwealth of Independent States, Latin America and Western Asia; and is maintained by the International Comparison Program Development Data Group of the World Bank. This work indicated that NZ had higher own-PEs than Australia in all eight food categories for which data were available. In all food categories for Australia, but only two out of eight categories for NZ, were the values less elastic than the rest of the OECD. The general pattern was that richer OECD countries had lower PEs. This may suggest that the approach taken for data selection in Table 4 may end to under-estimate the PEs for NZ (a relatively poorer OECD country).

Table 8: Food own-PEs in OECD countries (for 2005, n=32 countries, data from Seale et al)

For all OECD countries (excluding Australia & NZ)	**Cereals**	**Meats**	**Fish**	**Dairy**	**Oils & fats**	**Fruit & vegetables**	**Food Other**	**Beverages & tobacco**	**Median value**
Median	-0.05	-0.37	-0.29	-0.38	-0.09	-0.24	-0.48	-0.46	
Minimum	-0.25	-0.50	-0.41	-0.52	-0.27	-0.37	-0.70	-0.66	
Maximum	0.20	-0.25	-0.19	-0.26	0.08	-0.15	-0.32	-0.31	
SD	0.10	0.06	0.05	0.06	0.08	0.05	0.09	0.08	
Specific country data									
United Kingdom (UK)	0.01	-0.34	-0.26	-0.35	-0.05	-0.21	-0.43	-0.42	
United States (US)	0.06	-0.25	-0.19	-0.26	0.00	-0.15	-0.32	-0.31	
Australia	-0.03	-0.36	-0.28	-0.37	-0.08	-0.24	-0.47	-0.45	
NZ	-0.04	-0.39	-0.30	-0.40	-0.09	-0.25	-0.50	-0.48	
Differences (%) between countries									
Australia vs OECD	-31%	-2%	-3%	-2%	-12%	-2%	-3%	-3%	
NZ vs OECD	-16%	4%	4%	4%	-1%	5%	4%	4%	
Australia vs US	-49%	43%	46%	43%	Ignored[b]	53%	45%	45%	
NZ vs US	-38%	53%	57%	53%	Ignored[b]	64%	56%	55%	
Ranking of country[a]									
Australia's rank (all OECD including Australia & NZ)	14	14	13	14	14	14	13	14	
NZ's rank (all OECD including Australia & NZ)	16	21	21	21	17	21	21	21	

For all OECD countries (excluding Australia & NZ)	**Cereals**	**Meats**	**Fish**	**Dairy**	**Oils & fats**	**Fruit & vegetables**	**Food Other**	**Beverages & tobacco**	**Median value**
USA's rank (all OECD including Aus and NZ)	3	1	1	1	3	1	1	1	
Adjustment for Income Levels									Median value
Australia vs UK	2.91	1.07	1.08	1.07	1.71	1.10	1.08	1.08	1.08
NZ vs UK	3.55	1.15	1.16	1.15	1.92	1.18	1.16	1.15	1.16
UK vs US	0.17	1.33	1.35	1.33	Ignored[b]	1.39	1.35	1.34	1.34

[a]: Rank is from low to high PEs (ie, NZ's own-PEs for these foods are more elastic)

[b]: These values were ignored because they were infinitive (ie, divided by zero).

Own- and cross-PEs adjusted for Australia and NZ's food categories: All own- and cross-PEs values reported in Table 6 were multiplied by scaling factors of 1.08 and 1.16 to adjust from the UK to the Australia and NZ contexts, respectively, in order to account for differences in PEs values among OECD countries. These factors were calculated using the same method for deriving the scaling factor for the dairy group (to adjust from the US to the UK context) as mentioned above (Table 8).

Applying a budget share constraint: Given all the diverse origins of the PEs data used in our work and all the methodological steps described above, when considering modelling of pricing interventions we performed one additional step. That is we applied a constraint on the cross-PEs to ensure that the overall household food budget remained constant to maximise the theoretical integrity of our overall food PE model.

The theoretical constraint used was the Cournot aggregation conditions [Robert and Chung–Liang 1987, p. 7] to adjust the cross-PEs so that the whole PE estimations remained within a reasonable range (Appendix 1). In particular, we kept the own-PEs unchanged and adjusted the cross-PEs using a budgetary constraint (see Appendix 2 for the food budget share data) so that the PE data overall satisfied the Cournot aggregation conditions (see also see Appendix 2 for a rule to adjust the cross-PEs).

Final results – Food PEs available for modelling: As shown in Table 10, for NZ, own-PEs for 22 food categories of interest ranged from -0.14 to -1.09, for "potatoes and kumara" and "breakfast cereals", respectively. These data indicated that a 1% increase in price of potatoes and kumara/breakfast cereals leaded to 0.14% and 1.09% decreases in purchased quantity of these products, respectively. That is own-PE for potatoes and kumara was inelastic, and that for breakfast cereals was the most elastic. Own-PEs for fruit and vegetables was -0.69, and for soft drinks was -0.78. PE estimations for the dairy group were from -0.32 to -0.52, and for the meat group from -0.39 to -1.06. Accordingly, all own-PEs for Australia's food categories shown in Table 9 are lower than those for NZ's food categories reported in Table 10 by 7% $\left(= \frac{1.08-1.16}{1.16}\right)$.

Cross-PEs for NZ ranged from -0.72 for "poultry processed" and "pork processed" (ie, the consumption of poultry processed reduces by 0.72% for each 1% increase in price of pork processed) to 0.55 for "beef processed" and "pork fresh and unprocessed" (ie, conversely, the consumption beef processed goes up for 0.55% for each 1% increase in price of fresh pork. Cross-PEs values within the meat group were between -0.72 and 0.40.Within the meat group, cross-PEs could be both positive (eg, between processed poultry and processed pork) and negative (eg, between processed beef and processed pork). Therefore, disaggregated foods within the meat group could be either substitute or complementary foods. Cross-PEs between butter and margarine, and between low fat and high fat milk, were all positive, ranging from 0.08 to 0.32, and from 0.23 to 0.41, respectively. All cross-PEs for Australia were higher in absolute values than the NZ estimates, and by 3% on average.

Own-PEs for the dairy group were possibly quite low compared to the literature [Seale, Jr. et al. 2005; Andreyeva, Long et al. 2010]. Moreover, own-PEs for the dairy group in the literature were generally higher than or equal to those for fruit and vegetables. Similarly, the own-PE for the breakfast cereals group was possibly quite high since they are usually relatively cheap foods in NZ. On the other hand, own-PEs for the meat groups seemed to be plausible with respect to prices of these products in NZ. Cross-PEs within the meat groups also seemed to be reasonable.

Table 9: Own- and cross-PEs adapted for use in modelling work for Australia

Food items	PRICE	Bread	Pork processed	Poultry processed	Beef processed	Potatoes & kumara	Sauces	Breakfast cereals	Beef & veal*	Poultry*	Pork*	Lamb/mutton*	Cakes, muffins etc	Bread-based dishes	Milk - whole	Milk -low fat	Dairy products	Butter	Margarine	Pies & pastries	Cheese	Fruit & vegetables	Soft drinks	Other
QUANTITY	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bread	1	-0.43	0.01	0.01	0.00	0.00	-0.04	0.05	-0.13	-0.14	-0.09	-0.12	0.06	0.06	-0.08	-0.10	-0.07	-0.06	-0.06	0.06	0.13	-0.09	0.21	0.00
Pork processed	2	0.05	-0.62	-0.45	0.03	-0.11	-0.01	0.21	0.18	0.12	0.44	0.24	0.24	0.23	-0.16	-0.19	-0.14	-0.12	-0.12	0.22	0.04	-0.09	0.02	0.00
Poultry processed	3	0.05	-0.73	-0.36	0.11	-0.11	-0.01	0.21	0.18	0.12	0.44	0.24	0.24	0.23	-0.16	-0.19	-0.14	-0.12	-0.12	0.22	0.04	-0.09	0.02	0.00
Beef processed	4	0.05	0.02	0.08	-0.70	-0.11	-0.01	0.21	0.18	0.12	0.44	0.24	0.24	0.23	-0.16	-0.19	-0.14	-0.12	-0.12	0.22	0.04	-0.09	0.02	0.00
Potatoes & kumara	5	0.00	-0.02	-0.02	-0.02	-0.13	-0.01	-0.03	0.01	0.01	0.03	0.02	-0.03	-0.03	-0.06	-0.07	-0.05	-0.04	-0.04	-0.03	-0.14	-0.04	0.12	0.00
Sauces	6	-0.03	0.00	0.00	0.00	-0.01	-0.42	-0.02	0.01	0.00	0.01	0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.02	0.00	0.00	0.01	0.00
Breakfast cereals	7	0.06	0.04	0.06	0.03	-0.09	-0.06	-1.02	-0.09	-0.10	-0.07	-0.09	0.09	0.08	-0.06	-0.07	-0.05	-0.04	-0.04	0.08	0.02	-0.29	-0.65	0.00
Beef & veal*	8	-0.21	0.05	0.08	0.04	0.22	0.07	-0.04	-0.99	0.06	0.08	0.03	-0.04	-0.04	0.05	0.04	0.06	0.07	0.07	-0.04	-0.04	-0.20	0.33	0.00
Poultry*	9	-0.21	0.05	0.08	0.04	0.22	0.07	-0.04	0.26	-0.46	-0.50	-0.01	-0.04	-0.04	0.05	0.04	0.06	0.07	0.07	-0.04	-0.04	-0.20	0.33	0.00
Pork*	10	-0.21	0.05	0.08	0.04	0.22	0.07	-0.04	0.08	-0.47	-0.79	0.01	-0.04	-0.04	0.05	0.04	0.06	0.07	0.07	-0.04	-0.04	-0.20	0.33	0.00
Lamb/mutton*	11	-0.21	0.05	0.08	0.04	0.22	0.07	-0.04	0.10	0.04	0.16	-0.67	-0.04	-0.04	0.05	0.04	0.06	0.07	0.07	-0.04	-0.04	-0.20	0.33	0.00
Cakes, muffins and biscuits	12	0.06	0.04	0.06	0.03	-0.09	-0.06	0.08	-0.09	-0.10	-0.07	-0.09	-1.02	0.08	-0.06	-0.07	-0.05	-0.04	-0.04	0.08	0.02	-0.29	-0.65	0.00
Bread-based dishes	13	0.06	0.04	0.06	0.03	-0.09	-0.06	0.08	-0.09	-0.10	-0.07	-0.09	0.09	-1.02	-0.06	-0.07	-0.05	-0.04	-0.04	0.08	0.02	-0.29	-0.65	0.00
Milk-whole	14	-0.24	-0.18	-0.17	-0.18	-0.25	-0.09	-0.07	0.01	0.01	0.03	0.02	-0.06	-0.07	-0.38	0.54	0.02	0.12	-0.07	-0.07	0.12	-0.04	-0.09	0.00

Food items	PRICE	**Bread**	**Pork processed**	**Poultry processed**	**Beef processed**	**Potatoes & kumara**	**Sauces**	**Breakfast cereals**	**Beef & veal***	**Poultry***	**Pork***	**Lamb/mutton***	**Cakes, muffins etc**	**Bread-based dishes**	**Milk-whole**	**Milk-low fat**	**Dairy products**	**Butter**	**Margarine**	**Pies & pastries**	**Cheese**	**Fruit & vegetables**	**Soft drinks**	Other
QUANTITY	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Milk-low fat/trim/skim	15	-0.24	-0.18	-0.17	-0.18	-0.25	-0.09	-0.07	**0.01**	**0.01**	**0.03**	**0.02**	-0.06	-0.07	**0.27**	-0.40	0.00	**0.11**	-0.02	-0.07	**0.12**	-0.04	-0.09	0.00
Dairy products	16	-0.24	-0.18	-0.17	-0.18	-0.25	-0.09	-0.07	**0.01**	**0.01**	**0.03**	**0.02**	-0.06	-0.07	**0.06**	**0.18**	-0.41	-0.01	**0.16**	-0.07	**0.12**	-0.04	-0.09	0.00
Butter	17	-0.24	-0.18	-0.17	-0.18	-0.25	-0.09	-0.07	**0.01**	**0.01**	**0.03**	**0.02**	-0.06	-0.07	**0.24**	**0.36**	-0.01	-0.48	**0.41**	-0.07	**0.12**	-0.04	-0.09	0.00
Margarine	18	-0.24	-0.18	-0.17	-0.18	-0.25	-0.09	-0.07	**0.01**	**0.01**	**0.03**	**0.02**	-0.06	-0.07	-0.12	**0.05**	0.00	**0.11**	-0.30	-0.07	**0.12**	-0.04	-0.09	0.00
Pies and pasties	19	**0.06**	**0.04**	**0.06**	**0.03**	-0.09	-0.06	0.08	-0.09	-0.10	-0.07	-0.09	0.09	0.08	-0.06	-0.07	-0.05	-0.04	-0.04	-1.02	**0.02**	-0.29	-0.65	0.00
Cheese	20	**0.10**	**0.00**	**0.01**	**0.00**	-0.13	**0.01**	**0.02**	-0.02	-0.02	-0.01	-0.02	**0.02**	**0.02**	**0.13**	**0.09**	**0.14**	**0.16**	**0.16**	**0.02**	-0.38	-0.09	-0.04	**0.00**
Fruit & vegetables	21	-0.03	-0.02	-0.02	-0.02	-0.05	0.00	-0.04	-0.04	-0.04	-0.03	-0.03	-0.04	-0.04	0.00	0.00	0.00	0.00	0.00	-0.04	-0.13	-0.65	**0.16**	0.00
Soft drinks	22	**0.06**	0.00	0.00	0.00	**0.23**	0.00	-0.20	**0.04**	**0.03**	**0.10**	**0.06**	-0.19	-0.19	-0.02	-0.03	-0.02	-0.02	-0.02	-0.19	-0.07	**0.00**	-0.72	0.00
Other	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	**0.00**	0.00

Notes: PEs show how quantity of a food item (name shown in the far left column) changes (%) with respect to a 1% increase in price of another food item (name shown in the top row). Own PEs are shown in cells with larger font size, dark bordered, and no shading. Cross-PEs, which are taken from the key UK study.[Ministry of Agriculture 2000] are presented in cells without shading, and adjusted/assumed values are reported in cells with shading. Positive cross-PEs are presented in bold cells.

* Fresh and unprocessed meat.

Table 10: Own- and cross-PEs adapted for use in modelling work for New Zealand

Food items	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Bread	1	-0.46	0.01	0.01	0.01	0.00	-0.03	0.06	-0.12	-0.12	-0.09	-0.11	0.08	0.06	-0.10	-0.12	-0.06	-0.10	-0.09	0.06	0.07	-0.03	0.27	0.00
Pork processed	2	0.03	-0.67	-0.47	0.08	-0.16	-0.01	0.24	0.28	0.29	0.55	0.41	0.29	0.25	-0.20	-0.24	-0.13	-0.19	-0.18	0.24	0.02	-0.03	0.02	0.00
Poultry processed	3	0.03	-0.72	-0.39	0.24	-0.16	-0.01	0.24	0.28	0.29	0.55	0.41	0.29	0.25	-0.20	-0.24	-0.13	-0.19	-0.18	0.24	0.02	-0.03	0.02	0.00
Beef processed	4	0.03	0.04	0.10	-0.75	-0.16	-0.01	0.24	0.28	0.29	0.55	0.41	0.29	0.25	-0.20	-0.24	-0.13	-0.19	-0.18	0.24	0.02	-0.03	0.02	0.00
Potatoes & kumara	5	0.00	-0.02	-0.02	-0.02	-0.14	-0.01	-0.03	0.02	0.02	0.04	0.03	-0.02	-0.03	-0.07	-0.09	-0.05	-0.07	-0.06	-0.03	-0.17	-0.01	0.16	0.00
Sauces	6	-0.03	0.00	0.00	0.00	-0.01	-0.45	-0.02	0.01	0.01	0.02	0.01	-0.02	-0.02	-0.02	-0.03	-0.01	-0.02	-0.02	-0.02	0.00	0.00	0.01	0.00
Breakfast cereals	7	0.04	0.07	0.07	0.06	-0.13	-0.05	-1.09	-0.09	-0.09	-0.06	-0.08	0.11	0.09	-0.07	-0.09	-0.05	-0.07	-0.06	0.09	0.01	-0.08	-0.58	0.00
Beef & veal*	8	-0.24	0.10	0.11	0.08	0.16	0.09	-0.04	-1.06	0.14	0.10	0.04	-0.04	-0.04	0.05	0.03	0.07	0.05	0.05	-0.04	-0.04	-0.06	0.43	0.00
Poultry*	9	-0.24	0.10	0.11	0.08	0.16	0.09	-0.04	0.40	-0.49	-0.48	-0.01	-0.04	-0.04	0.05	0.03	0.07	0.05	0.05	-0.04	-0.04	-0.06	0.43	0.00
Pork*	10	-0.24	0.10	0.11	0.08	0.16	0.09	-0.04	0.13	-0.43	-0.85	0.02	-0.04	-0.04	0.05	0.03	0.07	0.05	0.05	-0.04	-0.04	-0.06	0.43	0.00
Lamb/mutton*	11	-0.24	0.10	0.11	0.08	0.16	0.09	-0.04	0.15	0.11	0.20	-0.72	-0.04	-0.04	0.05	0.03	0.07	0.05	0.05	-0.04	-0.04	-0.06	0.43	0.00
Cakes, muffins etc	12	0.04	0.07	0.07	0.06	-0.13	-0.05	0.09	-0.09	-0.09	-0.06	-0.08	-1.09	0.09	-0.07	-0.09	-0.05	-0.07	-0.06	0.09	0.01	-0.08	-0.58	0.00
Bread-based dishes	13	0.04	0.07	0.07	0.06	-0.13	-0.05	0.09	-0.09	-0.09	-0.06	-0.08	0.11	-1.09	-0.07	-0.09	-0.05	-0.07	-0.06	0.09	0.01	-0.08	-0.58	0.00
Milk-whole	14	-0.28	-0.17	-0.17	-0.18	-0.35	-0.07	-0.07	0.02	0.02	0.04	0.03	-0.06	-0.07	-0.40	0.41	0.02	0.09	-0.10	-0.07	0.06	-0.01	-0.08	0.00
Milk-low fat	15	-0.28	-0.17	-0.17	-0.18	-0.35	-0.07	-0.07	0.02	0.02	0.04	0.03	-0.06	-0.07	0.23	-0.43	0.00	0.08	-0.03	-0.07	0.06	-0.01	-0.08	0.00
Dairy products	16	-0.28	-0.17	-0.17	-0.18	-0.35	-0.07	-0.07	0.02	0.02	0.04	0.03	-0.06	-0.07	0.05	0.13	-0.44	-0.02	0.13	-0.07	0.06	-0.01	-0.08	0.00
Butter	17	-0.28	-0.17	-0.17	-0.18	-0.35	-0.07	-0.07	0.02	0.02	0.04	0.03	-0.06	-0.07	0.21	0.26	-0.01	-0.52	0.32	-0.07	0.06	-0.01	-0.08	0.00
Margarine	18	-0.28	-0.17	-0.17	-0.18	-0.35	-0.07	-0.07	0.02	0.02	0.04	0.03	-0.06	-0.07	-0.15	0.04	0.00	0.08	-0.32	-0.07	0.06	-0.01	-0.08	0.00
Pies & pasties	19	0.04	0.07	0.07	0.06	-0.13	-0.05	0.09	-0.09	-0.09	-0.06	-0.08	0.11	0.09	-0.07	-0.09	-0.05	-0.07	-0.06	-1.09	0.01	-0.08	-0.58	0.00
Cheese	20	0.07	0.01	0.01	0.01	-0.19	0.02	0.02	-0.02	-0.02	-0.01	-0.02	0.02	0.02	0.11	0.07	0.17	0.11	0.12	0.02	-0.41	-0.03	-0.04	0.00

Food items	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Fruit & vegetables	21	-0.04	-0.02	-0.02	-0.02	-0.07	0.00	-0.04	-0.04	-0.04	-0.03	-0.03	-0.04	-0.04	0.00	0.00	0.00	0.00	0.00	-0.04	-0.15	-0.69	**0.20**	0.00
Soft drinks	22	**0.04**	0.00	0.00	0.00	**0.17**	0.00	-0.21	**0.07**	**0.07**	**0.13**	**0.10**	-0.18	-0.20	-0.03	-0.03	-0.02	-0.02	-0.02	-0.21	-0.08	**0.18**	-0.78	0.00
Other	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	**0.00**	0.00

Notes: PEs show how quantity of a food item (name shown in the far left column) changes (%) with respect to a 1% increase in price of another food item (name shown in the top row). Own PEs are shown in cells with larger font size, dark bordered, and no shading. Cross-PEs, which are taken from the key UK study,[Ministry of Agriculture 2000] are presented in cells without shading, and adjusted/assumed values are reported in cells with shading. Positive cross-PEs are presented in bold cells.

4. Discussion – selected issues

Overall results: The use of international data and multiple assumptions is a far from optimal way of producing data on food PEs for NZ and Australia. This highlights the need for completion of the modelling of PEs for the SPEND Project and for finalising the preliminary Australian work [Ulubasoglu, Mallick et al. 2010]. Even so, to get precise results for many different food categories, future studies may need to be relatively large and so the type of approach taken here may still be required to some extent if modelling is to be performed in the near future.

Nevertheless, our impression is that the results obtained are fairly plausible and likely (with appropriate levels of caution) to be of value for modelling pricing interventions in these countries. But in all cases the results will benefit from performing uncertainty analyses, use of different scenarios and appropriate contextualisation of the results in terms of (i) theoretical plausibility; and (ii) comparison with results from elsewhere.

Direction of bias: The reliance on UK data (supplemented with mainly USA data) is likely to result in an underestimation of PEs results for NZ (as per the results in Table 8 and based on Seale et al [Seale, Jr. et al. 2005]). However, the use of the scaling process (using data in the 144-country comparison study) is likely to partly address this problem. Even so, some residual underestimation of PEs for both Australia and NZ (relative to the UK) is plausible for the following reasons:

- As both Australia and New Zealand are major food producers and exporters (relative to the UK), consumers in these countries have better access to discounted food produce (eg, fresh seasonal produce that can be sold at highly discounted prices).
- Both countries (compared to the UK and USA) may have relatively good options for obtaining food outside the formal economy (home-grown food and access to direct-from-the-farm produce eg, farm-killed meat). This form of competition may tend to impact on the PEs for food that is home-grown.

Uncertainty analyses: The PEs included in this report will be used for disease modelling, and are prone to uncertainty about their true values. This report does not provide definitive uncertainty intervals for every PE, not does it provide definitive instructions on how to model uncertainty in PEs. Rather, we provide options for later consideration, case-by-case, for future intervention modelling.

The first option is to specify an uncertainty range (and distributional form) about all PEs, and subject them to full probabilistic sensitivity analyses in future Monte Carlo simulations. However, this seems both unnecessary and impractical. Most food price interventions will affect a handful of food categories, requiring modelling of their PEs only. Second, some data exists on standard errors (ie, statistical imprecision) for own-PEs and occasionally cross-PEs, but it is often absent. Third, it will only be some PE (be it own or cross) that actually drive changes in relevant model outputs (eg, changes in salt intake, or saturated fat intake), due to either or both the magnitude of the PE or the proportion of total household food purchasing for the given food item. (Overall nutrient intake will not change much from either a commonly consumed food that has very low PE, or from an uncommonly consumed food with very high PE.) Finally, and as it made clear above, it would be misleading to assume that the only uncertainty in PEs was random error; there are many systematic factors to consider.

The second and more likely option that we will employ is a scenario-based set of sensitivity analyses, rather than full-blown probabilistic sensitivity analyses. This will entail careful consideration of the foods that influence model outputs (because of at least one of having a high PE, being commonly consumed, or containing a high proportion of the nutrient (eg, saturated fat) of interest), and then setting plausible minimum and maximum values to run basic sensitivity analyses. An additional, and very important, consideration is the level of disaggregation; from substitute foods, the more disaggregated the food grouping the higher will be the cross-PE (eg, the cross-PE for whole milk with low-fat milk will be much higher than for all milks with all soft drinks). We will draw on the standard errors from underlying data we used to specify our final models, but it will not be the only consideration in specifying a scenario range of uncertainty distribution. For the most influential parameters identified, it may then be appropriate to carry those (few) PE through to a probabilistic uncertainty analysis thorough specifying normal (or other) distributions or uncertainty about the best estimate.

We note that other authors have taken fairly simple approaches to uncertainty analyses for food PEs. For example, Wirsenius et al [Wirsenius, Hedenus et al. 2010] generated lower limit values by decreasing own-PEs by 50% while keeping all cross-PEs constant to maintain consistency with the other elasticities within the demand system. Similarly, for generating upper limits, all own- and cross-PEs were increased by 50%, and then these values were checked for consistency with other elasticities within the demand system. Another group [Mytton, Gray et al. 2007] varied cross-PEs between 0 and 1 for subcategory groups (eg, among butter and margarine) in their sensitivity analysis.

Applying a budget share constraint in future modelling: When considering modelling of pricing interventions we will again follow the approach of applying a budget constraint (as per the analysis in this Report). This is the budget constraint will result in adjustment of the cross-PEs to ensure that the overall household food budget remains constant after the pricing intervention (eg, after the rise in the price of a food group subjected to a tax). This is a somewhat conservation assumption as with an increased tax on a food group it is plausible that some overall small increases in total food expenditure would occur (ie, since demand is not fully elastic). Nevertheless, we will undertake a sensitivity analysis that produces results without such a constraint. Future work could also consider the application of yet another constraint around the maintenance of dietary energy. However, such a constraint is less theoretically robust given the routine excess (over nutritional requirements) of dietary energy consumed by most New Zealanders and Australians.

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6. Appendix One

Table 11: Food own- and cross-PEs from the key UK study*

Food categories	PRICE	Milk & cream	Cheese	Carcase meat	Other meats	Fresh fish	Processed fish	Prepared fish	Frozen fish	Eggs	Fats	Sugar	Fresh potatoes	Fresh green vegs	Other fresh vegs	Processed vegs	Fresh fruit	Other fruits	Bread	Other cereals	Beverages
QUANTITY	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Milk and cream	1	**-0.36**	**0.34**	**0.04**	**-0.09**	**0.38**	**0.56**	**-0.01**	**-0.11**	**-0.4**	**-0.16**	**-0.2**	**-0.24**	**-0.02**	**0.05**	**-0.13**	**-0.27**	**0.27**	**-0.14**	**-0.05**	**-0.04**
Cheese	2	**0.12**	**-0.35**	**-0.01**	**0.02**	**0.06**	**0.02**	**-0.09**	**0.01**	**0.07**	**0.14**	**0.43**	**-0.13**	**-0.2**	**0.23**	**-0.03**	**-0.04**	**-0.29**	**0.24**	**0.02**	**-0.02**
Carcase meat	3	**0.05**	**-0.02**	**-0.69**	**0.26**	**0.15**	**0.4**	**0.2**	**0.07**	**0.15**	**0.21**	**0.08**	**0.19**	**-0.11**	**-0.09**	**-0.02**	**-0.17**	**0.21**	**-0.12**	**-0.03**	**0.19**
Other meat and meat products	4	**-0.14**	**0.1**	**0.53**	**-0.52**	**-0.02**	**0.09**	**0.35**	**-0.04**	**0.03**	**0.01**	**-0.26**	**-0.11**	**0**	**-0.01**	**-0.11**	**-0.11**	**-0.04**	**0.11**	**0.27**	**0.01**
Fresh fish	5	**0.05**	**0.02**	**0.02**	**0**	**-0.8**	**-0.06**	**0.11**	**-0.09**	**0.14**	**-0.13**	**0.01**	**0.02**	**0**	**0**	**0.06**	**0.04**	**0.1**	**0.08**	**0.05**	**0**
Processed and shell fish	6	**0.04**	**0**	**0.04**	**0**	**-0.04**	**-0.17**	**-0.06**	**0.04**	**0.02**	**0.03**	**0.09**	**0.05**	**-0.02**	**0**	**0.02**	**-0.02**	**0.05**	**-0.03**	**0.01**	**-0.08**
Prepared fish	7	**0**	**-0.05**	**0.04**	**0.04**	**0.17**	**-0.15**	**0**	**-0.05**	**-0.22**	**-0.09**	**-0.15**	**-0.01**	**0**	**-0.13**	**0.01**	**-0.07**	**-0.22**	**0.01**	**0.01**	**-0.09**
Frozen fish	8	**-0.01**	**0.01**	**0.01**	**0**	**-0.1**	**0.06**	**-0.03**	**-0.32**	**0.19**	**0.01**	**0.03**	**0.05**	**0.05**	**0.06**	**-0.07**	**0.02**	**0.13**	**-0.02**	**-0.01**	**-0.1**
Eggs	9	**-0.05**	**0.03**	**0.02**	**0**	**0.16**	**0.04**	**-0.16**	**0.2**	**-0.28**	**-0.1**	**0.2**	**0.05**	**-0.08**	**0.02**	**-0.08**	**0.06**	**0**	**-0.01**	**0.02**	**0.02**
Fats	10	**-0.04**	**0.11**	**0.07**	**0**	**-0.3**	**0.12**	**-0.13**	**0.03**	**-0.19**	**-0.75**	**0.02**	**0**	**0.14**	**-0.07**	**0.01**	**-0.15**	**0.21**	**0.08**	**-0.03**	**0.02**
Sugar and preserves	11	**-0.02**	**0.16**	**0.01**	**-0.02**	**0.01**	**0.16**	**-0.1**	**0.03**	**0.2**	**0.01**	**-0.79**	**-0.04**	**0.11**	**-0.03**	**-0.01**	**0.04**	**0.07**	**-0.04**	**-0.03**	**0.08**
Fresh potatoes	12	**-0.05**	**-0.08**	**0.04**	**-0.01**	**0.04**	**0.15**	**-0.02**	**0.07**	**0.07**	**0**	**-0.06**	**-0.12**	**0.03**	**0.02**	**-0.02**	**-0.02**	**-0.09**	**0**	**-0.02**	**0.07**
Fresh green vegetables	13	**0**	**-0.11**	**-0.02**	**0**	**0**	**-0.05**	**0**	**0.08**	**-0.1**	**0.09**	**0.16**	**0.02**	**-0.66**	**0.01**	**0**	**-0.01**	**0.12**	**-0.02**	**0.03**	**0.09**
Other fresh vegetables	14	**0.02**	**0.26**	**-0.04**	**0**	**-0.01**	**0**	**-0.27**	**0.17**	**0.05**	**-0.1**	**-0.09**	**0.04**	**0.01**	**-0.33**	**0.03**	**0.09**	**0.05**	**0.04**	**-0.05**	**-0.02**
Processed	15	**-0.07**	**-0.06**	**-0.01**	**-0.04**	**-0.35**	**0.14**	**0.05**	**-0.31**	**-0.39**	**0.02**	**-0.05**	**-0.05**	**-0.02**	**0.05**	**-0.6**	**-0.05**	**0.03**	**-0.02**	**0.06**	**-0.19**

Food categories	PRICE	Milk & cream	Cheese	Carcase meat	Other meats	Fresh fish	Processed fish	Prepared fish	Frozen fish	Eggs	Fats	Sugar	Fresh potatoes	Fresh green vegs	Other fresh vegs	Processed vegs	Fresh fruit	Other fruits	Bread	Other cereals	Beverages
QUANTITY	Coding	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
vegetables																					
Fresh fruit	16	**-0.14**	**-0.07**	**-0.11**	**-0.03**	**0.16**	**-0.15**	**-0.2**	**0.06**	**0.25**	**-0.3**	**0.16**	**-0.06**	**-0.04**	**0.12**	**-0.04**	**-0.29**	**0.11**	**-0.1**	**-0.06**	**0.1**
Other fruit and fruit products	17	**0.07**	**-0.22**	**0.06**	**-0.01**	**0.23**	**0.17**	**-0.3**	**0.25**	**0**	**0.2**	**0.13**	**-0.11**	**0.17**	**0.03**	**0.01**	**0.05**	**-0.81**	**-0.02**	**-0.03**	**0.15**
Bread	18	**-0.07**	**0.36**	**-0.07**	**0.03**	**0.36**	**-0.22**	**0.03**	**-0.07**	**-0.04**	**0.15**	**-0.14**	**-0.01**	**-0.05**	**0.05**	**-0.02**	**-0.1**	**-0.04**	**-0.4**	**0.07**	**0.12**
Other cereals & cereal products	19	**-0.05**	**0.07**	**-0.05**	**0.18**	**0.48**	**0.16**	**0.06**	**-0.1**	**0.2**	**-0.15**	**-0.29**	**-0.09**	**0.22**	**-0.16**	**0.11**	**-0.13**	**-0.13**	**0.15**	**-0.94**	**-0.3**
Beverages	20	**-0.01**	**-0.02**	**0.07**	**0**	**0**	**-0.33**	**-0.16**	**-0.23**	**0.04**	**0.02**	**0.21**	**0.11**	**0.15**	**-0.02**	**-0.1**	**0.06**	**0.19**	**0.08**	**-0.08**	**-0.37**

*Source:[Ministry of Agriculture 2000]

Table 12: Own- and cross-PEs from a US 2010 study about dairy products*

Food categories	PRICE	Bulk ice cream	Sherbet/ice milk	Refrigerated yogurt	Frozen yogurt	Drinkable yogurt	Whole milk	Reduced fat milk	Canned milk	Natural cheese	Processed cheese	Cottage cheese	Butter	Margarine
QUANTITY		1	2	3	4	5	6	7	8	9	10	11	12	13
Bulk ice cream	1	-0.91	-0.01	0.01	0	0	-0.06	-0.05	0	0.06	-0.07	0.01	0.07	-0.06
Sherbet/ice milk	2	-0.08	-1.21	-0.12	-0.05	0.05	0.1	0.08	0.15	0.09	-0.01	0.13	-0.04	-0.04
Refrigerated yogurt	3	0.02	-0.02	-1.19	-0.05	0	-0.01	0.18	0.01	0	0.04	-0.06	-0.01	0.09
Frozen yogurt	4	0.03	-0.03	-0.19	-1.26	-0.11	0.16	0.17	0.02	0.06	0.04	-0.01	-0.02	0.14
Drinkable yogurt	5	0.05	0.04	0.03	-0.11	-1.73	0.04	0.3	0.05	0.06	0.11	0.06	0.02	0.14
Whole milk	6	-0.02	0.01	0.06	0.03	0	-1.7	0.52	0.03	0.19	0.01	0.1	0.07	-0.06
Reduced fat milk	7	-0.07	0	-0.05	0.02	0.02	0.19	-1.57	0.03	0.12	-0.02	0.04	0.06	-0.02
Canned milk	8	-0.04	0.11	0.03	0.03	0.06	0.2	0.26	-1.32	0	-0.19	0.11	-1.15	-0.17
Natural cheese	9	0.07	0.01	-0.02	0.01	0	0.32	0	0.02	-1.73	0.1	0.01	0.01	0.03
Processed cheese	10	-0.07	-0.01	0.08	0	0.02	-0.04	0.13	-0.05	0.16	-0.99	0.04	-0.01	-0.12
Cottage cheese	11	0.02	0.05	-0.15	0	0.03	0.23	0.19	0.05	0.01	0.07	-1.68	0.04	0.05
Butter	12	0.2	-0.01	-0.04	-0.02	0	0.17	0.34	-0.07	0.05	0.01	0.04	-1.87	0.23
Margarine	13	-0.04	0	0.05	0.01	0	-0.08	0.05	-0.02	0.03	-0.05	0	0.06	-0.95

Notes: *Source:[Davis, Dong et al. 2010]

We use the median PEs values of items 1, 2, 3, 4, and 5 as cross–PEs for dairy products, and those of items 9, 10, and 11 for cheese. We don't use the own–PEs values in this study.

Table 13: Options for use of PEs for the uncertainty analyses relating to pricing soft drinks

Option number (No.)	Source	Own-PEs in original study	Scaling factor	Adjusted own-PEs for UK (=*original own-PEs* X *scaling factor*)	Scaling factor for cross-PEs
1 (this is the approach currently used)	The systematic review[Andreyeva, Long et al. 2010]	-0.79	0.85 $(=\frac{\text{average UK}}{\text{average US}})$	-0.67	1.81 $(=\frac{-0.67}{-0.37\text{UK value}})$
2	Smith el al 2010[Smith, Lin et al. July 2010]	-1.01 $(=\frac{-1.26+(-0.75)}{2})$	0.37 $(=\frac{\text{average UK}}{\text{average US}})$	-0.46	1.27 $(=\frac{-0.46}{-0.37})$
3		-1.01	1.34 for OECD	-1.35	3.65* $(=\frac{-1.35}{-0.37})$
4		-1.01	0.39	-0.39	1.08

Notes: * We suspect that this figure is implausibly high for the NZ and Australian settings.

Calculating cross-PEs in the absence of other data

Missing cross-PEs can be calculated based on demand restrictions (for uncompensated PEs) as follows:

Let b_i be the budget share, ε_{ij} be the cross-price elasticity (how quantity of good *i* change with respect to the change in the price of good *j*), η_i be the income elasticity, and *n* be the number of goods.

Cournot aggregation conditions[Robert and Chung–Liang 1987, p. 7]:

$$\sum_{i=1}^{n} b_i \varepsilon_{ij} = -b_j, j = 1, \ldots, n \quad (1)$$

Englel aggregation (adding-up) condition[Robert and Chung–Liang 1987, p. 7]:

$$\sum_{i=1}^{n} b_i \eta_i = 1 \quad (2)$$

Slutsky symmetry conditions[Robert and Chung–Liang 1987, p. 7]:

$$b_i(\varepsilon_{ij} + \eta_i b_j) = b_j(\varepsilon_{ji} + \eta_j b_i),\ i, j = 1, \dots, n \quad (3)$$

Homogeneity conditions[Robert and Chung–Liang 1987, p. 7]:

$$\sum_{i=1}^{n} \varepsilon_{ij} + \eta_i = 0, i = 1, \dots, n \quad (4)$$

To calculate the missing cross-PEs, any of the equations from (1) to (4) above could be used since they are common properties of many demand systems. However, equation (1) is the most preferred for our analyses because it requires only budget shares to generate the missing cross-PEs. Nevertheless, a limitation of this equation is that at least half of the cross-PEs should be already available.

Budget shares for food items can be generated from expenditure weights (2010) by Statistics New Zealand[Statistics New Zealand 2010] and household expenditure (2009/10) by the Australian Bureau of Statistics[Australian Bureau of Statistics] (see Appendix 2).

Another method to calculate the missing cross-PEs is to employ a method developed by Beghin et al.[Beghin et al. 2004] This method is claimed to recover an exact welfare measure, and require only own-PEs and income elasticities.

Quantifying the changes in food demands as a results of several price changes

There are currently two approaches to quantify the changes in food demands when several price changes: theoretical and empirical ones. In theory, the changes in food demands are simply the total sum of demand changes across food items.[Robert and Chung–Liang 1987] In particular:

$$\%\Delta q_i = \sum_{j=1}^{n} \varepsilon_{ij}(\%\Delta p_j) + \eta_i(\%\Delta Y) \qquad (5)$$

Where Y is total household income.

If there is no change in total income (ie, $\%\Delta Y = 0$), the last term on the right hand side equals zero. The demand system is assumed to satisfy adding-up, homogeneity, and symmetry restrictions (ie, uncompensated PEs and a complete demand system).[Robert and Chung–Liang 1987, p. 155-156]

Empirically, the changes in food demands are the power functions of the changes across food prices.[Johnson et al. 1984; Wirsenius, Hedenus et al. 2010] In particular:

$$q_i = A_i Y^{\eta_i} \prod_{j=1}^{n} p_j^{\varepsilon_{ij}}, i = 1, \ldots, n \qquad (6)$$

Where A_i is a scaling factor.[Johnson, Hassan et al. 1984, p. 75]

This equation is claimed to violate the adding-up restriction, but still being preferred by many applied researchers because of "superior fit, ease of estimation, and the ready interpretation of the estimated parameters" [Johnson, Hassan et al. 1984, p. 75]. Wirsenius et al [Wirsenius, Hedenus et al. 2010], employed this equation to estimate the changes in food demands given the changes in food prices with A_i and Y^{η_i} being constant (though we note that the authors did not provide details on the source of their demand function). Assuming that A_i and Y^{η_i} do not change, the changes in food demands are as follows.

$$\%\Delta q_i = \left[\prod_{j=1}^{n} \left(\frac{p'_j}{p_j}\right)^{\varepsilon_{ij}}\right] - 1, i = 1, \ldots, n \qquad (7)$$

1. Since equation (5) has theoretical background and is valid for any demand functions, while equation (7) is only valid for the empirical demand function, we employed equation (5) for NZACE modelling.

7. Appendix Two

Budget share distributions for food purchases in NZ and Australia.

Method – New Zealand

The 2006 household economic survey data [Statistics New Zealand 2010] were used for several food item groupings (see the table below) but these data were was generally too aggregated to be used for other items.

Food items	Proportion of food expenditure	Adjusted when considering expenditure on restaurant meals and ready-to-eat foods*
Fruit	4.73%	6.17%
Vegetables	6.70%	8.74%
Soft drinks, waters & juices	3.69%	4.81%
Meat & poultry	12.35%	16.12%

* Adjusted considering that these foods are also included in restaurant meals (10.38% of the food budget) and ready-to-eat foods (13.02%).

For the remaining items we used as a proxy for budget share the proportion of energy derived from each food grouping (based on the National Nutrition Survey). Various adjustments were made based on:

1. The separation of potatoes from vegetables (since potatoes were included with vegetables in the household survey data).
2. The Household survey data on meat was subdivided into specific meats by the energy contributions (see the Table below).
3. Online supermarket data was used to determine distribution patterns of: (i) whole vs trim milk (details in a separate report on food pricing to go onto the BODE[3] website in late 2011); (ii) the Household survey data covering the grouping "soft drinks, bottled water and juices"; and (iii) and the pattern for butter vs margarine.

Table 14: **Budget share estimates used in the NZ analyses**

Food group	**Energy contribution (NNS) (%)***	**NZ Budget share (%)**	**Notes on calculations**
Breads	11	11.3	Used energy contribution.
Processed meats and sausages			
Pork	1.5	1.9	Based on HES data – but with specific per meat divisions based on relative energy contribution
Poultry	0.8	1.0	As above
Beef	0.4	0.5	As above
Other			
Potatoes and kumara	7	7.2	Used energy contribution.
Sauces	2	2.1	Used energy contribution.
Breakfast cereals	3	3.1	Used energy contribution.
Meat and poultry *(fresh, unprocessed)*			
Beef & veal	4	5.1	Based on HES data – but with specific per meat divisions based on relative energy contribution
Poultry	3	3.8	As above
Pork	2	2.5	As above
Lamb/mutton	1	1.3	As above
Other			
Cakes, muffins and biscuits	8	8.2	Used energy contribution.
Bread-based dishes	4	4.1	Used energy contribution.
Milk and dairy			
Milk - whole	2.4	2.5	Used energy contribution / online supermarket data.
- trim	2.6	2.6	As above
Dairy products	2	2.1	Used energy contribution.
Butter and margarine			
Butter	3	4.6	Used energy contribution / online supermarket data.
Margarine	3	1.6	As above
Other			
Pies and pasties	3	3.1	Used energy contribution.
Cheese	2	2.1	Used energy contribution.
Fruit and vegetables	6	8.1	Based on HES data – but the vegetable part adjusted for energy intake to exclude potatoes (considered separately)

Food group	Energy contribution (NNS) (%)*	NZ Budget share (%)	Notes on calculations
Non-alcoholic beverages (soft drinks)	5	2.7	Based on HES data and online supermarket data
Other	18	18.5	Used energy contribution.
Total	-	100.0	

* Percentages from the NNS with additional breakdown as per the Methods. The NNS included alcohol (5% of dietary energy) – but this is not included in the budget share analysis (ie, it is considered separately in the Household Economic Survey).

Method – Australia

We used data from the Household Expenditure Survey (2009-2010) [Australian Bureau of Statistics]. This survey occurred at an equal time period away from the 2006 base year as that of the preceding HES in Australia (in 2003-2004). As for the New Zealand situation, there was substantial expenditure in the full meal categories. That is, pre-prepared meals, meals out (eg, restaurants) and takeaway meals comprised a total of 32.9% of expenditure. Therefore we scaled up proportionately the contributions for all categories except for items that were less likely to be part of such meals (relative to home use): “breakfast cereals”, “milk”, “butter”, “margarine”, “dairy products”, and “other”. Scaling was also not applied to the two rather complex groupings (ie, “bread-based dishes” and “pies and pasties”) where the NZ proportions were used. Other details are shown in the Table below.

The final results seem plausible with the poorer country (NZ) spending proportionately less on fruit and vegetables – but proportionately more on “potatoes and kumara” and on bread. The NZ dietary preference for milk and butter is also apparent.

Table 15: Budget share estimates used in the Australian analyses (with NZ results for comparison purposes)

Food group	NZ Budget share (%)	Aus Budget share (%)	Notes on calculations
Breads	11.3	**5.1**	Used the specific category
Processed meats and sausages			
Pork	1.9	**3.4**	Used the ham and bacon data
Poultry	1.0	**1.4**	For unspecified processed meats – this was divided evenly between these 3 categories of processed meats
Beef	0.5	**1.4**	As above
Other			
Potatoes and kumara	7.2	**1.9**	A proportion of the undefined vegetable category was assigned to this one based on the ratio of potatoes to all other specified vegetables.
Sauces	2.1	**1.3**	Used the specific category (which salad dressing)
Breakfast cereals	3.1	**1.2**	Used the specific category
Meat and poultry *(fresh, unprocessed)*			
Beef & veal	5.1	**4.1**	In addition to specific types of meats, the various undefined meats were distributed in proportion to the expenditure on these 4 unprocessed meat categories.
Poultry	3.8	**4.3**	As above
Pork	2.5	**1.1**	As above
Lamb/mutton	1.3	**2.1**	As above
Other			
Cakes, muffins and biscuits	8.2	**6.2**	Used the specific categories
Bread-based dishes	4.1	**4.1**	It was too difficult to identify constituents for this category so the NZ value was used (4.1%).
Milk and dairy			
Milk - whole	2.5	**1.2**	The ratio of whole to trim milk was not available in the HES data so this was obtained from online supermarket data.
- trim	2.6	**1.9**	As above

Food group	NZ Budget share (%)	Aus Budget share (%)	Notes on calculations
Dairy products	2.1	**1.9**	Used the specific categories
Butter and margarine			
Butter	4.6	**0.4**	Used the specific category
Margarine	1.6	**0.3**	Used the specific category
Other			
Pies and pasties	3.1	**3.1**	It was too difficult to identify constituents for this category so the NZ value was used (3.1%).
Cheese	2.1	**3.2**	Used the specific category
Fruit and vegetables	8.1	**23.2**	Specific items were totalled and a proportion of the undefined vegetable category was assigned to this one based on the ratio of all specified vegetables to potatoes.
Non-alcoholic beverages (soft drinks)	2.7	**3.9**	Used the specific category for soft drinks.
Other	18.5	**23.3**	This category comprised all other items (except for the pre-prepared meals and purchased meals (eg, restaurant meals) and takeaways.
Total	100.0	**100.0**	

Method – rules used in applying the budget share constraint

The working rule that we used to adjust the cross-PEs was that when there was a gap between the budget shares of the current PE estimations and the theoretically targeted ones, we increased/decreased proportionally both negative and positive PEs towards a targeted value in order to remove the gap. This also helps to minimise the risks of changing signs of the PEs, which will alter the nature of elasticities between the two goods in questions (eg, change the relationship from substitute to complementary goods and vice versa). For example, in the "bread" category for NZ, the gap in budget share between the current PE estimation and the theoretically targeted one was 6.6%, the total value of positive PEs was 4.68% and that of negative one was -4.16%. Then we proportionally scaled all positive PEs so that the total value increased by 3.5%, and proportionally decreased all negative ones so that its total value increased by

3.1%. As a result, the gap in budget share became zero. Using this rule, the sign of almost all adjusted cross-PEs for both Australia and NZ was unchanged. One exceptional was the cross-PE of “soft drinks” with regard to the price of “fruits and vegetables”, which changed from 0.12 to -0.005, in the Australia PE data. Since the value -0.005 was very small, we ignored it and forced the cross-PE between “soft drink” and “fruits and vegetables” to be zero.