Estimating LES Parameters with Heterogeneous Households for a CGE Model

Mohammad Reza Gharibnavaz[1] and George Verikios[2]

KPMG Australia

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Abstract

In CGE models exogenously-specified elasticity parameters describing the behaviour of consumers, producers and trade patterns calibrate the model equations to analyse a wide array of socio-economic issues, such as tax policy reforms. Since CGE models give no insight into how aggregate changes in the economy affect individuals, a tendency of linking microsimulation and CGE models has emerged in recent studies to highlight the distributional effects of policy simulations by using the complementary advantages of both approaches. In this regard, the treatment of households as a single representative agent is the main limitation of standard CGE models. Similarly, labour supply responses in CGE models usually do not reflect heterogeneity across households. Therefore, it is desirable to represent disaggregated households in a CGE model to evaluate the distributional effects of policy simulations.

We estimate the behavioural parameters essential for the calibration of the demand side of a CGE model, including linear expenditure system (LES) parameters and expenditure elasticities for 5 household types in Australia, grouped according to income. We utilise the 2009-10 Household Expenditure Survey (HES) to estimate the LES parameters and expenditure elasticities for Australian households. The Seemingly Unrelated Regression Equations (SURE) model is used to solve a 21-good demand system simultaneously. It is worth noting that the econometric estimation is done in a model whose structure is consistent with the CGE model in which the estimated parameters and elasticities are applied, since the conditions that are inherent in the CGE model are incorporated as constraints in the econometric estimation.

A comparison of the results for household income quintiles suggests that except for the highest quintile the estimated subsistence consumption parameters for some commodities such as *Agricultural Products, Processed Food, Electricity, Gas and Water* are relatively higher for lower income quintiles. This makes intuitive sense since these commodities are more important items in the consumption bundle of low income households, so their subsistence levels are expected to be relatively higher. Results also confirm that higher income households have larger subsistence consumption for *all other goods and services*.

The estimated expenditure elasticities for the 21 aggregated commodities indicate that *Agriculture, Forestry and Fishing, Electricity, Gas, Water and Waste, Transport and Postal Services, Administrative Services and Other Services* are necessities for all income groups. Results also reveal that most of the remaining commodities are luxuries for lower income quintiles, while they appear to be necessities for the wealthier households.

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[1] Senior Consultant, Deals Tax Legal, KPMG Australia, Tower Two Collins Square, 727 Collins Street Melbourne VIC 3008 Australia, rgharibnavaz@kpmg.com.au.

[2] Director, Deals Tax Legal, KPMG Australia, Riparian Plaza 71 Eagle St Brisbane QLD 4000 Australia, gverikios@kpmg.com.au.

1. Introduction

Forecasting the impacts of government policies on different socio-economic actors in a country can be done by applying different modelling approaches. Econometric models, input-output models and Computable General Equilibrium (CGE) models have all been employed to evaluate economic and social consequences of government policy changes and the distribution of economic resources in both developing and developed nations. Among others, Dick, Gupta, Mayer, and Vincent (1983), Shoven and Whalley (1984), Wong (1990), Bandara (1991), and Baldwin and Venables (1995) have shown the pros and cons of these approaches.

It may be appropriate to use a partial equilibrium framework when the government policy being considered is expected to have relatively small effects on the economy with limited intersectoral repercussions (Harris & Rebecca Lee, 2000). However, the increasing trade-off between economic sectors, consumers, producers and government has been a cause for concern for inadequacy and inefficiency of partial equilibrium methods. Partial equilibrium methods fail not only to analyze interactions among a number of different markets at the same time, but also to answer many questions of economic policy once large policy changes are considered. An important requirement of econometric models is that feedback effects arising from policy shocks must be limited to specific sectors of the economy or the effects on other sectors have to be insignificant. But most developing countries lack both time series and cross-sectional data which are necessary for econometric analysis. CGE modelling is an appropriate technique in circumstances where feedback consequences of a socio-economic shock are significant. In addition, CGE models are able to take into account linkages between factors of production, commodities and economic sectors simultaneously within the economy and between the economy and the rest of the world.

A CGE model is characterized by a range of functional forms that describe the behaviour of firms, households, the government and the rest of the world. Given an initial general equilibrium dataset, the calibration process determines the numerical values of the different parameters of interest in the production, utility, and other functions which characterize economic behaviour. Parameter calibration is vital since results from CGE models are sensitive to the parameter values. According to Devarajan and Robinson (2005), two kinds of parameters are necessary in CGE studies. First, it is necessary to calibrate share parameters from a social accounting matrix (SAM) based on the assumption that an equilibrium solution of model is determined by the SAM base year. Second, exogenously specified elasticity parameters describing the behaviour of consumers, producers and trade patterns in the model are required.

In general, the elasticity values, which on the one hand, rely on assumptions that the economy is in equilibrium and on the other hand, influence the outcomes of policy and external shock simulations, feed the CGE equations to analyse a wide array of socio-economic issues, such as tax policy reforms. However, Shoven and Whalley (1992) and McKitrick (1998) argue that appropriate estimation of these key behavioural parameters has been contentious and affects the empirical validity of these models. Furthermore, Hansen and Heckman (1996) note that estimated behavioural parameters from the partial equilibrium framework cannot be properly employed to the more aggregate household representations frequently present in CGE models. This absence of consistency between econometric models in which parameters are being estimated and the CGE models in which they are being used, along with a paucity of data, theoretical and computational complications in estimation of behavioural parameters have been cited by CGE modellers as challenging barriers to application of appropriate econometric techniques (Arndt, Robinson, & Tarp, 2002).

To evaluate the distributional effects of policy simulations, it is important to represent disaggregated households in a CGE model. Since CGE models give no insight into how aggregate changes in the economy affect individuals, a tendency of linking microsimulation and CGE models has emerged in a number of computational economics studies to highlight the distributional effects of policy simulations by using the complementary advantages of both models. Decaluwé, Dumont, and Savard (1999), Cogneau, Denis and Robilliard, and Anne-Sophie (2000), Cockburn (2001), Cororaton (2003), Bussolo and Lay (2003), Jensen and Tarr (2003), and Boccanfuso, Cissé, Diagne, and Savard (2003) are some of the studies which have used disaggregated private final demands in CGE models in order to better capture the effects of policy changes on the behaviour of representative households. For instance, for five developing countries (Brazil, Pakistan, Tanzania, Uruguay, Vietnam), the MIRAGE model of the world economy disaggregates the representative household into up to 40 households, grouped according to income and consumption structures. As expected, the disaggregated model better captures the behaviour of the public agent in terms of revenues collected and expenditures (Bouët, Estrades, & Laborde, 2011).

The aim of this paper is to estimate the behavioural parameters essential for the calibration of the demand side of a CGE model for Australia. In particular, we estimate linear expenditure system (LES) parameters and expenditure elasticities for five household types, grouped according to income. While these estimated LES demand elasticities are primarily intended for calibration of a CGE model of Australia, they should also be appropriate for calibration of CGE models of other comparable countries. Most importantly, the econometric estimation is done in a model whose structure is consistent with the CGE model in which the estimated parameters and elasticities are being used, since the conditions which are inherent in the general equilibrium model are incorporated as constraints in the econometric estimation.

The paper proceeds as follows. A brief overview of structure of a standard CGE model is provided in section 2. Section 3 addresses the most commonly used functional forms in estimating own-price and expenditure elasticities in the consumption block of CGE models used to describe household behaviour with high levels of household disaggregation. After providing a comprehensive description of the data employed in section 4, section 5 provides the estimation results for own-price and expenditure elasticities across Australian households. Finally, Section 6 concludes.

2. Overview of Structure of a Standard CGE Model

General equilibrium analysis attempts to analyze the economy as a system of mutually dependent markets. Once a government's economic policy is implemented in order to accomplish an economic objective, many socio-economic variables other than those directly targeted are likely to be affected. Therefore, the economic results can be different from the direct economic predictions of partial equilibrium techniques and the objective of economic policy. Consequently, given the complex interdependencies included in the general equilibrium analysis, policy makers often prefer general equilibrium analysis over partial equilibrium models (Thissen, 1998).

In a CGE model, a number of consumers are initially endowed with N commodities and a set of preferences. Demand functions for each good and service and accordingly market demands are derived from the sum of each consumer's demands. Market demands for commodities are continuous, nonnegative, homogeneous of degree zero, a function of all prices and satisfy Walras' law[3]. On the production side of the model, production technology is often characterized as being either non-increasing-returns-to-scale production functions or constant returns- to-scale activities (Greenaway, Leybourne, Reed, & Whalley, 1993).

The mathematical structure of a CGE model implies that the number of simultaneous and nonlinear equations is balanced by the number of variables in the model. However, this is not a sufficient condition for the existence of a solution. In general, the equations of a CGE model are decomposed into prices, production and trade, institutions, and system constraint blocks. The choice of functional form of the equations in the general equilibrium model is influenced by the policy issue being addressed. The Leontief function, the Cobb-Douglas function, the Constant Elasticity of Substitution (CES) function, the Constant Elasticity of Transformation (CET) function and the Linear Expenditure System (LES) function are the familiar functional forms used to model both preferences of households and production technologies of firms in CGE models (Pauw, 2003). A number of studies (Hertel (1985), Despotakis and Fisher (1988), Robinson, Soule, and Weyerbrock (1991), and McKitrick (1998)) drew attention to the significant bearing of the choice of functional form upon the simulation results in CGE modeling.

According to Heathfield and Wibe (1987, p. 76) the most frequently used functional forms to model production are Cobb-Douglas (CD) and constant-elasticity-of-substitution (CES) functions. In general equilibrium analysis, the CD and CES functions are commonly specified to represent substitution among primary factors of production such as labour, capital, land and natural resources in a sector. The main drawback to use the CD functional form in the production side of CGE models is that the factor substitution elasticities always take on a value of unity, while the CES functional form allows for greater flexibility in choosing different factor substitution elasticities when nested CES functions are employed (Partridge & Rickman, 1998). Most CGE models use nested CES production functions that make it possible to distinguish between intermediate inputs and value added in production function.

Having made the choice of functional forms as well as dimensions of the model, compilation of an appropriate data set and calibrating the selected functional forms to the initial equilibrium data set are the crucial steps prior to moving to the implementation of policy change. In general, national accounts, household income and expenditure surveys, input-output tables

[3] According to Walras' law, at any set of prices, the total value of excess demands in all markets must equal zero.

and social accounting matrixes are the common sources to construct a benchmark data set in CGE models. Once the calibration[4] process is done, the CGE modellers use a computer-base replication check in order to ensure consistency between the functional forms of the model and the benchmark data set. After this stage, the model is ready to analyse change in exogenous variables or parameters of the model and study a variety of policy scenarios.

3. Functional Forms for Modelling Consumption Behaviour

Shoven and Whalley (1984) note that the selected functional form should be homogeneous of degree zero, continuous and produce a demand system which satisfies Walras Law. These constraints have caused CGE modellers to choose functional forms such as the Cobb-Douglas (C-D) function, the constant elasticity of substitution (CES) function, or the linear expenditure system (LES) to model preferences of households in CGE models (Pauw, 2003). A number of studies (Hertel (1985), Despotakis and Fisher (1988), Robinson, Soule, and Weyerbrock (1991), and McKitrick (1998)) have drawn attention to the significant bearing of the choice of functional form upon simulation results. Gohin (2005) argued that the selection of functional forms employed to characterize preferences of households as well as production technologies of firms directly affects the specification of price and income effects in CGE models. This section begins by reviewing the functional forms commonly used in estimating expenditure and own-price elasticities used in CGE models. Selecting an appropriate functional form to model consumption behaviour in CGE models with heterogeneous households will also be discussed in the section.

The most common functional form in consumer theory is the Cobb-Douglas utility function which displays constant average budget shares. The Cobb-Douglas utility function is defined in equation (1) where U shows the utility related to the consumption bundle $X = (X_1, X_2, , , , , X_n)$, X_i represents demand for commodity i, and α_i, which lies between zero and one is marginal expenditure share, with $\sum_{i=1}^{n} \alpha_i = 1$.

$$U(X) = \prod_{i=1}^{n} X_i^{\alpha_i} \qquad (1)$$

$$\sum_{i=1}^{n} P_i . X_i = m \qquad (2)$$

$$X_i = \frac{\alpha_i . m}{P_i} \qquad (3)$$

Maximization of the utility function (1) with respect to the expenditure constraint (2), where P_i and m represent price of commodity i and total expenditure respectively, leads to the consumer's demand equation (3). Values for the price and expenditure elasticities from the above demand function are all equal to one. This is recognized as a drawback of the Cobb-Douglas utility function since unitary uncompensated own-price and expenditure elasticities are not consistent with empirical evidence. Therefore, using the Cobb-Douglas functional

[4] Calibration refers to a standard process including estimating and adjusting the structural parameters of the model to fit the model to the benchmark data set.

form could give rise to biased estimations of behavioural parameters of interest for many general equilibrium simulations (Hertel, 1999).

Given the restrictive assumptions of the Cobb-Douglas functional form, the Constant Elasticity of Substitution (CES) function has become a popular functional form in calibration process of general equilibrium models. It relaxes some of the limitations of the Cobb-Douglas utility function in estimating the required elasticities in calibration process. The CES utility function is defined as:

$$U(X) = \left(\sum_{i}^{n} \alpha_i X_i^{\rho}\right)^{\frac{1}{\rho}} \qquad 0 < \alpha_i < 1\,, \ \sum_{i=1}^{n} \alpha_i = 1 \qquad (4)$$

where α_i (i = 1, 2, …, n) and ρ represent the share parameters and the substitution parameter, respectively. Maximization of equation (4) with respect to the expenditure constraint ($m = \sum_{i=1}^{n} P_i X_i$) yields the consumer demand function:

$$X_i = \frac{m}{P_i} \frac{P_i^{1-\sigma} \alpha_i^{\sigma}}{\sum_{j=1}^{n} P_j^{1-\sigma} \alpha_j^{\sigma}} \qquad (5)$$

where the elasticity of substitution is $\sigma = \frac{1}{1-\rho}$. For $\sigma \to 0$ ($\sigma \to \infty$), ρ approaches $-\infty$ ($\rho \to 1$) and consumption goods are perfect complements (substitutes). It is common to assume that $\sigma = 1$ ($\rho = 0$), so that the CES reduces to a Cobb-Douglas function where expenditure shares are constant ($\alpha_i = P_i X_i / m$).

The major advantage of CES is that, unlike the Cobb-Douglas form, it allows for the possibility of non-unitary price and substitution elasticities. Given the increasing use of the CES function in econometric analysis, the CES functional form proposes a degree of flexibility in modelling substitution choices among products in CGE models. While the CES utility function relaxes the unit price elasticity restriction imposed by the Cobb-Douglas utility function, it still restricts expenditure elasticities to unity. This implies that budget shares of commodities are independent of the level of income across different income groups of households.

To overcome this limitation, CGE modellers have used the linear expenditure system (LES) to represent consumer preferences. The LES function generalizes the Cobb-Douglas utility function by imposing positive subsistence consumption in the LES functional form (Boer, 2009). Unlike the Cobb-Douglas and CES functions, the LES functional form allows calibration to non-unitary expenditure elasticities, removing a major shortcoming of the two previous functional forms (Shoven & Whalley, 1992). Equation (6) shows the LES or Stone-Geary utility function, where $\mu_i \geq 0$ is the subsistence consumption of commodity i:

$$U(X) = \prod_{i=1}^{n} (X_i - \mu_i)^{\alpha_i} \qquad 0 < \alpha_i < 1\,, \ \sum_{i=1}^{n} \alpha_i = 1 \qquad (6)$$

It is assumed that the consumer first allocates an amount of income for consuming the subsistence bundle. The α_i parameters give the marginal expenditure shares. Maximization of the LES utility function subject to the income constraint ($m = \sum_{i=1}^{n} P_i X_i$) yields the LES Marshallian demand function (7):

$$X_i = \mu_i + \frac{\alpha_i}{P_i}\left(m - \sum_j P_j \mu_j\right) \tag{7}$$

where $\sum_j P_j \mu_j$ corresponds to income spent on subsistence consumption, and the term in parentheses $\left(m - \sum_j P_j \mu_j\right)$ refers to supernumerary income, representing the income available after the consumption of subsistence bundle has been allocated.

In CGE applications, estimating expenditure and price elasticities of commodities of interest for each income group of households from the LES demand systems is a high priority in the calibration process. Following common practice, we denote the demand for good i and the income of household h as X_{ih} and m_h, respectively, where $h \in \{1,2,\dots,5\}$ signifies the income group of the household. The LES demand function for consumption of commodity i by household h is given in equation (8), where the LES parameters μ_{ih} and α_{ih} are defined as before. Each individual household first spends its income on subsistence consumption, irrespective of its income level. The residual income is then allocated across all marketed goods in the proportions specified by α_{ih}.

$$X_{ih} = \mu_{ih} + \frac{\alpha_{ih}}{P_i}\left(m_h - \sum_j P_j \mu_{jh}\right) \tag{8}$$

To estimate the LES parameters and elasticities, we multiply equation (8) by P_i and augment it by the ϵ_{ih} error term (or disturbance) to obtain (9), a more concise econometric model for the LES function:

$$P_i X_{ih} = P_i \mu_{ih} + \alpha_{ih}\left(m_h - \sum_j P_j \mu_{jh}\right) + \epsilon_{ih} \tag{9}$$

To rule out positive own-price elasticities in the model, the Frisch parameter is employed as a substitution parameter quantifying the sensitivity of the marginal utility of income to total expenditures. According to move bracket to year Lluch, Powell, Williams, and Fomento (1977), the Frisch parameter is "interpreted within the LES as the elasticity with respect to total per capita nominal consumption spending of the marginal utility of the last dollar optimally spent". The Frisch parameter is the negative of the ratio of total expenditure by household h to supernumerary income:

$$Frisch_{hn} = \frac{-m_{hn}}{(m_{hn} - \sum_j P_j \mu_{jhn})} \tag{10}$$

Since price elasticities can be determined as a function of the Frisch parameter and expenditure elasticity, calculating the Frisch parameter for each income group of households is crucial in studies where detailed price data to estimate reliable own-price elasticities are not available. Gelan (2007) and Powell, McLaren, Pearson, and Rimmer (2002) characterize the algebraic relationship between the LES variables for estimating the minimum consumption level. Equation (11) shows a simplified relationship between subsistence consumption of commodity i by household h and the LES variables, where φ_h is the negative inverse of the Frisch parameter ($\varphi_h = (-Frisch_h)^{-1}$).

$$\mu_{ih} = X_{ih}\left(1 - \varphi_h\left(\frac{\alpha_{ih} m_h}{P_i X_{ih}}\right)\right) \tag{11}$$

The formulae for the estimation of income/expenditure and own-price elasticities are shown in equations (12) and (13), respectively. The expenditure elasticity must be positive ($\varepsilon_{ih} > 0$), which rules out the possibility of inferior commodities. The own-price elasticity must be between minus one and zero ($-1 < \gamma_{ip} < 0$), so the LES allows only for the existence of inelastic demand (Boer & Missaglia, 2006).

$$\varepsilon_{ih} = \frac{\alpha_{ih} m_h}{P_i X_{ih}} \quad , \quad \varepsilon_{ih} > 0 \tag{12}$$

$$\gamma_{ip} = \frac{(1 - \alpha_{ih})\mu_{ih}}{X_{ih}} - 1 \quad , \quad -1 < \gamma_{ip} < 0 \tag{13}$$

The LES has been recognized as an appropriate tool to estimate large systems of demand equations (Braithwait, 1977; S.D. Braithwait, 1980; Capps, 1983). Even though the LES model of consumer behavior is linear in prices and disposable income, its estimation is a highly complex process because the μ_{ih} and α_{ih} coefficients enter the model in a multiplicative manner. Since combining all demand equations as a system results in an estimation efficiency gain, we rely on the seemingly unrelated regression equations (SURE) model proposed by Zellner (1962). In particular, we use a system of regression equations, where each equation has its own dependent variable as well as a potentially different set of exogenous variables, to model all demand equations (9) simultaneously and to estimate the expenditure and price elasticities across sample households whose consumption patterns are given by the LES demand function.

Since the primary purpose of this paper is to estimate LES parameters to be used in the calibration of CGE models, it is important that own-price and expenditure elasticities are estimated in an econometric model whose structure is consistent with the CGE model in which the estimated parameters and elasticities will be used. In order to reduce the number of unknown parameters and to ensure that we estimate the LES parameters consistently, two economic constraints are imposed, adding-up and homogeneity, which are essential for the analysis of household behaviour in a general equilibrium framework. The adding-up constraint implies that the marginal expenditure shares across all consumer goods sum to one ($\sum_{i=1}^{n} \alpha_i = 1$). The second constraint is homogeneity of degree zero in prices and incomes, implying that if all prices and total expenditures change by the same proportion, there is no change in the quantity demanded. How this is operationalized in the econometric model is detailed in the first paragraph of Section 5.

4. The data

This section provides an exhaustive description of the data employed in this research as well as their aggregations and modifications. For estimation purposes we rely on the 2009-10 Household Expenditure Survey (HES) Survey of Income and Housing (SIH) conducted by the Australian Bureau of Statistics (ABS). Analysing the survey provides appropriate tools to evaluate sources of income and expenditure of Australian households. The main objective of employing the survey is to estimate the expenditure and price elasticity of demand for consumption and income distribution across the country.

The 2009-10 HES comprises much more information on individual household expenditure and income than the data contained in Australian input-output tables. The main components of the survey are the income and expenditure data of nearly 10,000 sample households living in eight state and territories throughout the country. The survey has been carried out solely through interviews from usual residents[5] of private dwellings in urban and rural areas of Australia.

Table 4.1 depicts the distribution of the HES final sample households (including the pensioner sample) between states and territories, and between capital cities and the balance of state. Of the 9,774 sample households in the 2009-10 HES, over 4,200 households (44 per cent) were selected from New South Wales and Victoria, while the remaining 56 per cent were selected from other states and territories.

Table 4.1. HES final household sample, 2009– 10

	Capital City	Balance of State	Total
New South Wales	1,826	592	2,418
Victoria	1,540	314	1,854
Queensland	1,116	349	1,465
South Australia	1,062	213	1,275
Western Australia	1,038	205	1,243
Tasmania	629	128	757
Northern territory	297	67	364
Australian Capital Territory	398	—	398
Australia	**7,906**	**1,868**	**9,774**

Source: ABS, the 2009–10 Household Expenditure Survey (HES) (http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6503.02009-10)

[5] Usual residents were residents who regarded the dwelling as their own or main home.

The major attributes of the survey, including the reference unit, the geographical levels of the data, as well as the various items under consideration, provide an appropriate form for identifying the consumption and income distribution patterns of sample households. The nature of the survey makes it possible for the government to measure the socio-economic outcomes of economic policies and planning schemes. Thus, improvements in the quality and accuracy of the survey have been considered of prime importance by the ABS.

The 2009-10 HES provides a snapshot of Australian household's spending on more than 600 disaggregated goods and services. In the 2009–10 HES, expenditure estimates have been classified according to both "Household Expenditure Classification (HEC)" and the "Classification of Individual Consumption According to Purpose (COICOP)". To incorporate the information of heterogeneous households' incomes and expenditures from HES database in a CGE database, it is first necessary to construct an appropriate mapping between the two databases. Given that CGE models are based mainly on official input-output data, the commodities for which data were available in the HES were re-categorized to match the commodities classification provided in Australia's input output table.

For the sake of simplicity in representing the model and interpreting the results, the 600-sector HES data base is aggregated to a more manageable number of sectors of interest according to the research objectives. The 600 HES commodities are first aggregated to 114 aggregated commodities that are consistent with the 114 input-output product classification (IOPC). The 114 aggregated commodities are then aggregated to 21 groups of commodities, maintaining as much disaggregation as possible for major commodities such as food, energy and services. Table 4.2 portrays a listing of 21 aggregated sectors along with their relationship to the 114 sectors available in the input-output data base.

Table 4.2. Aggregated Sectors

21 Aggregated Sectors	input-output Sectors
1. Agriculture, Forestry and Fishing	Sheep, Grains, Beef and Dairy Cattle, Poultry and Other Livestock, Other Agriculture, Aquaculture, Forestry and Logging, Fishing, hunting and trapping, Agriculture, Forestry and Fishing Support Services.
2. Mining	Coal mining, Oil and gas extraction, Iron Ore Mining, Non Ferrous Metal Ore Mining, Non Metallic Mineral Mining, Exploration and Mining Support Services.
3. Manufactures_Processed Food	Meat and Meat product Manufacturing, Processed Seafood Manufacturing, Dairy Product Manufacturing, Fruit and Vegetable Product Manufacturing, Oils and Fats Manufacturing, Grain Mill and Cereal Product Manufacturing, Bakery Product Manufacturing, Sugar and Confectionery Manufacturing, Other Food Product Manufacturing, Soft Drinks, Cordials and Syrup Manufacturing, Beer Manufacturing, Wine, Spirits and Tobacco
4. Manufactures_Light Goods	Textile Manufacturing, Tanned Leather, Dressed Fur and Leather Product, Manufacturing, Textile Product Manufacturing, Knitted Product Manufacturing, Clothing Manufacturing, Footwear Manufacturing, Sawmill Product Manufacturing, Other Wood Product Manufacturing, Pulp, Paper and Paperboard Manufacturing, Paper Stationery and Other Converted Paper Product Manufacturing, Printing (including the reproduction of recorded media), Domestic Appliance Manufacturing, Specialised and other Machinery and Equipment Manufacturing, Furniture Manufacturing, Other Manufactured Products.
5. Manufactures_Heavy Goods	Petroleum and Coal Product Manufacturing, Human Pharmaceutical and Medicinal Product Manufacturing, Veterinary Pharmaceutical and Medicinal Product Manufacturing, Basic Chemical Manufacturing, Cleaning Compounds and Toiletry

	Preparation Manufacturing, Polymer Product Manufacturing, Natural Rubber Product Manufacturing, Glass and Glass Product Manufacturing, Ceramic Product Manufacturing, Cement, Lime and Ready-Mixed Concrete Manufacturing, Plaster and Concrete Product Manufacturing, Other Non-Metallic Mineral Product Manufacturing, Iron and Steel Manufacturing, Basic Non-Ferrous Metal Manufacturing, Forged Iron and Steel Product Manufacturing, Structural Metal Product Manufacturing, Metal Containers and Other Sheet Metal Product manufacturing, Other Fabricated Metal Product manufacturing, Motor Vehicles and Parts; Other Transport Equipment manufacturing, Ships and Boat Manufacturing, Railway Rolling Stock Manufacturing, Aircraft Manufacturing, Professional, Scientific, Computer and Electronic Equipment Manufacturing, Electrical Equipment Manufacturing.
6. Electricity, Gas, Water and Waste	Electricity Generation, Electricity Transmission, Distribution, On Selling and Electricity Market Operation, Gas Supply, Water Supply, Sewerage and Drainage Services, Waste Collection, Treatment and Disposal Services.
7. Construction	Residential Building Construction, Non-Residential Building Construction, Heavy and Civil Engineering Construction, Construction Services.
8. Wholesale Trade	Wholesale Trade
9. Retail Trade	Retail Trade
10. Accommodation and Food	Accommodation, Food and Beverage Services.
11. Transport and Postal Services	Road Transport, Rail Transport, Water, Pipeline and Other Transport, Air and Space Transport, Postal and Courier Pick-up and Delivery Service, Transport Support services and storage.
12. Telecommunication	Publishing (except Internet and Music Publishing), Motion Picture and Sound Recording, Broadcasting (except Internet), Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing, Telecommunication Services, Library and Other Information Services.
13. Insurance and Finance	Finance, Insurance and Superannuation Funds, Auxiliary Finance and Insurance Services.
14. Rental Services	Rental and Hiring Services (except Real Estate), Ownership of Dwellings, Non-Residential Property Operators and Real Estate Services.
15. Professional Services	Professional, Scientific and Technical Services, Computer Systems Design and Related Services.
16. Administrative Services	Employment, Travel Agency and Other Administrative Services, Building Cleaning, Pest Control and Other Support Services.
17. Public Administration Services	Public Administration and Regulatory Services, Defence, Public Order and Safety.
18. Education	Primary and Secondary Education Services (incl Pre-Schools and Special Schools), Technical, Vocational and Tertiary Education Services (incl undergraduate and postgraduate), Arts, Sports, Adult and Other Education Services (incl community education).
19. Health	Health Care Services, Residential Care and Social Assistance Services.
20. Arts, Sports and Recreation	Heritage, Creative and Performing Arts, Sports and Recreation, Gambling.
21. Other Services	Automotive Repair and Maintenance, Other Repair and Maintenance, Personal Services, Other Services.

Source: Author’s calculations

Sample households in the survey are decomposed into five household groups according to income levels to simplify the analysis of the socio-economic effects of government policies on different groups of households. For this purpose, household income estimates on the 2009-10 SIH were combined with the 2009-10 HES. In order to define household quintiles, equivalised disposable household income (EDHI) estimates compiled from the 2009–10 SIH were used.

Equivalised household disposable income refers to the total net income of a household (household income after income tax and other deductions such as the Medicare levy and the

Medicare levy surcharge) divided by the number of 'equivalent adults', using a standard (equivalence) scale. This concept is broadly used to study income distribution and poverty in Australia. Given the fact that a multi person household would normally need more income than a single person household if the two households are to enjoy the same standard of living, equivalence scales have been developed to make adjustments to the actual incomes of households in a way that enables analysis of the relative wellbeing of households with different sizes. In the 2009-10 SIH, household income is adjusted according to the 'modified OECD' equivalence scale (ABS, 2012). Thus, the equivalised income disposable which is generally based on numbers of people rather than numbers of households represents the economic resources available to a standardised household.

Table 4.3 presents the expenditure shares of food, energy and other commodities by household types. Expenditure shares of agriculture products, food and energy commodities decrease with income. Summary statistics from the survey show that lower income households also consistently spend a large share of this income on manufactures-processed food and rental services. However, the higher income groups prefer to spend relatively more on the remaining non-food and non-energy commodities such as manufactures-light goods, accommodation, transport, finance, insurance, education and health. The expenditure shares of other commodities appears to be fairly steady across different income groups of households.

Table 4.3: Descriptive Data for Expenditure Shares of the Commodities by Household Type

Income groups	Lowest quintile	Second quintile	Third quintile	Fourth quintile	Highest quintile
Number of Observations	1955	1955	1955	1955	1955
Agriculture, Forestry and Fishing	2.4%	2.7%	2.6%	2.3%	2.1%
Mining	1.3%	1.9%	1.5%	1.3%	1.4%
Manufacturing_Processed Food	16.0%	15.2%	15.2%	12.7%	9.1%
Manufacturing_Light Goods	14.2%	14.8%	16.1%	16.5%	15.6%
Manufacturing_ Heavy Goods	22.9%	22.9%	22.5%	24.2%	21.9%
Electricity, Gas, Water and Waste	3.2%	3.5%	3.3%	3.0%	2.5%
Construction	0.7%	1.4%	0.8%	0.7%	1.1%
Wholesale Trade	0.2%	0.3%	0.2%	0.2%	0.3%
Retail Trade	0.2%	0.3%	0.2%	0.2%	0.3%
Accommodation and Food	5.3%	4.7%	5.7%	6.5%	7.2%
Transport and Postal Services	2.5%	2.7%	2.8%	2.9%	3.5%
Telecommunication	3.2%	3.9%	3.6%	3.6%	3.3%
Insurance and Finance	5.9%	5.8%	8.2%	7.4%	13.1%
Rental Services	12.4%	8.9%	6.7%	5.7%	6.0%
Professional Services	1.0%	1.1%	0.8%	0.9%	1.3%
Administrative Services	0.5%	0.6%	0.6%	0.8%	0.8%
Public Administration Services	0.5%	0.9%	0.6%	0.7%	0.8%
Education	1.5%	1.4%	1.5%	2.1%	2.3%
Health	1.9%	2.4%	2.7%	3.3%	2.9%
Arts, Sports and Recreation	1.2%	1.2%	1.7%	1.8%	1.4%
Other Services	2.9%	3.2%	3.0%	3.2%	3.4%

Source: Author's calculations

5. Estimation Results

The system of seemingly unrelated regression (SUR) equations with non-negativity constraints imposed on the coefficients is used to estimate the LES parameters (μ_{ih} and α_{ih}) in equation (9). The LES demand system is estimated from the variation of unit values and quantities, and consequently from the variation in household incomes and expenditures. To estimate the LES parameters μ_{ih} and α_{ih}, the 2009 Consumer Price Index (CPI) provided by the ABS for commodities are employed as price variables. The LES parameters by household type are estimated by the SUR algorithm of EViews (version 9).

Given that total expenditure and total income are equivalent, the disturbances in the system add up to zero. Therefore, the estimation breaks down due to the singularity of the covariance matrix. As a solution to this problem, Judge, Hill, Griffiths, Lutkepohl, and Lee (1988) and Nganou (2004) recommend omitting one arbitrary equation for the estimation of the demand system: The absent equation can be retrieved from the adding-up restriction $(m_h = \sum_i P_i X_{ih})$. Estimation results are robust to which equation is omitted, since changing the equation which is omitted does not affect the estimation results.

Tables 5.1 and 5.2 present the estimated LES parameters μ_{ih} and α_{ih} respectively. Results suggest that most of estimated subsistence consumption and marginal budget share for the entire sample across all households are statistically significant at the 10 percent level ($p < 0.10$) and at the 1 percent level ($p < 0.01$) respectively.

A comparison of the results for household income quintiles suggests that except for the highest quintile the estimated subsistence consumption parameters for some commodities such as *Agricultural Products, Electricity, Gas and Water* are relatively higher for lower income quintiles. This makes intuitive sense since these commodities are more important items in the consumption bundle of low income households, so their subsistence levels are expected to be relatively higher. Results also confirm that higher income households have larger subsistence consumption for *all other goods and services*.

Table 5.1: Estimation of the Subsistence Consumption of Each Commodity by Household Type

	Lowest quintile	Second quintile	Third quintile	Fourth quintile	Highest quintile
	μ_{i1}	μ_{i2}	μ_{i3}	μ_{i4}	μ_{i5}
Agriculture, Forestry and Fishing	17.9	16.7	13.6	11.9	33.6***
Mining	2.9*	3.6*	6.2	2.2*	11.7***
Manufacturing_Processed Food	111.2	151.9*	205.3*	188.9	176.3***
Manufacturing_Light Goods	59.3*	69.3	100.4*	182.2*	235.7***
Manufacturing_ Heavy Goods	44.6*	98.6**	132.5*	224.6*	350.5**
Electricity, Gas, Water and Waste	12.9*	18.8***	15.9*	12.8*	44.3***
Construction	0.1	0.3*	0.7**	0.8	0.7*
Wholesale Trade	0.1*	0.1*	0.2*	0.2	0.2*
Retail Trade	1.7**	0.1**	0.2*	0.2*	0.2*
Accommodation and Food	20.8*	57.2***	72.3*	93.5*	131.1***
Transport and Postal Services	9.1**	14.5***	25.9*	31.0*	62.1***
Telecommunication	1.2*	9.9	14.9*	19.2*	39.0***
Insurance and Finance	4.4***	13.5**	22.4*	80.3*	209.9***
Rental Services	21.3*	44.8**	79.4*	36.3*	105.3***
Professional Services	0.1*	0.6*	1.0*	11.4*	13.2***
Administrative Services	1.3*	4.5**	4.8*	15.0*	10.6***
Public Administration Services	0.1**	1.6*	2.5**	0.4	4.3***
Education	14.3*	48.3***	79.7*	109.1	15.7*
Health	3.0*	1.9**	6.7*	56.0*	51.9***
Arts, Sports and Recreation	4.2**	8.4***	17.0**	23.9**	27.7***
Other Services	15.8*	10.9***	7.1*	16.4*	56.1***

Source: Author's calculations

Note. $*** = p < 0.01,\ ** = p < 0.05,\ * = p < 0.10$

Table 5.2: Estimation of the Marginal Expenditure Share of Each Commodity by Household Type

	Lowest quintile	Second quintile	Third quintile	Fourth quintile	Highest quintile
	α_{i1}	α_{i2}	α_{i3}	α_{i4}	α_{i5}
Agriculture, Forestry and Fishing	0.018***	0.023***	0.023***	0.023***	0.019***
Mining	0.019	0.017***	0.012***	0.007***	0.015***
Manufacturing_Processed Food	0.180***	0.190***	0.203***	0.150***	0.049***
Manufacturing_Light Goods	0.154***	0.164***	0.155***	0.167***	0.179***
Manufacturing_ Heavy Goods	0.255***	0.207***	0.208***	0.231***	0.207***
Electricity, Gas, Water and Waste	0.024***	0.029***	0.024***	0.024***	0.019***
Construction	0.009*	0.014*	0.005***	0.002***	0.017***
Wholesale Trade	0.002	0.003*	0.001***	0.001***	0.004***
Retail Trade	0.004	0.003*	0.001***	0.001***	0.004***
Accommodation and Food	0.036***	0.059***	0.074***	0.074***	0.055***
Transport and Postal Services	0.017***	0.022***	0.030***	0.028***	0.024***
Telecommunication	0.037***	0.033***	0.031***	0.028***	0.031***
Insurance and Finance	0.056***	0.041***	0.032	0.069***	0.166***
Rental Services	0.122***	0.077***	0.082***	0.045***	0.046***
Professional Services	0.010	0.012***	0.005***	0.009***	0.014***
Administrative Services	0.004	0.002	0.001	0.002	0.008***
Public Administration Services	0.006	0.008***	0.005***	0.003	0.011***
Education	0.021***	0.036***	0.050***	0.054***	0.072***
Health	0.017***	0.021***	0.019***	0.041***	0.027***
Arts, Sports and Recreation	0.009***	0.018***	0.019***	0.020***	0.004***
Other Services	0.001	0.021***	0.021***	0.022***	0.028***

Source: Author's calculations

Note. $*** = p < 0.01,\ ** = \ p < 0.05,\ * = p < 0.10$

The estimated results of the *LES* parameters derived from the SURE method and the average budget shares are employed to estimate the expenditure elasticities of the 21 aggregated commodities for each income group of households. Table 5.3 reports the expenditure elasticities of the LES demand by household type. Since the expenditure elasticities for *Agriculture, Forestry and Fishing, Electricity, Gas, Water and Waste, Transport and Postal Services, Administrative Services and Other Services* are either less than one or very close to one across all households, these commodities are necessities for all of the income groups. The estimated expenditure elasticities of *Manufacturing_Processed Food* and *Education* are greater than one for almost all household income quintiles, implying that these commodities are luxuries across all households. As expected, *Manufacturing_Processed Food* and *Education* are stronger luxuries for lower income groups.

Results also show that some commodities such as Manufacturing_Light Goods, Manufacturing_ Heavy Goods, Construction, Wholesale and Retail Trades, Accommodation and Food, Telecommunication, Insurance and Finance, Rental and Professional Services are luxuries for lower income quintiles, while they appear to be necessities for the wealthier households. The exception is Health, whose expenditure elasticity is greater than one for the fourth income quintile.

Table 5.3: Expenditure Elasticities of the LES Demand by Household Type

	Lowest quintile	Second quintile	Third quintile	Fourth quintile	Highest quintile
Agriculture, Forestry and Fishing	0.88	0.78	0.76	0.85	0.40
Mining	1.58	0.79	0.72	0.48	0.47
Manufacturing_Processed Food	1.28	1.13	1.15	1.02	0.23
Manufacturing_Light Goods	1.22	1.01	0.83	0.87	0.49
Manufacturing_ Heavy Goods	1.26	0.82	0.79	0.82	0.40
Electricity, Gas, Water and Waste	0.84	0.74	0.61	0.68	0.32
Construction	1.42	0.90	0.56	0.30	0.66
Wholesale Trade	1.21	0.90	0.56	0.30	0.66
Retail Trade	2.49	0.90	0.56	0.30	0.66
Accommodation and Food	0.76	1.13	1.11	0.99	0.32
Transport and Postal Services	0.79	0.74	0.94	0.82	0.30
Telecommunication	1.30	0.76	0.73	0.66	0.41
Insurance and Finance	1.07	0.65	0.33	0.81	0.54
Rental Services	1.12	0.79	1.06	0.68	0.33
Professional Services	1.16	0.93	0.46	0.87	0.45
Administrative Services	0.88	0.31	0.11	0.24	0.40
Public Administration Services	1.31	0.77	0.72	0.65	0.61
Education	1.62	2.40	2.91	2.23	1.31
Health	1.00	0.81	0.60	1.08	0.40
Arts, Sports and Recreation	0.84	1.39	0.98	0.98	0.13
Other Services	0.06	0.60	0.62	0.58	0.35

Source: Author’s calculations

6. Conclusion

To evaluate the distributional effects of policy simulations, it is important to represent disaggregated households in a CGE model. The aim of this paper was to estimate the behavioural parameters in a system of LES demand functions, to provide expenditure elasticities for a representative country (Australia) which could be used for modelling consumption behaviour in a static CGE model. It is well understood that such elasticity parameters have an important influence on the outcomes of policy and external shock simulations in CGE models which are used to analyse a wide array of socio-economic issues. Using income and expenditure data of the 2009-10 Household Expenditure Survey and Survey of Income and Housing conducted by the Australian Bureau of Statistics, we estimate expenditure elasticities for five household types, grouped according to income. We ensured that the econometric model used to estimate these elasticities is consistent with the CGE model in which they will be used.

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