Estimation of the parameters of a linear expenditure system (LES) demand function for a small African economy

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Estimation of the Parameters of a Linear Expenditure System (LES) Demand Function for a Small African Economy

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Abstract:

The validity of the key behavioral parameters used in the calibration process of computable general equilibrium (CGE) models remains a debated issue in the CGE literature. CGE modelers prefer to borrow from the handful of estimates available in the literature rather than estimating these parameters empirically. The dearth of data is often mentioned as the major reason for compromises to the empirical basis for the parameters used in CGE models. While the empirical literature on demand elasticities based on household expenditure surveys has been relatively available for both developed and developing countries, it remains lacking for African countries. This paper uses a seemingly unrelated regressions method to estimate own-price and income elasticities, as well as Frisch parameters for households whose consumption behavior is described by a Linear Expenditure System (LES) demand function. All the parameters estimated are intended for use in a Lesotho CGE model. The estimation results are generally consistent with the theory predictions.

Keywords: CGE; Demand System (LES); Seemingly Unrelated Regressions (SUR); Africa; Lesotho

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1 Introduction

The validity of the key behavioral parameters used in the calibration process of computable general equilibrium (CGE) models remains a debated issue in the CGE literature. CGE modelers prefer to borrow from the handful of estimates available in the literature rather than estimating these parameters empirically. The dearth of data is often mentioned as the major reason for compromises to the empirical basis for the parameters used in CGE models. The empirical literature on demand elasticities based on household expenditure surveys has been relatively available for both developed and developing countries (e.g., Lluch, Powell, and Williams (1977), Tulpule and Powell (1978), Creedy (1996)). However, no such study exists for Lesotho.

The purpose of this paper is to address some of the criticisms leveled against the use of parameters taken from the literature in CGE models. We estimate parameters of a linear expenditure system (LES) demand function, including elasticities of expenditures, own-price elasticities, and Frisch parameters, all intended for use in the Lesotho CGE model (Nganou, 2005).

2. The Data

For the estimation of LES parameters, the 1994/95 Lesotho Household Expenditures Survey (HES) of the Lesotho Bureau of Statistics was used to derive expenditure levels. The commodities for which data were available in the HES were re-categorized to match the commodities classification provided in the Lesotho SAM (STLESAM). Thus, Lesotho households direct most of their spending to the following nine commodities: Agriculture, Food, Beverages and Tobacco, Textiles, Utilities, Private Services, Government Services, Transport, Other Manufacturing, and Financial Services.

Table 1 presents the descriptive statistics for commodities expenditures and consumer price indices for each category of household. The data set contains a maximum of 1932 observations for urban households and 2628 observations for rural households. In general, expenditure and price levels are higher for urban households than their rural counterparts. As expected, the average annual expenditure amounts to 91,721.86 Maloti for urban households compared to only 35,185.76 Maloti for rural households. Financial services (including all forms of informal sources of finance such as through funeral homes) seem to be the most purchased service for urban households (12,000 Maloti on average) whereas rural households consumed mostly textile products (10,160 Maloti). It was not useful to break the data set down into several sub-samples according to income and location to agree exactly with the disaggregation provided in the STLESAM because the number of observations was significantly smaller for some sub-samples. Prices data are also needed to estimate LES parameters. This study uses the 2000 Consumer Price Index (CPI) series by commodities and location (rural and urban) provided by the Lesotho Bureau of Statistics as price variables (1997 was the base year)[2] .

TABLE 1 HERE

3. Estimation of Parameters

Zellner's SUR method was used to estimate LES parameters because efficiency gain can be achieved by combining each demand equation as a system.

3.1 Estimating the Parameters and Elasticities of the LES Demand

3.1.1 Theoretical Background and Methodology[3]

In many CGE models, household preferences are derived from the maximization of Cobb Douglas or CES utility specifications. A fundamental limitation of such functional forms for

[2]The 2000 CPI were used instead of the 1994/95 CPI because the Lesotho SAM that serves as the dataset for the CGE is of 2000.

[3]The basic theoretical foundations of the linear expenditure system (LES) demand presented in this section are taken in its entire text from Nganou (2005, Chapter 7).

consumption is that they imply unitary income elasticity of demand since average and marginal propensities to spend are constant and equal for these specifications. Another limitation of CES specifications in consumer preferences can be seen in the case where there are many small consumer goods. In this case, there is an excessive symmetry between goods since the compensated own-price elasticity for each good converges on the common elasticity of substitution between all goods (Shoven and Whalley, 1984). Unlike CES functions, linear expenditure system (LES) utility functions assume that average propensities to spend vary systematically with income level due to the minimum subsistence requirement imposed on each good (Davies, 2003). To avoid such drawbacks, an interesting feature of the Lesotho CGE model is its assumption that, each household maximizes a linear expenditure system (LES) or Stone-Geary utility function subject to its consumption expenditure constraint.

Household h's consumption problem under this set-up is the following:

$$\text{Max}\, U_h = \sum_{c=1}^{10} \beta_{ch}.\ln\left(QH_{ch} - \gamma_{ch}\right) \tag{1}$$

subject to the budget constraint and the Engel aggregation condition[4] on the *βs*:

$$EH_h = \sum_{c=1}^{10} PQ_c.QH_{ch} \tag{2}$$

$$\sum_{c=1}^{10} \beta_{ch} = 1 \tag{3}$$

where γ_{ch} and β_{ch} are the LES parameters. More precisely, the former is the marginal share of consumption spending for household h on marketed commodity c, and the latter is the subsistence requirement on each marketed commodity c for household h; QH_{ch} is the

[4] The Engel aggregation condition requires that $\sum_{c=1}^{10} \beta_{ch} = 1$

household h's consumption quantity of marketed commodity c; PQ_c is the price of commodity c.

The Lagrangian for this optimization problem is as follows:

$$\text{Max } L = U_h + \lambda\left(EH_h - \sum_{c=1}^{10} PQ_c.QH_{ch}\right) \tag{4}$$

Differentiating the above Lagrangian equation with respect to *QHc*, and after some rearrangements of the first order conditions, yields the demand function of the household h on commodity c which later will be estimated econometrically:

$$QH_{ch} = \gamma_{ch} + \frac{\beta_{ch}}{PQ_c}\left(EH_h - \sum_{c'=1}^{10} PQ_{c'}.\gamma_{c'h}\right) \tag{5}$$

It is clear from equation (1) that a household's spending on individual commodities is a linear function of the total consumption spending (or income) EH_h. The usual interpretation of the above demand function is that consumption has two components. The first component has been referred to as the subsistence minima (or consumption floor), γ_{ch}. The expression in parentheses represents the residual income (supernumerary income), or, as some researchers call it, luxury expenditures/usages. It is the remainder of income after subtracting expenditures on the subsistence minima. The second term of the demand function is therefore a share of supernumerary income. In fact, γ_{ch} represents subsistence quantities while β_{ch} reflects the relative contribution of each commodity to utility after subsistence has been achieved.

For estimation purposes, it is common practice to multiply both sides of eq. (5) by PQ_c to obtain a linear expenditure system of equations, so designated because expenditure is a linear function of income and prices. The expenditure system is clearly not linear in the parameters (γ_{ch} and β_{ch}) (see Judge, Hill, Griffiths, Lutkepohl, and Lee (1988)). The corresponding econometric model for the linear expenditure system is the following:

$$PQ_c.QH_{ch} = PQ_c.\gamma_{ch} + \beta_{ch}\left(EH_h - \sum_{c'=1}^{10} PQ_{c'}.\gamma_{c'h} \right) + \varepsilon_{ch} \qquad (6)$$

where ε_{ch} is the error term, γ_{ch} and β_{ch} are the parameters to be estimated, $c=c'$ represents the commodities for which sample data on prices, quantities, and income are available for the estimation of parameters (i.e., c= Agriculture, Food, Beverages and Tobacco, Textiles, Utilities, Private Services, Government Services, Transport, Other Manufacturing, and Financial Services). Meanwhile, only two household categories had appropriate data (i.e., h= urban, rural). The system represented by equation (6) can be viewed as a set of nonlinear seemingly unrelated regression equations since it can be shown that the covariance matrix of the system is not diagonal.

Due to the fact that the sum of expenditures should equal the total income (i.e., the sum of the dependent variables is equal to one of the explanatory variables for all observations), the sum of error terms for each equation of the system is equal to 0, leading to the singularity of the covariance matrix. In such conditions, estimation procedure breaks down. To overcome this singularity problem, it is common practice that one equation be omitted for the estimation of the demand system (Judge, Hill, Griffiths, Lutkepohl, and Lee, 1988).

The adding-up constraint $EH_h = \sum_{c=1}^{10} PQ_c.QH_{ch}$, ensures that the omitted equation is deducible by difference. The choice of the omitted equation is arbitrary. Given that the estimation method used here is iterative, the choice of starting values is also crucial. There is no clear rule on these values[5]. But as stated in Judge, Hill, Griffiths, Lutkepohl, and Lee (1988), "the nature of the model provides some guide as to what might be good starting values for an iterative algorithm." For each commodity they suggest the minimum value of the quantity demanded as a reasonable starting value for the associated γ_{ch}. Also, they proposed the

[5] It is worth noting that our results were insensitive to alternative starting values.

average budget shares to be good starting values for the β_{ch}. Consequently for our purposes, the starting values used are summarized in table 2 below.

TABLE 2 HERE

The ITSUR method available in SAS (version 9.0) was employed in the estimation of eq. (6) with restrictions of non-negativity of coefficients imposed (i.e., $\gamma_{ch} >= 0$, and $0 < \beta_{ch} < 1$). According to Zellner (1962), seemingly unrelated regression equations (SURE) are systems whose equations, at first examination unrelated, are in reality related through the correlation in the errors. In short, a set of equations that has contemporaneous correlation between the disturbances in different equations is a seemingly unrelated regression system. ITSUR procedure adjusts for cross-equation contemporaneous correlation and consequently takes into account the optimization process underlying the demand system. The iterative process of the ITSUR ensures that the obtained estimates approach asymptotically those of the maximum likelihood method. Moreover, ITSUR unlike Seemingly Unrelated Regression (SUR) is insensitive to the excluded equation (in our case the financial services equation) (Judge, Hill, Griffiths, Lutkepohl, and Lee, 1980)[6]. Breusch-Pagan and White tests for heteroskedasticity were performed for separate equations of the system in this study. Both tests significantly rejected the null hypothesis, indicating the presence of cross equation contemporaneous correlation[7]. Thus, the set of demand equations to be estimated is a seemingly unrelated system. Therefore, Zellner's estimation approach (SUR) is appropriate for this purpose.

3.1.2 Estimation Results

The results of estimation are presented in Table 3 below. Interestingly, findings suggest that the subsistence requirement parameter (γ_{ch}) is higher for urban households compared to that for their rural counterparts in the following commodities: Agriculture, Food, Utilities,

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[6] ITSUR iterates from initial guesstimates specified.
[7] Tests results are not reported in this chapter but are available upon request from the author.

Government services, and Other Manufacturing. In most of these commodities, the value of those parameters is double the value for rural households. The subsistence parameter for Transport is relatively larger among rural households (M2739.90 compared to M128.68 for urban households). This makes sense since in rural areas, given the scarcity of transport and communication infrastructure, the subsistence levels should be higher. The subsistence parameter for Financial Services is estimated to be zero among urban households while it is around M2900 for their rural counterparts. In fact, in rural areas, given that funeral homes are, in general, the only financial intermediaries (informal), households do not have many options as compared to urban households. Findings also reveal that for urban households, the share of supernumerary income (β_{ch}) is important toward Financial Services (38 percent), Transport (23 percent) and Private Services (12 percent). Meanwhile, rural households spend 26 percent of their supernumerary income on Other Manufacturing commodities, 22 percent on Private Services (personal care, etc.), and 20 percent on Financial Services. These results suggest that for each household group, the commodities mentioned above are luxuries. This is also confirmed by their associated income elasticities greater than unity (see Table 5 below). Interestingly, urban households spend more of their supernumerary income on Transport than do rural households (4 percent). This suggests that transport and communication is a luxury in urban areas whereas it is a necessity in rural zones.

TABLE 3 HERE

In CGE models that adopt LES demand systems to represent the consumption behavior of households, income elasticity of each commodity and Frisch parameters for each household category are crucial in the calibration process. The Frisch parameter is the substitution parameter measuring the sensitivity of the marginal utility of income to income/total expenditures. The Frisch parameter, also called money flexibility, establishes a relationship between own-price and income elasticities. It is important for cases (such as cross sectional studies) where reliable price data are difficult to be obtained and to provide good estimates of own-price elasticities. Consequently, the relationship for directly additive preferences proposed by Frisch (1959) and embodied in the Linear Expenditure System (LES) is often used to derive own- and cross-price elasticities. In fact, price elasticities of demand are determined simply by the income elasticity in conjunction with the Frisch parameter. Moreover, relying on Frisch parameters prevent us from using own-price elasticities with positive signs in the CGE model. Also, given the huge number of cross-price elasticities (i.e., n(n-1)) to be estimated, there would be an enormous saving in statistical investigation if the Frisch parameters were used to derived those elasticities instead of making any separate analysis for each of the cross-price elasticities (Frisch, 1959).

The formula used to derive Frisch parameters is simply the negative ratio between a household's total expenditures and the supernumerary income (i.e., the difference between household income and total expenditures on subsistence requirements) at the sample means (indicated by a bar over a variable). Frisch parameters are

$$Frisch_h = -\frac{\overline{EH}_h}{\left(\overline{EH}_h - \sum_{c'=1}^{10} \overline{PQ}_{c'} . \gamma_{c'h}\right)} \tag{7}$$

Similarly, we calculate Marshallian own-price and expenditure elasticities at the sample means. The Marshallian own-price elasticities are

$$\varepsilon_{ch} = \frac{\overline{\gamma}_{ch} . (1 - \beta_{ch})}{\overline{QH}_{ch}} - 1 \tag{8}$$

The expenditure/income elasticities are

$$\eta_{ch} = \frac{\beta_{ch} . \overline{EH}_h}{\overline{PQ}_{ch} . \overline{QH}_{ch}} \tag{9}$$

After estimating the LES parameters, we use a feature of the SAS software (i.e., "Estimate") to compute/derive own-price, income/expenditure elasticities, as well as Frisch parameters for the two household subcategories and the entire sample. These results are presented in Table 4 along with associated standard errors.

With regard to own-price elasticities, we observe that the demand for the majority of commodities listed is either price inelastic or unitary elastic in some cases. There are some commodities whose price elasticities have the wrong sign (positive). More specifically, for urban households, findings indicate negative own-price elasticities for all commodities, with few exceptions (Agriculture, Food, and Textiles), as predicted by the neoclassical consumer theory. While the demand for Financial Services is unitary elastic, the price elasticity of demand for Transport nears unity. Other Manufacturing and Utilities sectors have the lowest own-price elasticities (-0.004 and -0.160) for urban households. It is worth mentioning that Textiles and Other Manufacturing are the only commodities for urban households whose price elasticities are not statistically significant. Among rural households, the demand for Agriculture, Textiles, and Transport is statistically significant unitary elastic, which means that a unit increase in the price of those commodities leads to a unit reduction in their respective quantities demanded. Meanwhile, rural households' demand for Government Services and Financial Services has own-price elasticities with a positive sign, which contradicts neoclassical consumer theory predictions. However, while the latter is not statistically significant, the former certainly is, which seems to suggest that Government Services is a Giffen "good" for rural households. It could also be the case that the estimated model is misspecified or incorrect in the sense that it is not appropriate to describe the consumption behavior of Basotho households[8]. Given that the own-price elasticity for Financial Services and Textiles is not statistically significant among rural and urban households respectively, it suggests that the demand for those commodities is vertical for both household groups. This finding indicates that a marginal increase in the price of those commodities leaves its demand unchanged. For the entire sample (across all households), the demands for Agriculture and Food commodities have statistically significant positive own-price elasticities (wrong sign).

TABLE 4 HERE

On the other hand, findings suggest that all the commodities listed are normal goods, given that their income elasticity is positive in sign. For urban households, Agriculture has the lowest income elasticity, followed by Food, Textiles, and Other Manufacturing (0.198-0.687). Also, given that the income elasticity for all other commodities, except Private Services, Transport, and Financial Services, is positive but less than one, those commodities are necessities for urban households. Meanwhile, among rural households, the income elasticity for Private Services, Other Manufacturing and Financial Services is greater than one, suggesting that those commodities are luxuries. Other Manufacturing is a luxury for rural households whereas it is a necessity for urban households. This makes sense since household appliances, which constitute part of Other Manufacturing, can be thought of as luxury goods in rural areas. In fact, rural households in general do not use modern household appliances; rather, they resort to rudimentary methods/tools. The same contrast can be drawn for Transport and Communication, which is a luxury for urban households and a necessity for rural households. Interestingly, the income elasticities on Agriculture, Food, and Textiles are larger for rural households. For instance, an increase of 100 units in the income of urban households leads to an increase of 20 units in their demand for Agriculture. A similar increase

[8]These remarks also apply to urban households demand elasticities which are incorrectly signed.

in the income of rural households causes an increase of 48 units in their demand for Agriculture. In sum, Agriculture, Food, and Textiles are more necessities for rural households than they are for their urban counterparts.

4 Conclusion

The objective of this paper was to estimate some key parameters intended for use in the CGE model for Lesotho. Using Household Expenditures Survey (HES) data, ITSUR methods were utilized in the estimation of own-price and income elasticities, and the derivation of Frisch parameters. The estimated coefficients were generally robust. We found that although Agriculture, Food, and Textiles can be thought of as necessity goods for both rural and urban households, a marginal change in the demand of these products will have a greater effect on rural households.

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Table 1. Descriptive Statistics (means) for Commodities Expenditures and Consumer Price Indices by Household type

	Urban Households			Rural Households			All Households	
	Obs.	Expenditures	CPI	Obs.	Expenditures	CPI	Expenditures	CPI
Agriculture	1900	6563.45	1.47	2326	4573.57	1.43	5468.22	1.45
Food & Bev. & Tobacco	1932	7886.18	1.53	2525	3504.49	1.48	5403.84	1.50
Textiles	1932	7780.45	1.33	1077	10159.18	0.57	8631.86	0.89
Utilities	1932	6287.66	1.29	2628	950.726	1.35	3211.9	1.32
Private Services	1932	6155.31	1.30	1503	6073.81	0.74	6119.65	0.98
Government Services	1932	7856.48	1.20	1374	2529.74	0.63	5642.64	0.87
Transport	1932	6457.14	1.50	799	3768.5	0.44	5670.53	0.89
Other Manufacturing	1932	6476.14	1.37	2449	4602.59	1.30	5428.82	1.33
Financial Services	1932	12007.06	1.30	866	6355.26	0.43	10257.79	0.79
Total Expenditures	1932	91721.86		2628	35185.76		59139.21	

Source: Author's calculations

Table 2. Starting values for the iterative process of estimation of LES parameters

	Urban Households		Rural Households		All Households	
	γ_c^0	β_c^0	γ_c^0	β_c^0	γ_c^0	β_c^0
Agriculture	33.380	0.072	0.000	0.130	7.440	0.092
Food	0.000	0.086	0.000	0.100	0.000	0.091
Textiles	0.000	0.085	0.000	0.289	0.000	0.146
Utilities	0.000	0.069	0.000	0.027	0.000	0.054
Private Services	0.000	0.067	0.000	0.173	0.000	0.103
Government Services	0.000	0.086	0.000	0.072	0.000	0.095
Transport	0.000	0.070	0.000	0.107	0.000	0.096
Other Manufacturing	0.000	0.071	0.000	0.131	0.000	0.092
Financial Services	0.000	0.131	0.000	0.181	0.000	0.173
Total		1		1		1

Source: Author's Calculations

Table 3. Estimation Results of parameters of the LES Demand System

	Urban Households		Rural Households		All Households	
	γ_c	β_c	γ_c	β_c	γ_c	β_c
Agriculture	6115.67[a]	0.014[a]	3696.41[a]	0.089[a]	4745.30[a]	0.025[a]
Food & Bev. & Tobacco	6993.31[a]	0.031[a]	2864.39[a]	0.072[a]	4446.53[a]	0.041[a]
Textiles	6415.99[a]	0.042[a]	7919.98[a]	0.09[a]	6307.41[a]	0.048[a]
Utilities	4345.50[a]	0.06[a]	782.58[a]	0.02[a]	1903.72[a]	0.058[a]
Private Services	2126.28[b]	0.123[a]	2192.90[a]	0.216[a]	1436.41[a]	0.133[a]
Government Services	5046.26[a]	0.080[a]	2103.88[a]	0.020[a]	2610.10[a]	0.075[a]
Transport	128.68	0.230[a]	2739.90[a]	0.040[a]	0.00	0.201[a]
Other Manufacturing	4966.32[a]	0.050[a]	2020.60[a]	0.261[a]	3586.74[a]	0.074[a]
Financial Services	0	0.38	2916.91[a]	0.20	0.00	0.35

Source: Author's Calculations.

Note. a = significant at 1 percent level, b= significant at 5 percent level; γ_c is the subsistence requirement parameter on commodity c; β_c is the supernumerary income share parameter on commodity c.

Table 4. Own-Price and Income/Expenditures Elasticities of the LES Demand

	Urban Households		Rural Households		All Households	
	ε_c	η_c	ε_c	η_c	ε_c	η_c
Agriculture	0.376[a]	0.198[a]	-1.00[a]	0.480[a]	0.267[a]	0.271[a]
	(0.033)	(0.015)	(0.000)	(0.016)	(0.026)	(0.012)
Food & Bev. & Tobacco	0.313[a]	0.364[a]	-0.212[a]	0.490[a]	0.206[a]	0.444[a]
	(0.043)	(0.019)	(0.030)	(0.016)	(0.031)	(0.013)
Textiles	0.05[a]	0.497[a]	-1.00[a]	0.539[a]	-0.074[b]	0.325[a]
	(0.066)	(0.03)	(0.000)	(0.023)	(0.034)	(0.013)
Utilities	-0.160[b]	0.871[a]	-0.198[a]	0.500[a]	-0.279[a]	1.066[a]
	(0.065)	(0.032)	(0.049)	(0.029)	(0.054)	(0.025)
Private Services	-0.608[b]	1.836[a]	-0.508[a]	1.688[a]	-0.736[a]	1.282[a]
	(0.197)	(0.091)	(0.120)	(0.051)	(0.101)	(0.040)
Government Services	-0.288[a]	0.930[a]	0.559[a]	0.428[a]	-0.485[a]	0.787[a]
	(0.106)	(0.048)	(0.079)	(0.035)	(0.07)	(0.027)
Transport	-0.977[a]	3.21[a]	-1.00[a]	0.852[a]	-1.00[a]	2.092[a]
	(0.254)	(0.118)	(0.000)	(0.063)	(0.00)	(0.052)
Other Manufacturing	-0.004	0.687[a]	-0.654[a]	1.534[a]	-0.165[a]	0.807[a]
	(0.074)	(0.034)	(0.079)	(0.042)	(0.062)	(0.028)
Financial Services	-1.00[a]	2.867[a]	0.069	2.537[a]	-1.00[a]	1.998[a]
	(0.00)	(0.069)	(0.235)	(0.085)	(0.00)	(0.033)
Frisch Parameter	-2.188[a]		-1.634[a]		-2.415[a]	
	(0.224)		(0.092)		(0.132)	

Source: Author's Calculations.

Note. a = significant at 1 percent level, b= significant at 5 percent level; standard errors are in the parenthesis; ε represents own-price elasticity; η is the income elasticity.