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Demographics and demand: Evaluation of alternative functional forms

Panayiota Lyssiotou *

Department of Economics, University of Cyprus, PO Box 20537, CY 1678 Nicosia, Cyprus

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ABSTRACT

We evaluate the role of functional form of demographics in demand analysis by proposing the GQL 'unstructured' demographically transformed model which nests the Barten–Gorman demographically modified model and popular rank-3 and rank-2 demand systems. We use UK individual data and find that the equivalence of the 'unstructured' and Barten–Gorman forms and identification of meaningful equivalence scales depend on the degree of flexibility of the demand system in demographic, price and income effects.

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1. Introduction

A substantial amount of work has been devoted to the development of demand models that exhibit flexibility in income and price effects (Banks et al., 1997; Ryan and Wales, 1999; Lyssiotou et al., 2002). Although the significance of demographics in demand analysis has long been recognized (Engel, 1895), the role of their functional form on consumer behavioural and welfare measures remains an open question. As Slesnick (1998) comments, 'In measuring the welfare effects of changes in prices and expenditures, efforts have been directed towards incorporating price and expenditure effects flexibly in the demand functions. Demographic variables are often treated as an afterthought in an effort to account for heterogeneity. With equivalence scales, the issue is how to model demographic effects in a way that does not overly restrict preferences'.

However, this issue has recently been given more attention. Research concentrated on shape-invariant demand functions, to model demographics in demand systems, that are consistent with utility maximization and IB/ESE (independent of base/equivalence scale exact) equivalence scales useful for welfare comparisons. The Engel curve of a given good is shape invariant if, in the budget share and log expenditure space, demographics affect the curve by translating its location vertically and horizontally. Semi-parametric tests of shape invariance do not reject this hypothesis for some inter-household comparisons whereas parametric tests widely reject it. Studies, which concentrated on theory and non-parametric and parametric tests and estimates of shape-invariant Engel curves and IB/ESE scales, include among others Lewbel (1989, 2010), Blackorby and Donaldson (1989, 1993), Blundell and Lewbel (1991), Gozalo (1997), Pendakur (1999), Stengos et al. (2006), Lyssiotou (2003) and Blundell et al. (2007).

Two main demographic functional forms have been proposed. First, the Barten–Gorman form which, is firmly grounded in economic theory and, allows demographics to modify the household's cost function through household production technologies (Gorman, 1976; Lewbel, 1985). According to this functional form, demographics scale prices (Barten, 1964), with a commodity specific equivalence scale, and translate the subsistence parameters of a demand system. Second, the 'unstructured' form which allows demographics to transform all the parameters of a demand system. This approach facilitates easier empirical estimation, even with cross section data, whereas the Barten–Gorman approach requires time series cross section data. Muellbauer and Pashardes (1982) nested the Barten approach within the 'unstructured' AIDS model and, using average household expenditure data, found it to

* Tel.: +357 22893710; fax: +357 22895047.
E-mail address: p.lyssiotou@ucy.ac.cy.

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be rejected. However, they also found that it identifies more meaningful equivalence scales than the 'unstructured' approach. It has also been rejected by studies using micro household data (Barnes and Gillingham, 1984; Ray, 1996).

In this study, we test the equivalence of the 'unstructured' and Barten–Gorman approaches and investigate their implication on behavioural and welfare measures using a demand system which exhibits greater flexibility than the AIDS and micro household data. Specifically, we extend the Generalized Quadratic Logarithmic (GQL) model, proposed by Lyssiotou et al. (2002) to allow for the same flexibility in demographic as in price effects. We refer to this model as the GQL 'unstructured' demographically transformed model. The proposed framework has the advantage that it nests all known rank-3 and rank-2 demand systems, the restrictions of which have been rejected against the GQL. It allows the effects of demographics on the budget shares to differ with the level of total expenditure, just as changes in prices do, and with the level of prices. The proposed framework also nests the Barten–Gorman demographic approaches and allows us to test the equivalence of the two demographic forms within rank-3 demand systems, like the GQL, shape-invariant GQL and QUAIDS (Banks et al., 1997), and rank-2 demand systems, like the AIDS.

We find that the observational equivalence of the two alternative demographic approaches cannot be rejected for the GQL but is rejected for the AIDS. Also, the greater the flexibility of the demand system in demographics, price and income effects the more meaningful are the equivalent scales identified from both demographic procedures. In less flexible demand systems than the GQL, the Barten–Gorman form identifies more sensible equivalence scales.

Section 2 presents the 'unstructured' and Barten–Gorman forms of the GQL and discusses the conditions under which they are observationally equivalent. Section 3, presents the empirical findings and assesses the bias in equivalent scale estimates. Section 4 concludes.

2. GQL demographic demand systems

Household h minimizes a Quadratic Logarithmic (QL) cost function of Lewbel (1990) which allows for non-linearity in income effects and the specification of a rank-3 demand system which is consistent both with utility theory and empirical evidence. We distinguish between household size ($\mathbf{z}_h$), and composition ($\mathbf{s}_h$) effects.

2.1. 'Unstructured' demographically transformed model

The QL demographically 'unstructured' cost function takes the form:

$$\ln C\,(\mathbf{p}, \mathbf{s}_h, z_h, u) = a(\mathbf{p}, \mathbf{s}_h, \mathbf{z}_h) + b(\mathbf{p}, z_h)\left[\frac{1}{f(u, \mathbf{z}_h)^{-1} - g(\mathbf{p}, \mathbf{z}_h)}\right], \qquad (1)$$

where $f(\cdot)$ is a utility transformation function which depends on utility u and $\mathbf{z}_h$, $a(\cdot)$ is homogeneous of degree one in prices $\mathbf{p}$, and $b(\cdot)$ and $g(\cdot)$ are homogeneous of degree zero in $\mathbf{p}$. The functions, $a(\cdot)$, $b(\cdot)$ and $g(\cdot)$ take the GQL parametric form:

$$a(\mathbf{p}, \mathbf{s}_h, \mathbf{z}_h) = a_o + \Sigma_r \epsilon_r \ln z_{rh} + 0.5\,\Sigma_r \Sigma_{rl} \phi_{rl} \ln z_{rh} \ln z_{lh} + \Sigma_i (a_i + \Sigma_r a_{ri} s_{rh}) \ln p_i + \Sigma_i \Sigma_r \delta_{ri} \ln z_{rh} \ln p_i + 0.5\,\Sigma_i \Sigma_j \gamma_{ij} \ln p_i \ln p_j \qquad (2)$$

$$b(\mathbf{p}, \mathbf{z}_h) = \beta_o + \frac{[(\Pi_r z_{rh}^{\kappa_{ro}}) \Pi_i p_i^{\beta_i + \beta_{di} D_h}]^{\beta} - 1}{\beta} \qquad (3)$$

$$g(\mathbf{p}, \mathbf{z}_h) = [b(\mathbf{p}, \mathbf{z}_h)]^{\theta} \xi(\mathbf{p}, z_h) \qquad (4)$$

$$\xi(\mathbf{p}, \mathbf{z}_h) = \lambda_o + \frac{[(\Pi_r z_{rh}^{\upsilon_{ro}}) \Pi_i p_i^{\lambda_i + \lambda_{di} D_h}]^{\lambda} - 1}{\lambda}. \qquad (5)$$

The Marshallian budget shares take the form:

$$w_{ih} = a_i(\mathbf{p}, \mathbf{s}_h, \mathbf{z}_h) + \frac{b_i(\mathbf{p}, \mathbf{z}_h)}{b(\mathbf{p}, \mathbf{z}_h)} [\ln x_h - a(.)] + \{\theta [b(\mathbf{p}, \mathbf{z}_h)]^{\theta - 2} \times b_i(\mathbf{p}, \mathbf{z}_h) \xi(\mathbf{p}, \mathbf{z}_h) + [b(\mathbf{p}, \mathbf{z}_h)]^{\theta - 1} \xi_i(\mathbf{p}, \mathbf{z}_h)\} [\ln x_h - a(\cdot)]^2, \qquad (6)$$

where x_h is log household expenditure,

$$a_i(\mathbf{p}, \mathbf{s}_h, \mathbf{z}_h) = \alpha_{oi} + \Sigma_r a_{ri} s_r + \Sigma_r \delta_{ri} \ln z_r + \Sigma_j \gamma_{ij} \ln p_j,$$

$$b_i(\mathbf{p}, \mathbf{z}_h) = [\beta_{co}(\beta_i + \beta_{di} D) \Pi_i p_i^{\beta_i + \beta_{di} D}]^{\beta},$$

$$\xi_i(\mathbf{p}, \mathbf{z}_h) = [\lambda_{co}(\lambda_i + \lambda_{di} D) \Pi_i p_i^{\lambda_i + \lambda_{di} D}]^{\lambda}.$$

The terms $\beta_{co} = \Pi_r z_{rh}^{\kappa_{ro}}$ and $\lambda_{co} = \Pi_r z_{rh}^{\upsilon_{ro}}$ allow demographics to rescale utility. The known integrability restrictions apply. Shape invariance requires that the marginal base utility effect of each budget share should be independent of demographics. In (6), shape invariance requires that: $\beta_{di} = \lambda_{di} = 0$ for all i and $\kappa_{or} = \upsilon_{or} = 0$ for all r. The QUAIDS requires that: $\theta = 0$, $\beta \to 1$, $\lambda \to 0$, $\beta_o = 1$, $\lambda_o = 0$ and $\kappa_{or} = \upsilon_{or} = 0$ for all r. The AIDS in addition requires that: $\lambda_i = 0 = \lambda_{di} = 0$ for all i.

2.2. Barten–Gorman demographically modified model

The Barten–Gorman demographically modified QL cost function takes the form:

$$\ln C^*\left(\mathbf{p}_h^*, \mathbf{s}_h, \mathbf{z}_h, u\right) = a^*(\mathbf{p}_h^*, \mathbf{s}_h) + b^*(\mathbf{p}_h^*, \mathbf{z}_h)\left[\frac{1}{f^*(u, z_h)^{-1} - g^*(\mathbf{p}_h^*, \mathbf{z}_h)}\right] \qquad (7)$$

where $f^*(\cdot)$ is a utility transformation function which depends on utility u and $\mathbf{z}_h$, $a^*(\cdot)$ is homogeneous of degree one in $\mathbf{p}$, and $b^*(\cdot)$ and $g^*(\cdot)$ are homogeneous of degree zero in $\mathbf{p}$. The functions $a^*(\cdot)$, $b^*(\cdot)$ and $g^*(\cdot)$ take the GQL form:

$$a^*(\mathbf{p}_h^*, \mathbf{s}_h, \mathbf{z}_h) = a_o^* + \Sigma_i(\alpha_i^* + \Sigma_r \alpha_{ri}^* s_{rh})(\ln p_i + \Sigma_r \mu_{ri} \ln z_{rh}) + 0.5\,\Sigma_i \Sigma_j \gamma_{ij}^* (\ln p_i + \Sigma_r \mu_{ri} \ln z_{rh}) \times (\ln p_j + \Sigma_r \mu_{rj} \ln z_{rh}) \qquad (8)$$

$$b^*(\mathbf{p}_h^*, \mathbf{z}_h) = \beta_o^* + \frac{[\Pi_i (p_i \Pi_r z_{rh}^{\mu_{ri}})^{(\beta_i^* + \beta_{di}^* D_h)}]^{\beta^*} - 1}{\beta^*} \qquad (9)$$

$$g^*(\mathbf{p}_h^*, \mathbf{z}_h) = [b^*(\mathbf{p}_h^*, \mathbf{z}_h)]^{\theta^*} \xi^*(\mathbf{p}_h^*, \mathbf{z}_h) \qquad (10)$$

$$\xi^*(\mathbf{p}_h^*, \mathbf{z}_h) = \lambda_o^* + \frac{[\Pi_i (p_i \Pi_r z_{rh}^{\mu_{ri}})^{(\lambda_i^* + \lambda_{di}^* D_h)}]^{\lambda^*} - 1}{\lambda^*}. \qquad (11)$$

We define $p_i^* = p_i m_i(\mathbf{z}_h)$, where $m_i(\mathbf{z}_h) = \Pi_r z_{rh}^{\mu_{ri}}$ is the specific equivalence scale of commodity i and measures economies of size (scale) which may result from bulk purchases of a private good and the degree of publicness of other goods. A value close to zero implies large economies of size and close to one absence of economies of size.

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