EAST-WEST CENTER WORKING PAPERS

EAST-WEST CENTER

Pacific Islands Development Series

No. 9, July 1995

Complex Demographic Effects on Demand Behavior: Micro-data Evidence from a Pacific Islands Economy

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Complex Demographic Effects on Demand Behavior:
Micro-data Evidence from a Pacific Island Economy

Saia Kami*

Capitalizing on the rich details contained in expenditure micro-data and price variations tapped from spatial and inter-temporal domains, we estimate particular variants of theoretically plausible demand systems--specifications that represent different methods of accounting for the effects of demographic variables on household demand patterns. Such specifications and effects--contextualized in terms of parameter variations among differing demographic profiles of households in a Pacific island economy--are evaluated and compared. The unrestricted specification shows superior properties implying, *inter alia*, that demographic characteristics interact and influence household consumptions in complex ways; specifications richer in parameters should be favored; and the efficacy of employing micro-data is commendable. Consequently, we empirically stylize demand behaviors based on this superior specification.

I. INTRODUCTION

Consumption expenditure is the largest item in the net outputs (GDPs) of Pacific island nations. Yet, there is no empirical evidence that pin-points, *via* conceptually meaningful behavioral parameters, the principal determinants of consumption demands of households in these island nations. Of particular significance--propelled by recent resurgences of interests and debates on the "exact" nature of the population-economic growth relationship--is the

* *The author is very grateful to Denzil Fiebig, Sitiveni Halapua, and Alan Woodland for valuable discussions and comments to Sarah Tangianau and Losena Taumoepeau for able research assistance, and to Denise Hera, Jane Ho, Christopher Klutz-Simanu, Nancy Lui-Kwan, and Darlene Spadavecchia for much needed word-processing related inputs.*

lack of objective, theoretically sound and informative insights into the substantive effects (if any) of variabilities in household demographic characteristics on household expenditure patterns. This shortcoming must be disconcerting to those policymakers who are well aware of the several areas of the development problem, to which analyses of household demand patterns and their links to differing household demographic profiles can make positive empirical contributions.

Purposefully engineered changes to the structures and scopes of Pacific island nations' industries require sound understandings of how the demographically corrected components of consumption demands evolve in response to increasing incomes. The responsibilities of these island nations' governments for formulating and implementing effective fiscal policies and relevant forms of economic control and maintenance, *inter alia,* require sound quantitative knowledge of how the patterns of consumptions are influenced by changes in prices and conditioned on variations of demographic profiles of the consuming units.

Much of the works requiring these types of inputs have been based on "empirical abstractions" rigged from either highly aggregated summary statistics (*e.g.*, national accounts estimates), "snap-shot" basic statistics (*e.g.*, statistics summarizing levels of consumption per consuming unit), and/or conjectures that have been presumed to be plausible in the case of Pacific island nations. These approaches inherit only extremely limited serviceabilities for predictions and thus disaggregated planning. Further highlighting this "dire" situation is the observation that there is no specific account at all on Pacific island nations in the "core" literature on consumer demand (let alone, on the "demographic variables-demand behavior" relationship).

This study aims at providing an important contribution toward the filling-in of important gaps. In particular, it attempts, based on a sound conceptual framework, to

characterize alternative specifications for capturing stylizable influences of demographic variables on household demand behaviors. These alternative specifications embody different conceptual contents and relative degrees of serviceability. Thus, to further crystalize the contribution made, this investigation puts the implying underlying hypotheses into a specially designed form of empirical testing. The relevant empirical material is taken from Tonga--one of the developing island nations of the Pacific.

A number of features of this study may be considered as unique and/or significantly insightful.

Our adopted mean of explicit conceptualization is akin to an "ordered" survey of the treatment of demographic variables in consumer demand analysis. We begin with the approach in which the demand system is agnostic toward demographic effects and work "slowly up" in the ladder of increasing conceptual content--with regard to the "demographics-consumptions" connection--reaching the approach in which therein all demand system parameters are allowed to depend on demographic variables. This ordered approach is highly serviceable--especially in terms of its bringing home in perspective the available alternatives--since, *inter alia,* it facilitates plausible solutions to the following applied question: What alternative empirical research endeavors with respect to the debate on the "demographics-consumptions" connection, may optimally be pursued in the various Pacific island nations given the differences in scope, range, and intensity of the resource constraints researchers and policymakers in these island nations face?

To ensure that our approach secures a sound interpretive content, we root our formal working hypotheses on the demand theory of a utility maximizing consumer. This approach's durability lies in the conceptually consistent conclusions (general and particular restrictions) inherent in the demand functions that can be derived from it, and the highly

serviceable role of utilizing such theoretical restrictions in the econometric estimation of such functions.

Thus, *inter alia,* this study spells out plausible interpretations attached to alternative means of specifying the *modus operandi* by which demographic variables enter the original demand systems. By viewing, for instance, the said alternative means as alternative ways of allowing for demand parameter variations among household demographic profiles, certain specifications are interpretable as equivalent to the original systems but involving demographically scaled prices, scaled quantities, and/or some fixed-cost parameterizations.

This study, in fact, is one of a very few that explicitly models and empirically estimates and thus corrects for the effects of demographic variables in the context of complete systems of theoretically plausible consumer demand equations. Moreover, resembling only the studies of Barnes and Gillingham (1984) and Pollak and Wales (1980), (1981), this study makes a substantial effort to compare alternative methods of incorporating demographic variables into complete consumer demand systems. In the context of developing economies (let alone the small developing island economies of the Pacific), this effort is unparalleled.

Our principal focus is on alternative methods of incorporating demographic variables that insure that the consequent modified consumer demand systems continue to inherit the theoretical plausibility that characterized the parent demand systems. In fact, our investigation shows that it significantly matters to the analysis which particular method of treating demographic variables that is adopted. It reveals, in particular, that demographic variables interact in somewhat complex ways--implicating the need to favor specifications rich in parameters and/or the procedure that allows the maximum number of demand system parameters to depend on the impacts of demographic variables.

This study utilizes a set of micro-data that despite its essentially cross-sectional nature, contains price measures--tapped from both spatial and inter-temporal sources--with significant variabilities. Our estimation of complete theoretically plausible consumer demand systems based on micro-data is paralleled only to the works of Barnes and Gillingham (1984) and Strauss (1982). This study, however, utilizes a set of micro-data from a developing country to compare alternative ways of treating demographic variables in the context of estimating complete consumer demand systems.

Section II gives a brief "ordered" survey of methods of accounting for effects of demographic variables on household expenditure patterns. The specific original consumer demand systems adopted in this study are discussed in Section III; their demographically modified counterparts which are subsequently subjected to estimation, are delineated in Section IV. Issues relating to the data, empirical counterparts of variables, and estimation of parameters are dealt with in Section V. Section VI presents our empirical results and a discussion of such results, and Section VII offers some concluding remarks on the "demographic variables-demand behavior" relationship.

II. METHODS OF ACCOUNTING FOR DEMOGRAPHIC EFFECTS

A. UNDER A GENERAL DEMAND SYSTEM

Presume that the underlying preference of a household is conditional on its demographic profile. Thus, the observed consumption pattern manifests the household's optimal choice of consumption vector <u>conditional</u> on the given configuration of price-total expenditure-demographic profile the household faces. This is an appropriate conceptual foundation for entering demographic variables into household consumption demand analysis (Pollak and Wales 1979).

By focusing attention on the modeling (as contrasted with the data handling) aspect of the task of treating demographic variables in consumer demand analysis, two broad approaches are logically demarcateable. We refer to them, respectively, as the "Implicit Correction Method" and the "Explicit Correction Method." The former approach enacts the necessary treatment implicitly (as far as modeling is concerned) by appropriately demarcating the data in such a way that the demand model is estimated separately for different subsets--each with an "uniform" demographic profile. The latter approach corrects for demographic effects by explicitly incorporating conditional equivalence scales to modify the original demand system.

The Explicit Correction Method manifests itself through many variants with inheritedly varying conceptual contents. A number of these variants could be straightforwardly explained in the context of a general demand system--one that is not constrained by the choice of functional form. We proceed to delineate variants of this approach, and we canvass them in order of increasing content of their respective underlying theoretical bases.

1. The Naive Specification

Demand analysis may be agnostic toward the effects of demographic variables. Operationally, this is equivalent to fitting a "Naive" specification--the procedure of estimating the (original) demand system by combining data from different demographic profiles under the assumption that demographic variables do not affect household demands.

Alternatively viewed, the Naive specification is interpretable as modeling (and estimating) a demand system under "full" constraints--the modeled demand behavior is constrained to be the same (*i.e.*, is not allowed to vary freely) across demographic profiles.

2. The *A Priori* Specification

For various reasons (*e.g.*, convenience, simplicity, and/or an *a priori* belief), one may attempt to correct for demographic effects on demand patterns by utilizing an *a priori* specification. This *ad hoc* approach involves assumptions about equivalence scales--their specific forms and ways such scales enter the demand systems. The approach in terms of statistical estimation is efficient since all data points are used and no new parameters require estimation. The procedure that involves working on a *per capita* basis--*i.e., per capita* consumption and *per capita* total-expenditure--is an example of explicit correction (for effects of demographic variables) based on the *A Priori* specification.

3. The Extraneous Information Based Specification

Attempts have been exercised to correct for demographic effects *via* incorporations of equivalence scales constructed and estimated from extraneous sources. Examples include those cited in Cramer (1969:165), Seneca and Taussinga (1971), and Nicholson (1976) as well as the so-called "Amsterdam scale" adopted by Stone (1954). A large number of these scales is based on either nutritional and energy requirements or other *ad hoc* criteria--*e.g.*, "necessity versus luxury" status of goods and proportions of total-expenditure spent on selected consumption categories.

The approach is arbitrary and lacks a strong logical foundation (Friedman 1952). It, *inter alia*, sheds no light on the important phenomenon of "economies of scale in

consumption;" and moreover, it lacks meaningful and rigorous means of reconciling with and relating to, say, the need-based criteria and units of analysis inherently adopted--*e.g.*, the reconciling of nutritional requirements of households with two adults as the "standard household type" with all other "household types" differentiated only by number of children. Of most significance to this study is the fact that the approach does not exploit the data in any manner that can illuminate the "demographics-consumptions" connection and is not based on the market behaviors of households.

Nevertheless, the approach is a clear improvement over the Naive and *A Priori* specifications. It efficiently utilizes the data and is parsimonious in the sense that no parameters additional to those of the parent general demand system require estimation.

B. UNDER THE ENGEL CURVES FRAMEWORK

4. The Engel Specification

The earliest and simplest specification that addressed explicitly in demand Engel curves analysis the effects of demographic variables (equivalently expressed as "household composition") was proposed by Engel (1857).

Consider a population of T households with F distinctive demographic characteristics. The basic Engel curves system is representable by:

$$e_{ij} = \tilde{h}^i(\mu_j \ , \ \theta_i) \quad , \ j = 1,\ldots, T; \quad i = 1,\ldots, n; \tag{1}$$

where e_{ij} denotes expenditure incurred on good i by the jth household; μ_j denotes total-expenditure (on the n goods) incurred by household j--*i.e.*, $\mu_j = \sum_{i=1}^{n} e_{ij}$, $j = 1,\ldots, T$; θ_i denotes a vector of parameters specific to good i; and $\tilde{h}^i(.)$ represents a functional form specific to good I.

System (1) is agnostic toward demographic effects. Thus, a clear improvement--with estimation based on the economic behavior of the households--is the following specification of Engel (1857):

$$\frac{e_{ij}}{\tilde{m}_{jo}} = \tilde{h}^i\left(\frac{\mu_j}{\tilde{m}_{jo}} , \theta_i\right) \quad , j = 1,\ldots, T; \quad i = 1,\ldots, n; \tag{2}$$

where $\tilde{m}_{jo} = \tilde{M}^{\circ}(\Gamma)$ is the conditional equivalence scale with $\Gamma = (\Gamma_{j1}\ldots\Gamma_{jF})^T$ denoting the demographic characteristics vector of household j. Notice that in terms of "household composition," if the standardized reference household consists of a single adult, then $\tilde{m}_{jo}$ is the "size" of the household in terms of (conditional) equivalent adults.

Engel's formulation, in fact, is consistent with utility maximizing behavior. Based on the duality concept of expenditure function, Muellbauer (1977) revealed that Engel's formulation "can be interpreted to say that the increase in cost (owing to an addition of a person of a given type), is equivalent to an equal percentage increase in each of the prices." We can grant access to this interpretation *via* a straightforward derivation without resorting to duality theory.

Denote the budget share of good i by w_i, and thus write:[1]

$$w_i = \frac{e_i}{\mu} = \frac{\tilde{m}_\circ}{\mu}\tilde{h}^i\left(\frac{\mu}{\tilde{m}_o}, \theta_i\right) = \tilde{\tilde{h}}^i\left(\frac{\mu}{\tilde{m}_o}, \theta_i\right) \quad . \tag{3}$$

Imposing the adding-up restriction [*i.e.*, $\sum_{i=1}^{n} w_i = 1$] yields this interesting property:

$$\mu = \tilde{m}_\circ \sum_{i=1}^{n} \tilde{h}^i\left(\frac{\mu}{\tilde{m}_o}, \theta_i\right) \quad . \tag{4}$$

Equation (4) confirms that the implicit defining of the conditional equivalence scale $\tilde{m}_\circ$ with the budget constraint together with its implied determination based on the market behavior of households is a conceptually sound implication of Engel's formulation.

Let us further express (4), making use of the (Engel curves framework) presumption that all households face n fixed prices.

$$\mu = \sum_{i=1}^{n} \tilde{m}_\circ \bar{p}_i \, \tilde{h}^i\left(\frac{\mu}{\tilde{m}_o}, \theta_i\right) = \sum_{i=1}^{n} \bar{p}_i^{\bullet} \tilde{h}^i\left(\frac{\mu}{\tilde{m}_o}, \theta_i\right) \quad ; \tag{5}$$

where $\bar{p}_i^{\bullet} = \tilde{m}_\circ \bar{p}_i$. Thus, equation (5) highlights the interpretation that the effects of demographic variables as embodied within Engel's formulation, is equivalent to an inherent adoption in the original formulation of demographically scaled prices, with the associated weighing factor being constant for all the scaled prices.

[1]We drop the subscript j for notational convenience.

5. The Prais-Houthakker Specification

The Engel specification is quite restrictive in the sense that the proportional change in scaled prices is the same for all goods. A more general formulation is that of Prais and Houthakker (1955), and it takes the following refined form:

$$\frac{e_i}{\tilde{m}_i} = \tilde{h}_i\left(\frac{\mu}{\tilde{m}_o}, \theta_i\right) \quad , \quad i = 1,\ldots, n; \tag{6}$$

where $\tilde{m}_i = \tilde{M}^i(\Gamma) = \sum_{d=1}^{F} \tau_{id}\Gamma_d$, (6a)

and $\tilde{m}_o = \tilde{M}^o(\Gamma) = \sum_{d=1}^{F} \vartheta_d \Gamma_d$ with $\vartheta_d = \frac{\sum_{i=1}^{n}\theta_i\tau_{id}}{\sum_{i=1}^{n}\theta_i}$, $d = 1,\ldots,F$. (6b)

The rationale behind the Prais-Houthakker formulation is intuitively sensible. As revealed through the "specific scales" $(\tilde{m}_i \;\; i = 1,\ldots,n)$, different household composition categories impose different weights on the different goods consumed. A "general scale" or "income scale" ($\tilde{m}_o$), is also postulated. Through such a scale, the individuals of a given category are weighted according to the specific relative impacts they have on household's total-expenditure--since the weight θ_i is approximately proportional to the budget share w_i (Prais and Houthakker 1955:129-130).

As in the case of the Engel formulation, an alternative viewing is retrievable by defining within the implication of the adding-up restriction the said scales implicitly through the budget constraint and by recognizing that Engel curves framework presupposes that households face a set of constant fixed prices for the n goods.[2]

[2]Thus, one may specify for all households a "collapsed" demand system, which relates household expenditure on each good to household total-expenditure. Hence, under this setting, through appropriate choices of quantity units, one could set the prices of individual goods in a given consumption category to unity. Thus, e_i also could be viewed as the household demanded "quantity" for good i.

Thus, one may perceive the "cost" of an additional person from a given category to involve changes in demand equivalent to effects of differing scaled prices as well as an additional effect with a relative magnitude that is closely linked to the relative responsiveness of demands to changes in total-expenditure. Derived in elasticity-form, this interpretation is clearly brought out in the following (Barten 1964; Muellbauer 1974):

$$f_{id} = \tilde{g}_{id} - E_i \tilde{g}_{0d} = \tilde{g}_{id} - E_i \sum_{j=1}^{n} w_j \tilde{g}_{jd} \quad , d = 1,\ldots, F \; ; \; i = 1,\ldots, n \; ;$$

where $f_{id} = \left(\frac{\Gamma_d}{q_i}\right)\left(\frac{\partial q_i}{\partial \Gamma_d}\right)$, $\tilde{g}_{id} = \left(\frac{\Gamma_d}{\tilde{m}_i}\right)\left(\frac{\partial \tilde{m}_i}{\partial \Gamma_d}\right)$ and $E_i = \left(\frac{\mu}{q_i}\right)\left(\frac{\partial q_i}{\partial \mu}\right)$ (7)

is total-expenditure elasticity for good 1.

While the Prais-Houthakker specification is a more informative mechanism in revealing the quasi-price effects of changes in household demographic variables as they operate within the market behavior setting of allocation models, its embodiment of this demographic-price effects analogy is, in fact, restrictive.

The Slutsky equation in elasticity form is:

$$\varepsilon_{ij} = S_{ij} - E_i w_j \quad , \; i, j = 1,\ldots,n \; ; \tag{8}$$

where $\varepsilon_{ij} = \left(\frac{p_j}{q_i}\right)\left(\frac{\partial q_i}{\partial p_j}\right)$ and $S_{ij} = \left(\frac{p_j}{q_i}\right)\left(\frac{\partial q_i}{\partial p_j}\right)\Bigg|$ given utility level $\bar{u}$ constant.

That is, $\{S_{ij}$ and $\{\varepsilon_{ij}$ are the Slutsky and Frisch substitution elasticity matrices, respectively. Thus, since $E_i w_j = S_{ij} - \varepsilon_{ij}$ [from (8)], equation (7) under the Prais-Houthakker specification may be rewritten as:

$$f_{id} = \tilde{g}_{id} - \sum_{j=1}^{n} (S_{ij} - \varepsilon_{ij}) \tilde{g}_{jd} \quad , \; d = 1,\ldots,F \text{ and } i = 1,\ldots, n \; . \tag{9}$$

On the other hand, the corresponding result under the framework of consumer demand systems is (Barten 1964):

$$f_{id} = g_{id} + \sum_{k=1}^{n} \varepsilon_{ik} g_{kd} \quad , \; d = 1,\ldots,F \text{ and } i = 1,\ldots,n \; . \tag{10}$$

Equation (10) conveys the notion that the elasticity of demand (f_{id}) for the ith good in response to a change in demographic variable Γ_d is equal to a specific effect (g_{id}--the elasticity of m_i with respect to Γ_d) plus a general effect $\left(\sum_{k=1}^{n} \varepsilon_{ik} g_{dk}\right)$--the weighted sum of the specific effects, with the weights being the price elasticities of demand for good i (ε_{ik} , $k = 1,\ldots,n$) .Thus, by comparing (9) and (10), it is obvious that they are equivalent if we force the Slutsky substitution effects $[\{s_{ij}\}$ to be identically equal to zero (for all i, j). That is, compensated changes in demands due to changes in household composition are not accommodated for under the Prais-Houthakker specification. Viewed alternatively (Barten 1964; Muellbauer 1974, 1977), the underlying indifference curves of the Prais-Houthakker specification are of the (non-homogeneous) Leontief type, and all goods are consumed in fixed proportions.

Unlike the Prais-Houthakker specification, the subsequently discussed specification, "Demographic Scaling," is a variant of the Explicit Correction Method based on market behavior; however, its underlying preferences given Γ constant are unrestricted and permit non-zero price substitution effects.

C. UNDER THE COMPLETE CONSUMER DEMAND FUNCTIONS FRAMEWORK

The formulations to follow are specified under the framework of complete theoretically plausible consumer demand functions.[3] Those formulations also represent examples of the Explicit Correction Method; thus, the effects of differing demographic profiles are explicitly incorporated into the demand systems by allowing some of the parameters of the demand systems to become functions of them. Such functions are conditional equivalence scales and their presence, in fact, conceptually allows their concurrent estimation with parameters of the demand system to be based on the whole data (observed market behaviors of households with differing demographic profiles).

[3] A system of consumer demand functions is said to be "complete" if total-expenditure is exhaustively allocated among the consumption categories; it is also "theoretically plausible" if it can be derived from "well-behaved" preferences--ones that satisfy the regularity properties of the utility-maximizing hypothesis [see, for instance, Goldberger (1967), Uzawa (1964), and Varian (1984:111-115].

Thus, it follows that under certain regularity conditions (completeness, reflexivity, transitivity, continuity, strong monotonicity, local nonsatiation, and strict convexity) presumed to be satisfied by the underlying preferences of the consumer, there exists a continuous and "well-behave" utility function that represents those preferences. That is, a direct utility function $\bar{u}\,(q)$ exists, and it possesses the following (classical) properties: (i) defined and positive, (ii) continuous and at least twice differentiable, (iii) weakly increasing ("non-satiety" axiom)--*i.e.*, $q^1 > q^\circ \Rightarrow \bar{u}(q^1) > \bar{u}(q^\circ)$, (iv) strictly quasi-concave--*i.e.*, for any $\lambda \in (0,1)$, $\bar{u}\left[\lambda q^\circ + (1-\lambda)q^1\right] > \left[\lambda\bar{u}(q^\circ) + (1-\lambda)\bar{u}(q^1)\right]$, and (v) weakly monotomic--*i.e.*, for any $\bar{u}^\circ > 0$ there exists a q such that $\bar{u}(q) \geq \bar{u}^\circ$.

These properties, together with the assumption that q_i, p_i and μ are all positive, imply the following informative axiomized preference-based responses of the consumer: (i) the marginal utilities of the goods $\left[\bar{u}_q = \dfrac{\partial\bar{u}}{\partial q^T}\right]$ are everywhere positive, (ii) the Hessian $\bar{u} = \dfrac{\partial\bar{u}_q}{\partial q^T} = \begin{bmatrix}\bar{u}_{11}\cdots\bar{u}_{1n}\\ \vdots \quad \vdots\\ \bar{u}_{n1}\cdots\bar{u}_{nn}\end{bmatrix}$ is negative definite everywhere--implying that the condition of diminishing marginal utility holds for each good, and (iii) the Hessian $\bar{\mathbf{u}}$ and hence its inverse

$$\bar{\mathbf{u}}^{-1} = \left(\frac{\partial\bar{u}_q}{\partial q^T}\right)^{-1} = \begin{bmatrix}\bar{u}^{11}\cdots\bar{u}^{1n}\\ \vdots \quad \vdots\\ u^{n1}\cdots u^{nn}\end{bmatrix}$$ are symmetric (as ascertained by "Young's Theorem").

In fact, in the context of this general method, sound responses to the following specific issues are needed: (i) the defining of equivalence scales, (ii) the methods of accommodating equivalence scales within the original consumer demand system, (iii) the estimation of the equivalence scales, and (iv) the implications of the elicited responses to the above issues, on estimation, economic plausibility, and interpretation of the consequent modified consumer demand system.

Represent our original consumer demand system by:

$$q_i = \bar{h}^i(P,\mu) \quad , \; i = 1,\ldots,n \; ; \tag{11}$$

where $P = (p_1,\ldots,p_n)^T$ is an $(n \times 1)$ vector of goods prices. We assume that (11) is theoretically plausible and denote its corresponding indirect utility and direct utility functions by $\bar{\Psi}(P,\mu)$ and $\bar{u}(q)$, respectively.

In allowing for the effects of demographic variables, we operationally identify (*prior* to estimation) three distinctive steps: (i) the specification of the form of the original demand system (11), (ii) the identification and introduction of new parameters to the original demand system accompanied by the postulation that only such parameters depend on the demographic variables $\Gamma_1,\ldots,\Gamma_F$, and (iii) the specifying of a functional form that relates these newly introduced parameters to the F demographic variables.

6. The Modified Prais-Houthakker Specification[4]

The essential distinguishing features of the Modified Prais-Houthakker specification from the original formulation of Prais and Houthakker (1955:125-145) are the following:

[4] The name "Modified Prais-Houthakker" (specification) is due to Pollak and Wales (1981).

(i) its reconciliation (implicit defining) of the general scale with the budget constraint, (ii) its adoption of the complete consumer demand system approach--thus adhering to original demand sv^ ms that are theoretically plausible, and (iii) its allowing under certain conditions (*e.g.*, particular properties of the underlying preference orderings) its consequent modified consumer demand system to be theoretically plausible. These distinguishing features which have thus allowed for a richer and better serviceable re-formulation of the Prais-Houthakker specification, have surfaced through the works of Muellbauer (1977, 1980) and Pollak and Wales (1981).

The Modified Prais-Houthakker specification replaces the original demand system (11) by:

$$h^i(P,\mu) = s_i \bar{h}^i\left(P, \frac{\mu}{S_\circ}\right) \quad ,i = 1,\ldots,n \; ; \tag{12}$$

where s_i denotes a "specific scale" for good i postulated to depend on the demographic variables $\Gamma = (\Gamma_1 \ldots \Gamma_F)^T$--*i.e.*, $s_i = S^i(\Gamma)$, and $S_\circ$ denotes a "general scale" or "income scale" implicitly defined *via* the budget constraint:

$$\mu = \sum_{i=1}^{n} p_i s_i \bar{h}_i\left(P, \frac{\mu}{S_\circ}\right) \quad . \tag{13}$$

Evidently (from 13), $S_\circ$ is a function of P,μ and the specific scales $s_1,\ldots,s_n$ --*i.e.*, $S_\circ = S^\circ(P,\mu, s_i,\ldots,s_n)$

As pointed out by Pollak and Wales (1981), if the right-hand side of (13) is an increasing function of $\left(\frac{\mu}{S_\circ}\right)$, then $S_\circ$ can be determined uniquely--thus, in the instance that the Modified Prais-Houthakker specification, say does not admit inferior goods, this

condition is automatically fulfilled. It is also noteworthy to point out (Pollak and Wales 1981) that the Modified Prais-Houthakker specification need not be theoretically plausible. However, under special conditions--*e.g.*, the case involving a demand system corresponding to an additive direct utility function--the property of theoretical plausibility is fulfilled by the implied Modified Prais-Houthakker specification.

We may choose the specific scale functions to be linear functions of the demographic variables without the constant terms[5]--*i.e.*, $s_i = 1 + \sum_{d=1}^{F} f_{id}\Gamma_d \quad , \; i = 1,\ldots,n$. Thus, the consequent Linear Modified Prais-Houthakker specification has added to the original demand system at most $n \times F$ new independent parameters.[6]

7. The Demographic Scaling Specification[7]

Demographic scaling transforms the original demand system (11) into the modified system:

$$h^i(P,\mu) = m_i \bar{h}^i(p_1 m_1 \;,\ldots,\; p_n m_n \;,\; \mu) \quad , \; i = 1,\ldots,n. \tag{14}$$

[5] We yield to the experience and sound arguments of Pollak and Wales (1980, 1981)--that these constant terms are better described as belonging to the original demand system rather than the demographic specification; and in noticing that if the linear specification of the specific scale functions is used and the original demand system is mis-specified in the sense that constant terms are (incorrectly) excluded, then a demographic variable which shows little variation may appear to be significant in the corresponding modified system-simply because it has acted as a *proxy* of the omitted constant terms.

[6] The name, "Linear Modified Prais-Houthakker" (specification) is due to Pollak and Wales (1981), who have also pointed out that the number of new independent parameters is "at most" $n \times F$, since with certain demand systems (*e.g.*, the Leontief fixed coefficient system), not all of the newly introduced parameters are identified.

[7] This specification was first established by Barten (1964). The name, "Demographic Scaling" is due to Pollak and Wales (1980).

Thus, the specification introduces n new parameters $\{m_1,\ldots,m_n$ to the original demand system. Moreover, it relates these n scaling parameters to the vector of demographic variables $\Gamma = (\Gamma_1 \ldots \Gamma_F)^T$; *i.e.*,

$$m_i = M^i(\Gamma) \quad , \quad i=1,\ldots,n. \tag{15}$$

A functional form for $M_i(\cdot)$ needs to be specified and their associated parameters estimated concurrently with those of the original demand system. The m_i's may be interpreted as (conditional) equivalence scales.

Linear demographic scaling, which specifies (15) to take the form:

$$m_i = 1 + \sum_{d=1}^{F} \delta_{id}\Gamma_d \quad , \quad i = 1,\ldots,n \; ; \tag{16}$$

adds at most $n \times F$ new independent parameters to the original system.[8]

As explained or implied by Pollak and Wales (1980, 1981), if the original demand system is theoretically plausible, then (14) is also theoretically plausible--at least for m's close to one.[9]

Under the Demographic Scaling specification, the modified demand system corresponds to the indirect utility function [direct utility function],

[8] See footnote 6 for the rationale behind the qualification "at most." The name, "Linear Demographic Scaling" is due to Pollak and Wales (1981).

[9] Strictly speaking, the modified system satisfies the Slutsky symmetry conditions but the substitution matrix need not be negative semi-definite except when all the m's are unity. Under suitable assumptions about the original system, the modified system is theoretically plausible for m's sufficiently close to unity; a global result, however, is not possible (Pollak and Wales 1980, 1981).

$$\Psi(P,\mu) = \Psi(p_1 m_1,\ldots,p_n m_n,\mu) \tag{17}$$

$$\left[u(q) = \bar{u}\left(\frac{q_1}{m_1},\ldots,\frac{q_n}{m_n}\right)\right] \quad . \tag{18}$$

Thus, the modified indirect utility [direct utility] function is a function of scaled prices [scaled quantities].

8. The Demographic Translating Specification[10]

Demographic translating introduces into the original demand system a set of new parameters (*d's*) and postulates that only these new parameters are functions of the demographic variables, *i.e.*,

$$d_i = D^i(\Gamma) \quad , \; i = 1,\ldots,n \; . \tag{19}$$

Demographic translating allows these new parameters to enter the original demand system in a particular way, *viz.*, to replace (11) by:

$$h^i(P,\mu) = d_i + \bar{h}^i\left(P,\mu - \sum_{k=1}^{n} p_k d_k\right) \quad , \; i = 1,\ldots,n \; . \tag{20}$$

If (11) is theoretically plausible, then (20) is also theoretically plausible, at least for *d's* close to zero.[11]

[10] Demographic translating is not more general than the ones earlier delineated; however, in addition to the important conceptual content that it in itself possesses, it plays an integral and crucial role on the formulations of the two specifications to follow, which are both more general than demographic scaling. The name, "Demographic Translating" (specification) is due to Pollak and Wales (1978), who have demonstrated how the procedure is made amenable to an elegant characterization.

[11] The caveat given in footnote 9 is fully relevant here except that references to "*m's*" and "unity" are to be appropriately substituted with appropriate references to "d's" and "zero," respectively.

The modified system (20) satisfies the first-order conditions of the "consumer problem" with corresponding indirect and direct utility functions taking the following respective forms (Pollak and Wales 1978, 1980):

$$\Psi(P,\mu) = \overline{\Psi}\left(P,\mu - \sum_{k=1}^{n} p_k d_k\right) \tag{21}$$

and

$$u(q) = \overline{u}(q_1 - d_1,\ldots,q_n - d_n \tag{22}$$

We may interpret the *d's* as conditional equivalence scales. These scales are related by the functions $\{D^i(\cdot)$, i = 1,...,n to the vector of demographic variables $\Gamma = (\Gamma_1,\ldots,\Gamma_F)^T$. Specific functional forms for $\{D^i(\cdot)$, i = 1,...,n need to be specified. Thus, one that postulates a linear relationship without constant terms between the *d's* and the demographic variables, *i.e.*,

$$d_i = \sum_{d=1}^{F} \delta_{id}\Gamma_d \quad , \; i = 1,\ldots,n \tag{23}$$

adds at most $n \times F$ new independent parameters to the original demand system.[12]

Demographic translating reveals a close relation between the effects of changes in demographic variables and effects of changes in total-expenditure. Since total-expenditure (μ) is treated as an exogeneous variable and enters the analysis in a fixed form *via* the budget constraint, the *d's* imply a reallocation of it *(i.e.* of μ*)* among the consumption categories, which leaves total-expenditure unchanged.

[12] As in footnote 6, "at most" is applicable since with certain demand systems (*e.g.*, the nonhomogeneous fixed coefficient system), not all of the newly introduced parameters are identified. Moreover, the caveat given in footnote 5 is very relevant in this particular context--thus, it is important that when demographic translating is used to incorporate demographic variables into the original demand system, the modified system does possess constant terms.

To see this in greater detail, consider the modified demand system (20) in its expenditure form:

$$
\begin{aligned}
p_i h_i(P,\mu) &= p_i d_i + p_i \bar{h}^i\left(P, \mu - \sum_{k=1}^{n} p_k d_k\right) \\
&= p_i D^i(\Gamma) + p_i \bar{h}^i\left[P, \mu - \sum_{k=1}^{n} p_k D^k(\Gamma)\right] \quad , \; i = 1,\ldots, n.
\end{aligned}
\tag{24}
$$

The effect of a change in Γ_d *on* $p_i h^i(\cdot)$ is given by $\left(\frac{\partial p_i h^i(\cdot)}{\partial \Gamma_d}\right)$, which in light of (24) gives:

$$
\frac{\partial p_i h^i(\cdot)}{\partial \Gamma_d} = p_i\left(\frac{\partial D^i(\Gamma)}{\partial \Gamma_d}\right) - p_i\left[\frac{\partial \bar{h}^i\left(P, \mu - \sum_{k=1}^{n} p_k \Gamma_k\right)}{\partial \mu}\right]\left[\sum_{k=1}^{n} p_k\left[\frac{\partial D^k(\Gamma)}{\partial \Gamma_d}\right]\right] \tag{25}
$$

Thus, $\left(\frac{\partial p_i h^i(\cdot)}{\partial \mu}\right)$ is the marginal budget share of the ith good, and $\left(\frac{\partial D^i(\cdot)}{\partial \Gamma_d}\right)$ represents the (infinitesimal) change in the conditional equivalence scale appropriate for good i, due to an infinitesimally small unit change in the magnitude of the dth demographic variable.[13] Thus, evidently a change in Γ_d causes a reallocation of total-expenditure among the consumption goods. And specifically, the extent of the consequent change to the demand of a particular good depends on (i) the relative strength of the marginal budget share of that good, and (ii) the relative sensitivity of the conditional equivalence scale associated with that specific good to changes in the magnitude of the demographic variable. Moreover, because of the adding-up constraint, the reallocation is constrained to maintain the total-expenditure in its original level. Therefore, changes in the levels of consumption among the goods are obviously compensatable in nature--any increases in the

[13] Such small changes as pointed out by Barten (1964) are less unrealistic than they seem. For instance, Γ may be expressed in terms of household composition, which includes "age" as a defining cross-classifier, hence, implying that household composition does change from day to day as members over time grow old.

consumptions of certain goods must be compensated for by decreases in the consumptions of others.

We also notice [equation (25)] that the sign of the effect of a change in Γ_d on $p_i h^i(\cdot)$ cannot be equated to or deduced from the sign of the effect of a change in Γ_d on the specific conditional equivalence scale d_i. Moreover, we can only agree with the argument put forward by Pollak and Wales (1978, 1980)--that there is no *a priori* presumption that an increase in Γ_d increases rather than decreases d_i (*i.e.*, that $\frac{\partial D^i(\cdot)}{\partial \Gamma_d}$ is necessarily positive even if Γ_d merely denotes household size). In fact, the underlying reallocation property says (Barten 1964), that demographic effects satisfy the homogeneity condition--a natural consequence of the special nature of the allocation process (*i.e.*, its administration with firm respect for the budget constraint).

9. The Gorman Specification[14]

If demographic scaling is first applied followed by demographic translating to the original demand system (11), the resultant specification is:

$$h^i(P,\mu) = d_i + m_i \bar{h}^i\left(p_1 m_1, \ldots, p_n m_n, \mu - \sum_{k=1}^{n} p_k d_k\right) \quad , \; i = 1,\ldots,n \; ; \tag{26}$$

where $d_i = D^i(\Gamma)$ and $m_i = M^i(\Gamma)$.

[14] The name, "Gorman specification" is due to Pollak and Wales (1981). The underlying procedure was developed by Gorman (1975), who was motivated by the desire to further generalize the pivotal role of the procedure (demographic scaling) developed by Barten (1964). A characterization of the Gorman specification based on duality theory and by *via* which its utility maximizing theoretical basis is clearly revealed, was given by Muellbauer (1977). Pollak and Wales (1981), however, gave the specification a high degree of finish by, *inter alia*, characterizing the theoretical plausibility status of the consequent modified system and by actually confronting the specification with actual data.

We postulate that the *d's* and the *m's* and only these parameters depend on the vector of demographic variables Γ .

Once we impose particular forms for $D^i(\cdot)$ and $M^i(\cdot)$, demand system (26) can be distinctively referred to as the "Gorman specification." The Gorman specification is theoretically plausible at least for *d's* near zero and m's near unity.[15] Thus, the specification satisfies the first-order conditions of the consumer problem, with corresponding indirect and direct utility functions given, respectively, by:

$$\Psi(P,\mu) = \overline{\Psi}\left(p_1 m_1,\ldots,p_n m_n,\mu-\sum_{k=1}^{n} p_k d_k\right)$$

and

$$u(q) = \overline{u}\left(\frac{[q_1-d_1]}{m_1},\ldots,\frac{[q_n-d_n]}{m_n}\right)$$

Clearly, demographic translating and demographic scaling are special cases of the Gorman specification. Demographic translating (demographic scaling) is retrievable from (26) by assigning to all the *m's* [*d's*], the value zero [unity].

We may specify the *d's* and the *m's* to be (joint) linear functions of $\Gamma = (\Gamma_1,\ldots,\Gamma_F)^T$, *i.e.*, as:[16]

$$d_i = D^i(\Gamma) = \upsilon\sum_{d=1}^{F}\delta_{id}\Gamma_d \tag{27a}$$

and

$$m_i = M^i(\Gamma) = 1 + (1-\upsilon)\sum_{d=1}^{F}\delta_{id}\Gamma_d \quad . \tag{27b}$$

[15] Remarks given in footnotes 9 and 11 are jointly relevant in this context.

[16] As detailed in footnote 5, the constant terms are best treated as part of the specification of the original demand system rather than as part of the demographic specification.

Notice that functions (27a) and (27b) are jointly restricted linear forms; and add one more parameter, υ, to the separate estimation of either linear demographic translating or linear demographic scaling. Linear demographic translating, *per se* (linear demographic scaling, *per se*), corresponds to $\upsilon = 1$ $[\upsilon = 0]$.

If, however, υ is allowed to differ for different goods and $F = 1$--*i.e.* $\Gamma = \Gamma_\circ$ (a scalar), then (27a) and (27b) are unrestricted linear forms representable, respectively, by:

$$D^i(\Gamma) = D^i(\Gamma_\circ) = \upsilon_i \delta_{i\circ} \Gamma_\circ = \gamma_i \Gamma_\circ \quad , \; i = 1,\ldots, n$$

and

$$M^i(\Gamma) = M^i(\Gamma_\circ) = 1 + (1-\upsilon_i)\delta_{i\circ}\Gamma_\circ = 1 + \gamma_i^* \Gamma_\circ \quad , \; i = 1,\ldots, n.$$

10. The Reverse Gorman Specification[17]

Incorporating demographic variables into (11) by first applying demographic translating and then demographic scaling yields the modified demand system:

$$h^i(P,\mu) = m_i\left[d_i + \bar{h}^i\left(p_1 m_1,\ldots,p_n m_n, \mu - \sum_{k=1}^{n} p_k d_k\right)\right] \quad , \; i = 1,\ldots, n. \tag{28}$$

Again, postulate that the d's and the m's, and only these parameters, depend on the vector Γ. Thus, we write: $d_i = D^i(\Gamma)$ and $m_i = M^i(\Gamma)$. Now, once we give $D^i(\cdot)$ and $M^i(\cdot)$ specific functional forms, the implied modified system is distinct from the Gorman specification.

[17] This specification arises from a plausible and logically non-trivial adaptation of the Gorman specification. The particular procedure it represents, together with the name, "Reserve Gorman" specification, are due to Pollak and Wales (1981).

That is, the consequent counterpart of (28) becomes what Pollak and Wales (1981) have referred to as the "Reverse Gorman Specification."[18]

The Reverse Gorman specification is theoretically plausible, at least for *d's* near zero and *m's* near unity. In such a context, it satisfies the first-order conditions of the consumer problem with corresponding indirect and direct utility functions representable, respectively, by:

$$\Psi(P,\mu) = \Psi(p_1 m_1,\ldots,p_n m_n,\mu - \sum_{k=1}^{n} p_k m_k d_k)$$

and

$$u(q) = \bar{u}\left(\left[\frac{q_1}{m_1}\right]-d_1,\ldots,\left[\frac{q_n}{m_n}\right]-d_n\right)$$

We may postulate that the *d's* and *m's* are joint linear functions of the demographic variables (*i.e.*, they take the specifications (27a) and (27b), respectively). In such a context, the Reverse Gorman specification contains one more parameter, (υ), as compared to the number of parameters contained in a modified system defined under either linear demographic translating *per se* or linear demographic scaling *per se*.

11. The Implicit Correction Specification

The Implicit Correction specification is a key stylization of the Implicit Correction Method and it works under a general demand system--thus, it is not constrained by the choice of functional form for the original demand/Engel curves system. According to this specification, the original system is unaltered (*i.e.*, no modification to the econometric

[18] It can be demonstrated straightforwardly that if we do not impose specific functional forms on $D^i(\cdot)$ and $M^i(\cdot)$, then the general modified system (28) is not distinct from (26).

specification of it is effected). It follows that the Implicit Correction specification does not commit to the formulation and estimation of conditional equivalence scales and related requirements (*e.g.*, those deemed necessary in order for the modified demand system to inherit theoretical plausibility). Instead, the correcting for demographic effects as far as modeling is concerned is done implicitly--by estimating the model separately for different demographically demarcated groups represented by relevant subsets of the data. Each subset represents households with a "homogeneously distinct" demographic profile.[19]

The Implicit Correction specification is statistically inefficient since the available data are not jointly utilized in full in estimation. However, it substantially improves the estimates of the demand system parameters since, by construction, it effectively "eliminates" the effects of differences in demographic profiles. Thus, the approach is very appropriate for estimating price and income elasticities because its mandatory data handling procedure circumvents direct dealings with households of different demographic profiles; thus, the specification allows the *ceteris paribus* condition to be very nearly attained.

Stated alternatively, the Implicit Correction specification allows all the parameters of the demand system to vary freely from the influences of differing household demographic profiles. Consumption behavior as so described is thus regarded as "free" from the confounding effects of demographic variables. Hence, as a non-trivial point in favor of it, the Implicit Correction specification leads to clear views of the connection between consumptions and the exogeneously given (total) expenditure--prices configurations.

[19] Due to the practical impossibility of finding two or more households with demographic profiles that are strictly identical, the approach effectively involves some degree of "pooling" across households of differing demographic characteristics.

D. GENERALITIES DUE TO CERTAIN NESTING PROPERTIES

We consider certain "orders" of generalities implied by certain inherently nested properties of the modified consumer demand systems. As evidenced subsequently, such perspectives are useful, *inter alia*, in crystalizing and discriminating the relative theoretical contents and empirical efficacies of the previously delineated alternative means of modeling demographic effects.

Under the Modified Prais-Houthakker specification, if $s_i = s^*$ (a constant) for (all) $i = 1,\ldots,n$, then the budget constraint (13) implies that $s_0 = s^*$--a common value.[20] In this context, the Modified Prais-Houthakker specification is equivalent to the Demographic Scaling specification, with all the scaling parameters [m's in (15)] being identical.[21] Demographic translating, like demographic scaling, is nested within both the Gorman specification and the Reverse Gorman specification. Notice, however, that all these specifications are nested within the so-called Implicit Correction specification, where all parameters of the original demand system are allowed to depend on the demographic variables. Finally, note that the so-called, Naive specification--in which the consumer demand system is formulated and estimated based on an agnostic attitude toward the effect of demographic variables--is nested within all the specifications delineated above.

III. ORIGINAL CONSUMER DEMAND SYSTEMS

We consider two special variants to represent the original consumer demand system (11). These chosen variants do in fact constitute a pair of closely related systems of consumer demand functions. The fundamentally common feature that characterizes these

[20] s^* could thus be interpreted as the number of "conditional equivalent consumer units."

[21] This result follows immediately from the homogeneity property of demand functions.

two demand systems relates to the way quantities demanded $\{ q_i , i = 1,...,n\}$ and total-expenditure (μ) are conjectured to be behaviorally linked.

The first system is the familiar "Linear Expenditure System," which exhibits linearity in the relations between quantities demanded and total-expenditure. The second system is a more recently introduced system, the "Quadratic Expenditure System," which accommodates curvature by admitting regular relations of a quadratic nature between quantities demanded and total-expenditure. On the basis of linearity and quadratic curvature alone, numerous demand systems with distinctive properties are admissible.[22] In choosing our ultimately adopted variants we narrow down admissible possibilities by adopting the following criteria (and asserting that such criteria be fulfilled by our adopted demand systems): (i) theoretical plausibility--*i.e.*, the underlying generating mechanism is that of (classical) utility maximization, (ii) relative parsimony in parameters and accommodation of some flexibility in behavior, and (iii) capability to exhibit compatibility and intimate connection between the two chosen systems.[23]

Consistent with the stated criteria are the following closely related consumer demand systems.

A. The Linear Expenditure System (LES)[24]

By nominating Stone's (1954) Linear Expenditure System (LES) as the original consumer demand system, we thus specify (11) as:

[22] See, for instance, Howe (1974), Howe, Pollak, and Wales (1979), and Pollak (1971).

[23] A systematic way of narrowing down admissible alternatives using the stated criteria--thus, leading to two favored variants of consumer demand systems (*viz.*, LES and QES)--is given in Kami (1991).

[24] For a thorough characterization of LES and its utility-linked foundation, see Goldberger (1967), Geary (1949-50), Pollak (1971), Samuelson (1947-48), and Stone (1954).

$$q_i = \bar{h}^i(P,\mu) = \tau_i + \beta_i p_i^{-1}\left(\mu - \sum_{j=1}^{n} p_j \tau_j\right) \quad , \; i = 1,\ldots,n \; , \tag{29}$$

satisfying the restriction $\sum_{j=1}^{n} \beta_j = 1$.

In expenditure form, (29) becomes:

$$p_i q_i = p_i \bar{h}^i(P,\mu) = p_i \tau_i + \beta_i\left(\mu - \sum_{j=1}^{n} p_j \tau_j\right) \quad , \; i = 1,\ldots,n \; , \tag{30}$$

satisfying the restriction $\sum_{j=1}^{n} \beta_j = 1$.

As can be easily deduced, with respect to good i, β_i is the marginal budget share and $p_i \tau_i$ and $\left(\mu - \sum_{j=1}^{n} p_j \tau_j\right)$ may be interpreted as "subsistence expenditure" (or "committed expenditure") and "supernumerary total-expenditure," respectively.

B. The Quadratic Expenditure System (QES)[25]

By nominating Howe, Pollak, and Wale's (1979) Quadratic Expenditure System (QES) as the original consumer demand system, we specify (11) as:

$$q_i = \bar{h}^i(P,\mu) = \tau_i + \left(\frac{\beta_i}{p_i}\right)\left(\mu - \sum_{j=1}^{n} p_j \tau_j\right) + \left[\frac{(\alpha_i - \beta_i)}{p_i}\right] \Omega \prod_{j=1}^{n} p_j^{-\alpha_j}\left(\mu - \sum_{k=1}^{n} p_k \tau_k\right)^2 \quad , \; i = 1,\ldots, n \; ; \tag{31}$$

satisfying the restrictions $\sum_{j=1}^{n} \beta_j = 1$ and $\sum_{j=1}^{n} \alpha_j = 1$.

In expenditure form, (31) becomes:

[25] For the genesis and formal characterization of QES and its "theoretical plausibility" foundation, see Howe (1974) and Howe, Pollak, and Wales (1979). For derivations of specific utility-based features of QES, demonstrations in the general context of how certain satisfied restrictions could be used to systematically narrow down admissible variants in a class for which QES is a member, and a direct verification of the fact that QES satisfies the demand-theoretic restrictions of the utility maximizing hypothesis, see Kami (1991).

$$p_i q_i = p_i \bar{h}^i(P,\mu) = p_i\tau_i + \beta_i\left(\mu - \sum_{j=1}^{n} p_j\tau_j\right) + (\alpha_i - \beta_i)\Omega\prod_{j=1}^{n} p_j^{-\alpha_j}\left(\mu - \sum_{k=1}^{n} p_k\tau_k\right)^2 \quad , \; i = 1,\ldots, n \; ; \quad (32)$$

satisfying the restrictions $\sum_{j=1}^{n}\beta_j = 1$ and $\sum_{j=1}^{n}\alpha_j = 1$

The $p_i\gamma_i$'s may be interpreted as "subsistence expenditures," and notice that $\left[\mu - \sum_{j=1}^{n} p_j\tau_j\right] > 0$ *(i.e.,* the "supernumerany total-expenditure") must be positive.[26]

Notice that *QES* [with *(3n-1)* parameters] reduces to the *LES* [with *(2n-1)* parameters] when $(\alpha_i - \beta_i) = 0$ for all $i=1,\ldots,n$, or $\Omega = 0$. In fact, as pointed out by Howe, Pollak, and Wales (1979), the QES includes well-behaved non-trivial generalizations of the LES. If the β_i's and τ_i's are such that the associated LES is "well-behaved," then the corresponding QES is well-behaved for values of the α_i's sufficiently close to the corresponding β_i's .

While LES is inherited from a strongly separable utility function, QES is not. Thus, those supposedly adverse implications of strong separability may be significantly mitigated by working with broad consumption categories--so that, *inter alia,* the inherited properties of, say, non-admittances of inferior and net substitutability goods are not viewed as being too unreasonable. In any case, our inclusive adoption of QES--which is readily reducible to LES--means, *inter alia*, that we are accessing to a more flexible functional form, and that more complex (utility *cum* market-based demand) behaviors could be put into some sound form of empirical testing.

[26] In fact, this result becomes accessible to us only when we impose the restriction of diminishing marginal utility of total-expenditure since the relevant underlying utility function only implies a non-zero supernumerary total-expenditure--*i.e.,* $\left[\mu - \sum_{j=1}^{n} p_j\tau_j\right] \neq 0$. For discussions on this and other pertinent elements of the LES-QES analogies, see Kami (1991).

IV. MODIFIED CONSUMER DEMAND SYSTEMS

The focus of the empirical results presented in this paper are on the Implicit Correction Method and those variants of the Explicit Correction Method that incorporate conditional equivalence scales directly into the consumer demand system and estimate the said scales jointly with the parameters of the system based on the market behaviors of households.

Given that LES and QES are variants of the original consumer demand system (11), the corresponding modified systems consequent of the applications of the Explicit Correction Method specifications could be straightforwardly derived. We shall refer to these modified variants, together with the corresponding ones under the Implicit Correction specification, as MLES and MQES variants.

A. The Modified Linear Expenditure System (MLES)

Under MLES, the Scaling, Translating, Gorman, and Reverse Gorman specifications give identical estimating equations.[27] Thus, apart from the Implicit Correction specification, we only specify two distinct MLES variants of the Explicit Correction Method.

The LES (30) in its (budget) share form is:

$$w_i = \left(\frac{p_i}{\mu}\right)\tau_i + \beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\tau_k\right] \quad , \; i = 1,\ldots,n \; , \tag{33}$$

satisfying the restriction $\sum_{i=1}^{n}\beta_i = 1$.

[27] For a proof of this result, see Pollak and Wales (1981) or Kami (1991).

1. Scaling/Translating/Gorman/Reverse Gorman

a. In share form, (33) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)(d_i+\tau_i) + \beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)(d_k+\tau_k)\right] \quad , \; i = 1,\ldots,n \; , \tag{34}$$

where β's, τ's and d's are parameters satisfying the restriction $\sum_{k=1}^{n}\beta_k = 1$, and the condition--that the d's and only the d's depend on $\Gamma_1,\ldots,\Gamma_F$.

b. In share form with Linear Demographic Translating, (34) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)\left(\tau_i+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right) + \beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left(\tau_k+\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right)\right] \quad , \; i = 1,\ldots,n \; , \tag{35}$$

where β's, τ's and δ's are parameters satisfying the restriction $\sum_{i=1}^{n}\beta_i = 1$.

2. Modified Prais-Houthakker

a. In share form, (33) becomes:

$$w_i = s_i\left[\left(\frac{p_i}{\mu}\right)\tau_i+\beta_i\left[s_\circ^{-1}-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\tau_k\right]\right] \quad , \; i = 1,\ldots,n \; , \tag{37}$$

where β's, τ's, s's, and $s_\circ$ are parameters satisfying the restrictions $\sum_{i=1}^{n}\beta_i = 1$, and

$$\mu = \sum_{i=1}^{n} p_i s_i \bar{h}^{i}\left[P,\frac{\mu}{s_\circ}\right] \text{--i.e.,}$$

$$s_\circ(P,\mu,s_1,\ldots,s_n) = \frac{\left[\mu\sum_{i=1}^{n}\beta_i s_i\right]}{\left[\mu+\left(\sum_{i=1}^{n}\beta_i s_i\right)\left(\sum_{k=1}^{n}p_k\tau_k\right)-\left(\sum_{i=1}^{n}p_i s_i\tau_i\right)\right]}$$

; and the condition--the s_i's and $s_\circ$ and only these parameters depend on $\Gamma_1,\ldots,\Gamma_F$.

b. In share form with linear specific scale functions,

$$s_i = s_i(\Gamma) = 1+\sum_{d=1}^{F}\delta_{id}\Gamma_d \quad , \; i = 1,\ldots, n\text{--(37) becomes:}$$

$$w_i = \left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\left[\left(\frac{p_i}{\mu}\right)\tau_i+\beta_i\left[s_\circ^{-1}-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\tau_k\right]\right] \quad , \; i = 1,\ldots, n \; , \tag{38}$$

where the β's, τ's, δ's and $s_\circ$ are parameters satisfying the restrictions, $\sum_{i=1}^{n}\beta_i = 1$, and $\mu = \sum_{i=1}^{n}p_i s_i \bar{h}^{-1}\left[P,\frac{\mu}{s_\circ}\right]$--*i.e.*,

$$s_\circ(P,\mu,\Gamma) = \frac{\left[\mu\sum_{i=1}^{n}\beta_i\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\right]}{\left[\mu+\sum_{i=1}^{n}\beta_i\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\left[\sum_{k=1}^{n}p_k\tau_k\right]-\sum_{i=1}^{n}p_i\tau_i\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\right]}$$

Thus, (38) can be alternatively written in the closed form:

$$w_i = \frac{\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\left[\left(\frac{p_i}{\mu}\right)\tau_i+\beta_i\left[\left[\mu+\left[\sum_{i=1}^{n}\beta_i\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\right]\right]\left[\sum_{i=1}^{n}p_k\tau_k\right]-\sum_{i=1}^{n}p_i\tau_i\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\right]\right]}{\left[\left[\mu\left[\sum_{i=1}^{n}\beta_i\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\right]-\sum_{i=1}^{n}\left[\frac{p_k}{\mu}\right]\tau_k\right]\right]} \; , \tag{39}$$

$i = 1,\ldots, n$,

where β's, τ's and δ's are parameters satisfying the restriction, $\sum_{k=1}^{n}\beta_k = 1$.

B. The Modified Quadratic Expenditure System (MQES)

Under MQES, we do not specify (and thus attempt to estimate) a variant of the Modified Prais-Houthakker specification. Unlike the corresponding MLES case, by defining the general scale (s.) *via* the budget constraint, it has not been possible to yield an explicit expression of it and a closed form characterization of the implied demand functions. Thus, apart from the Implicit Correction specification we only specify four distinct MQES variants under the Explicit Correction Method.

The QES (32) in its (budget) share form is:

$$w_i = \left(\frac{p_i}{\mu}\right)\tau_i + \beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\tau_k\right] + (\alpha_i-\beta_i)\Omega\prod_{k=1}^{n}\left(\frac{p_k}{\mu}\right)^{-\alpha_k}\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\tau_k\right]^2 \quad , \; i = 1,\ldots, n \; , \tag{40}$$

where β's, τ's, α's and Ω are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$ and $\sum_{k=1}^{n}\alpha_k = 1$.

1. Demographic Scaling

a. In share form, (40) becomes:

$$w_i = \left(\frac{p_i}{\mu_i}\right)m_i\tau_i + \left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)m_k\tau_k\right] + (\alpha_i-\beta_i)\Omega\prod_{k=1}^{n}\left[\left(\frac{p_k}{\mu}\right)m_k\right]^{-\alpha_k}\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)m_k\tau_k\right]^2 , \tag{41}$$

$i = 1,\ldots, n$,

where β's, τ's, δ's, m's and Ω are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$ and $\sum_{k=1}^{n}\delta_k = 1$, and the condition (the m's and only the m's depend on $\Gamma_1,\ldots,\Gamma_F$).

b. In share form with linear demographic scaling, (41) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)\tau_i\left[1+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right] + \beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\tau_k\left[1+\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right]\right] + (\alpha_i-\beta_i)\Omega\prod_{k=1}^{n}\left[\left(\frac{p_k}{\mu}\right)\left[1+\sum_{k=1}^{F}\delta_{id}\Gamma_d\right]\right]^{-\alpha_k}$$

$$x\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\tau_k\left[1+\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right]\right]^{2} \quad , \; i = 1,\ldots, n \; , \tag{42}$$

where β's, τ's, α's, δ's, and Ω are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$ and $\sum_{k=1}^{n}\alpha_k = 1$.

2. Demographic Translating

a. In share form, (40) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)(d_i+\tau_i)+\beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)(d_k+\tau_k)\right] + (\alpha_i-\beta_i)\Omega\prod_{k=1}^{n}\left(\frac{p_k}{\mu}\right)^{-\alpha_k}\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)(d_k+\tau_k)\right]^{2} \; , \tag{43}$$

$i = 1,\ldots, n$,

where β's, τ's, α's, d's, and Ω are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$ and $\sum_{k=1}^{n}\alpha_k = 1$, and the condition--the d's and only the d's depend on $\Gamma_1,\ldots,\Gamma_F$.

b. In share form with linear demographic translating, (43) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)\left(\tau_i+\sum_{d=1}^{F}\delta_{id}\Gamma_d\right)+\beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left[\left(\tau_k+\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right)\right]\right] +$$

$$(\alpha_i-\beta_i)\Omega\prod_{k=1}^{n}\left(\frac{p_k}{\mu}\right)^{-\alpha_k}\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left[\tau_k+\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right]\right]^{2} \quad , \; i = 1,\ldots, n \; , \tag{44}$$

where β's, τ's, α's, δ's, and Ω are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$ and $\sum_{k=1}^{n}\alpha_k = 1$.

3. Gorman

a. In share form, (40) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)(d_i + m_i\tau_i) + \beta_i\left[1 - \sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)(m_k\tau_k + d_k)\right]$$
$$+(\alpha_i - \beta_i)\Omega\prod_{k=1}^{n}\left[\left(\frac{p_k}{\mu}\right)m_k\right]^{-\alpha_k}\left[1 - \sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)(m_k b_k + d_k)\right]^2 \quad , \; i = 1,\ldots, n \; , \tag{45}$$

where β's, τ's, α's, d's, and Ω and are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$ and $\sum_{k=1}^{n}\alpha_k = 1$, and the condition--the d's and m's and only these parameters depend on $\Gamma_1,\ldots,\Gamma_F$

b. In share form with joint linear functions for $D^i(\bullet)$ and $M^i(\bullet)$, (45) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)\left[\left[\upsilon + (1-\upsilon)\tau_i\right]\sum_{d=1}^{F}\delta_{id}\Gamma_d + \tau_i\right] + \beta_i\left[1 - \sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left[\left[\upsilon + (1-\upsilon)\tau_k\right]\sum_{d=1}^{F}\delta_{kd}\Gamma_d + \tau_k\right]\right] +$$
$$(\delta_i - \beta_i)\Omega\prod_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left[\left[1 + (1-\upsilon)\sum_{d=1}^{F}\delta_{kd}\Gamma_d + \tau_k\right]\right]^{-\delta_k} x\left[1 - \sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left[\left[\upsilon + (1-\upsilon)\tau_k\right]\sum_{d=1}^{F}\delta_{kd}\Gamma_d + \tau_k\right]\right]^2, \tag{46}$$

$i = 1,\ldots, n$,

where β's, τ's, α's, δ's, υ, and Ω are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$, $\sum_{k=1}^{n}\alpha_k = 1$ and $\upsilon \in [0,1]$.

4. Reverse Gorman[28]

In share form with joint linear functions for $D^i(\cdot)$ and $M^i(\cdot)$, (45) becomes:

$$w_i = \left(\frac{p_i}{\mu}\right)\left[(1-\upsilon)\sum_{d=1}^{F}\delta_{id}\Gamma_d\right]\left[\upsilon\sum_{d=1}^{F}\delta_{id}\Gamma_d+\tau_i\right] + \beta_i\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left[\upsilon+(1-\upsilon)\tau_k\right]\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right]$$
$$+(\alpha_i-\beta_i)\Omega\prod_{k=1}^{n}\left[\frac{p_k}{\mu}\left[(1-\upsilon)\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right]\right]^{-\alpha_k}\left[1-\sum_{k=1}^{n}\left(\frac{p_k}{\mu}\right)\left[\upsilon+(1-\upsilon)\tau_k\right]\sum_{d=1}^{F}\delta_{kd}\Gamma_d\right]^2 \quad , \; i = 1,\ldots,n; \quad (47)$$

where β's, τ's, α's, δ's, υ, and Ω are parameters satisfying the restrictions $\sum_{k=1}^{n}\beta_k = 1$, $\sum_{k=1}^{n}\alpha_k = 1$ and $\upsilon \in [0,1]$.

C. "Optimum" Forms and Redefinitions of Parameters

The MLES and MQES variants we have specified involve conditional equivalence scale functions (the *d's*, *m's* and *s's*) that are linear functions of the demographic variables, $\Gamma_1,\ldots,\Gamma_F$. In fact, the "optimum" form(s) for these conditional equivalence scale functions is (are) largely a matter to be determined empirically.

The choice of the form of the original demand system is also of paramount importance. Using, for instance, QES as the original demand system means that the scaling functions (the *m*'s) of the relevant MQES variants (Scaling, Gorman, and Reverse Gorman) need to be positive.[29] Thus, if a linear specification is earmarked for the scaling functions, it

[28]As already pointed out, without specifying particular functional forms for $D^i(\cdot)$ and $M^i(\cdot)$, the Reverse Gorman specification is not distinct from the Gorman specification.

[29]This is so, since the m_i's scale prices; moreover, they need to be raised to the power of α_i's $(i = 1, \ldots, n)$, but since the α_i's are not integers the m_i's need to be positive.

necessarily needs to be constrained to be positive. An alternative is to specify the scaling functions to be an exporential form of the demographic variables (*i.e.*, to be of the form).[30]

$$m_i = \prod_{j=1}^{F} \Gamma_j^{\delta_{ij}} \quad , \; i = 1,\ldots, n \; . \tag{48}$$

As a matter of fact, the various delineated variants of the modified consumer demand systems, MLES and MQES, actually imply particular transformations of the parameters of the original consumer demand systems, LES and QES.

Under the MLES variants, the redefinitions of the parameters of (the original) LES are as follows:

1. Scaling/Translating/Gorman/Reverse Gorman:

$$\tau_i^* = \tau_i + d_i \quad , \; i = 1,\ldots, n \; .$$

2. Modified Prais-Houthakker:

$$\tau_i^* = \tau_i m_i \quad , \; i = 1,\ldots, n \; ; \qquad \text{and} \qquad \beta_i^* = \beta_i m_i \quad , \; i = 1,\ldots, n \; .$$

Under the MQES variants, the redefinitions of the parameters of (the original) QES are as follows:

1. Scaling:

$$\tau_i^* = \tau_i m_i \quad , \; i = 1,\ldots, n \; ; \qquad \text{and} \qquad \Omega^* = \Omega \prod_{k=1}^{n} m_k^{-\alpha_k} \; .$$

2. Translating:

$$\tau_i^* = \tau_i d_i \quad , \; i = 1,\ldots, n \; ;$$

[30]Notice that when the exporential form (48) is used the Γ_j's in the data must be positive--since the derivatives of the implied likelihood function would involve these variables in their logarithmic form.

3. Gorman:

$$\tau_i^* = d_i + m_i \tau_i \quad , \; i = 1, \ldots, n \; ; \text{ and } \; \Omega^* = \Omega \prod_{k=1}^{n} m_k^{-\alpha_k} \; .$$

4. Reverse Gorman:

$$\tau_i^* = m_i(\tau_i + d_i) \quad , \; i = 1, \ldots, n \; ; \text{ and } \; \Omega^* = \Omega \prod_{k=1}^{n} m_k^{-\alpha_k} \; .$$

Thus, it is legitimate to interpret these (Explicit Correction Method) specifications as ways of allowing for parameter variations among household demographic profiles. As earlier indicated, translating parameters (the d_i's) and scaling parameters (the m_i's) may be further interpreted as subsistence parameters and household equivalence scales, respectively.

V. DATA AND EMPIRICAL COUNTERPARTS OF VARIABLES

The empirical component of this study utilizes a particular set of consumption data ("Tongan Data," for brevity), which is forthcoming *via* the first ever nationwide survey of household incomes and expenditures ("HIES," for brevity) conducted in the South Pacific island nation of Tonga (HIES was actually administered in 1984). This set of empirical realities (Tongan Data) needs to be made intelligible through appropriate remodeling and by subjecting it to formal hypotheses. Like the "remodeling" aspect, the latter confrontation can only be properly operationalized through the construction and articulation of appropriate empirical counterparts (of the relevant model variables and formal hypotheses).[31]

[31]Thus, considerable care and sharp attention need to be taken to ensure that our study embarks on a valid transition from theoretical abstraction to empirical reality. For a detailed discussion on this and other closely related issues in the context of the Tongan Data, see Kami (1990, 1991).

A. Selected Features of the Tongan Data

The Tongan Data is a set of micro-data--a household unit record data set. Its coverage is clearly delineated in at least two important respects: (1) to 709 households (roughly 6.3 percent of the 1984 population of households) in Tongatapu--the main island (with two principal regions *viz.* Vahekolo and Vahe'uta) of Tonga, and (2) to the consumption goods acquired *via* market transactions only--that is, the non-market goods are not included.[32]

The expenditures incurred by members of the sample households allowing for the whole nondurable goods regimen and over four quarters of 1984 have been appropriately aggregated into four broad consumption categories[33] --"domestic food," "imported food," "non-food," and "services."[34] Moreover, appropriate price indexes for these consumption

[32] Goods (including services) that are purchased by cash or on credit (*i.e.*, on a time-monetary basis) are termed market goods; the term non-market goods is used to refer to those goods acquired through alternative modes of transaction--in particular, *via* own-account production, barter, or as gifts/transfers (*i.e.*, transactions without a *quid pro quo*).

[33] Based on special features of the Tongan Data and HIES, the procedures adopted for aggregations over goods and time have been rationalized based on "Hicksian separability" and certain functional separabilities. In the case of aggregation over household members, appeals have been made to (i) Samuelson's (1956) rationalization, (ii) the view that consumption activity is a household production process [see, for instance, Becker (1976) and Shultz (1973)], and (iii) the concept of a "representative consumer" advocated by Hicks (1956). A detailed discussion is given in Kami (1990).

[34]Principal categories included in (i) *domestic food* are "fruit and vegetables," "staple starch," and "fresh meat (pork, beef, and goat), poultry, and fish," (ii) *imported food* are "meat (mutton), poultry and fish," and "dairy products, beverages, and 'assorted' items," (iii) *non-food* are "fuels," "household (clothing, footwear, cosmetic, and stationery) supplies," "medical goods," and "alcohol and tobacco," and (iv) *service* are "household services and power," "transportation," education," and "legal, financial, and vocational services" (note that "housing services" is not included). For a detailed discussion of selected quantitative and relevant qualitative features of the Tongan Data and HIES, see Kami (1991).

categories based on average prices and concordances of selected (concomitant) goods at particular space x time (*i.e.*, region x quarter) loci, have been computed.[35]

Facilitated within the coverage of HIES and consequently having found their way into the Tongan Data, are 16 accessible demographic variables. The associated empirical counterparts of these variables are statistical demarcations of household profiles based on members' "age," "sex," and "occupational status" as well as the household's "size" and "(regional) location."[36] A crude overall impression of the population of households for which the Tongan Data represents is that of a population that is constituted largely of large-sized households (61 percent have sizes of at least six persons), has members that are fairly evenly distributed over the two genders but predominantly are young (55 percent with ages not greater than 19 years), and with the majority (87 percent) of the households being supported by either one, two, or three income earners.

HIES was based on a "stratified systematic simple random sampling" (SSRS) statistical model. Thus, it has been argued that any "non-randomized" impact of the associated "design effect," is likely to be insignificant, if not nil.[37] Hence, as strongly taken in this study, the assumption of statistical independence (in the survey sampling context) and statistical representativeness' relation to it is considered to be soundly fulfilled.

[35] The computations have been based on geometrically weighted price indexes of the type: $\ell np_i = \sum_{j \in I_i} w_{ij} \ell np_j$, i = 1,..., n . Under certain conditions these indexes are "exact" (Diewert 1976, 1978).

[36]Tables A1 and A2 of the Appendix provide stylized features of the empirical counterparts of these demographic variables; together with a rudimentary view of the extent that variabilities among these empirical counterparts exist in the Tongan Data.

[37]SSRS is not a "complex" sampling design, hence, it does not represent a significant departure from "Simple Random Sampling" (SRS). This argument is well supported by large-scale empirical studies--*e.g.*, Frankel (1971).

The Tongan Data may or may not have contained significant measurement errors. Even in the case that they have, the relevant degree of significance is not known. However, based on insights into the *modus operandi* of HIES, various operational measures applied in the data-handling phase, and the analytical approach pursued, it is argued that in this study the "measurement error" problem could be safely assumed away.[38]

B. Threshold Questions

The major goal of this paper is to seek empirical evidence in light of the Tongan Data on the following propositions:

1. Stylizations based on micro-data of effects of demographic variables *via* alternative parameter variation specifications of the complete theoretically plausible consumer demand systems, LES and QES, are practically amenable to Zellner's SUR estimation set-ups using standard numerical estimating algorithms.

[38]Induced deleterious effects (statistical biases), if any, of the "measurement error" problem must have been substantially attenuated, if not totally eliminated, by the following adopted operational measures: (i) aggregations over variables; (ii) accommodations of stochastic error terms in the estimating equations systems; (iii) exclusion of non-market transactions; and (iv) the inherent adoption *via HIES* of a short "survey-period" coupled with careful executions of the procedures of editing, cleaning, and collating of primary data.

Note that it has been primarily due to consideration regarding the "measurement error" problem that the non-market transactions have not been included in the Tongan Data. [If measurement errors have been considered serious, then an avenue one could have pursued is to effect modeling under the so-called "Errors in Variables" or "Latent Variables" type of framework--see for instance, Aigner (1974), Griliches (1974), and Stapleton (1984)].

2. Household demographic variables are significant determinants of household consumption pattern.

3. The influences of demographic variables on consumption pattern are adequately manifested *via* selected demand system parameters. Thus, the approach of allowing for all parameters to depend on these variables (the Implicit Correction specification) is unnecessary or inefficient.

4. The workings of demographic variables are more prominently manifestable *via* certain selected parameters than others. Thus, certain specifications of the Explicit Correction Method are superior to others.

5. Behavioral policy-relevant statistics (*e.g.*, total-expenditure and price elasticities of demand) are significantly sensitive to variations in demographic variables.[39]

In this empirical analysis our foremost concern is to maximize accessible accuracies in estimates of demand system parameters and policy-relevant (elasticity) statistics. This takes precedence over, say, the goal of quantifying the effects of demographic variables on the conditional means of demands for specific consumption categories.

C. A "Parsimonious" Set of Demographic Variables

All of the five specifications of the Explicit Correction Method (Modified Prais-Houthakker, Scaling, Translating, Gorman, and Reverse Gorman) individually introduce ($n \times F$) new parameters. That is, each demographic variable is associated with n additional parameters. Thus, remembering that LES and QES possess ($2n-1$) and ($3n-1$)

[39]This proposition is not necessarily a corollary of proposition "2."

parameters, respectively, it is obvious that given the 16 accessible demographic variables of the Tongan Data the number of parameters requiring estimation (especially those of the variants under MQES) is quite large (even for a moderately small value of n).[40] Thus, given the desiderata and circumstances of this study it may not be feasible nor desirable and productive to include all the accessible household demographic variables in the estimation phase.

For the selection of a "final" set of demographic variables that should enter our MLES/MQES variants we follow the following simple procedure:[41]

1. We adopt a (single-equation) linearized proxy of QES--*viz.*, one that is specified by the share equation:[42]

$$w_i = \frac{p_i q_i}{\mu} = a_0 + a_1\left(\frac{\mu}{p_i}\right) + \sum_{k=1}^{n} b_k\left(\frac{p_k}{\mu}\right) \quad , i = 1,\ldots, n. \tag{49}$$

2. We run demand regressions based on (49) using all the 16 accessible demographic variables in the Tongan Data and confine our exercise to the Demographic Translating specification.

[40] For most variants of the Explicit Correction Method (Modified Prais-Houthakker, Scaling, Gorman, and Reverse Gorman), specifications and estimations of scaling functions $\{ M_i = M^i(\Gamma) \quad , \ i = 1,\ldots, n\}$ are required. Since these m_i's scale prices, they necessarily need to be positive. Moreover, since under MQES the m_i's are raised to the power of $-\alpha_i$ $(i = 1,\ldots,n)$, they need to be positive or constrained to be positive; thus, *inter alia,* if functional forms of the type given by (48) are adopted, then the Γ_j's must be positive or appropriately manipulated.

[41] Essentially the same procedure was adopted by Strauss (1982).

[42] Observe that QES's linearized proxy (49) is homogeneous of degree zero in prices and total-expenditure and that a quadratic form of total-expenditure is implicitly involved, this is clearly seen if (49) is re-expressed in expenditure form.

3. In undertaking step "2", we experiment with subsets of the accessible Γ_j's--pooling wherever appropriate variables displaying coefficients of close magnitudes (especially if they occur somewhat consistently over consumption categories). In all regressions, however, we include the price and total-expenditure variables.

4. We "rank" using the maximum adjusted R^2 criterion the fitted equations. Consequently, we choose the demographic variables in the "parsimonious" *cum* maximum adjusted R^2 equation as the ones that are more likely to be genuine determinants of consumer demand in Tonga and, thus, subsequently subjecting them to a more thorough empirical assessment.

This preliminary exercise gives the following insights:

a. The adjusted R^2 values are invariably quite low, with the majority yielding values of less than 10 percent.[43]

b. In most of the regressions, REGION and NIE are among the included demographic variables. These variables (REGION and NIE) display coefficients that consistently imply significant impacts on the translation parameters.

c. When the number of included demographic variables shrinks to six[44]--the ones included being PEOPLE, NMALE, NIE, N1519, N2034, and REGION--the adjusted R^2 changes only slightly, with the exception of the "non-food" regression. A similar "good-of-fitness" result is observed when PEOPLE and

[43]This type of result is, of course, quite commonly encountered in estimations involving cross-section data.

[44]A notable influence in this regard is the result of aggregations across individual genders for contiguous age groups, where relevant corresponding coefficients have been judged as "similar."

N2034, in addition to REGION and NIE are the ones retained. In this context however, the PEOPLE and N2034 coefficients display only near statistical significance with regard to the two food consumption categories, but with clearly insignificant effects in the cases of the two non-food regressions.

d. In terms of a consistent showing of significant magnitude, the demographic variables NIE and REGION are clearly of a relatively superior rank. This reasonable regularity in relative superior performance is realized somewhat consistently across the consumption categories and alternative regression configurations with which we have experimented.

Consequently, we choose with "confidence," REGION and NIE, and to a much lesser extent PEOPLE and N2034.

The consistently significant showing of REGION prompts us to ask the following question: Is it econometrically sound to pool observations across the two regions, or estimate the demand systems separately for each region? To gain an empirically relevant insight we conducted a series of Chow tests based on a linearized mimic version of LES.[45] The relevant specific null hypothesis is:

H_o: All structural parameters--the τ_i's (committed quantities) and the β_i's (marginal budget shares) are the same across the two regions (Vahekolo and Vahe'uta).

[45]In share form, the linearized proxy of LES used is: $w_i = \frac{p_i q_i}{\mu} = b_o + \frac{b_i p_i}{\mu} + \sum_{k=1}^{n} a_k \left(\frac{p_k}{\mu}\right)$, $i = 1,\ldots,n$, which is easily seen to be homogeneous of degree zero in prices and total-expenditure.

The relevant empirical results based on the Tongan Data are summarized in Table 1.

Table 1. Chow Tests for Testing Whether Regressions (Linearized Versions of LES) are Uniform Across Vahekolo and Vahe'uta

Test Statistic	Demand Equations			
	Domestic food	Imported food	Non-food	Service
F	3.72	1.90	2.03	0.17
(*Critical Values*: $F_{4,200,.10} = 1.97$; $F_{4,200,.05} = 2.42$; $F_{4,200,.01} = 3.41$)				

Thus, we may assert[46] that apart from "service," the Tongan household consumption pattern differs significantly across the two regions. It would be sound practice, therefore, to provide estimates of the demand systems separately for Vahekolo and for Vahe'uta.

D. The Adopted Estimation *Modus Operandi*

In light of these preliminary tests and the need to keep to a "parsimonious" number of parameters in each estimation step, we evaluate only the impacts and roles of REGION (regional location of household) and NIE (number of income earners of household). We consider each additional demographic partitioning at a time, examining at the first stage the influences of REGION, and at the second stage, the impacts of NIE separately for each partition of REGION.[47]

Moreover, in each stage of estimation we adopt when dealing with procedures under the Explicit Correction Method, the following: (i) the linear specification (23) for the translating parameters, (ii) two alternative specifications for the scaling parameters *viz.*, the linear specification (16) and the exponential specification (48), and (iii) concurrent

[46]This assertion is made subject to self-evident caveats (*e.g.*, limited applicability due to the adoption of a linearized version of LES).

[47]Distinguishing five levels of NIE, *viz.*, "0," "1," "2," "3," and "4 or more" number of income earners of household (NIE).

linear forms for the translating and scaling parameters, as in (27a) and (27b). In addition to variants implied by these specifications, we also estimate appropriate MLES and MQES variants under the Implicit Correction specification as well as under the Naive specification.

To the presumed deterministic forms for MLES and MQES variants, we add stochastic terms--with first and second order moments satisfying standard assumptions--which are presumed to be i.i.d. Normal.[48] We estimate each system by adopting numerical algorithms for estimating Zellner's non-linear seemingly unrelated regression (SUR) systems which are available in White's (1978) generalized computer program for econometric methods, SHAZAM. Maximum likelihood estimation of a complete consumer demand system takes into full account relevant restrictions--the budget constraint and stochastic structure of the system of demand equations. Since we choose to work with the share forms of MLES and MQES, with the said restrictions fully respected, the implied variance-convariance matrix is singular. Hence, following Barten (1969) and Theil (1976:185) we delete one equation from each of the systems, and without loss we consistently delete the fourth equation.

VI. EMPIRICAL RESULTS AND DISCUSSIONS

The following empirical results yielded from utilizing the Tongan Data in applications of the alternative models proposed for treating demographic variables in demand pattern analysis may shed lights on the threshold questions put forward.

[48]The Normality assumption is assessed as reasonable. We argue that in the case of the Tongan Data the sample size is sufficiently large. Thus, coupled with the asserted fulfillment of independence of observations (adoption of SSRS in HIES), the case is allowed access to the statistical results of asymptotic theory (*e.g.*, particular implications of the Central Limit Theorem). Moreover, recall the relevant and useful implications of the basic result--that the disturbance may be approximately Normal even if the dependent variable is not.

A. ALTERNATIVE MANIFESTATIONS OF DEMOGRAPHIC EFFECTS: ESTIMABILITIES, IMPACTS, AND RELATIVE SIGNIFICANCES

1. Practical Feasibility of Alternative Specifications

Relevant responses to the first threshold question may be deduced from the empirical results of Tables 2(a) and 2(b).

Generally, the representations of (Tongan micro-data based) effects of demographic variables through alternative parameter variation specifications with LES as the original demand system are practically amenable to Zellner's SUR estimation set-up utilizing standard numerical algorithms.[49] However, this extensive degree of "numerical feasibility" is <u>not</u> carried forth with a comparable force to the case when QES is the system acting as the original demand system.

Under MQES, considerable problems of convergence have been encountered with the applications of the Scaling, Gorman, and Reverse Gorman specifications.[50] Thus, these

[49]The exception is directly linked to two specific partitions of the Tongan Data (see footnote 50 for details).

[50]In fact, considerable numerical difficulties have been encountered despite exercising the following measures: (i) adoption of alternative specifications for the scaling functions--the m_i's [see sections 4(c) and 5(d)], (ii) experimentation with different starting values, and (iii) testing out under alternative non-linear numerical algorithms (DFP and BFGS algorithms).

Interestingly enough, the said estimation problems have been further experienced when fitting both MQES and MLES under the Implicit Correction specification for a few selected partitions of the Tongan Data (e.g., those partitions characterized by NIE = 0, NIE $\geq$ 4 and when these two partitions are pooled). Since the Implicit Correction specification inherits no theoretically undefined regions for its existence, the observed severe ill-conditioning appears to a large extent to be data-domain specific.

Since convergence in estimation has been realized when MLES is estimated under the Modified Prais-Houthakker specification--an incorporation that mimics to an extent equivalent roles of the scaling parameters--one may strongly suspect that the impeding ill-conditioning is due to some undefined regions (consumption categories and observations) linked to the quadratic terms of particular variants of MQES.

However, given the high significances of the quadratic terms and most other MQES parameters (Table A5), it appears unlikely that the severe problems of ill-conditioning are due to the likelihood functions being flat. Also, we make note of the fact that the numerical difficulties have persisted (identical

specifications, at least in the context of the Tongan (Micro) Data, are not in practical terms promisingly serviceable alternatives.[51]

2. Significance of Demographic Variables

Are demographic variables significant determinants of consumer demand? Tables 2(a) and 2(b) provide relevant likelihood values for comparing, say, the Naive specification and other specifications that incorporate demographic effects in alternative ways. The appropriately computed Likelihood Ratio (LR) test statistics are reported in Tables 3(a) and 3(b).

responses are encountered) despite our setting up of runs, *ceteris paribus*, with substantially dispariate pre-specified (maximum) numbers of iterations--no output-based indications have been received that the pre-specified numbers of iterations have been reached. Thus, we suspect that the impeding ill-conditioning is due to the existences of "spikes" and that the DFP/BFGS alogorithms have kept getting "stuck" on edges of the objective functions.

Observe that very similar experiences have been encountered by those very few attempts to incorporate demographic variables using QES functional forms based on cross-section (micro) data [see Barnes and Gillingham (1984) and Strauss (1982)]. These estimation difficulties, however, appear to have yielded to insignificance where aggregate data (of time-series or cross-section/time-series hybrid nature) have been used [see, for instance, Pollak and Wales (1980, 1981)].

The convergence problems encountered by Strauss (1982) are highly akin to the ones we have encountered. Such encounters caused Strauss to abandon Scaling in conjunction with his QES demand system. In the experience of Barnes and Gillingham (1984), the ill-conditioning problems were very severe for the cases where their QES demand system was modified according to the Gorman, an untranslated form of Scaling and Reverse Gorman--with these specifications applied to certain partitions of their micro-data set (with "Tenure Status" and "Family Type" as the adopted stratifiers). In this case, however, the available evidence pointed to the existence of very flat likelihood functions.

Given the alternatives tried in this study, it has been evident that under the MQES variants characterized by scaling and its two generalizations, the ill-conditioning problems are local.

[51]The implying problems may not be insurmountable. It is argued, however, that even if resources were made available the implying efforts would have constituted a considerably marked diversion from the principal focus of the investigation. Nevertheless, given the scope of this study it is argued that the empirical evidence so far yielded is adequate to provide sound responses to at least the threshold questions raised and to fulfill the principal desiderata of the investigation.

Table 2(a). Log Likelihood Values for Alternative Methods of Incorporating Demographic Variables Under LES

Sample Partitioning Variable(s)	Estimation Procedure	Log Likelihood Values[1] Region: Tongatapu	Vahekolo							Vahe'uta						
			Number of Income Earners (NIE)							Number of Income Earners (NIE)						
		Total	Total	0	1	2	3	≥ 4	0 or ≥ 4	Total	0	1	2	3	≥ 4	0 or ≥ 4
I. Location of Household (Region)	1. Naive	1347.0 (7)														
	2. Translating/ Scaling/ Gorman/ Reverse Gorman	1362.0 (11)														
	3. Modified Prais-Houthakker	1356.6 (11)														
	4. Implicit Correction	1369.0 (14)	570.0 (7)							799.0 (11)						
II. Location of Household (Region) and Number of Income Earners (NIE)	1. Naive	1369.0 (14)	570.0 (7)							799.0 (7)						
	2. Translating/ Scaling/ Gorman/ Reverse Gorman	1376.1 (22)	574.4 (11)							801.7 (11)						
	3. Modified Prais-Houthakker	1372.8 (22)	571.2 (11)							801.6 (11)						
	4. Implicit Correction[2]	1434.3 (56)	600.1 (28)	N/A (7)	206.8 (7)	204.9 (7)	121.1 (7)	N/A	67.3 (7)	834.2 (28)	N/A[6]	393.7 (7)	246.8 (7)	92.9 (7)	N/A	100.8 (7)
	5. Implicit Correction[5]	TNA[3] (70)	TNA (35)	CNA[4] (7)	206.8 (7)	204.9 (7)	121.1 (7)	CNA	N/A (7)	845.4 (35)	64.3 (7)	393.7 (7)	246.8 (7)	92.9 (7)	47.7 (7)	N/A

[1]Number of parameters in the demand system (a particular MLES variant) are given in parentheses.
[2]The log likelihood in column "0 or ≥ 4" NIE is based on the sub-sample encompassing both households with no primary income earners (NIE) and those with at least 4 NIE.
[3]"TNA" stands for "Total Not Attained."
[4] "CNA" stands for "Convergence Not Attained."
[5] The sub-sample for each region was partitioned in mutually exclusive and exhaustive basis among the five categories, indexed by "0," "1," "2," "3," and "≥ 4" NIE.
[6] "N/A" stands for "Not Applicable."

Table 2(b). Log Likelihood Values for Alternative Methods of Incorporating Demographic Variables Under QES

Sample Partitioning Variable	Estimation Procedure	Log Likelihood Values[4] Region: Tongatapu	Vahekolo							Vahe'uta						
				Number of Income Earners (NIE)							Number of Income Earners (NIE)					
		Total	Total	0	1	2	3	≥ 4	0 or ≥ 4	Total	0	1	2	3	≥ 4	0 or ≥ 4
I. Location of household (Region)	Naive	1370.2 (11)														
	Translating	1384.7 (15)														
	Scaling	CNA (15)														
	Gorman	CNA (16)														
	Reverse Gorman	CNA (16)														
	Implicit Correction	1391.8 (22)	581.7 (11)							810.1 (11)						
II. Location of household (Region) and Number of Income Earners (NIE)	Naive	1391.8 (22)	581.7 (11)							810.1 (11)						
	Translating	1398.9 (30)	586.2 (15)							812.7 (15)						
	Scaling	TNA[1] (30)	CNA (15)							CNA[5] (15)						
	Gorman	TNA (32)	CNA (16)							CNA (16)						
	Reverse Gorman	TNA (32)	CNA (16)							CNA (16)						
	Implicit[2] Correction	TNA (88)	TNA (44)	N/A	216.8 (11)	208.5 (11)	132.5 (11)	N/A	CNA (11)	855.5 (44)	N/A[6]	398.9 (11)	251.9 (11)	99.4 (11)	N/A	105.3 (11)
	Implicit[3] Correction	1533.4 (110)	654.5 (55)	32.3 (11)	216.8 (11)	208.5 (11)	132.5 (11)	64.4 (11)	N/A	878.9 (55)	72.4 (11)	398.9 (11)	251.9 (11)	99.4 (11)	56.3 (11)	N/A

[1]"TNA" stands for "Total Not Attained."
[2]The Log Likelihood value in column "0 or ≥ 4" is based on the sub-sample encompassing both households with no primary income earners (NIE) and those with at least 4 NIE.
[3]The sub-sample for each region was partitioned in three mutually exclusive and exhaustive basis among the five categories, indexed by "0," "1," "2," "3," and "≥ 4" NIE.
[4]Number of parameters in the demand system (a particular MQES variant) are given in parantheses.
[5]"CNA" stands for "Convergence Not Attained."
[6]"N/A" stands for "Not Applicable."

From these results we could deduce the following:

Demographic variables (*e.g.*, REGION and NIE) are significant determinants of household consumption demand in Tonga. (At the first stage, for instance, allowing all or some of the system parameters to depend on REGION leads to non-trivial improvements over the Naive specification. Even when the full impact of REGION has been allowed for [the second stage], the effects of NIE when all parameters are allowed to depend on it [the Implicit Correction specification] is highly significant).

3. Relative Strengths of Alternative Specifications

We now address the third and fourth threshold questions. Of relevance here are the empirical results of Tables 3(a) and 3(b).

For the first case, the relevant comparisons are between the Implicit Correction specification and the other specifications under the Explicit Correction Method. Thus, according to the procured evidence--as conveyed through the relevant Likelihood Ratio test statistics--the Implicit Correction specification represents (in both stages) a highly significant improvement over both Translating and Modified Prais-Houthakker specifications in the case of MLES[52] and over Translating in the case of MQES.[53] Thus, the Implicit Correction specification is clearly a superior specification compared with the specifications under the Explicit Correction Method, through which influences of demographic variables on consumer demand are manifested *via* only selected parameters of the demand systems.[54]

[52] Translating under MLES is identically equivalent to Scaling, Gorman, and Reverse Gorman (see Section IV A).

[53] Excepting the first stage under QES, the generalizations associated with all cases are significant at the 0.005 level.

[54] That is, Implicit Correction is superior at least over all variants under MLES and the Demographic Translating under MQES.

Table 3(a). Summary Statistics for Incorporating Demographic Variables Under LES

Region: Statistic[1]	Procedure: Translating/ Scaling/ Gorman/ Reverse Gorman	Modified Prais-Houthakker	Implicit correction	Naive
Tongatapu (Two regions combined): [Setting Γ ≡ Region]				
1. Log likelihood	1362.0	1356.6	1369.0	1347.0
2. Number of estimated parameters	11	11	14	7
3. Number of observations	709	709	[304,405][2]	709
4. Chi-square1[3]	30.0	19.2	44.0	N/A
5. Chi-square2[4]	14.0	24.8	N/A	44.0
Vahekolo: [Setting Γ ≡ NIE]				
A1. Log likelihood	574.4	571.2	600.1	570.0
A2. Number of estimated parameters	11	11	28	7
A3. Number of observations	304	304	[116,96,52,40][5]	304
A4. Chi-square1[3]	8.0	2.4	60.2	N/A
A5. Chi-square2[4]	51.4	57.8	N/A	60.2
Vahe'uta: [Setting Γ ≡ NIE]				
B1. Log likelihood	801.7	801.6	834.2	799.0
B2. Number of estimated parameters	11	11	28	7
B3. Number of observations	405	405	[203,119,32,51]	405
B4. Chi-square1[3]	5.4	5.2	70.4	N/A
B5. Chi-square2[4]	65.0	65.2	N/A	70.4

[1]"N/A" stands for "Not Applicable."

[2]Gives the number of observations for "Vahekolo" and "Vahe'uta," respectively.

[3]Calculated as minus twice the difference between the log likelihood value in the column and the corresponding log likelihood value under the Naive procedure.

[4]Calculated as minus twice the difference between the log likelihood value under the "Implicit Correction" procedure and the log likelihood value in the column (*Selected Critical Values:* $X^2_{.05/.01,3} = 7.81/11.34$; $X^2_{.05/.01,7} = 27.59/33.41$).

[5]Gives the number of observations for "1," "2," "3," and "0 or ≥ 4" NIE.

Table 3(b). Summary Statistics for Incorporating Demographic Variables Under QES

Region: Statistic[1]	Procedure: Translating	Implicit correction	Naive
Tongatapu (Two regions combined): [Setting $\Gamma \equiv$ Region]			
1. Log likelihood	1384.7	1391.8	1370.2
2. Number of estimated parameters	15	22	11
3. Number of observations	709	[304,405][2]	709
4. Chi-square1[3]	29.0	43.2	N/A
5. Chi-square2[4]	14.2	N/A	43.2
Vahekolo: [Setting $\Gamma \equiv$ NIE]			
A1. Log likelihood	586.2	654.5	581.7
A2. Number of estimated parameters	15	55	11
A3. Number of observations	304	[19,116,96, 52,21][5]	304
A4. Chi-square1[3]	9.0	145.6	N/A
A5. Chi-square2[4]	136.6	N/A	145.6
Vahe'uta: [Setting $\Gamma \equiv$ NIE]			
B1. Log likelihood	812.7	878.9	810.1
B2. Number of estimated parameters	15	55	11
B3. Number of observations	405	[30,203,119, 32,21]	405
B4. Chi-square1[3]	5.2	137.6	N/A
B5. Chi-square2[4]	132.4	N/A	137.6

[1]"N/A" stands for "Not Applicable."
[2]Gives the number of observations for "Vahekolo" and "Vahe'uta," respectively.
[3]Calculated as minus twice the difference between the log likelihood value under the Naive procedure and the log likelihood value in the column (Selected Critical Values: $X^2_{.05/.01,7}$ = 14.1/18.5; $X^2_{.05/.01,40}$ = 55.8/63.7).
[4]Calculated as minus twice the difference between the likelihood value in the column and the likelihood value under the Implicit Correction procedure (*Selected Critical Values:* $X^2_{.05/.01,7}$ *= 14.1/18.5;* $X^2_{.05/.01,40}$ *= 55.8/63.7).*
[5]Gives the number for "0," "1," "2," "3," and "0 or ≥ 4" NIE.

Notice this further useful finding. Once the full impact of REGION has been allowed for, the conditional effects of NIE as facilitated by the Translating or Modified Prais-Houthakker specifications do not amount to significant improvements over the Naive specification.[55]

Thus, it seems that the specifications under the Explicit Correction Method (or in particular, the Translating and Modified Prais-Houthakker specifications) do not offer adequate representations of the ways in which variations in household demographic profiles influence household consumption behavior (at least in the case of Tonga).

We now consider the second case--*i.e.*, the issue that questions: Do workings of demographic variables manifest themselves more prominently *via* certain selected parameters than others?[56] In fact, the only insight that may be gained from our empirical results is a comparison of Demographic Translating against Modified Prais-Houthakker under the MLES set-up. Nevertheless, interestingly enough, despite the fact that Translating and Modified Prais-Houthakker represent two non-nested hypotheses; in general, the fact that they are both nested in a composite specification (*e.g.*, the Implicit Correction specification) with a known parametric size facilitates (under some situations) an unambiguous formal ranking of their relative superiorities.[57]

[55] See values of LR statistics reported on Rows A4 and A5 of Tables 3(a) and 3(b). In fact, all the associated generalizations are not significant at the 0.05 level. But notice, however, that the generalizations to Demographic Translating from the Naive specification involving NIE for Vahekolo under both MLES and MQES, are significant at the 0.01 level.

[56] Notwithstanding the conditional nature of the non-significance of NIE earlier stated, that non-significance conclusion may be viewed as imposing a diluting effect on the relative importance of the case presently being considered. However, the fact that we have been unable to adopt the MQES variants characterized by Scaling, Gorman, and Reverse Gorman in our estimation may imply that our empirical results (including the Tongan Data) are not particularly well-suited for the task of comparing the relative merits of specifications under the Explicit Correction Method.

[57] This is possible *via* the "Dominance Ordering" approach to model selection of Pollak and Wales (1991).

Define the "adjusted likelihood value" V_i associated with the likelihood value L_i of the hypothesis H_i as: $V_i = L_i + C[K_c-K_i]/2$; where K_c is the parametric size of a composite hypothesis H_c within which H_i is nested, and $C(k)$ is the value associated with a specified significance level of the Chi-square distribution with k degrees of freedom. Clearly, in the present case [and with i=1 and i=2 identifying Demographic Translating (H_1) and Modified Prais-Houthakker (H_2), respectively], a comparison of the two V_i's under any admissible composite specification (H_c) is equivalent to the straightforward comparison of the two likelihood values L_1 and L_2 yielded under H_1 and H_2, respectively. This is true for the specific case considered since H_1 and H_2 have the same number of parameters.

From Table 3(a), $V_1[=L_1] > V_2[=L_2]$. Thus (in the terminology of Pollak and Wales [1991]), "H_1 dominates H_2;" that is, Demographic Translating "dominates" Modified Prais-Houthakker. And, therefore, under the "Dominance Ordering" principle, the Demographic Translating hypothesis is superior (in the model selection context), to the Modified Prais-Houthakker hypothesis.[58]

4. Some Implications of the Superiority of the Implicit Correction Specification

Thus, it is clear that, at least in the case of Tonga, not only is it of paramount importance to take into account the variations in household demographic profiles in

[58]Note that this relative superiority does not imply that such a status is bound or likely to eventuate should we proceed with the usual Likelihood Ratio Test based on an appropriately estimated composite specification. (This point is clearly demonstrated by our above results--H_1 and H_2 are both rejected at the first stage in favor of H_c and are both accepted at the second stage with respect to H_c. Thus, no formal ranking of the two non-nested specifications is possible under these outcomes). What needs to be emphasized is that *via* the Dominance Ordering principle the claimed relative superiority is justified on the grounds that if the Likelihood Ratio Test accepts either H_1 or H_2 and rejects the other, then in the present case it must accept H_1 (Demographic Translating) and reject H_2 (Modified Prais-Houthakker).

examining household consumption behavior; but the specific method for the objective tapping of such variations that is adopted is also important.

Our empirical results, especially those that highlight the markedly dominant role of the Implicit Correction specification, advocate the notion that as far as consumer demand in Tonga is concerned demographic variables operate in a somewhat complex manner; thus, they cannot be adequately manifested *via* partially selected consumption behavioral parameters. Specifications under the Explicit Correction Method--such as Demographic Translating and Modified Prais-Houthakker, which allow only some but not all the system parameters to depend on demographic variables--are inadequate representations of the true impacts.

These stylized findings are strongly concurrent with the empirical findings of Muellbauer (1977) and Barnes and Gillingham (1984), even though these researchers have based their works on different specific demand systems and data sets. Our empirical findings, however, substantially depart from those advocated by the empirical works of Pollak and Wales (1981), who found the Modified Prais-Houthakker procedure to be the specification that made the strongest showing; thus, they were unable to reject such a procedure in favor of the Implicit Correction ("non-pooled") specification. Pollak and Wales (1981), however, based their work on grouped household data for seven years and employed a generalized CES demand system.

Like the findings of Muellbauer (1977) and Barnes and Gillingham (1984), our empirical evidence suggests that the apparent complex manner upon which household demographic variables tend to operate (as implied by the strength of the Implicit Correction framework) calls for the adoption of demand systems with sufficiently large

numbers of parameters so that all essential elements of household consumption behavior are adequately captured.

Note that given the paramount significance of the Implicit Correction specification we may naturally consider proceeding to a higher level of partitioning (a third stage), in which a third demographic variable (PEOPLE for instance) is used as a stratifier. However, despite the fact that we started off with a relatively large sample size, there are, after the second stage (which involved 56 to 110 parameters), insufficient degrees of freedom to allow us to proceed with confidence to further finer levels of nesting. Thus, it is not feasible to, say, test the null hypothesis that further partitioning of the sample data is necessary.

This point of practicality may be crucial in many research contexts. Restrictions on the available degrees of freedom may preclude the avenue of utilizing the Implicit Correction specification to tap the impacts of demographic variables. In such contexts the productive way to proceed is to opt for one of the specific procedures under the Explicit Correction Method. As clearly supported by the evidence procured in this study, this approach is still superior to the Naive specification, which is agnostic toward the effects of demographic variables on consumption behavior.

B. DEMOGRAPHICALLY CORRECTED SYSTEM PARAMETER ESTIMATES AND POLICY-BASED STATISTICS

1. System Structural Parameter Estimates

Because of the superiority of the Implicit Correction specification over alternative methods for incorporating demographic variables into LES and QES, we henceforth confine our attention to the system parameter estimates generated under such a superior

specification. The relevant estimates, together with values of their corresponding (asymptotic) t-statistics, are presented in Tables A4 and A5 of the Appendix.

With the exception of the estimate of β_3 *(i.e.*, β associated with "Non-food") for the " ≥4 NIE" sub-sample of Vahe'uta estimated under MQES, all the β_i's estimates (*i.e.*, for all consumption categories, REGION-NIE sub-samples, and both MLES and MQES Implicit Correction set-ups) are statistically significant at the 0.05 level. In fact, the majority of the estimates are significant at the 0.01 level. In the case of MLES, this amounts to saying that all the marginal budget shares estimates are significant.

While certain estimates of the τ_i's have negative signs, their associated t-statistics imply that they are not significantly different from zero. Thus, the interpretation of the τ_i's as "committed" quantities is not violated. Overall, however, the estimates of the committed quantities are mostly small and insignificantly different from zero. The τ_i's estimates under MQES for all partitionings also are mostly insignificant. The conspicuous exceptions are those associated with "Imported food" for Vahe'uta for all NIE household types (except those with three income earners--3 NIE).

Considering the MQES set-up (Table A5), the quadratic terms as reflected in the estimates for Ω are clearly significant. This is particularly true when MQES variants are fitted to Vahekolo and Vahe'uta separately but with households pooled across NIE sub-groups, or when they are fitted separately under the "1 NIE" or "3 NIE" sub-groups for Vahekolo and under the "3 NIE" sub-group for Vahe'uta.

2. Marginal Budget Shares and Total-Expenditure Elasticities

Regarding estimates of average marginal budget shares and total-expenditure elasticities, the relevant results are summarized in Table 4.

Consider first, the estimates of average marginal budget shares. Here we observe a close similarity among the estimates associated with a given consumption category within a given region for the three household types characterized by 1, 2, or 3 income earners (NIE). The said similarity is more consistent in the case of Vahekolo as compared with the case of Vahe'uta. And, in fact, the uniformity in magnitudes is striking for the cases of "Imported food" at Vahekolo and "Domestic food" at Vahe'uta.

Notice that the marginal budget shares for the above (1, 2, or 3 NIE) household types as compared with those for the "0 NIE" household type on one hand and "≥4 NIE" category on the other are markedly different. In the case of Vahekolo, both the "0 NIE" and "≥4 NIE" household types tend to display weaker marginal responses to an extra dollar of total-expenditure in terms of the demands for "Domestic food," "Non-food," and "Service." As expected (due to our dealing with a budget-constrained allocation model), the reverse trend holds in the case of the remaining consumption category ("Imported food").

For the case of Vahe'uta, comparable trends are not evident. Apart from the "≥4 NIE" household type--where "Non-food" displays the largest average marginal budget share (40 percent)--all the other household types (as in all household types of Vahekolo) indicate that "Imported food" dominates the competition for any marginal increase in the household budget. Notice that this stance is still preserved even in the case when our estimates are agnostic toward differences in household type according to NIE.[59]

[59]See estimates for each REGION under the "Naive" column (Table 4).

Table 4. MQES Estimates of Marginal Budget Shares and Total Expenditure Elasticities (Implicit Correction--Second Stage: Setting $\Gamma \equiv$ NIE)

Commodity	Number of Income Earners (NIE)					
	0	1	2	3	≥4	Naive[1]
A. Average marginal budget shares						
I. Vahekolo						
Domestic food	0.21	0.21	0.21	0.17	0.18	0.20
Imported food	0.45	0.34	0.31	0.32	0.40	0.34
Non-food	0.28	0.29	0.29	0.29	0.23	0.32
Service	0.06	0.16	0.19	0.23	0.18	0.14
II. Vahe'uta						
Domestic food	0.18	0.19	0.20	0.18	0.17	0.19
Imported food	0.49	0.42	0.37	0.36	0.29	0.39
Non-food	0.13	0.23	0.27	0.28	0.40	0.25
Service	0.20	0.17	0.16	0.19	0.14	0.18
B. Total expenditure elasticities						
I. Vahekolo						
Domestic food	0.89	0.96	0.96	0.82	1.77	0.95
Imported food	1.14	0.76	0.84	0.76	1.05	0.83
Non-food	1.38	1.26	1.18	1.14	0.79	1.23
Service	-0.29	1.29	1.25	1.73	1.22	1.02
Average total expenditure (T$)	88.60	130.61	190.95	196.40	279.97	168.61
Number of observations	19	116	96	52	21	304
II. Vahe'uta						
Domestic food	1.75	1.08	1.30	1.02	1.40	1.11
Imported food	0.90	0.91	0.86	0.81	0.83	0.87
Non-food	0.65	0.94	1.05	1.12	1.68	1.02
Service	1.94	1.27	1.15	1.15	0.50	1.28
Average total expenditure (T$)	83.23	97.55	153.71	152.29	248.30	125.13
Number of observations	30	203	119	32	21	405

[1]This corresponds to the Implicit Correction, first stage estimation (Setting $\Gamma \equiv$ REGION).

Next, consider the estimates of total-expenditure elasticities (Table 4). The following intuitively appealing observations and suggestive inferences could be made.[60]

a. Differences between regional estimates are non-trivial. This is particularly true for the cases of "Domestic food" for all household types and for all the consumption categories considered under the "0 NIE" and "≥4 NIE" household types.

b. In the case of Vahekolo (ignoring consumers of the "0 NIE" and "≥ 4 NIE" household types), "Non-food" and "Service" are relative luxuries and the two food consumption categories are relative necessities.

c. For Vahe'uta and for all household types, only "Imported Food" is the "clear" relative necessity; and apart from "Non-food" of the "0 NIE" and "1 NIE" household types and "Service" of the "≥4 NIE" category, consumption categories other than "Imported food" may be considered as relative luxuries.

d. The stylized patterns referred to in "b" and "c" above are preserved even when corresponding estimates are generated for each of the two regions on the assumption that consumption patterns are uniform across the (NIE-based) household types.

Note that despite our earlier finding--that "Imported food" dominates the competition for an extra dollar--it has been consistently revealed that "Imported food" is a "clear" relative necessity. This result is made possible primarily by the fact that "Imported food" dominates the budget shares of Tongan households (it accounts on

[60]We consider the inferences as "intuitive" and "suggestive" since they are not backed up by formal statistical significance tests.

average for 43 percent of the average total budget). Also recall the fact that our empirical work deals only with the market component of household consumption demand in Tonga. Thus, the showing of (market) "Domestic food" as a relative necessity for households at Vahekolo but as a relative luxury for households at Vahe'uta is in fact not surprising. Vahe'uta is essentially the rural sector of Tongatapu, constituted largely of households typically regarded as small agricultural holders. These "smallholders" are significantly involved in some agricultural productions for own consumption. Moreover, in terms of market expenditures the households of Vahekolo are clearly more affluent than their Vahe'uta counterparts (Table 4).[61]

Notice further that somewhat evidenced in our empirical results is a lack of comparability of estimates of marginal budget shares and total-expenditure estimates among households <u>within</u> the extreme types according to NIE (*i.e.*, the "0 NIE" and "≥ 4 NIE" categories) and <u>between</u> these types and the other (*i.e.*, "1 NIE," "2 NIE," and "3 NIE") household types. At least two alternative explanations for these apparent differences (or lack of a reasonable degree of consistency) are available. First, the differences may reflect genuinely significant differences in consumption behaviors among these household types. Notice, for instance, that (as expected) average total-expenditure correlates positively with number of income earners (NIE) (Table 4)--thus, the two extreme NIE-based household types, "0 NIE" and "≥4 NIE," are categorically the types with households that predominantly have the "lowest" and "highest" incomes (total-expenditures), respectively.

[61]Also note that the <u>relativity</u> notion adopted (*i.e.*, relative necessity or relative luxury) is important. This is so since our demand models have firm respect for the adding-up restriction--thus, the outcome of weighting total-expenditure elasticities with corresponding marginal budget shares is inherently constrained by the models to consistently equal unity.

Alternatively, we may view the marked differences as symptomatic of statistical data "inadequacies." The relevant numbers of observations available for analysis are 19 (for "0 NIE" of Vahekolo), 21 (for "≥4 NIE" for each of the two regions), and 30 (for "0 NIE" of Vahe'uta). These available degrees of freedom may have not been enough to adequately tap the variations in consumption patterns represented within these two extreme household types; and allowed for, by the parameters of the flexible MQES (Implicit Correction) variant.

3. Estimates of Price Elasticities[62]

Table 5 presents estimates of both the uncompensated and compensated price elasticities for the two regions separately under the (Implicit Correction) MQES.[63]

For both regions, the magnitudes of the uncompensated cross-price elasticities are quite small, with the majority near zero. However, all own-price elasticities have markedly larger magnitudes. "Imported food" and "Non-food" are more elastic to own-price changes among households at Vahekolo as compared to households at Vahe'uta.

The reverse tendency however, dominates the own-price elasticity estimates for "Domestic food" and "Service."

[62] The remark of footnote 60 is also applicable to the following discussion.

[63] Both the own- and cross-price elasticities in this context are non-linear functions of total-expenditure (see Table A3 of the Appendix).

Table 5. MQES Estimates of Uncompensated and Compensated Price Elasticities (Implicit Correction--First Stage: Setting $\Gamma \equiv$ REGION)

Quantity Elasticity of	With Respect to the Price of: Domestic food	Imported food	Non-food	Service
A. Uncompensated price elasticities				
I. Vahekolo				
Domestic food	-0.99	-0.06	0.09	0.01
Imported food	-0.01	-1.03	0.19	0.03
Non-food	0.01	0.09	-1.28	-0.05
Service	0.02	0.01	-0.05	-0.99
II. Vahe'uta				
Domestic food	-1.02	0.01	-0.01	0.04
Imported food	0.00	-0.97	0.02	0.03
Non-food	0.00	-0.04	-0.94	-0.05
Service	0.01	0.00	-0.13	-1.16
B. Compensated price elasticities				
I. Vahekolo				
Domestic food	-0.79	0.32	0.33	0.14
Imported food	0.17	-0.69	0.39	0.14
Non-food	0.27	0.58	-0.96	0.11
Service	0.23	0.42	0.21	-0.86
II. Vahe'uta				
Domestic food	-0.84	0.52	0.25	0.54
Imported food	0.15	-0.58	0.23	0.20
Non-food	0.18	0.42	-0.69	0.10
Service	0.23	0.58	-0.18	-0.98

As revealed by the estimates reported in Table 5, the compensated cross-price elasticities are positive and not small. This result generally applies to both regions and across all four consumption categories [except for a negative estimate (-0.18) for compensated (quantity) elasticity of demand for "Service" with respect to a change in the price of "Non-food"]. Thus, the influences of the income effects are non-trivial and hence, *inter alia,* "prompting" all consumption categories to become net substitutes.

This same pattern is also consistent with the trend followed by the magnitudes of estimated own-price elasticities--when uncompensated price elasticity estimates are adjusted to reflect genuine effects of "pure" price changes. Notice that the consistent negativity in the signs of compensated own-price elasticities (for all consumption categories over both regions) implies that our empirical results endorse the "downward sloping-demand curve" hypothesis.

The uncompensated and compensated price elasticity estimates based on the second stage system parameter estimates are summarized in Tables 6 and 7, respectively. In the case of uncompensated price elasticities there appears to be some general agreement among the estimates within each region for the "1 NIE," "2 NIE," and "3 NIE" household types. These estimates are also reasonably comparable with the ones obtained at the first stage (see Table 5).[64]

Generally, the estimates of uncompensated price elasticities procured under the "0 NIE" and "≥4 NIE" partitions differ from those procured under the other NIE-based household types. These differences are particularly prominent in the cases of own- (and cross-) price elasticities of (between) "Non-food" and "Service," and the quantity elasticity of demand for "Service" when prompted by a change in the price of "Imported food" in the case of Vahekolo.[65]

[64]This is intuitive since these types represent 87 percent of the sample households and that the first stage estimation inherently involves appropriate weighting of estimates derived from the different NIE-based household types (to be later explicitly demarcated and separately treated in the second stage).

[65]It is in perspective to take into account in interpreting these results the rationale and caveat mentioned above [Section VI.B.2.] regarding the two extreme NIE-based household types.

Table 6. MQES Estimates of Uncompensated Price Elasticities (Implicit Correction--Second Stage: Setting $\Gamma \equiv$ NIE)

Number of Income Earners (NIE)	Quantity elasticity of:	With Respect to the Price of: Domestic food	Imported food	Non-food	Service
I. Vahekolo					
0	Domestic food	-0.96	-0.09	0.03	-0.02
	Imported food	-0.06	-1.31	0.66	-0.44
	Non-food	-0.12	0.80	-3.50	1.44
	Service	0.21	-4.75	16.38	-11.55
1	Domestic food	-0.10	-0.10	0.08	0.06
	Imported food	-0.02	-1.04	0.18	0.13
	Non-food	-0.05	-0.00	-1.07	-0.14
	Service	0.02	0.12	-0.28	-1.15
2	Domestic food	-1.00	-0.01	0.04	0.03
	Imported food	0.01	-1.24	0.37	0.03
	Non-food	-0.01	0.23	-1.46	0.05
	Service	-0.00	-0.08	0.09	-1.26
3	Domestic food	-0.97	-0.08	0.07	0.06
	Imported food	0.02	-1.02	0.11	0.13
	Non-food	-0.00	0.04	-1.10	-0.07
	Service	-0.11	-0.03	-0.31	-1.29
≥ 4	Domestic food	-0.92	-11.60	-0.29	-0.09
	Imported food	-0.03	-0.57	-0.55	0.10
	Non-food	-0.09	-0.85	0.58	-0.43
	Service	-0.04	0.16	-0.74	-0.60
II. Vahe'uta					
0	Domestic food	-1.08	0.15	-0.28	0.19
	Imported food	0.00	-0.84	0.22	-0.28
	Non-food	-0.05	0.61	1.85	-3.06
	Service	0.14	-1.82	-6.50	6.25
1	Domestic food	-1.02	0.01	-0.03	0.04
	Imported food	0.00	-0.96	-0.04	0.09
	Non-food	0.00	-0.20	-0.98	0.13
	Service	0.01	0.43	0.13	-1.50
2	Domestic food	-1.01	-0.02	-0.06	-0.01
	Imported food	-0.01	-1.00	0.10	0.05
	Non-food	0.01	0.04	-1.03	-0.08
	Service	0.01	-0.02	-0.17	-0.97
3	Domestic food	-1.06	0.03	0.02	0.01
	Imported food	0.03	-1.01	0.10	0.08
	Non-food	-0.01	0.01	-0.97	-0.14
	Service	-0.02	0.01	-0.23	-0.92
≥ 4	Domestic food	-1.04	0.39	0.03	-0.06
	Imported food	0.01	-0.83	0.03	-0.04
	Non-food	-0.06	-0.29	-6.05	4.72
	Service	0.09	-0.08	6.64	-7.14

Table 7. MQES Estimates of Compensated Price Elasticities (Implicit Correction--Second Stage: Setting $\Gamma \equiv$ NIE)

Number of Income Earners (NIE)	Quantity elasticity of:	With Respect to the Price of: Domestic food	Imported food	Non-food	Service
I. Vahekoio					
0	Domestic food	-0.75	0.29	0.22	0.08
	Imported food	0.26	-0.86	0.88	-0.29
	Non-food	0.27	1.34	-3.23	1.62
	Service	0.17	-4.87	16.19	-11.49
1	Domestic food	-0.77	0.32	0.30	0.17
	Imported food	0.15	-0.71	0.35	0.21
	Non-food	0.24	0.52	-0.77	0.01
	Service	0.30	0.65	0.04	-0.98
2	Domestic food	-0.79	0.35	0.28	0.19
	Imported food	0.19	-0.92	0.57	0.16
	Non-food	0.25	0.69	-1.17	0.23
	Service	0.27	0.41	0.39	-1.07
3	Domestic food	-0.81	0.26	0.29	0.16
	Imported food	0.18	-0.70	0.31	0.21
	Non-food	0.23	0.49	-0.81	0.09
	Service	0.23	0.66	0.17	-1.06
≥4	Domestic food	-0.73	-10.73	0.15	0.18
	Imported food	0.16	-0.16	-0.26	0.26
	Non-food	0.03	-0.51	0.81	-0.32
	Service	0.19	0.63	-0.40	-0.42
II. Vahe'uta					
0	Domestic food	-0.90	1.25	0.07	0.30
	Imported food	0.13	-0.35	0.41	-0.19
	Non-food	0.04	0.99	1.97	-3.00
	Service	0.44	-0.80	-6.09	6.45
1	Domestic Food	-0.83	0.50	0.23	0.18
	Imported Food	0.16	-0.54	0.18	0.21
	Non-Food	0.16	0.24	-0.75	0.25
	Service	0.23	1.00	0.46	-1.32
2	Domestic food	-0.80	0.56	0.29	0.17
	Imported food	0.15	-0.64	0.32	0.17
	Non-food	0.21	0.48	-0.76	0.07
	Service	0.21	0.47	0.12	-0.81
3	Domestic food	-0.88	0.46	0.27	0.17
	Imported food	0.18	-0.66	0.28	0.19
	Non-food	0.20	0.46	-0.70	0.04
	Service	0.20	0.47	0.06	-0.73
≥4	Domestic food	-0.86	1.03	0.31	0.25
	Imported food	0.13	-0.54	0.23	0.18
	Non-food	0.19	0.32	-5.65	5.14
	Service	0.13	0.23	6.65	-7.01

Table 7 provides estimates of compensated price elasticities procured from the second stage set-up of our estimation. The deviating features of the estimates procured under the "0 NIE" and "≥4 NIE" household types, as compared with the set of estimates linked to the remaining household types, are still conspicuously evident in these results. And, again, consistently evident across household types is the claim that income effects are of non-trivial magnitudes.

By and large, the sets of elasticity estimates realized under the "non-extreme" household types support the claim that the consumption categories considered are net substitutes. Moreover, the empirical results further endorse the hypothesis that compensated demand functions "slope" downward.

VII. CONCLUDING REMARKS

When we compare the summary statistics such as total-expenditure elasticities and uncompensated/compensated price elasticities derived from the (Implicit Correction) MQES and those (Tables A6-A8) of QES--derived on the presumption that consumption patterns in Tonga are uniform across household demographic profiles (the Naive specification)--we notice that "marked" differences exist.

This is not surprising given the emphatic support provided by our substantive empirical findings in favor of the following: (i) the paramount need to take into account variations in household demographic profiles in the examination of consumption patterns, and (ii) the paramount need to adopt sufficiently rich specifications in the analysis of consumption patterns. This is so since variations in demographic variables somewhat interact and operate in complex ways. Thus, *inter alia*, the adoption of the approach (Implicit Correction specification) of allowing all parameters of the demand

systems to depend on demographic variables represents an effective above-threshold requirement.

Nudged by these strong findings, we have empirically stylized consumption patterns in Tonga in an appropriate way. Thus, *inter alia,* the sets of demographically adapted parameter and elasticity estimates and other behavioral (summary) statistics provided serve to convey perspective stories about consumption behavior in Tonga--stories that need to be fruitfully translated into and utilized as relevant management and policy inputs. As practicing economists/economic policy analysts channel efforts into this task, the boundaries to the inferential and predictive scopes of said empirical harvests as delineated and implied by the underlying conceptual foundation of the adopted methodology need to be perpetually respected.

In any event, the optimal approach evidenced and thus employed in this study, *inter alia,* highlights the commendable serviceability and efficacy of utilizing micro-data (and micro-economic principles) for econometric stylizations and analyses of household consumption demand behavior.

APPENDIX

Table A1(a). Tongan Data's Inherently Defined Demographic Variables: Selected Age Categories and their Characteristic Features

Age category (years)	Name of age category	Stylized features
1. 0≤Age≤14	Children (N0014)	Schooling for the majority of this class begins at primary school level. Preschooling is either deemed unnecessary or is restricted to members of families with "higher" socioeconomic status. (The nature of the available data does not allow further subclassifications of this category).
2. 15≤Age≤19	Adolescents (N1519)	The vast majority of individuals under this category undertakes secondary school education; the influence of the extended family forces on them is quite strong.
3. 20≤Age≤34	Young adults (N2034)	Persons under this class are the ones most susceptible to "outside" forces (e.g., migration and marriage); the mean age at marriage for Tonga falls within this category.
4. 35≤Age≤54	Adults (N3554)	The official retiring age in Tonga is 50 years, however, there are still some who choose to remain in the work-force, "hence" the upper limit point of 54 years.
5. 55≤Age	Aged adults (N55P)	The strength of extended family living "hinders" the prevalence of nursing homes for the elderly, and members of this group constitute a pivotal part of the household in terms of leadership and family identity.

Table A1(b). Tongan Data's Accessible Demographic Variables: Descriptions, Symbols, and Stylized Features

Variable Condensed Description	Variable Symbol	Variable Stylized Features
Number of persons	PEOPLE	Straight count of number of "heads" (persons).
Number of adults	ADL	Including young adults and aged adults.
Number of male persons	NMALE	Straight count of male persons in the household.
Number of female persons	NFEMALE	Straight count of female persons in the household.
Number of male aged adults	NM55P	Male gender, aged 55 years or older.
Number of female aged adults	NF55P	Female gender, aged 55 years or older.
Number of male adults	NM3554	Male gender, aged between 35 and 54 years.
Number of female adults	NF3554	Female gender, aged between 35 and 54 years.
Number of male young adults	NM2034	Male gender, aged between 20 and 34 years.
Number of female young adults	NF2034	Female gender, aged between 20 and 34 years.
Number of male adolescents	NM1519	Male gender, aged between 15 and 19 years.
Number of female adolescents	NF1519	Female gender, aged between 15 and 19 years.
Male child	NM0014	Male gender, aged 14 years or younger.
Female child	NF0014	Female gender, aged 14 years or younger.
Number of income earners	NIE	Persons of any gender or age engaged in paid employment.
Location of household	REGION	Physical location (in a regional context) of household; only 2 regional divisions: Vahekolo and Vahe'uta

Table A2. Central Tendency and Dispersion Summary Measures of Demographic Variables

Variable Symbol	T	Mean	Std. Dev.	Variance	Minimum	Maximum
(A) TONGATAPU [Pooled]						
PEOPLE	709	6.5	2.95	8.69	1.0	19.0
NMALE	709	3.1	1.79	3.20	0.0	13.0
NFEMALE	709	3.4	1.93	3.72	0.0	12.0
ADL	709	2.9	1.54	2.37	0.0	12.0
N55P	709	0.6	0.80	0.63	0.0	5.0
N3554	709	1.1	0.88	0.77	0.0	4.0
N2034	709	1.3	1.22	1.48	0.0	8.0
N1519	709	0.9	1.18	1.40	0.0	12.0
N0014	709	2.6	2.15	4.61	0.0	13.0
NM55P	709	0.3	0.48	0.23	0.0	3.0
NF55P	709	0.3	0.51	0.26	0.0	3.0
NM3554	709	0.5	0.54	0.29	0.0	2.0
NF3554	709	0.6	0.56	0.32	0.0	3.0
NM2034	709	0.6	0.75	0.56	0.0	5.0
NF2034	709	0.7	0.78	0.62	0.0	4.0
NM1519	709	0.5	0.83	0.69	0.0	12.0
NF1519	709	0.5	0.77	0.60	0.0	4.0
NM0014	709	1.3	1.38	1.91	0.0	9.0
NF0014	709	1.3	1.35	1.83	0.0	7.0
NIE	709	1.7	1.06	1.12	0.0	7.0
(B) VAHEKOLO [Region 1]						
PEOPLE	304	6.6	3.09	9.55	1.0	18.0
NMALE	304	3.1	1.84	3.39	0.0	13.0
NFEMALE	304	3.5	2.02	4.07	0.0	11.0
ADL	304	2.8	1.57	2.47	0.0	12.0
N55P	304	0.7	0.84	0.71	0.0	5.0
N3554	304	1.1	0.92	0.85	0.0	4.0
N2034	304	1.5	1.32	1.74	0.0	8.0
N1519	304	1.0	1.36	1.86	0.0	12.0
N0014	304	2.4	2.09	4.37	0.0	12.0
NM55P	304	0.3	0.52	0.27	0.0	3.0
NF55P	304	0.4	0.54	0.30	0.0	3.0
NM3554	304	0.5	0.55	0.30	0.0	2.0
NF3554	304	0.6	0.61	0.37	0.0	3.0
NM2034	304	0.7	0.81	0.65	0.0	5.0
NF2034	304	0.8	0.84	0.71	0.0	4.0
NM1519	304	0.5	1.00	1.00	0.0	12.0
NF1519	304	0.6	0.84	0.71	0.0	4.0
NM0014	304	1.2	1.33	1.77	0.0	7.0
NF0014	304	1.2	1.35	1.82	0.0	7.0
NIE	304	1.8	1.13	1.28	0.0	7.0
(C) VAHE'UTA [Region 2]						
PEOPLE	405	6.4	2.28	8.05	1.0	19.0
NMALE	405	3.1	1.75	3.07	0.0	10.0
NFEMALE	405	3.3	1.86	3.46	0.0	12.0
ADL	405	2.9	1.52	2.30	0.0	8.0
N55P	405	0.5	0.76	0.57	0.0	4.0
N3554	405	1.0	0.85	0.72	0.0	3.0
N2034	405	1.2	1.12	1 26	0.0	6.0
N1519	405	0.9	1.02	1.04	0.0	4.0
N0014	405	2.7	2.18	4.76	0.0	13.0
NM55P	405	0.3	0.45	0.20	0.0	2.0
NF55P	405	0.3	0.48	0.23	0.0	3.0
NM3554	405	0.5	0.53	0.28	0.0	2.0
NF3554	405	0.6	0.53	0.28	0.0	2.0
NM2034	405	0.5	0.70	0.49	0.0	4.0
NF2034	405	0.7	0.73	0.54	0.0	4.0
NM1519	405	0.4	0.68	0.47	0.0	3.0
NF1519	405	0.4	0.72	0.52	0.0	3.0
NM0014	405	1.4	1.41	2.00	0.0	9.0
NF0014	405	1.4	1.35	1.83	0.0	6.0
NIE	405	1.5	0.99	0.97	0.0	7.0

Table A3. Forms of Selected (Behavioral) Summary Statistics

Feature	LES Specification	QES Specification
1. Average marginal budget share	$\theta_i = \beta_i$	$\theta_i = \beta_i + 2(\alpha_i - \beta_i)\Omega\Pi\, p_k^{-\alpha_k}\ (\mu - \sum p_i\tau_i)$
2. Average budget share	$W_i = \left[\frac{p_i}{\mu\tau_i} + \beta_i\right]\left[1 - \frac{\sum p_k}{\mu\tau_k}\right]$	$W_i = \frac{p_i}{\mu\tau_i} + \beta_i\left(1 - \frac{\sum p_k}{\mu\tau_k}\right) + (\alpha_i - \beta_i)\Omega\Pi\left(\frac{p_k}{\mu}\right)^{-\alpha_k} x \left(\frac{1 - \sum p_i}{\mu\tau_i}\right)^2$
3. Total-expenditure elasticity	$E_i = \frac{\beta_i}{W_i} = \beta_i\left[\left(\frac{p_i}{\mu\tau_i}\right) + \beta_i(1 - \sum p_k\tau_k)\right]^{-1}$	$E_i = \frac{\theta_i}{W_i} = (\beta_i + 2(\alpha_i - \beta_i)\Omega\Pi\, p^{-\alpha_k}(\mu - \sum p_i\tau_i))\, x \frac{p_i}{\mu\tau_i} + \beta_i\left(\frac{1 - \sum p_k}{\mu\tau_k}\right)$
4. Super numerary total-expenditure	$\mu^* = \mu - \sum p_k\tau_k$	
5. Total-expenditure flexibility	$\varnothing = \frac{-\mu}{(\mu - \sum p_k\tau_k)}$	$\varnothing = \frac{-(\mu - \sum p_i\tau_i)}{2\mu}$
6. Super-numerary ratio (absolute total-expenditure flexibility)	$\lvert\varnothing\rvert = \left\lvert\frac{-\mu}{\mu - \sum p_k\tau_k}\right\rvert$	
7. Commited expenditure ratio (ratio of "commited" expenditure to total-expenditure)	$\varnothing^* = 1 - \lvert\varnothing\rvert$	
8. Average commited budget share	$W_j^* = \frac{p_i\tau_i}{\sum p_k\tau_k}$	
9. Uncompensated (Cournot) price elasticity	$\epsilon_{ij} = \begin{cases} E_i\left(\frac{\varnothing - p_i}{\mu\tau_i}\right) & i = j \\ \frac{-E_i p_j}{\mu\tau_i} & i \neq j \end{cases}$ $= \begin{cases} (1 - \beta_i)\frac{\tau_i}{q_i} - 1 & i = j \\ \frac{-\beta_i\tau_i p_i}{p_i q_i} & i \neq j \end{cases}$	$\epsilon_{ij} = \left(\frac{\partial p_i}{\partial p_i}\right)\left(\frac{p_i}{q_i}\right)$, $i = j$ where $\frac{\partial p_i}{\partial p_i} = \frac{-\tau_i\beta_i}{p_i} - \left[\frac{\beta_i}{p_i^2} + \frac{2\tau_i}{p_i}(a_i - \beta_i)\Omega\pi p^{-\alpha_i}\right]\left[\mu - \sum p_k\tau_k\right]\frac{-(1 + a_i)}{p^{2_i}(a_i - \beta_i)\Omega\pi\, p^{-\alpha_i}(\mu - \sum p_k\tau_k)^2}$ $\epsilon_{ij} = \left(\frac{\partial p_i}{\partial p_j}\right)\left(\frac{p_j}{q_i}\right)$, $i \neq j$ where $\frac{\partial p_i}{\partial p_j} = \frac{-\tau_j\beta_i}{p_i} - \frac{a_j}{p_i p_j(a_i - \beta_i)\Omega\pi p_k^{-\alpha_k}(\mu - \sum p_i\tau_i)^2}\ \frac{-2\tau_j(a_i - \beta_i)}{p_i\Omega\pi\, p_k^{-\alpha_k}(\mu - \sum p_i\tau_i)}$
10. Utility-compensated (Slutsky) price elasticity	$\epsilon_{ij}^* = \begin{cases} \varnothing E_i(1 - \beta_i) & , i = j \\ -\varnothing E_i\beta_i & , i \neq j \end{cases}$ $\begin{cases} -(1 - \beta_i)\left(\frac{1 - \tau_i}{q_i}\right) & i = j \\ \beta_j\left(\frac{1 - \tau_i}{q_i}\right) & , i \neq j \end{cases}$	$\epsilon^* = \epsilon + EW^T$
11. Marginal utility of total-expenditure compensated (Frisch) elasticity	$\epsilon_{ij}^{**} = \begin{cases} \varnothing E_i & i = j \\ 0 & i \neq j \end{cases}$	$\epsilon^{**} = \epsilon^* + \varnothing EW^T E$

Table A4. Modified (Implicit Correction) Linear Expenditure System Parameter Estimates[1] (Implicit Correction--Second Stage: Setting $\Gamma \equiv$ NIE)

Parameter	Naive	Implicit correction Number of Income Earners (NIE)			
		1	2	3	0 or ≥ 4
I. Vahekolo					
τ_1	0.015	0.115	0.006	0.113	0.097
	(2.02)	(1.60)	(0.24)	(0.54)	(2.27)
τ_2	0.011	0.015	0.037	-0.002	0.017
	(0.85)	(0.84)	(0.96)	(-0.06)	(0.23)
τ_3	-0.015	-0.007	-0.050	-0.023	-0.025
	(-1.68)	(-0.54)	(-1.78)	(-1.11)	(-0.62)
τ_4	-0.006	-0.004	-0.031	0.007	0.008
	(-1.32)	(-0.84)	(-1.48)	(0.65)	(0.39)
β_1	0.207	0.214	0.204	0.197	0.191
	(21.43)	(12.41)	(11.63)	(10.13)	(5.24)
β_2	0.383	0.402	0.326	0.397	0.396
	(38.38)	(22.14)	(16.12)	(16.78)	(11.50)
β_3	0.265	0.251	0.383	0.290	0.288
	(26.76)	(14.94)	(14.20)	(13.39)	(9.35)
II. Vahe'uta					
τ_1	-0.010	-0.008	-0.004	-0.028	-0.010
	(-1.24)	(-0.75)	(-0.21)	(-1.49)	(-0.59)
τ_2	0.035	0.028	0.051	0.003	0.052
	(6.30)	(3.90)	(4.01)	(0.05)	(3.32)
τ_3	0.010	0.008	0.022	-0.005	0.011
	(2.99)	(1.87)	(2.61)	(-0.15)	(1.23)
τ_4	-0.002	-0.001	0.004	-0.000	-0.012
	(-0.82)	(-0.52)	(0.70)	(-0.01)	(-1.25)
β_1	0.191	0.189	0.209	0.191	0.162
	(24.61)	(16.47)	(13.66)	(8.67)	(8.70)
β_2	0.414	0.429	0.392	0.401	0.415
	(44.43)	(31.51)	(24.42)	(12.71)	(13.43)
β_3	0.238	0.236	0.248	0.249	0.211
	(30.03)	(20.13)	(17.56)	(7.15)	(9.81)

[1]Numbers in parentheses are the corresponding (asymptotic) t-statistics; the subscripts "1," "2," "3," and "4," stand for "Domestic food," Imported food," "Non-food," and "Service," respectively.

Table A5. Modified (Implicit Correction) Quadratic Expenditure System Parameter Estimates[1] (Implicit Correction--Second Stage: Setting Γ = NIE)

Parameter	Naive	Implicit correction Number of Income Earners (NIE)				
		0	1	2	3	≥ 4
I. Vahekolo						
τ_1	0.0237	0.0717	0.0265	0.0078	0.0985	4.6867
	(2.92)	(1.48)	(2.37)	(0.30)	(5.07)	(5.07)
τ_2	0.0249	-0.0524	0.0337	0.0506	-0.0267	0.2164
	(1.75)	(-0.52)	(1.70)	(1.35)	(-0.57)	(5.06)
τ_3	0.0013	-0.0173	0.0092	-0.0422	-0.0193	0.0344
	(0.18)	(-0.59)	(1.87)	(-1.43)	(-0.95)	(0.47)
τ_4	0.0021	0.0982	0.0021	-0.0278	0.2667	0.0345
	(0.47)	(0.34)	(0.55)	(-1.35)	(3.64)	(1.74)
α_1	-0.0497	0.2167	-0.4576	0.2090	0.0912	-0.0943
	(-1.18)	(0.42)	(-1.05)	(0.60)	(-1.19)	(-1.19)
α_2	-0.5398	-4.5796	-0.5435	-8.8570	0.0472	-1.3764
	(-0.98)	(-0.86)	(-0.93)	(-1.75)	(0.17)	(-0.34)
α_3	1.3625	15.654	0.9565	9.7050	0.2911	3.2811
	(2.46)	(1.11)	(2.82)	(1.63)	(2.42)	(1.31)
β_1	0.2323	0.2108	0.2514	0.2084	0.2298	0.1604
	(16.81)	(3.97)	(10.78)	(11.45)	(8.93)	(5.42)
β_2	0.4414	0.4802	0.4865	0.3325	0.5300	0.2602
	(27.12)	(6.48)	(17.57)	(15.61)	(11.28)	(4.12)
β_3	0.2003	0.1905	0.1800	0.2717	0.2807	0.4755
	(12.41)	(3.62)	(7.11)	(11.38)	(6.31)	(5.69)
Ω	0.0655	0.0001	0.1322	0.0007	0.0857	-0.0567
	(2.75)	(0.14)	(3.07)	(0.29)	(2.37)	(-1.17)
II. Vahe'uta						
τ_1	-0.0105	-0.0157	-0.0085	-0.0035	-0.0236	-0.1770
	(-1.33)	(-0.91)	(-0.78)	(-0.18)	(-1.27)	(-0.53)
τ_2	0.0348	0.0431	0.0282	0.0503	-0.0059	0.1564
	(6.19)	(2.42)	(3.81)	(3.96)	(-0.11)	(3.63)
τ_3	0.0121	0.0099	0.0077	0.0252	0.0353	0.0093
	(3.76)	(0.86)	(1.62)	(3.36)	(1.27)	(0.53)
τ_4	0.0004	-0.0001	0.0004	0.0050	0.0283	0.0028
	(0.21)	(-0.03)	(0.17)	(1.03)	(1.35)	(0.05)
α_1	-0.0291	-0.1433	-0.0212	-0.1003	0.0687	0.1134
	(-0.59)	(-2.51)	(-0.24)	(-1.10)	(1.69)	(1.63)
α_2	-0.5418	2.0632	-0.7108	-1.1060	-0.0127	^.2097
	(-1.34)	(1.83)	(-0.31)	(-1.14)	(-0.03)	(0.14)
α_3	0.5786	7.7211	-0.7323	1.5075	0.5075	0.0431
	(2.74)	(1.46)	(-0.16)	(1.63)	(2.10)	(1.95)
β_1	0.2004	0.1710	0.1928	0.2176	0.2381	0.1736
	(22.55)	(6.94)	(11.62)	(13.13)	(6.90)	(5.39)
β_2	0.4540	0.5268	0.4481	0.4351	0.5471	0.2028
	(35.48)	(12.67)	(16.93)	(19.90)	(8.67)	(6.41)
β_3	0.2238	0.2952	0.2523	0.2113	0.1550	0.0883
	(19.11)	(6.40)	(8.15)	(10.58)	(2.56)	(1.76)
Ω	0.0599	-0.0024	0.0440	0.0523	0.1124	0.0007
	(2.77)	(-0.40)	(0.83)	(1.87)	(2.27)	(0.75)

[1]Numbers in parentheses are the (asymptotic) t-statistics, and the subscripts "1," "2," "3," and "4," stand for "Domestic food," "Imported food," "Non-food," and "Service," respectively.

Table A6. Average Marginal Budget Shares, Average Budget Shares, and Total-expenditure Elasticities Based on QES According to Total-expenditure Level

Total Expenditure Level[1]	Commodities			
	Domestic food	Imported food	Non-food	Service
A. Average marginal budget shares				
Low	0.20	0.41	0.24	0.14
Medium	0.19	0.34	0.28	0.19
High	0.17	0.24	0.32	0.27
"Naive"	0.19	0.37	0.26	0.18
B. Average budget shares				
Low	0.19	0.43	0.24	0.14
Medium	0.19	0.43	0.24	0.14
High	0.19	0.35	0.27	0.19
"Naive"	0.19	0.43	0.24	0.14
C. Total-expenditure elasticities				
Low	1.06	0.95	1.02	1.02
Medium	0.97	0.79	1.17	1.44
High	0.90	0.69	1.18	1.41
"Naive"	1.02	0.85	1.08	1.24

[1]Household total-expenditure (market) levels considered are (T$ per fortnight):

Low: T$0.00-T$139.99

Medium: T$140.00-T$220.99

High: T$230.00-T$∞.

["T$" stands for Tonga's legal tender ("Pa'anga"). In 1984, T$ was fixed at *par* to the Australian dollar (A$).]

Table A7. Uncompensated Price Elasticities Based on QES According to Total-expenditure Level

Uncompensated Quantity Elasticity of:	For Total-Expenditure Level[1]	With Respect to Price of: Domestic food	Imported food	Non-food	Service
Domestic food	Low	-0.98	0.56	-0.83	-0.99
	Medium	-0.97	0.69	-0.79	-0.98
	High	-0.97	0.71	-0.78	-0.98
	"Naive"	-0.99	0.62	-0.81	-0.99
Imported food	Low	0.02	-0.44	-0.83	-0.99
	Medium	0.03	-0.31	-0.79	-0.98
	High	0.03	-0.29	-0.78	-0.98
	"Naive"	0.02	-0.38	-0.81	-0.99
Non-food	Low	0.02	0.56	-1.83	-0.99
	Medium	0.03	0.69	-1.70	-0.98
	High	0.03	0.71	-1.78	-0.98
	"Naive"	0.02	0.62	-1.81	-0.99
Service	Low	0.02	0.56	-0.83	-1.99
	Medium	0.03	0.69	-0.79	-1.98
	High	0.03	0.71	-0.78	-1.98
	"Naive"	0.62	0.62	-0.81	-1.99

[1]Household total-expenditure (market) levels considered are (T$ per fortnight):

Low: T$0.00-T$139.99

Medium: T$140.00-T$229.99

High: T$230.00-T$∞.

["T$" stands for Tonga's legal tender ("Pa'anga"). In 1984, T$ was fixed at *par* to the Australian dollar (A$).]

Table A8. Utility-compensated Price Elasticities Based on QES According to Total-expenditure Level

Compensated Quantity Elasticity of:	For Total-Expenditure Level[1]	With Respect to Price of: Domestic food	Imported food	Non-food	Service
Domestic food	Low	-0.78	1.02	-0.58	-0.84
	Medium	-0.79	-1.11	-0.56	-0.85
	High	-0.81	1.03	-0.54	-0.81
	"Naive"	-0.79	1.05	-0.57	-0.84
Imported food	Low	0.20	-0.03	-0.60	-0.85
	Medium	0.18	0.04	-0.60	-0.88
	High	0.16	-0.05	-0.60	-0.81
	"Naive"	0.18	-0.02	-0.61	-0.86
Non-food	Low	0.21	1.00	-1.59	-0.84
	Medium	0.25	1.20	-1.51	-0.82
	High	0.25	1.13	-1.46	-1.76
	"Naive"	0.23	1.09	-1.55	-1.83
Service	Low	0.21	1.00	-0.59	-1.84
	Medium	0.30	1.32	-0.45	-1.79
	High	0.29	1.21	-0.40	-1.71
	"Naive"	0.27	1.15	-0.52	-1.81

[1]Household total-expenditure (market) levels considered are (T$ per fortnight):

Low: T$0.00-T$139.99
Medium: T$140.00-T$229.99
High: T$230.00-T$∞.

["T$" stands for Tonga's legal tender ("Pa'anga"). In 1984, T$ was fixed at *par* to the Australian dollar (A$).]

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