DEMANDS FOR FOOD PRODUCTS ACROSS THE DEVELOPMENT SPECTRUM: APPLICATION OF A RANK FOUR DEMAND SYSTEM

By

J. A. L. Cranfield[1]

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DEPARTMENT OF AGRICULTURAL ECONOMICS AND BUSINESS
UNIVERSITY OF GUELPH
GUELPH, ONTARIO

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1. Associate Professor in the Department of Agricultural Economics and Business, University of Guelph, Guelph, Ontario, CANADA, N1G 2W1. E-mail: jcranfie@uoguelph.ca, telephone: (519) 824-4120; fax: (519) 767-1510

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Abstract

A rational rank four AIDS model (RAIDS) is used to estimate consumer demands for final goods and services in countries spanning the development spectrum. RAIDS is used as it provides more general price and expenditure responses. It also nests the Quadratic and non-linear AIDS models. RAIDS is estimated using the entire sample and sub-samples based on the country's level of per capita expenditure. Results indicate selection of nested functional form differs by sub-sample. AIDS is selected for the low per capita expenditure countries, while QUAIDS is selected for the middle and high per capita countries, and when the whole sample is considered. Differences in parameter estimates manifest themselves in price and Engel elasticities. Such differences warrant caution when using global demand systems to undertake policy analysis.

JEL Classification: D12, Q11

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Economists have spent considerable time and effort modelling consumer demand for final goods and services. Much of this analysis has used empirically tractable demand systems, including the Linear Expenditure System, the Rotterdam model and the Almost Ideal Demand System. However, few of the applied demand studies for food products go beyond the AIDS and/or Rotterdam models. Such inertia is problematic given the limitations of the models used. The AIDS model is a rank two-demand system[1], while the Rotterdam model has constant marginal budget shares[2]. Such weaknesses limit the application of these models to data sets that show wide variation in expenditure levels (such as across countries spanning the development spectrum). Moreover, recently developed demand systems offer not only more flexible expenditure responses, but also more flexible price effects. In this regard, scope exists to assess performance of these more general models when expenditure (or prices) widely varies.

This paper uses a newly developed demand system to model consumer demand for final goods and services using data spanning a broad range of countries. The specific demand

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[1] For all demand systems that are linear in functions of income, demand system rank is the maximum rank of a matrix of coefficients associated with functions of income (or expenditure). More precisely, demand system rank is the "…maximum function space spanned by the Engel curves of the demand system," (Lewbel, p. 711). Gorman proved the rank of such a demand system is at most three; thus, such demand systems are referred to as "full rank demand systems." The concept of rank is useful in developing a taxonomy of demand systems according to Engel curve shape. Rank one demands, the most restrictive demand systems, are independent of income; rank two demand systems are less restrictive, allowing linear Engel curves not necessarily through the origin; while rank three (*i.e.*, full rank) demand systems are least restrictive, allowing for non-linear Engel responses.

[2] A marginal budget share is "…the fraction of an additional dollar of expenditure spent on each good…" (Pollak and Wales 1992, p.5).

system is Lewbel's (2003) rational, rank-four AIDS model (RAIDS). The data are from the 1996 International Comparison's Project (ICP), which contains expenditure data for many final goods and services in countries spanning the development spectrum. The value of using the RAIDS model relates to its flexible (and more general) price and expenditure responses. Such flexibility is advantageous when modeling international demand patterns, as one may suspect that scope exists for different preference structures according to a country's position in the development spectrum. Such differences might arise from cultural differences, differences in the scope and nature of goods available in the market place, and other institutional and development based features.

The choice of the RAIDS model stems from recent generalizations of the AIDS model. Specifically, Banks, Blundell and Lewbel generalize PIGLOG preferences by introducing a term that is quadratic in the logarithm of real expenditure into Deaton and Muellbauer's Almost Ideal Demand System (AIDS) model.[3] They show that for exactly aggregable, rank-three demands, the resulting demand system is quadratic in the logarithm of real expenditure. This Quadratic AIDS (QUAIDS) model allows for more general income effects than the AIDS. Lewbel's RAIDS model is a further generalization of Banks, Blundell and Lewbel. Lewbel (2003) showed that utility derived, budget share based demands can be expressed as a general polynomial of deflated expenditure. In addition, the RAIDS model is a rank for demand system that nests the QUAIDS and AIDS models as special cases that can be tested with linear restrictions on estimated parameters. As such, one would be able to test the rank of the demand system, as supported by the data. The ability to undertake demand system rank tests will further add to economists understanding of the structure of consumer preferences.

The paper proceeds as follows. The RAIDS model is presented in the next section, followed by discussion of the data and econometric methods. The analysis proceeds by estimating the RAIDS model with the full data set, with tests of nested demand systems using Likelihood Ratio Tests. As the data are cross-sectional in nature, and span a wide variety of countries, the RAIDS model is also estimated using three subsets of the data, delineated according to per capita expenditure levels. Doing so allows for systematic differences in price and expenditure responses across the different country-groups. The nested demand systems in the RAIDS model are then tested using the expenditure-based groupings of data. Results based on the whole sample are compared to those based on the sub-samples to see if the preferred demand system varies with the countries considered, and whether this translates into different elasticity estimates.

THE RATIONAL, RANK FOUR AIDS MODEL

Before discussing the RAIDS model, it is important to explicitly state that a representative consumer is assumed. While such an assumption is limiting, it enables empirical analysis. Furthermore, a static utility maximization problem underlies the approach used to modeling consumer demands. It is also assumed that the representative individual's labour market participation decision is separable from their decisions related to consumption of final goods and services. By way of introduction, note that Lewbel's rational rank-four AIDS model (RAIDS) [4] written in share form appears as:

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[3] Other modifications of the PIGLOG structure exist, such as Piggott's (2003) nested PIGLOG demand system.
[4] Two small typos appear in Lewbel's original paper. The corrected version of the model can be found at

$$w_{it} = \frac{\delta_i \sum_{l=1}^{n} \delta_l \ln(p_l)}{y_t} + \left(1 - \frac{\sum_{l=1}^{n} \delta_l \ln(p_l)}{y_t}\right)\left(\alpha_i + \sum_{l=1}^{n} \zeta_{il} \ln(p_l) + \beta_i \times \right.$$

$$\left. \ln\left(\frac{y_t - \sum_{l=1}^{n} \delta_l \ln(p_l)}{P_t^*}\right) + \lambda_i \left(\prod_{l=1}^{n} p_{lt}^{\beta_l}\right)^{-1} \left[\ln\left(\frac{y_t - \sum_{l=1}^{n} \delta_l \ln(p_l)}{P_t^*}\right)\right]^2 \right). \tag{1}$$

where δ_i α_i, β_i, ζ_{il} and λ_i are unknown parameters, adding up requires $\sum_{i=1}^{n} \alpha_i = 1$, $\sum_{i=1}^{n} \beta_i = 0$, $\sum_{i=1}^{n} \zeta_{il} = 0$, $\sum_{i=1}^{n} \lambda_i = 0$, $\sum_{i=1}^{n} \delta_i = 1$, symmetry requires $\zeta_{il} = \zeta_{li}$, while homogeneity in prices and income further requires $\sum_{l=1}^{n} \zeta_{il} = 0$. The generality embodied by RAIDS is achieved by estimating $(n+8)(n-1)/2$ parameters. This differs from other flexible function forms which typically have $n(n-1)/2$ parameters.

One could view RAIDS as an AIDS model that has been scaled and translated by the parameters δ_i and price index $\sum_{l=1}^{n} \delta_l \ln(p_l)$. In this regard, note that if $\delta_i = 0$ for all goods, then RAIDS becomes the QUAIDS model (a rank three demand system). As well, if $\delta_i = \lambda_i = 0$ for all goods, then RAIDS becomes the non-linear AIDS model (a rank two demand system). Given these are linear parametric restrictions, and given the nested structure, one can use nested tests to test the null of demand models with lower order rank, and less general preference structures.

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http://www2.bc.edu/~lewbel/rank4fix.pdf. The function that appears here is the correct version.

DATA & ESTIMATION

The 1996 International Comparisons Project (ICP) data are used for this analysis. These data are useful in analyzing international demand patterns since they are provided in identical units (*i.e.*, international dollars). The raw data are composed of real and nominal expenditure on 26 final goods and services in 114 countries (which range in expenditure levels from Malawi to the USA). For estimation, the data are aggregated into four goods: food (F), other non-durables (OND), durables (D), and services (S). Expenditure on each aggregate good is computed as the sum of nominal expenditure on each good in the aggregate group. Total per capita expenditure equals total nominal expenditure divided by population. Unit prices for each good equals nominal expenditure divided by real expenditure, and have been normalized on the respective sample means. Nominal expenditure is defined in exchange rate converted US dollars, while real expenditure is defined in purchasing power parity converted international dollars. Finally, budget shares are computed as the ratio of nominal expenditure on the good to total nominal expenditure.

The 114 countries in the 1996 data base are parsed into three mutually exclusive and exhaustive sub-sets. The rational for doing so is that demands responds to price and expenditure may differ according to a country's position in the development spectrum. The whole sample is divided into three equally sized sub-sets of 38 countries. While somewhat arbitrary (for instance divisions based on the World Bank's World Development Report could have been used), the delineation based on equaled sized sub-samples has the advantage of ensuring the same number of observations are in each sub-set. The sub-samples will be referred to as the low, middle and high per capita expenditure countries.

The models are estimated with adding-up, symmetry and homogeneity of degree zero as maintained hypotheses. Given the cross-equation nature of these restrictions and the non-linear structure of the models, iterated non-linear seemingly unrelated regression (ISUR) is used. For estimation, a regression error is appended to each equation in each demand system. Each n vector of residuals, $\tilde{\boldsymbol{v}}_t$, is assumed to be independently and identically distributed across observations as a multivariate normal with expectation $\mathrm{E}[\tilde{\boldsymbol{v}}_t] = 0$ and a finite covariance matrix given by $\mathrm{E}[\tilde{\boldsymbol{v}}_t \tilde{\boldsymbol{v}}_s'] = \tilde{\Sigma}$ for all $t \neq s$, 0 otherwise. By the adding up property of demands $\tilde{\Sigma}$ is singular. Dropping the last equation from each system allows one to define Σ (an $(n$-1)x$(n$-1) covariance matrix) in terms of the n-1 vector $\boldsymbol{v}_t$.

RESULTS

Table 1 reports log-likelihood function (LLF) values for the RAIDS, QUAIDS and AIDS models and likelihood ratio (LRT) statistics testing the null of the QUAIDS (under the alternative hypothesis of RAIDS) and AIDS models (under the alternative hypothesis of QUAIDS). Note that the LRT statistics have been adjusted using Italianer's (1985) size correction. LLF and LRT values are reported for the entire sample, as well as for the sub-samples delineated by per-capita expenditure. The latter breakdown allows for a comparison of functional form selection across the low, middle and high per-capita expenditure groupings. When the whole sample is considered, the values of the LRT statistics indicate failure to reject the restrictions for the QUAIDS model under the alternative of the RAIDS model at the ten percent level. However, results do show failure to accept the restrictions for the AIDS model under the alternative of the QUAIDS model at the five percent level. In terms of model selection thresholds, a five percent significance rule will be applied – if a model cannot be rejected at the five percent level, it will be used as the model of choice for that particular data set, or sub-set as the case may be. As such, results suggest that when the sample is taken as a whole, the QUAIDS model is preferred over RAIDS and the non-linear AIDS model.

Nevertheless, grouping all 114 countries together in one sample may well mask important differences that exist between sub-samples of the group. For instance, the nature of demand's response to price or expenditure changes is likely different in countries with low per capita expenditure levels versus countries with high per capita expenditure levels. When low per capita expenditure countries are considered (these are the 38 countries with lowest level of per capita expenditure), LRT statistics indicate failure to reject the restrictions for QUAIDS (under the alternative of the RAIDS model) and AIDS (under the alternative of the QUAIDS model). By ruling out the more general variants of AIDS, it would appear the non-linear AIDS is a more appropriate means of characterizing consumer preferences in the low per capita expenditure countries.

When the middle per-capita expenditure countries are considered (these are the 38 countries in the middle of the sample), the restrictions for the QUAIDS model (under the alternative of the RAIDS model) cannot be rejected at the five percent level, while restrictions for the AIDS model (under the alternative of the QUAIDS model) cannot be accepted at the five percent level. These results are rather telling, as they indicate that for the middle 38 countries of the sample, the added generality of the RAIDS model is not supported by the evidence, while the lower rank AIDS model is also rejected when compared to a demand system that offers more general Engel (and price) responses – namely, QUAIDS. This conclusion seems like the more reasonable outcome when one notes these middle per-capita expenditure experience significant change as they move through the development spectrum. As these countries grow, so too does disposable income. As countries become wealthier, the nature and scope of products available to consumers will likely change; consumer preferences may change as well. These points all suggest that the flux which often accompanies economic growth leads to more involved price and expenditure effects.

For the 38 highest per capita countries, the LRT results indicate failure to accept the restrictions for the AIDS model (under the alternative of the QUAIDS model) at the five percent level, but failure to reject restrictions for the QUAIDS model (under a null of the RAIDS model) at the five percent level. For these high per capita expenditure countries, the QUAIDS model appears to be the preferred model (compared to RAIDS and AIDS). Across all three sub-samples, it would thus appear that the nature of demand's response to price and expenditure changes differs across the development spectrum. Evidence of such a result has been presented previously (see Cranfield *et al*. 2002, 2003), but using a different functional form (AIDADS), older data and a smaller sample with less complete country coverage.

The question now becomes whether differences in the selected functions translate into differences in price and Engel elasticities. Prior to discussing these elasticities, note that Table 2 provides parameter estimates from the selected functional forms and country groupings. Note first that the estimated models satisfy the negativity and monotonicity conditions of well behaved demands at the means of the data.[5] While differences exist in the significance, magnitude and sign of some parameters, the estimates are with reason of expectations. Nevertheless, it is interesting to note that only two of the estimated six ζ_{ij}

[5] The eigenvalues of the matrix of compensated price effects are all equal to or less than zero at the means of the data, while the fitted budget shares (include that for the omitted good) are all positive.

terms are significant when the whole sample is used for estimation. When the low per capita expenditure countries are considered, only one estimate of ζ_{ij} is significant, while three are significant when the middle expenditure countries are modeled, and five are significant for the high expenditure country group. It would thus appear that price effects become increasingly important as one moves from low to high per capita expenditure.

Nevertheless, the number of significant estimates of β_i does not vary much across the four models. Two of three estimated β_i s are significantly different from zero when the whole sample is modeled with the QUIADS model, as is the case for the AIDS and QUAIDS models for the low and middle per capita expenditure cohorts of countries. When QUAIDS is used to model demands for the 38 countries with the highest per capita expenditure levels, all estimates of β_i are significant at the one percent level. It would thus appear that income effects are import across the entire sample.

Note, however, that the significance of the nesting parameters in the estimated QUAIDS models varies. Only one nesting parameter is significant in the QUAIDS when the whole sample is used for estimation. When the middle 38 countries are modeled with the QUAIDS model, two of the estimates of λ_i are significant, while all three estimate λ_i s are significant when the 38 countries with the highest level of per-capita expenditure are used for estimation. Differences in the significance and size of the estimated nesting parameters suggests that failure to partition the sample into country groupings based on per capita expenditure might lead to misleading elasticity estimates. Moreover, differences in the significance of the various parameter estimates suggest the drivers affecting each good's share vary across the development spectrum. Specifically, price effects do not seem to play as important a role as expenditure effects in low per capita expenditure countries (i.e., expenditure effects may be more important), while both price and expenditure effects seem to play an important role in middle and high per capita expenditure countries.

The question now becomes whether differences in the various parameters and selected functional forms lead to differences in the various elasticities. Table 3 provides uncompensated price and Engel elasticities, while Table 4 provides the compensated price elasticities, evaluated at the sample and sub-sample means. The top left panel in Table 3 shows the uncompensated price and Engel elasticity for the QUAIDS model estimated with the full data set, and evaluated at the sample means. Consistent with previous work (see, for example, Cranfield et al 2002), food is a normal good, while all other goods are luxuries. Uncompensated price elasticities suggest that magnitude of the Engel effects do not overwhelm the compensated price effects, with the result being downward sloping Marshallian demands. As well, food and other non-durable goods have inelastic own price effects, while durable goods and services have elastic price effects. All cross-price effects are smaller than the own-price effects, but differences in size suggest a mix of gross complementary and gross substitute relationships.

While the elasticities at the means of the data, and computed from a demand system estimated across all observations, are useful, they are not the focal point of the paper. Rather, the foci are on how selection of demand system(s) differs across the development spectrum and how these differences translate into differences in the elasticity estimates. In this regard, note that the panels on the right hand side of Table 3 show uncompensated price and Engel elasticities for the demand systems estimated with the sub-sample cohort countries, and evaluated at the means of the sub-sample datasets. Since different demand systems were selected for different country cohorts, it is natural to expect some differences across the three sub-samples.

In this regard, note that the Engel elasticities change in different patterns for different goods. Engel elasticities for food become more inelastic as one moves from the low to the high per-capita expenditure sub-samples. In contrast, Engel elasticities for other non-durable goods become more elastic as one goes from the low per-capita expenditure sub-sample to the high per-capita expenditure sub-sample. Durable goods and services follow a different pattern of adjustment; for these goods they initially become less elastic, and then more elastic at per capita expenditure rises. Note, however, that the pattern is less obvious for services than for durable goods.

Differences in uncompensated own-price elasticities are also evident across the sub-samples. While all uncompensated own-price elasticities are negative, the categorization of demands across the sub-samples varies. Food is always inelastic, while other non-durables are initially inelastic, but end up being elastic in the high per-capita expenditure group. Durable goods follow an opposite pattern, starting out as an elastic good then becoming an inelastic good. Services are elastic for the low per-capita group, inelastic for the middle per-capita expenditure group and then elastic again for the high per-capita group.

Uncompensated cross-price elasticities tend to be negative – suggesting a gross complement relationship amongst goods at a general level. Moreover, all uncompensated cross-price elasticities are inelastic, regardless of the sub-sample being considered. However, the order of magnitude of some cross-price elasticities differs across sub-samples, for instance the cross price elasticity between durable goods and food. Given the broad expenditure levels spanned by the data, such a result is not terribly surprising. Interestingly, the nature of some cross price relationships differs across sub-samples. In some instances, goods are gross complements, in other instances gross-substitutes.

Why might all of this matter? If one were to use elasticities drawn from the entire sample for analysis related to tax incidence in a CGE model, and the nature of the cross-price relationship were incorrect, then mis-leading analysis will result, possibly leading to second best policy outcomes. The question now becomes whether the elasticities based on the entire sample differ from those based on the analysis of the sub-samples. Indeed, a comparison of the upper-left panel of Table 3 with the three panels on the right hand side shows modeling demands using the while sample (with one functional form) affects the estimated elasticities magnitude, and in some cases magnitude. Recognize, however, that any differences between the “global” elasticities at the sample means and those estimated for the sub-sample cohorts (at the respective sub-sample means) reflect differences in functional form (and resultant differences in parameter estimates) as well as differences in the means of the prices and per capita expenditure used.

The latter issue can be resolved by calculating the elasticities for the QUAIDS model estimated with the entire sample, but at the respective sub-sample means. The bottom three panels on the left hand side of Table 3 show these elasticities. A number of points stand out. First, Engel elasticities are not appreciably different from one another. One exception to this would be the Engel elasticity for services in the 38 middle per capita expenditure countries. Here, the Engel elasticity with the QUAIDS model estimated with the entire sample is about eleven percent larger than that from the QUAIDS model estimated with the middle 38 observations. Second, larger differences are noted in the uncompensated price elasticities. Examples of the latter include the own price elasticity for food in the 38 middle and high per capita expenditure countries, as well as that for durable goods in the high per capita expenditure countries. Lastly, there are numerous differences in the sign and magnitude of the cross price elasticities.

Nonetheless, the role of the Engel and substitution elasticities cannot be ignored. This is highlighted by the signs and magnitudes of the compensated price elasticities in Table 4. All compensated own-price elasticities are negative, regardless of the sample used. However, there are several points of note. First, with all but one exception, the compensated own price elasticities are inelastic. The exception to this is the compensated own price elasticity for durables in the lowest per capita expenditure cohort estimated with the AIDS model. Second, most cross price elasticities are positive, thus indicating goods are net complements. The exception to this is the compensated cross price elasticity of demand between food and durable goods, which is negative for the QUAIDS model estimated with the 38 high per capita expenditure countries. As with the uncompensated elasticities, there are large differences between many cross-price elasticities estimated with the while sample QUAIDS model and those demand systems estimated with the sub-sample.

To further investigate the consequences of using the entire sample to estimate a demand system spanning the development spectrum, Figure 1 plots five different sets of Engel elasticities for food holding prices fixed at the respective means, but allowing per capita expenditure to vary. The first set, labelled “QUAIDS (full)”, plots the Engel elasticities for food using estimates of the QUIADS model estimated with the entire sample, evaluated at the means of the prices. The three series labelled “AIDS (low)”, “QUAIDS (middle)” and “QUAIDS (high)” plot the food Engel elasticities for the demand systems estimated with the respective country sub-samples (i.e., the 38 countries with the lowest, middle and higher per capita expenditure levels, respectively), evaluated at the means of the prices for the respective sub-sample. The last series, labelled "QUAIDS (sub-sample)" plots the Engel elasticities for food using the QUAIDS model estimated with the whole sample, but evaluated at the sub-sample means of the prices.

The quadratic nature of the QUAIDS model is quite evident when the whole sample is used to model consumer demands – at least as evidenced by the change in food's Engel elasticities as one progresses through the development spectrum. When the AIDS model is estimated with data from 38 low per capita expenditure countries the resulting Engel elasticities for food are all less than those for the QUAIDS (full) model. Note, however, that the Engel elasticities for food evaluated using parameter estimates from the QUAIDS model estimated with the full data, but at the means of the poorest sub-sample's prices, lie between those for QUAIDS (full) and AIDS (low). While differences are evident, they do not appear remarkable, but do increase as one moves from the lowest observed level of per capita expenditure to higher levels of per capita expenditure.

Within the middle 38 countries, it is apparent that more drastic differences exist in food's Engel elasticities. Those for the QUAIDS (full) and QUAIDS (sub-sample) are virtually identical to one another, while the Engel elasticities for QUAIDS (middle) (i.e., the QUAIDS model estimated with data from the 38 middle countries), are vastly different. As the same functional form is used to calculate these elasticities, differences between QUIADS (middle) and QUAIDS (sub-sample) are attributable only to differences in the parameter estimates for QUAIDS when the whole sample or middle 38 observations are used for estimation. (Recall the Engel elasticities for food for QUAIDS (middle) and QUAIDS (sub-sample) are calculated at the middle sub-samples price means – consequently, these elasticities are calculated at the same data point, and hence their differences are drive solely by differences in the QUAIDS parameter estimates which underlie them.)

Less dramatic differences are noted for food's Engel elasticities across expenditure levels in the 38 countries with highest per capita expenditure levels. Specifically, the Engel elasticities for food from QUAIDS (high) are similar in value to those from QUAIDS (whole), but note that the former crosses the latter from below as per capita expenditure grows. Nevertheless, when the parameter estimates from the QUAIDS model estimated with the whole sample are used to calculate food's Engel elasticities, but using the means of the prices from the high per capita expenditure group, these elasticities lie well above the two other sets of Engel elasticities for food in the high per capita expenditure group, and the difference increases with per capita expenditure.

Figure 1 illustrates an important point. It appears as though differences in Engel elasticities (at least for food in this sample of countries) are dramatically affected by the nature of the demand system one estimates. When a rank three demand model (i.e. QUAIDS) is utilized, there are more dramatic differences between the Engel elasticities arising from a "global" demand system (i.e. a demand system estimated using the entire database) and those arising from a demand system estimated with a sub-set of data reflecting countries in a more similar per capita expenditure cohort. This point is further echoed by the fact that the differences between the three sets of food Engel elasticities in the lowest per capita expenditure sub-set are smaller (compared to the other two sub-sets) – even when demand systems of different ranks are utilized. This might suggest the inaccuracy arising from using a global demand system to measuring Engel elasticities (at least for food) is dampened for low per capita expenditure countries.

CONCLUSIONS

This paper uses a rational, rank-four AIDS model (RAIDS) and data from the 1996 International Comparison's Project (ICP) to model consumer demands for final goods and services across the development spectrum. The RAIDS model is employed because it nests both the quadratic AIDS (QUAIDS) and non-linear AIDS as special cases. Moreover, RAIDS possesses more general price and expenditure responses. Such flexibility is advantageous when modeling international demand patterns, as one may suspect scope exists for different preference structures according to a country's position in the development spectrum. Indeed, results suggest systematic differences exist in the structure of consumer preferences across the development spectrum.

Specifically, when the whole sample is modeled, the QUAIDS model is preferred to the RAIDS and AIDS models. When the data is parsed into groups with 38 countries each, the AIDS model is preferred for the group with low per capita expenditure levels, while QUAIDS is preferred for the 38 country groups characterized with middle and high per capita expenditure levels. The associated price and Engel elasticities illustrate how parameter differences can impact up on one's characterization of demands, and how failure to account for differences in preference structure across the development spectrum may lead to inaccurately measured elasticities, potentially biasing policy analyses which rely on these elasticities.

More fundamentally, results illustrate that for the sample of countries and goods considered, rank two demands systems appear appropriate when modeling demands using low per capita expenditure countries, but rank three demand systems are appropriate when modeling demand for countries with higher levels of per capita expenditure. In this light, application of demand systems offering variable Engel responses may seem appropriate. As well, these results suggest scope for development of demand systems which allow for a different demand system ranks as one moves through different levels of per capita expenditure.

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Table 1. Log-likelihood values and Likelihood Ratio Test Statistics[a]

	RAIDS (k=18)	QUAIDS[c] (k=15)	AIDS[d] (k=12)
	Whole Sample (n=114)		
LLF	566.461	563.577	559.232
LRT[b]		5.388	8.195
	Low Expenditure Countries (n=38)		
LLF	182.338	181.532	179.859
LRT		1.294	2.772
	Middle Expenditure Countries (n=38)		
LLF	200.917	196.123	190.198
LRT		7.697	9.823
	High Expenditure Countries (n=38)		
LLF	231.167	231.167	220.390
LRT		0.001	17.865

a. Chi-square critical values are 6.251 at ten percent, 7.815 at five percent and 11.341 at one percent.
b. Italianer adjusted likelihood ratio test statistics.
c. LRT values in this column test the null hypothesis of the QUAIDS model (compared to the RAIDS model).
d. LRT values in this column test the null hypothesis of the AIDS model (compared to the QUAIDS model).

Table 2. Parameter estimates based on sample groupings and functional form

Parameter estimate	Whole Sample (QUAIDS)	Low per capita expenditure countries (AIDS)	Middle per capita expenditure countries (QUAIDS)	High per capita expenditure countries (QUAIDS)
α_F	1.121***	1.081***	-0.808*	1.899***
	(7.146)	(5.277)	(-2.266)	(6.475)
α_{OND}	0.211**	0.193*	1.656***	-1.511***
	(2.247)	(1.946)	(6.828)	(-7.624)
α_S	-0.109*	-0.060	0.036	-0.686**
	(-1.811)	(-1.024)	(0.188)	(-2.518)
$\zeta_{F,F}$	-0.075	-0.088	-0.474*	-0.387**
	(-1.361)	(-0.923)	(-1.725)	(-2.545)
$\zeta_{F,OND}$	-0.032	-0.045	0.568**	0.452***
	(-1.577)	(-1.260)	(2.297)	(4.387)
$\zeta_{F,S}$	0.015	0.012	-0.012	0.172**
	(0.895)	(0.524)	(-0.169)	(2.370)
$\zeta_{OND,OND}$	0.017	0.051**	-0.678***	-0.555***
	(1.439)	(2.377)	(-2.872)	(-4.848)
$\zeta_{OND,S}$	0.013*	0.015	0.023	-0.233***
	(1.802)	(1.241)	(0.288)	(-3.259)
$\zeta_{S,S}$	-0.014*	-0.012	-0.002	-0.095
	(-1.863)	(-1.324)	(-0.166)	(-1.382)
β_F	-0.126***	-0.097***	0.364***	-0.264***
	(-3.263)	(-3.212)	(3.756)	(-4.436)
β_{OND}	-0.001	0.004	-0.414***	0.341***
	(-0.052)	(0.272)	(-5.832)	(8.631)
β_S	0.048***	0.023**	0.007	0.163***
	(3.182)	(2.511)	(0.151)	(3.148)
λ_F	0.003		-0.029***	0.009**
	(1.129)		(-4.060)	(2.594)
λ_{OND}	0.000		0.030***	-0.016***
	(0.306)		(5.411)	(-7.459)
λ_S	-0.003***		0.001	-0.008***
	(-2.894)		(-0.007)	(-3.423)

*** significant at the one percent level
** significant at the five percent level
* significant at the ten percent level

Table 3. Uncompensated Price and Engel Elasticities

	QUAIDS model estimated with the complete sample					Models estimated using different per capita expenditure sub-samples				
	F	OND	S	D	Engel	F	OND	S	D	Engel
Elasticities evaluated at the sample means										
F	-0.873	-0.051	-0.004	0.214	0.713	None Estimated				
OND	-0.159	-0.931	0.056	0.006	1.027					
S	-0.114	0.117	-1.061	-0.002	1.060					
D	0.025	-0.032	-0.014	-1.167	1.188					
Elasticities evaluated at the sub-sample means of the 38 lowest per capita expenditure countries										
						Estimated model: AIDS				
F	-0.916	-0.040	0.004	0.185	0.767	-0.982	-0.073	0.020	0.282	0.752
OND	-0.175	-0.922	0.063	0.008	1.026	-0.250	-0.740	0.076	-0.108	1.022
S	-0.121	0.127	-1.091	-0.041	1.127	-0.109	0.115	-1.119	-0.129	1.242
D	0.041	-0.035	-0.019	-1.209	1.222	0.162	-0.104	-0.036	-1.240	1.217
Elasticities evaluated at the sub-sample means of the 38 middle per capita expenditure countries										
						Estimated model: QUAIDS				
F	-0.873	-0.049	-0.006	0.210	0.718	-0.548	-0.153	0.017	-0.004	0.687
OND	-0.157	-0.932	0.055	0.006	1.027	-0.232	-0.953	0.024	0.016	1.146
S	-0.119	0.124	-1.063	-0.001	1.058	-0.049	0.100	-1.023	-0.106	1.077
D	0.024	-0.033	-0.013	-1.167	1.189	-0.095	0.038	-0.026	-0.983	1.067
Elasticities evaluated at the sub-sample means of the 38 highest per capita expenditure countries										
						Estimated model: QUAIDS				
F	-0.809	-0.070	-0.018	0.255	0.643	-0.970	0.222	-0.068	0.315	0.501
OND	-0.147	-0.938	0.050	0.005	1.030	0.043	-1.144	0.057	-0.171	1.214
S	-0.115	0.126	-1.038	0.031	0.995	-0.283	0.150	-0.786	-0.208	1.127
D	0.014	-0.030	-0.010	-1.137	1.163	0.033	-0.075	-0.053	-1.015	1.111

Table 4. Compensated Price Elasticities

	QUAIDS model estimated with the complete sample				Models estimated using different per capita expenditure sub-samples			
	F	OND	S	D	F	OND	S	D
Elasticities evaluated at the sample means								
F	-0.663	0.108	0.067	0.488	None estimated			
OND	0.143	-0.702	0.159	0.400				
S	0.197	0.353	-0.954	0.404				
D	0.374	0.232	0.106	-0.712				
Elasticities evaluated at the sub-sample means of the 38 lowest per capita expenditure countries								
					Estimated model: AIDS			
F	-0.622	0.114	0.070	0.438	-0.688	0.074	0.091	0.524
OND	0.218	-0.716	0.152	0.346	0.149	-0.541	0.172	0.220
S	0.310	0.353	-0.994	0.330	0.376	0.358	-1.002	0.269
D	0.508	0.211	0.087	-0.806	0.637	0.134	0.079	-0.850
Elasticities evaluated at the sub-sample means of the 38 middle per capita expenditure countries								
					Estimated model: QUAIDS			
F	-0.659	0.113	0.063	0.484	-0.381	0.058	0.081	0.242
OND	0.148	-0.699	0.153	0.398	0.046	-0.601	0.129	0.426
S	0.196	0.363	-0.962	0.402	0.213	0.431	-0.924	0.280
D	0.377	0.236	0.101	-0.714	0.164	0.365	0.072	-0.601
Elasticities evaluated at the sub-sample means of the 38 highest per capita expenditure countries								
					Estimated model: QUAIDS			
F	-0.669	0.086	0.048	0.535	-0.856	0.345	-0.013	0.524
OND	0.077	-0.688	0.156	0.454	0.318	-0.845	0.191	0.336
S	0.102	0.368	-0.935	0.466	-0.027	0.427	-0.662	0.262
D	0.267	0.253	0.110	-0.630	0.284	0.198	0.069	-0.552

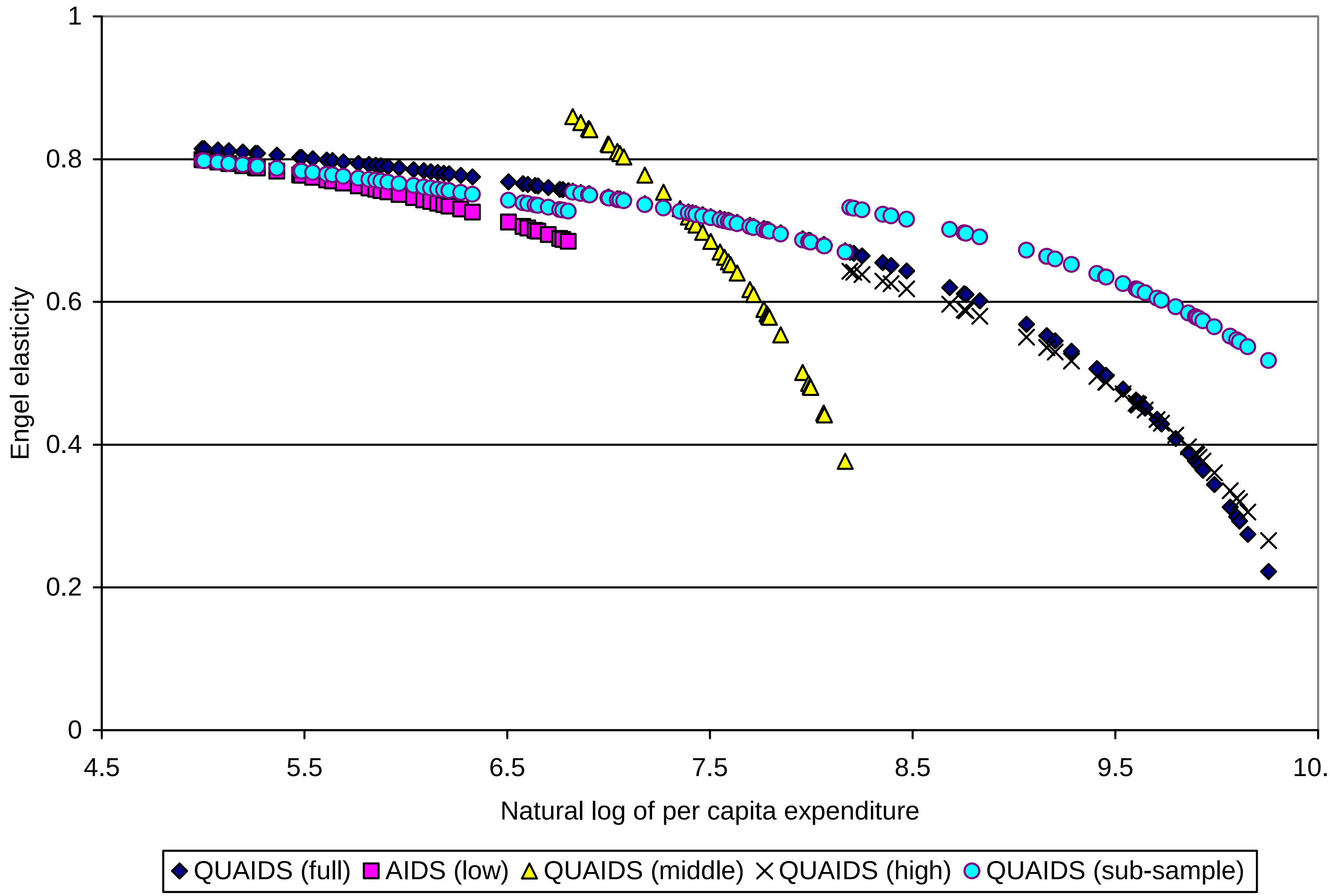

Figure 1. Engel elasticities for food from the models estimated with different samples, as per-capita expenditure varies.