Estimating the Demand for Organic Food:
Cross-sectional Evidence Using the QUAIDS Model

1. Objective

Estimating demand equations as a system has fascinated many economists and generated new ideas and empirical results. The Almost Ideal Demand System (AIDS) model suggested by Deaton and Muellbauer (1980) has several advantages compared to other approaches used before. Banks et al (1997) extended the standard AIDS model in a very important way. They first showed that actual data on expenditure shares do not exhibit the linear relationship between expenditure shares and the log of expenditure as postulated in the AIDS model. They suggested an extended model, the Quadratic AIDS (QUAIDS) model which basically includes the square of log(expenditure) in addition to the ordinary log(expenditure). They showed that the QUAIDS model better explained the actual variations in the data.

In this study, we estimated the QUAIDS model using the cross-sectional data on organic food consumption from Zepeda and Li (2007) and investigated the empirical relevance of the QUAIDS model. We also estimated the income elasticity for different food categories at various income level to see whether there are meaningful dynamics in income elasticity. By doing so, we indirectly tested the relevance of Engel's Law. We used two different utility setups, separable and non-separable utility. We compared the empirical results in two cases to see whether there are again meaningful differences.

2. Significance (Theoretical Model)

AIDS vs. QUAIDS Model

In the AIDS, the following expenditure share function is considered.

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log m \tag{3}$$

, where $m = x/P,$ and P is a well-defined composite price index.

The Quadratic AIDS (QUAIDS) model considers a slightly different expenditure share function given below.

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\left[\frac{x}{a(\boldsymbol{P})}\right] + \frac{\lambda_i}{b(\boldsymbol{P})}\left[\log\left[\frac{x}{a(\boldsymbol{P})}\right]\right]^2 \tag{5}$$

If prices are fixed as in the case of typical cross-sectional data, eq. (3) and eq. (5) can be further simplified.

$$w_i = \alpha_i + \beta_i \log m \tag{3a}$$
$$w_i = \alpha_i + \beta_i \log m + \lambda_i [\log m]^2 \tag{5a}$$

Calculating Income Elasticity in the QUAIDS Model

Given eq. (5a), income elasticity is calculated as follows:

$$\varepsilon_m = \frac{\partial q_i}{\partial m} \cdot \frac{m}{q_i} = \frac{\partial q_i}{\partial m} \cdot \frac{1}{w_i} = 1 + \frac{\beta_i + 2\lambda_i \log m}{w_i} = 1 + \frac{\beta_i + 2\lambda_i \log m}{\alpha_i + \beta_i \log m + \lambda_i [\log m]^2} \tag{7}$$

According to eq. (7), the income elasticity is greater (less) than 1 if and only if $\beta_i + 2\lambda_i \log m$ is greater (less) than 0. So in order to see if a consumption good is a luxury or a necessity, we test whether $\beta_i + 2\lambda_i \log m = 0$ or not. Note that testing the size of income elasticity is also a test on the Engel's Law, since the Law essentially posits that food is a necessity in that its income elasticity is less than 1.

Separable vs. Non-separable Utility Functions

Separable utility functions have the following functional form:

$$U = U\left[v_1(q_1, q_2, \ldots q_j), v_2(q_{j+1}, q_{j+2}, \ldots q_k), \ldots, v_n(q_{l+1}, q_{l+2}, \ldots q_N)\right] \quad (8)$$

, where *N* is the total number of consumption goods that affects the utility.

If the utility is separable, the utility maximization can be regarded as a two-step approach, where the first step is to allocate expenditure shares optimally for each category, and then the second step is to allocate expenditure shares optimally among consumption goods within each category. This two-step approach significantly simplifies the analysis of demand equations as a system since the researcher can simply regard each separable category as if it a complete system of demand equations given the allocated expenditure of that category.

3. Method

Estimation Method and Tested Hypotheses

The basic equation to analyze is eq. (5a) which is of the QUAIDS type. Eq. (5) nested the AIDS (eq. (3a)) as a special case where λ_i's are all zero. While estimating eq. (5a), we distinguished two cases, the separable utility case, and the non-separable utility case. After the estimation, we can test several hypotheses. First, we can check the appropriateness of the QUAIDS model over the ordinary AIDS model by testing whether $\lambda_i = 0$. Unless λ_i's are all zero in all 3 equations, the QUAIDS model seems to be a better formulation.

The next feature we want to look at is the income elasticity. First, we test whether $\beta_i + 2\lambda_i lnfexp$ = 0 to see if income elasticity of good i is greater (less) than 1. Second, we actually track the movement of income elasticity by varying the level of food expenditure and plot the relationship.

Data Summary

The dataset used in this paper is the cross-section data Zepeda and Li (2007) gathered from U.S. household survey on food buying in fall 2003. The original dataset is composed of two parts, which are: (i) a telephone survey using CATI (computer-assisted telephone interview, N=434) and (ii) a mail survey (N=523). We used the mail survey data for the analyses in this proposal.

4. Results

Part 1: Separable Case (QUAIDS Model, 3-equation system)

The estimation result of the 3-equation QUAIDS Model in the separable case is given in Table 2. In the eating-out equation (*pctout*), neither the log of expenditure, nor the square of it is statistically significant.

The organic food equation (*pctorg*) shows quite different features. First, both log of expenditure and the square of it are significant. Since the level term has larger (in absolute value) and negative coefficient, the income elasticity will be less than 1 at the low level of expenditure, but will increase as the influence of the positive coefficient of the square term kicks in. Also note that since the square term is significant, the QUAIDS model explains the data better than the standard AIDS model.

As for the nonorganic food equation (*pctnorg*), the first thing to note is the presence of the adding-up constraint. It is easily verifiable that (i) the sum of all constants = 1 and (ii) the sum of coefficients of the same variable in 3 equations = 0. As for individual estimates, we can see that the quadratic term is again significant, reestablishing the empirical relevance of the QUAIDS Model. The coefficients are admittedly the mirror image of (the sum) of the coefficients of the other two variables.

The formal test results on income elasticity are given in Table 3. According to the test results, organic food turns out to be a luxury since the test clearly rejects the null of being 0 in favor of being positive. To the contrary, nonorganic food is a necessity since the test clearly rejects the null of being 0 in favor of being negative.

We also tracked the variations in income elasticity by evaluating its size at each expenditure level using equation (7). The scatter plots are shown in Figure 3.

Figure 3 clearly shows the advantage of the QUAIDS model which has richer dynamics than the standard AIDS model. In the organic food case, we can see the influence of the quadratic term (λ) as the log level of expenditure increases. Organic food quickly becomes luxury as expenditure on food rises. Nonorganic food, on the contrary, quickly becomes a necessity and stays there.

Part 2: Non-separable Case (quasi-QUAIDS Model, 4 individual demand equations)

The estimation results for the non-separable case are presented in Table 4. The first thing to note in Table 4 is the absence of the adding-up constraint. Now the expenditure shares are just a part of the much bigger system, they do not add up to 1.

The coefficients of income (both in log levels and in squares) are now quite similar across the 4 equations. It seems that the variations we saw in Part 1 (the separable case) are admittedly very small compared to the overall impact of the behavior of total food expenditure, so that the variations “got buried underground” The second thing to note is that again the square term is statistically significant, providing additional support for the QUAIDS over the AIDS.

5. Conclusions/Relevance

The QUAIDS Model suggested by Banks et al (1997) was estimated using the cross-section data from Zepeda and Li (2007). Both the case of separable utility and the case of non-separable utility are examined and the implied income elasticity was tested and recovered. The main findings are as follows:

First, the QUAIDS Model seems superior to the standard AIDS Model. The quadratic income terms were statistically significant in many expenditure share equations.

Second, the income elasticity evaluated at the sample mean of income showed interesting contrasts in the separable case. The elasticity of organic food is greater than 1, making organic food a luxury, whereas that of nonorganic food is less than 1, making the nonorganic food a necessity. So the Engel's Law holds only in the case of nonorganic food.

Third, the recovered income elasticity as a function of income showed rich dynamics in the separable case due to the influence of the quadratic income term. Especially the elasticity of organic food showed a very rapid increase around the mean income level.

Fourth, there were relatively little differences in the behavior of expenditure shares of food or other food items in the non-separable case. The estimations results are more or less dominated by the behavior of nonorganic food.

There seems to be an ample room for further research in this area. One could estimate the demand system more accurately if he/she has more accurate data on income. Also if price data for organic and nonorganic food are available, one could estimate the full-blown QUAIDS Model. Estimating Rotterdam model would be also possible if we have changes in prices.

<Tables (Selected)>

Table 2. Estimation Results of 3-equation QUAIDS Model: (Separable Case)

Dependent Variable	pctout	pctorg	pctnorg
constant	-.025 (.308)	.926*** (.249)	.099 (.380)
lnfexp	.0465 (.137)	-.399*** (.111)	.353** (.169)
ln2fexp	.006 (.015)	.046*** (.012)	-.052*** (.019)
gender	-.031** (.014)	.004 (.012)	.027 (.018)
edu	.001 (.005)	.006 (.004)	-.007 (.006)
nh	-.018*** (.007)	-.010* (.006)	.029*** (.008)
Adjusted R^2	**.094**	**.038**	**.103**
N	382	382	382

Note: Standard errors are in the parentheses. *** indicates significant at 1% level. ** indicates significant at 5% level. * indicates significant at 10% level.

Figure 3. Estimated Income Elasticity (evaluated at each expenditure level)

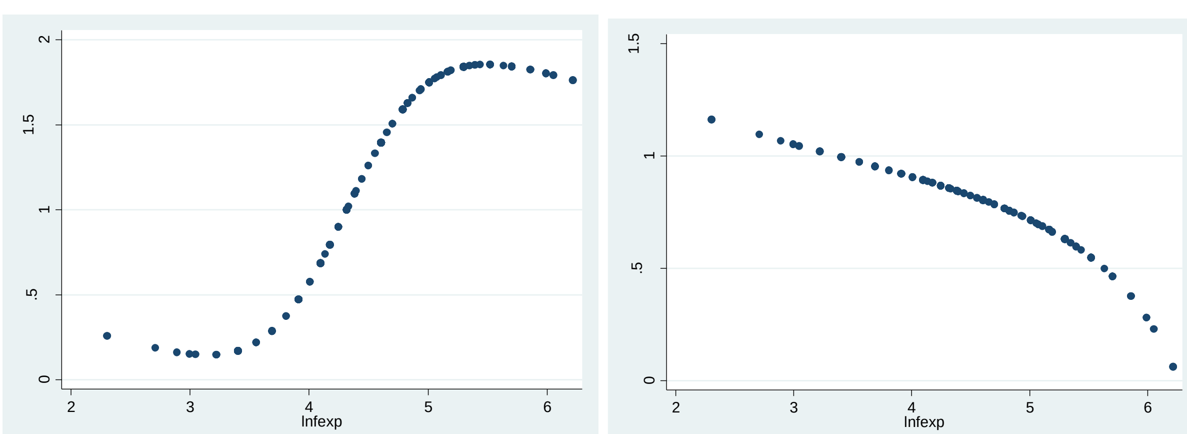

Table 3. Test on Income Elasticity (evaluated at average expenditure level)

	pctout	pctorg	pctnorg
$\hat{\beta} + 2 * \hat{\lambda} * \overline{\ln(m)}$	.005	.032**	-.133***
Standard errors	(.015)	(.014)	(.022)
t-value	0.36	2.24	-6.18

Note: $\varepsilon_m = 1 + (\hat{\beta} + 2\hat{\lambda}\ln(m))/(\hat{\alpha} + \hat{\beta}\log m + \hat{\lambda}[\log m]^2)$. *** indicates significant at 1% level. ** indicates significant at 5% level. * indicates significant at 10% level.

Table 4. Estimation Results of quasi-QUAIDS Model: (Non-separable Case)

Dependent Variable	fexpinc	outinc	orginc	norginc
constant	11.334*** (1.389)	3.213*** (.755)	3.283*** (1.199)	4.838*** (1.066)
lnminc	-2.009*** (.270)	-.578*** (.147)	-.596** (.233)	-.834*** (.207)
ln2minc	.089*** (.013)	.026*** (.007)	.027** (.011)	.036*** (.010)
gender	-.022** (.011)	-.013** (.006)	-.009 (.010)	-.001 (.009)
edu	.004 (.004)	.003 (.002)	.000 (.004)	.001 (.003)
nh	.026*** (.005)	.008*** (.003)	.005 (.004)	.013*** (.004)
Adjusted R^2	.413	.126	.041	.241
N	374	374	374	374

Note: The same as Table 2.

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