Pre-Determined Demand and Theoretical Regularity Conditions: Their Importance for Consumer Food Demand Using AIDS and Policy Analysis Implications

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Abstract

The consideration of theoretical regularity restrictions is an important factor in demand analysis that is often ignored in empirical demand studies. Empirical studies tend to ignore this factor as regularity conditions are often violated. Also important is the need to account for pre-committed demand. If pre-committed demand is present, then models that do not account for this are incorrectly specified. The objective of this research is to examine the affect that ignoring pre-determined demand and theoretical regularity conditions will have on consumer food demand. To accomplish this we use the AIDS because of its wide use. We pay additional attention to regularity by testing for and imposing local curvature conditions. This research also will check for the presence and levels of pre-committed food demand. We use the Nielsen Homescan data to create monthly household level purchases of nine per-capita fiber rich food categories (bread, pasta, tortilla, fresh fruit, fresh vegetables, frozen fruit, frozen vegetables, canned fruit, and canned vegetables) for 2004-2014 in the United States. Then the paper discusses the differences in the intake of fiber rich foods that the estimation procedures have due to a proposed government policy change, such as a subsidy on fruit and vegetables.

Keywords: AIDS, Regularity Conditions, Pre-Determined Demand, Nielsen Homescan Panel

JEL Classification: D12, Q18

Introduction

The government can influence its citizens' diets in a number of methods. One option available for the government is to influence the price of a product to encourage more consumption of this product. For example, it is possible that a 10-percent subsidy for low income Americans could increase their consumption of fruits by 2.1-5.2% and vegetables by 2.1-4.9% (Dong and Lin, 2009). A 20% subsidy on healthy dishes in a university cafeteria was followed by a 6% increase in the consumption of healthy foods and a 2% decline in the consumption of less-healthy foods (Michels et al., 2008). Experiments in laboratory settings have demonstrated that a reduction the price of certain healthier products by 10% led to an increase in the purchase of these products by 10.3% (Epstein et al., 2010).

The need to account for pre-committed demand seems especially important when examining consumer food demand. Importantly, to estimate the size of policy effects it is necessary to specify the correct functional form. One example of a functional form that incorporates pre-determined demand is the Generalized AIDS (GAIDS). This system extends the traditional AIDS specification in that it allows estimation of pre-committed demand components in the budget share equations.

Another important problem for consideration is the imposition of theoretical curvature restrictions on functional forms analysis. This problem stems from the use of specific flexible functional forms such as the Almost Ideal Demand System (Deaton and Muellbauer, 1980) or translog developed by Christensen et al. (1973) for which curvature properties are often violated in practice. Given that some (such as Barnett, 2002) believe theoretical regularity must guide the selection of a functional form, several studies have examined the implications imposition of theoretical regularity conditions without sacrificing flexibility to maintain the appeal of the flexible functional forms. Local curvature can be imposed so that curvature conditions are satisfied at every data point (Ryan and Wales, 1998) while maintaining consistency with neoclassical theory.

The objective of this research is to impose local curvature conditions on a generalized almost ideal demand system (GAIDS) and discuss the implications. We perform the empirical analysis using Nielsen Homescan data. We create a monthly time series of a representative U.S. consumer's purchases for the years 2004 through 2014.. This research will be able to estimate the presence and levels of pre-committed demand. If pre-committed demand is present, then models that do not account for this are incorrectly specified. Further, the results will be used to determine the effect on dietary fiber consumption from a 20% subsidy on canned, fresh, and frozen fruits and vegetables.

Literature Review

In their work introducing a method to impose local curvature conditions on flexible demand systems, Ryan and Wales (1998) apply their method to AIDS (Deaton and Muellbauer, 1980), normalized quadratic (Diewert and Wales, 19880), and the linear translog. Other authors have applied this method to other flexible systems including the generalized Leontief model (Serletis and Shahmoradi, 2007) and the quadratic AIDS (Chang and Serletis, 2012).

Various versions of the AIDS have been used to model the effects of taxes on soft drinks (Dharmasena and Capps, 2012), the demand for gasoline (Chang and Serletis, 2013), and household food demand in Tanzania (Abdulai and Aubert, 2004). The GQAIDS (quadratic form of GAIDS) has been used in a few studies that primarily are focused on Chinese consumers. Hovhannisyana and Gould (2011) examine food demand and its dynamics for 11 commodities in urban China based on household-level expenditure data for 1995 and 2003 with the GQAIDS model. The authors find that the average Chinese household has incorporated elements of Western diet into traditional Chinese diet over time. Hovhannisyana and Gould (2014) use the

GQAIDS model with provincial-level Chinese panel data from 2002 to 2010. The authors introduce a time transition function into the model and find that Chinese food preferences are changing over time. None of these GQAIDS studies seem to impose local curvature conditions in the method of Ryan and Wales (1998).

Dong and Lin (2009) estimate that a 10-percent subsidy would encourage low-income Americans to increase their consumption of fruits by 2.1-5.2% and vegetables by 2.1-4.9%. Klerman, Bartlett, Wilde, and Olsho (2014) study the effects of the USDA Healthy Incentives Pilot, which provided a 30% incentive for purchases of certain fruits and vegetables. These authors find that participants had a 24-percent higher intake of these fruits and vegetables compared to those in the control group. Lin, Yen, Dong, and Smallwood (2010) find that a 10% price subsidy for U.S. Food Stamp Recipients focused on fruits and vegetables is predicted to increase at-home consumption of vegetables would increase from 0.94 to 1 cup (6% increase) and fruits from 0.38 to 0.42 cup (11% increase).

Waterlander et al. (2012) use a sample in the Netherlands and conduct an online experiment on shopping behavior. The authors find that a 25% discount on the total amount of fruit and vegetables purchased would lead to a 25% increase fruits and vegetables purchase. Nnoaham et al. (2009) estimate that for a United Kingdom sample that a 17.5% subsidy along with a tax on less healthy food would lead to a 5% increase in fruit and vegetable consumption. A 20% subsidy on healthy dishes in a university cafeteria was followed by a 6% increase in the consumption of healthy foods and a 2% decline in the consumption of less-healthy foods (Michels et al., 2008).

Empirical Model and Estimation Procedure

The GAIDS is an extension the traditional AIDS (Deaton and Muellbauer, 1980) specification. Bollino (1987) generalizes the AIDS by incorporating the pre-committed expenditures into the total expenditures. Furthermore, Banks et al. (1997) incorporate a function into the indirect utility function that allows the expenditure share Engel curves to be dependent on the quadratic logarithm of total expenditure. An analysis of our data shows there to be no curvature in the Engel curves and the standard AIDS is used instead of QUAIDS.

The budget shares for GAIDS are specified as

$$\mathrm{w_i} = \frac{t_i p_i}{m} + \frac{s}{m}\left(\alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(p_j) + \beta \ln\left(\frac{s}{P}\right)\right).$$

In this specification w is the budget share, p is the price of the commodity, *α, γ, β* are parameters to estimate, ln (*P*) and *b*(*p*) are translog and Cobb–Douglass price aggregator functions ($\ln(P) = \alpha_0 + \sum_{j=1}^{n} \alpha_j \ln(p_j) + 0.5 \sum_{j=1}^{n} \sum_{i=1}^{n} \gamma_{ij} \ln(p_j) \ln(p_i)$), and s is the part of total expenditure sensitive to changes in economic factors

$$\mathrm{s} = \mathrm{m} - \sum\nolimits_{i=1}^{n} t_i p_i.$$

The pre-committed expenditure is defined as $\sum_{i=1}^{n} t_i p_i$ with t as the parameters for pre-committed quantity. For computational ease, Stone's price index is used so that a Linear Approximate Generalized Almost Ideal Demand System (LA/AIDS) will be estimated.

One may introduce demographic variables into the budget share equations through demographic translating of the pre-committed quantities (Pollak and Wales, 1981).

$$\widetilde{t_i} = t_{i0} + \sum_{j=1}^{d} t_{ij} D_j$$

Introducing consumer demographic variables into the GQAIDS via the pre-committed term guarantees the invariance of elasticities to the scale of data (Alston et al., 2001).

The procedure to impose local curvature condition on flexible functional forms is outlined in Ryan and Wales (1998) and Barnett and Serletis (2008). At the point of approximation the *n x n* Slutsky matrix can be written as **S=B+C**, where **B** is an *n x n* symmetric matrix with the some number of element as the Slutsky matrix and **C** is an *n x n* matrix containing elements that are function of other elements in the systems. Curvature is imposed by replacing **S** with –**KK'** (**K** is lower triangular matrix) and then solving for **B** to get **B=** –**KK' – C.** The model is then reparametrized by estimating the parameters in **K** and **C** (not **B** and **C)**. This procedure ensures that the matrix is negative semidefinite at any data point.

In order to find the effect of a proposed subsidy we begin by finding a baseline consumption of dietary fiber as an average of the last 12 months of data. Then for each category, we increase or decrease this amount by the corresponding own and cross price elasticities. This procedure assumes that any increase in demand will be met by an increase in supply at the current price. This is a situation with a relatively inelastic demand curve and an elastic supply curve, which means a 100% pass through to consumers. Four different scenarios are analyzed for the 20% subsidy: on all fruit and vegetables, only canned fruit and vegetables, only fresh fruit and vegetables, and only frozen fruit and vegetables.

Data

Data are obtained from Nielsen Homescan panel. We create a monthly time series of a representative U.S. consumer's purchases for the years 2004 through 2014 (44 quarters) by utilizing the sampling weights. Each participating household is given a scanner to read UPCs from products purchased at stores. Nielsen matches the scanned UPC with products characteristics in their database. The household is also asked to enter quantity, expenditure, and any coupon information about the products. The food products selected for study fresh fruit, fresh vegetables and beans, frozen fruit, frozen vegetables and beans, canned fruit, canned vegetables and beans. This total for each category is then divided by the sampling weights to create an approximation of monthly per capita purchase in grams consumed for the category.

In order to deal with possible endogeneity in the total expenditure variable we utilize a procedure from Capps et al. (1994). Predicted values of total expenditure are used as an instrument. Predicted values of total expenditure are obtained by regressing observed total expenditures on the prices of each product and income. Serial correlation is corrected using the procedure suggested by Berndt and Savin (1975). We estimate uncompensated and compensated elastic estimates for both models using the procedure from Alston, Foster, and. Green (1994). The elasticities are calculated at the means. For LA/GAIDS, the elasticities are the changes in the discretionary consumption and not necessarily at the mean.

Preliminary Results

Table 1 presents the coefficient estimates form both the LA/AIDS and LA/GAIDS side by side. Table 2 presents the uncompensated elasticities for both models. Table 3 presents the compensated elasticities for both models. A quick look at the results shows expected differences in the estimated coefficients when predetermined demand is included.

It is informative to compare with elasticity estimates for fruit and vegetables. Our estimates for our LA/AIDS are similar to those in the literature. Park et al. (1996) find own price elasticities of -0.34 for fruit and -0.32 for vegetables for low-income households. Dong and Lin (2009) find own-price elasticities of -0.52 for fruit and -0.69 for vegetables for low-income households.

The coefficients for pre-determined demand vary widely. The predetermined demand coefficients for frozen fruit, canned vegetable, and fresh vegetables are within a normal range. The predetermine demand for frozen vegetables is very large. Those for canned fruit and fresh fruit are negative. Tonsor and Marsh (2007) suggest that negative pre-committed expenditure estimates can be interpreted as a marginal response of pre-committed expenditures to the price of the commodity. This indicates that these products are only responsive to economic facts.

Table 4 shows the effects of a 20% subsidy applied to four scenarios. Scenario 1 is a 20% subsidy applied to all categories of fruits and vegetables. Scenario 2 is this subsidy applied to only canned products. Scenario 3 is the subsidy applied to only fresh products. Scenario 4 is the subsidy applied only to frozen produce. An immediate observation is the large difference between the effects in the LA/AIDS and the LA/GAIDS model effects. The elasticities from the LA/GAIDS are generally larger indicating that the discretionary portion of consumption in more elastic than the baseline consumption for LA/AIDS. More research will be done in order to compare these results.

An attempt was made to apply the curvature conditions using the method proposed by Ryan and Wales (1998). The statistical program used for this was not able to find a closed form solution. This is likely due to the complexity of the structure imposed by this method causing issues with the numerical estimation. Exploration of alternate methods to impose curvature is a next step.

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Table 1. Parameter estimates for the LA/AIDS and LA/GAIDS models

	LA/AIDS		LA/GAIDS	
Parameter	Estimate	p-value	Estimate	p-value
g_FcnFcn	0.067	0.025	0.207	<.001
g_FcnFfr	-0.103	<.001	-0.405	<.001
g_FcnFfz	-0.005	0.334	0.022	0.067
g_FcnVcn	0.112	<.001	0.076	0.111
g_FcnVfr	-0.050	0.002	-0.111	0.005
g_FcnVfz	-0.020	0.354	0.210	0.000
g_FfrFfr	0.233	<.001	0.112	0.008
g_FfrFfz	0.007	0.255	0.027	0.007
g_FfrVcn	-0.109	<.001	0.037	0.238
g_FfrVfr	0.070	0.000	0.037	0.110
g_FfrVfz	-0.098	<.001	0.192	0.001
g_FfzFfz	0.003	0.520	-0.045	0.007
g_FfzVcn	0.002	0.611	-0.002	0.537
g_FfzVfr	-0.001	0.844	0.010	0.057
g_FfzVfz	-0.006	0.282	-0.012	0.098
g_VcnVcn	-0.033	0.058	-0.156	0.036
g_VcnVfr	-0.087	<.001	0.015	0.236
g_VcnVfz	0.115	<.001	0.030	0.098
g_VfrVfr	0.130	<.001	0.012	0.718
g_VfrVfz	-0.061	<.001	0.037	0.083
rho1	0.809	<.001	0.839	<.001
rho2	-0.105	0.015	0.090	0.036
a_Fcn	0.562	0.228	3.880	<.001
b_Fcn	-0.057	0.314	-0.384	0.000
a_Ffr	-0.881	0.102	3.091	0.005
b_Ffr	0.146	0.026	-0.323	0.011
a_Ffz	-0.147	0.046	-0.363	0.011
b_Ffz	0.020	0.028	0.044	0.012
a_Vcn	0.879	0.015	-2.009	0.007
b_Vcn	-0.096	0.029	0.236	0.006
a_Vfr	-0.247	0.462	-0.559	0.088
b_Vfr	0.070	0.086	0.079	0.033
a_Vfz	0.835	0.016	-3.041	0.003
b_Vfz	-0.084	0.045	0.347	0.005
g_VfzFcn	-0.020	0.354	0.210	0.000
g_VfzFfr	-0.098	<.001	0.192	0.001
g_VfzFfz	-0.006	0.282	-0.012	0.098
g_VfzVcn	0.115	<.001	0.030	0.098
g_VfzVfr	-0.061	<.001	0.037	0.083
g_VfzVfz	0.070	0.004	-0.457	<.0001
t_Fcn			-4766.440	0.002
t_Ffr			-1871.840	0.012
t_Ffz			144.729	0.002
t_Vcn			721.285	0.081
t_Vfr			635.844	0.008
t_Vfz			1925.094	<.0001

Notes:

The table presents estimated coefficients from LA/AIDS and LA/GAIDS. The abbreviations are as follows: fcn = canned fruit, ffr = fresh fruit, ffz = frozen fruit, vcn = canned vegetables, vfr = fresh vegetables, vfz = frozen vegetables.

Table 2. Uncompensated Elasticity estimates for the LA/AIDS and LA/GAIDS models

	LA/AIDS		LA/GAIDS	
Term	Estimate	p-value	Estimate	p-value
ue_fcnfcn	0.290	0.610	3.199	0.000
ue_fcnffr	-1.562	<.0001	-5.114	<.0001
ue_fcnffz	-0.075	0.446	0.539	0.020
ue_fcnvcn	2.196	<.0001	2.293	0.030
ue_fcnvfr	-0.574	0.078	0.386	0.497
ue_fcnvfz	-0.232	0.587	4.784	0.000
ue_ffrfcn	-0.335	<.0001	-1.164	<.0001
ue_ffrffr	-0.444	<.0001	-0.341	<.0001
ue_ffrffz	0.012	0.505	0.099	0.005
ue_ffrvcn	-0.382	<.0001	0.232	0.078
ue_ffrvfr	0.060	0.384	0.443	0.003
ue_ffrvfz	-0.350	<.0001	0.702	0.001
ue_ffzfcn	-0.344	0.246	1.114	0.093
ue_ffzffr	-0.001	0.999	0.704	0.047
ue_ffzffz	-0.836	0.005	-3.561	0.000
ue_ffzvcn	-0.003	0.993	-0.438	0.091
ue_ffzvfr	-0.444	0.128	-0.273	0.219
ue_ffzvfz	-0.488	0.147	-1.002	0.049
ue_vcnfcn	0.939	<.0001	0.509	0.152
ue_vcnffr	-0.617	<.0001	-0.333	0.023
ue_vcnffz	0.033	0.400	-0.053	0.157
ue_vcnvcn	-1.169	<.0001	-2.483	0.000
ue_vcnvfr	-0.438	0.000	-0.529	0.003
ue_vcnvfz	1.019	<.0001	-0.002	0.992
ue_vfrfcn	-0.158	0.001	-0.335	0.003
ue_vfrffr	0.136	0.019	0.030	0.537
ue_vfrffz	-0.007	0.679	0.026	0.111
ue_vfrvcn	-0.281	<.0001	0.014	0.742
ue_vfrvfr	-0.691	<.0001	-1.046	<.0001
ue_vfrvfz	-0.204	<.0001	0.079	0.258
ue_vfzfcn	-0.119	0.480	1.491	0.001
ue_vfzffr	-0.545	0.000	0.597	0.019
ue_vfzffz	-0.037	0.427	-0.144	0.030
ue_vfzvcn	0.977	<.0001	-0.104	0.545
ue_vfzvfr	-0.251	0.036	-0.637	0.005
ue_vfzvfz	-0.373	0.065	-4.912	<.0001

Notes:
The table presents estimated uncompensated elasticities from LA/AIDS and LA/GAIDS. The abbreviations are as follows: fcn = canned fruit, ffr = fresh fruit, ffz = frozen fruit, vcn = canned vegetables, vfr = fresh vegetables, vfz = frozen vegetables.

Table 2. Compensated Elasticity estimates for the LA/AIDS and LA/GAIDS models

	LA/AIDS		LA/GAIDS	
Term	Estimate	p-value	Estimate	p-value
ce_fcnfcn	0.288	0.598	2.869	0.001
ce_fcnffr	-1.577	<.0001	-7.138	<.0001
ce_fcnffz	-0.076	0.434	0.430	0.056
ce_fcnvcn	2.191	<.0001	1.534	0.083
ce_fcnvfr	-0.589	0.044	-1.699	0.020
ce_fcnvfz	-0.237	0.547	4.004	0.000
ce_ffrfcn	-0.257	<.0001	-1.162	<.0001
ce_ffrffr	0.034	0.703	-0.331	0.009
ce_ffrffz	0.038	0.032	0.100	0.001
ce_ffrvcn	-0.202	0.000	0.236	0.013
ce_ffrvfr	0.553	<.0001	0.453	<.0001
ce_ffrvfz	-0.166	0.006	0.705	<.0001
ce_ffzfcn	-0.230	0.434	1.301	0.056
ce_ffzffr	0.703	0.032	1.853	0.001
ce_ffzffz	-0.798	0.006	-3.499	0.000
ce_ffzvcn	0.261	0.331	-0.007	0.975
ce_ffzvfr	0.281	0.370	0.910	0.003
ce_ffzvfz	-0.217	0.498	-0.559	0.177
ce_vcnfcn	0.951	<.0001	0.666	0.083
ce_vcnffr	-0.539	0.000	0.628	0.013
ce_vcnffz	0.037	0.331	-0.001	0.975
ce_vcnvcn	-1.140	<.0001	-2.123	0.000
ce_vcnvfr	-0.358	0.001	0.461	<.0001
ce_vcnvfz	1.049	<.0001	0.369	0.012
ce_vfrfcn	-0.093	0.044	-0.269	0.020
ce_vfrffr	0.537	<.0001	0.440	<.0001
ce_vfrffz	0.015	0.370	0.048	0.003
ce_vfrvcn	-0.130	0.001	0.168	<.0001
ce_vfrvfr	-0.279	<.0001	-0.624	<.0001
ce_vfrvcn	-0.130	0.001	1.692	0.000
ce_vfzfcn	-0.100	0.547	1.830	<.0001
ce_vfzffr	-0.430	0.006	-0.078	0.177
ce_vfzffz	-0.030	0.498	0.359	0.012
ce_vfzvcn	1.020	<.0001	0.634	0.000
ce_vfzvfr	-0.132	0.224	-4.437	<.0001
ce_vfzvfz	-0.328	0.076	-0.328	0.076

Notes:
The table presents estimated compensated elasticities from LA/AIDS and LA/GAIDS. The abbreviations are as follows: fcn = canned fruit, ffr = fresh fruit, ffz = frozen fruit, vcn = canned vegetables, vfr = fresh vegetables, vfz = frozen vegetables.

Table 4. Percent Change in Grams/month Consumed from a Proposed 20% Subsidy

	Canned Fruit	Fresh Fruit	Frozen Fruit	Canned Vegetables	Fresh Vegetables	Frozen Vegetables
LA/AIDS - Percent change from baseline grams/month						
Scenario 1	-0.86	28.78	42.32	-4.66	24.1	6.96
Scenario 2	-49.72	14.34	6.94	-4.6	8.78	-17.16
Scenario 3	42.72	7.68	8.9	-21.1	11.1	15.92
Scenario 4	6.14	6.76	26.48	21.04	4.22	8.2
LA/GAIDS - Percent change in discretionary consumption						
Scenario 1	-121.74	0.58	69.12	-57.82	24.64	74.18
Scenario 2	-109.84	8.64	-13.52	-39.48	6.42	-27.74
Scenario 3	94.56	-2.04	-8.62	-17.24	20.32	0.8
Scenario 4	-106.46	-16.02	91.26	-1.1	-2.1	101.12

Notes:
Scenario 1 is a 20% subsidy applied to all fruit and vegetables. Scenario 2 is this subsidy applied to only canned fruit and vegetables. Scenario 3 is the subsidy applied to only fresh fruit and vegetables. Scenario 4 is the subsidy applied to only frozen fruit and vegetables. The baseline grams per day is the average of last 12 months of the per capita consumption in the respective category. This baseline amount is increased or decreased by the corresponding own and cross price elasticities to find the percent change for each category.