Store-Differentiated Demand and Retail Food Availability

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Introduction

Poor food choices have been shown to contribute to the rise of major chronic diseases, including overweight and obesity. Several factors, such as price, income, social environment, socio-economic status and, more recently, limited access to nutritious food have been frequently held accountable for poor diet.

The literature findings on food access and food choice are mixed, often contradictory, due to, among other things, different considerations of 'healthy' or nutritious food and appropriate retail food outlets representing 'food access'. Fruits and vegetables, the staple healthy foods, have received the bulk of the attention in this debate. Food access is typically captured by various measures of food retail outlet availability. Among various food retail outlets, supermarkets and groceries received much attention primarily due the price affordability and wide assortments of foods, especially fruits and vegetables, these entities typically offer (Larson, Story and Nelson 2009; Larsen and Gilliland 2009).

For example, several studies (e.g. Kyureghian, Nayga and Bhattacharya 2013; Kyureghian and Nayga 2013) demonstrate that increased supermarket availability is not associated or even negatively associated with fruit and vegetable consumption, indicating substitution away from fruits and vegetables when a new supermarket opens in the vicinity. The issue of identifying foods that are substituted for fruits and vegetables remains unaddressed and largely unknown. It is important to understand that supermarkets are a more affordably priced source of not only 'healthy' foods, but also all other kinds of food, including 'unhealthy'.

The aforementioned shortcomings in the literature make it difficult to draw inference concerning the demand elasticities of different foods and virtually impossible to discern the effect of food retail environment on purchasing choices and patterns. The objective of this research is to step in this gap and offer a comprehensive analysis by offering a system approach through using for a representative choice of food groups and food retail outlets.

In particular, we would like to investigate how accessibility to food retail outlets influences the elasticity of demand for representative food groups, both ‘healthy’ and ‘unhealthy’. It could be that the less food retail store options consumers have (sometimes referred to as food deserts) the more inelastic is their demand for fruits and vegetables, so even a large decline in retail prices does not lead to large consumption of these foods.

We would employ a store-differentiated Almost Ideal Demand System (AIDS) to study this problem. The analysis would require a 2-step procedure. In the first stage we will use the store-differentiated AIDS model to estimate demand elasticities for all food groups. Once the elasticities estimated, we will estimate the effects of the availability of different food retail outlets on demand elasticities. The food groups we will consider in this analysis are fruits, vegetables, milk, grains, meats, sweets and snacks, carbonated soft drinks and other sugary drinks.

We will use the 2006 Nielsen HomeScan household-level panel data in this study. The panelists record all food at home purchases throughout the year. The dataset contains detailed information about products purchased, as well as panel demographics (household size and composition, age, education, race, income, residence, etc.). The food retail outlet availability data are obtained from the County Business Patterns, U.S. Census Bureau, for the reference period.

We expect to see differentiated demand elasticities, possibly reversed in significance by food group, such as ‘healthy’ vs ‘unhealthy’. The social, diet and health consequences and implications of policy intervention to increase food retail accessibility are discussed as well.

Data

The grocery purchase data are obtained from the Nielsen HomeScan panel. For this study we use the data for 2006 only. The store availability data come from the County Business Patterns, U.S. Census Bureau, for the same year.

The Nielsen Company (formerly ACNielsen) recruits a representative panel of households from 48 contiguous states based on demographic characteristics. Approximately 60,000 households participated in the panel in 2006. Each participating household is asked to scan the bar code (UPC code) of each item purchased and transfer the scanned data on weekly basis. The households record the quantities purchased and amount paid for the purchase. Observations from this data set corresponding the UPC’s are then combined into food groups following the procedure by Quarterly Food-at-Home Price Database (Todd *et al.* 2010). The food groups identified by this database are used to estimate the demand system for seven food groups – fruits, vegetables, milk, grains, meat, carbonated soft and other sugary drinks (CSD), and sweets. We also use a rich set of demographic variables – poverty-income ratio (PIR, a variation of per capita income), county of residence, outlet status, household size, race, etc. The data were aggregated on annual basis. After all transformations the final sample size was 37, 603.

Variables

The expenditures are expressed in cents. The price variable is expressed in cents per gram. The store type variable originally included seven types of stores – grocery stores, drug stores, mass merchandisers, supercenters, clubs, convenience stores and all other. Due to large number of products (seven) and store types (seven) considered, the missingness rates of the price variable due to non-purchase was high. Consequently, we combined some store types resulting only four store types – grocery, supercenter, mass merchandisers and clubs, and all other. Although the demand system we estimated included all seven food groups, we report the elasticities of only four food groups – fruits, vegetables, milk and CSD. The definitions and summary statistics of variables are reported in Table 1.

PIR's are calculated as the midpoint (the point between the upper and lower bounds of the particular category the income falls in) of the income category divided by government issued poverty guidelines by household size:

$$PIR = \frac{\frac{Upper\ Bound + Lower\ Bound}{2}}{\$9{,}800 + \$3{,}400 \times (Household\ Size - 1)}$$

The definitions and summary statistics of variables are reported in Table 2.

The statistics in Table 1 show that grocery stores have by far the bulk of the sales in all food categories, and, interestingly, have the highest prices in 'healthy' food categories and invariably the lowest prices in 'unhealthy' food categories. This is in line with our predictions stated above.

In our sample, the household size is slightly over 2 persons, with 83% whites and less than 3% with children. A substantial portion of female household heads have college degree or

Table 1. Means (Standard Deviations) of Expenditures and Prices by Product Group and Store Type

Variable	Grocery	Supercenter	Mass Merchandiser / Club	Other
Expenditures				
Fruits	9,207	1,276	1,897	674
	(10,799)	(3,518)	(5,460)	(2,659)
Vegetables	8,934	1,320	986	484
	(8,588)	(3,302)	(2,970)	(1,936)
Grain	2,660	523	410	253
	(3,784)	(1,663)	(1,363)	(891)
Milk	6,285	1,093	691	692
	(7,366)	(3,136)	(2,608)	(2,584)
Meat	12,767	2,383	2,107	739
	(16,782)	(6,307)	(6,320)	(3,974)
CSD	10,433	2,122	1,592	1,661
	(12,595)	(6,001)	(4,283)	(5,379)
Sweets	24,349	5,829	5,634	4,801
	(21,597)	(12,291)	(9,518)	(7,969)
Prices				
Fruits	0.318	0.260	0.300	0.272
	(0.176)	(0.150)	(0.406)	(0.159)
Vegetables	0.306	0.275	0.309	0.269
	(0.134)	(0.109)	(0.189)	(0.175)
Grain	0.484	0.457	0.448	0.436
	(0.172)	(0.106)	(0.115)	(0.136)
Milk	0.109	0.106	0.092	0.112
	(0.048)	(0.038)	(0.039)	(0.048)
Meat	0.805	0.710	0.714	0.714
	(0.385)	(0.280)	(0.345)	(0.341)
CSD	0.097	0.091	0.104	0.129
	(0.072)	(0.053)	(0.088)	(0.156)
Sweets	0.719	0.775	0.854	1.071
	(0.309)	(0.380)	(1.178)	(2.901)

higher. So does almost a half of the male household head sample. Store density variables indicate that, on average, there are just over 3 supercenters (includes all large stores except clubs) per 100 square miles, per county. There are less than half as many clubs. Convenience and specialty stores are, on average, fewer, with a relatively wide presence of food away from home facilities.

Table 2. Demographic and Store Density Variables – Descriptions and Means (Standard Deviations)

Variable Name	Variable Description	Mean (Standard Deviation)
Store Density Variables (DEN)		
Sup	Number of supermarkets in the county, per 100 sq mile	3.254 (5.792)
Club	Number of clubs in the county, per 100 sq mile	1.599 (6.359)
Con	Number of convenience stores in the county, per 100 sq mile	0.376 (1.884)
Spec	Number of specialty stores in the county, per 100 sq mile	0.673 (1.773)
FS	Number of full-service restaurants in the county, per 100 sq mile	13.133 (17.910)
QS	Number of quick-service restaurants in the county, per 100 sq mile	22.164 (34.908)
Demographic Variables		
PIR	Poverty Income Ratio	4.048 (2.790)
HH_Size	Household Size	2.302 (1.255)
AC_1_7	Binary variable indicating whether there are children in the household	0.026 (0.160)
FED_COLL	Binary variable indicating whether the female household head has collage or above education	0.617 (0.486)
FED_HS	Binary variable indicating whether the female household head has high school or below education	0.282 (0.450)
MED_COLL	Binary variable indicating whether the male household head has collage or above education	0.497 (0.500)
MED_HS	Binary variable indicating whether the male household head has high school or below education	0.230 (0.421)
Non_White	Binary variable indicating whether the household head is of non-white race	0.169 (0.375)

Estimation Method

The basis of our estimation is a regular AIDS model (Deaton and Muellbauer 1980). The store-differentiated AIDS model can be expressed as follows:

$$w_{ij} = \alpha_{ij} + \sum_{k=1}^{K} \sum_{s=1}^{S} \gamma_{ij,ks} lnP_{ks} + \beta_{ij} ln \frac{X}{P^*} \quad (1)$$

where

w_{ij} is the budget share of commodity i, $i = 1,2, \ldots, K$, purchased at store type j, $j = 1,2, \ldots, S$;

P_{ks} is the price of the k^{th} commodity purchased in the s^{th} store type;

X is the household expenditure on all commodities purchased in all store types

$\ln(P^*)$ is the AIDS price index defined as:

$$\ln(P^*) = \alpha_0 + \sum_{i=1}^{K} \sum_{j=1}^{S} \alpha_{ij} lnP_{ij} + \sum_{i=1}^{K} \sum_{j=1}^{S} \sum_{k=1}^{K} \sum_{s=1}^{S} \gamma *_{ijsk} \, lnP_{ij} \, lnP_{sk}$$

$\alpha_{ij}, \gamma_{ij,ks}, \beta_{ij}$ are parameters to be estimated.

Store density variables (DEN) are appended to (1) through the linear translation:

$$\alpha_{ij} = \alpha *_{ij} + \sum_{r=1}^{R} \delta_{ij} DEN_r$$

To estimate the demand system (1), we impose the regular restriction of adding up, symmetry and homogeneity:

Adding up: $\sum_{i=1}^{K}\sum_{j=1}^{S}\alpha *_{ij} = 1;$

Symmetry: $\gamma_{ij,ks} = \gamma_{ks,ij};$

Homogeneity: $\sum_{k=1}^{K}\sum_{s=1}^{S}\gamma_{ij,ks} = 0.$

We then use the Stone index:

$$lnP^{*} = \sum_{i=1}^{K}\sum_{j=1}^{S} w_{ij} lnP_{ij}$$

as a linear approximation of the (nonlinear) AIDS price index.

Finally we assume block separability. This assumption allows us to simplify (1) to

$$w_{ij} = \alpha_{ij} + \sum_{s=1}^{S}\gamma_{ij,ks} lnP_{is} + \beta_{ij} ln\left(\frac{x}{p^{*}}\right)$$

where x is expenditure on a single commodity across all stores. The corresponding restrictions and Stone index in the case of block separability then become:

1. Adding up: $\sum_{s=1}^{S} \alpha *_{is} = 1$;
2. Symmetry: $\gamma_{ij,is} = \gamma_{ij,si}$;
3. Homogeneity: $\sum_{s=1}^{S} \gamma_{ij,ks} = 0$;
4. Stone index: $lnP^{*} = \sum_{j=1}^{S} w_{is} lnP_{is}$

Results

The price elasticities are reported in Table 3. None of the product groups are particularly sensitive to cross price hikes in any type of stores. Interestingly, price hikes in fruits and vegetables in mass merchandising stores and clubs has large negative effect on milk demand in the same store, and the other way around. This seems to indicate complementary association between these food groups. A similar association exists between the ‘unhealthy’ food group – CSD, and fruits and vegetables in other stores. The availability of cheaper CSD seems to depress the demand for produce is grocery stores, but increases the demand for milk by 0.03%.

Income elasticites are positive and close to1 in all food groups at all food stores, except for produce, and vegetables, in particular.

The sensitivity of the demand for the key food groups we are interested in is demonstrated in Table 4.

A 1% increase in supermarkets and supercenters has a very large negative effect on the demand of fruits and vegetables in supercenters and supermarkets. It also has an effect of

Table 3. Price Elasticies.

		Fruit				Veg				Milk				CSD			
		Groc	**Sup**	**Mass**	**Other**	**Groc**	**Sup**	**Mass**	**Other**	**Groc**	**Sup**	**Mass**	**Other**	**Groc**	**Sup**	**Mass**	**Other**
		11	**12**	**13**	**14**	**21**	**22**	**23**	**24**	**31**	**32**	**33**	**34**	**41**	**42**	**43**	**44**
Fruit	11	-0.86***	-0.03***	-0.01	-0.01**	0.07***	-0.01***	0.00	0.01**	-0.01*	-0.01***	0.02***	-0.01**	0.08***	-0.02***	0.01**	0.00
	12	-0.17***	-0.90***	-0.01	0.00	0.00	0.11***	0.00	0.02	0.09***	0.01	0.05***	0.01	0.08***	0.06**	0.04*	0.09***
	13	-0.03	-0.01	-0.29***	0.05***	-0.02	0.01	0.12***	0.05***	0.08***	0.04***	-0.31***	0.06***	0.12***	0.06***	-0.12***	0.05***
	14	-0.04**	0.00	0.05***	-1.21***	-0.08*	0.04	0.07***	-0.08***	0.24***	-0.06*	0.16***	-0.03	0.43***	0.15***	0.11***	-0.28***
Veg	21	0.07***	0.00	-0.01	-0.01*	-0.71***	0.00	0.00	0.01***	0.02**	-0.01***	0.01***	-0.01	0.00	-0.04***	-0.01	-0.02***
	22	-0.05**	0.11***	0.11***	0.11***	0.02	-0.55***	0.05***	0.05***	0.08***	-0.04*	0.09***	0.05***	0.05**	-0.05**	0.03*	0.04**
	23	0.01	0.00	0.24***	0.06***	0.03	0.07***	-0.51***	0.05***	0.09**	0.04	-0.31***	0.10***	0.11***	0.11***	-0.13***	0.07***
	24	0.09**	0.06	0.16**	-0.11***	0.16***	0.11***	0.08***	-1.32***	0.42***	-0.16***	0.29***	0.07	0.30***	0.09**	0.09**	-0.53
Milk	31	-0.03***	0.01**	0.02**	0.03***	0.01	0.01**	0.01**	0.03***	-1.38***	0.02***	0.01*	0.04***	0.05***	0.03***	0.02**	0.04***
	32	-0.10***	0.01	0.06***	-0.04*	-0.10***	-0.05*	0.03	-0.07***	0.15***	-1.61***	0.04	0.14***	0.06	-0.15***	0.12***	0.08***
	33	0.17***	0.10***	-0.87***	0.18***	0.07	0.17***	-0.45***	0.24***	0.06	0.06	-3.23***	-0.04	0.19***	0.28***	-0.44***	0.22***
	34	-0.07*	0.03	0.14***	-0.03	-0.06	0.09***	0.12***	0.05	0.35***	0.20***	-0.03	-1.74***	0.07*	0.07*	0.04	0.13***
CSD	41	0.02***	0.00	0.01*	0.03***	-0.05***	0.00	0.00	0.01***	0.01	0.00	0.01***	0.00	-1.20***	0.01**	0.00	-0.01
	42	-0.09***	0.04**	0.05***	0.05***	-0.17***	-0.04**	0.05***	0.02**	0.10***	-0.08***	0.09***	0.02	0.10***	-0.99***	0.07***	0.04**
	43	0.06**	0.03*	-0.14***	0.05***	-0.05	0.03*	-0.08***	0.03**	0.08***	0.09***	-0.18***	0.02	0.09***	0.10***	-0.99***	0.10***
	44	-0.01	0.06***	0.05***	-0.12***	-0.12***	0.03**	0.03***	-0.16***	0.15***	0.05***	0.08***	0.06***	0.02	0.05**	0.08***	-1.06***

approximately same magnitude, but opposite in sign on milk on other stors. It also seems to have a moderate positive effect on fruit demand in grocery stores. Remarkable, this has no effect whatsoever on increasing the demand for CSD. Therefore, whatever triggers a decrease in produce purchase when the number of supermarkets increases in the vicinity, it cannot be blamed on CSD.

Table 4. Density Elasticities

Food Group	Store Type		*Supermarkets and Supercenters*	*Clubs*	*Convenience stores*	*Specialty stores*	*FS*	*QS*
Fruit	**Groc**	**11**	0.22	0.02			**0.15**	-0.30
	Sup	**12**	-0.62				**-0.41**	0.80
	Mass	**13**	-0.58	**-0.06**	**-0.01**	**0.08**		0.74
	Other	**14**		0.06			0.28	
Veg	**Groc**	**21**						
	Sup	**22**	**-0.69**				**-0.43**	**0.84**
	Mass	**23**		-0.05		**0.07**		
	Other	**24**						
Milk	**Groc**	**41**		**0.02**	**0.00**	**-0.02**	0.10	
	Sup	**42**					**-0.37**	
	Mass	**43**		-0.06	**0.00**	0.04		
	Other	**44**	0.70	0.05			0.32	-1.03
CSD	**Groc**	**61**				-0.02		
	Sup	**62**					**-0.35**	
	Mass	**63**		**-0.06**		**0.07**		
	Other	**64**						

Surprisingly, the only tangible increase in produce consumption was detected in relation with an increase in QS. The demand for milk seems to to decrease elastically in response to the increase in QS.

Concluding Remarks

Poor food choices have been shown to contribute to the rise of major chronic diseases, including overweight and obesity. Factor associated with food choice, therefore, are of prime interest in the fight of obesity. The findings of negative associations between increase numbers of stores and produce consumption is bolstered in our model as sell. We do not find any evidence of a substitution effects between CSD and produce food groups. Neither do we find any support of this hypothesis in the cross-price elasticities.

Future research focusing on redefining food access will perhaps shed light on the true associations between the healthy food and healthy food availability.

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