What's for Dinner? Meat Demand and Separability by Quality and Type in Indianapolis vs. Seattle

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Abstract

Our study compares the demand for high and low quality chicken, pork, and beef in Seattle and Indianapolis during 2008-2010. We determined which of the Barton's General Demand System specifications best fit the data and if beef, pork or chicken demands are asymmetrically separable by either quality or type of meat product. Our data is from a random weight syndicated grocery dataset. This data set provided weekly expenditures on meat products at sample stores within a given city. We found that the Indianapolis data best fist the AIDS model, while Seattle data does not satisfy any of the subset models nested in the Barton Demand system. There is no evidence of asymmetric separability by high quality, low quality, or type of meat, in either Indianapolis or Seattle.

Descriptive Statistics

Table 1: Descriptive Statistics

		Indianapolis				Seattle			
Item		Mean	SD	Min	Max	Mean	SD	Min	Max
High Quality Beef (BH)	Quantity	0.077	0.030	0.045	0.257	0.046	0.013	0.018	0.087
	Share (%)	23.9	5.5	16.1	54.6	16.3	3.5	9.3	26.0
Low Quality Beef (BL)	Quantity	0.248	0.036	0.130	0.375	0.320	0.045	0.225	0.457
	Share (%)	37.3	3.6	21.8	46.4	44.4	4.2	36.1	52.9
High Quality Chicken (CH)	Quantity	0.126	0.026	0.054	0.213	0.123	0.026	0.047	0.183
	Share (%)	17.6	1.5	9.6	21.2	14.4	1.5	9.7	18.5
Low Quality Chicken (CL)	Quantity	0.967	0.029	0.045	0.190	0.065	0.012	0.041	0.101
	Share (%)	5.8	1.1	3.6	9.1	4.2	7.2	3.0	7.1
High Quality Pork (PH)	Quantity	0.590	0.020	0.032	0.168	0.087	0.028	0.039	0.266
	Share (%)	8.6	1.6	5.4	15.1	12.3	1.9	7.7	20.2
Low Quality Pork (PL)	Quantity	0.615	0.028	0.026	0.205	0.078	0.027	0.039	0.220
	Share (%)	6.7	1.8	4.1	12.7	8.2	1.8	5.4	15.6
Population (millions)		3.213	0.004	3.142	3.283	2.057	0.002	2.018	2.095
Total per capita expenditure		2.045	0.220	1.241	2.782	1.819	0.234	1.057	2.443

Barton's General Demand System

Barten (1993) developed a generalized demand model that nests the Rotterdam, AIDS, NBR and CBS models (Eales, Durham, and Wessells (1997). This demand model was similarly used to model consumer demands by Eales, Durham, and Wessells (1997), Eales and Wessells (1999), and by Lee, Brown, and Seales (1994). The Barten model is:

$$dw_i = (\beta_i + \theta_1 \widetilde{w_i}) dlnQ + \sum_{k=1}^{K} (\gamma_{ik} + \theta_2 \widetilde{w_i}(\delta_{ik} - \widetilde{w_k}) dlnp_k \quad (1)$$

$$\mathrm{dln(Q)} = \sum_j \widetilde{w_j} dln(q_j), \quad w_i = q_i * \frac{p_i}{x}, \quad \widetilde{w_i} = 1/2(w_i + lag(w_i))$$

here dw_i is the change in the share of item i, dln(Q) is the Divisia volume index, k is the set of all items in the demand system, x is total expenditure, θ_1 and θ_2 are nesting parameters, β_i is a expenditure coefficient, γ_{ik} are the price coefficients, and δ_{ik} is the Kronecker's delta. The value on θ_1 represents the difference in the marginal budget shares within the Rotterdam and the CBS models (Okrent and Alston, 2011). The marginal budget shares vary with expenditure in AIDS and CBS model, while they are constant in the Rotterdam and NBR models (Okrent and Alston, 2011). The coefficient on θ_2 represents variation in the price coefficients between the Rotterdam and the NBR model (Okrent and Alston, 2011). The compensated slutsky substitution effects are constants in the Rotterdam and CBS models, but vary with expenditure in the NBR and AIDS models (Okrent and Alston, 2011). The values of the parameters $\theta_1$and $\theta_2$indicate which, if any, of the nested models is appropriate to use.

Testing for Nested Barton models

To test which, if any, of the nested models fit the data, a general Barten model was estimated for high and low quality beef, chicken, and pork imposing homogeneity and symmetry. To satisfy adding-up the demand for low quality pork was admitted. The parameter values required for each of the nested models were tested against the unrestricted Barton model using Wald tests. The parameter values and the results of the Wald tests are provided in table 2.

TABLE 2: BARTEN MODEL SPECIFICATIONS AND WALD TEST RESULTS

			Indianapolis			Seattle		
SPECIFICATION	θ_1	θ_2	Wald Test Value	DF	P-value	Wald Test Value	DF	P-value
Rotterdam	0	0	44.1	2	0.0000	347.6	2	0.0000
AIDS	1	-1	2.0	2	0.3745	130.7	2	0.0000
NBR	0	-1	32.7	2	0.0000	192.2	2	0.0000
CBS	1	0	17.4	2	0.0002	285.5	2	0.0000

DF= degrees of Freedom. The Wald test is distributed asymptotically chi-squared with degrees of freedom equal to the number of restrictions imposed. The p-value was based on a 95% confidence level rejection criteria.

For Indianapolis, we could reject with 95% confidence the parameter values for the NBR, CBS or Rotterdam models, but not those of the AIDS model. The Rotterdam, Aids, NBR and CBS models are rejected at a 99% confidence level for Seattle. We conclude that the Indianapolis data satisfies the AIDS model, and the Seattle data satisfies the general Barten model as estimated.

The resulting expenditure and price elasticities evaluated at the mean shares are provided in tables 3 and 4. The expenditure elasticities in both cities are close to one. This implies that a one percent increase in meat expenditure leads to roughly a one-percent increase in the expenditure on each individual item. The expenditure elasticities for high and low quality chicken and pork are higher than those for high and low quality beef in Indianapolis compared to Seattle. Consumers in Indianapolis demand more of these items when total meat expenditure increases than do consumers in Seattle.

The own-price elasticities are less than negative one for all meats, with the majority of these being close to negative two. This indicates that in both Seattle and Indianapolis consumers react strongly to price changes. The demand for meats after a one percent price change decreases by roughly two percent. The own price elasticities for high quality chicken, and high and low quality pork are higher, in Indianapolis compared to in Seattle. After a price increase, consumers in Indianapolis demand less high quality chicken and high and low quality pork than consumers in Seattle. In contrast, the own price elasticities are for high and low quality beef and low quality chicken are greater in Seattle than in Indianapolis. Consumers in Seattle demand less high and low quality pork and high and low quality chicken than do consumers in Indianapolis after a price increase.

Table 3: Indianapolis price and expenditure elasticities

	Price						Expenditure
	BH	BL	CH	CL	PH	PL	
BH	-1.535	0.255	0.193	0.046	-0.057	0.173	0.925
BL	0.085	-1.358	0.102	0.014	0.200	-0.017	0.974
CH	0.204	0.297	-1.858	0.125	0.158	0.061	1.013
CL	0.222	0.303	0.479	-1.894	0.110	0.146	0.633
PH	-0.088	0.707	0.187	0.022	-2.149	0.319	1.001
PL	0.255	-0.307	0.043	0.040	0.421	-1.909	1.456

The elasticities were calculated at the mean shares

Table 4: Seattle Price and Expenditure Elasticities

	Price						Expenditure
	BH	BL	CH	CL	PH	PL	
BH	-2.432	0.871	0.245	0.124	0.191	0.034	0.958
BL	0.538	-1.711	0.016	0.046	0.013	0.057	1.040
CH	0.349	0.072	-1.478	0.079	0.001	0.037	0.941
CL	0.535	0.365	0.255	-2.162	0.058	0.097	0.852
PH	0.523	0.073	-0.009	0.030	-1.804	0.188	0.999
PL	0.061	0.253	0.048	0.063	0.221	-1.857	1.212

The elasticities were calculated at the mean shares

All of the cross price elasticities between meats have absolute value of less than one. In both cities consumers will increase or decrease their demand for other meats less than one percent given a one percent increase in the price of a given meat. Most of the meats are substitutes (have a negative cross price elasticity). Where cross price elasticities are highlighted in red indicates, the goods are complements. Only high quality pork and high quality chicken are complements in Seattle. In Indianapolis, the opposite is true. High and low quality chicken are complements. In Indianapolis we find that high quality pork and high quality beef are complements, as well as low quality beef and low quality pork. These goods are substitutes in the Seattle market.

Asymmetric Separability

A key element of asymmetric separability is that the utility one derives from the consumption of items within separable groups can be examined separately from items not within the groups. This allows us to write the utility function as:

$$u = u\left(q_k, q_m, u(q_i, q_j)\right) \quad (2)$$

Where items i and j are in separable group g, and items k and m are not in group g. Items in group g are asymmetrically separable from each item within groups k and m.

It is necessary that consumers conduct a two stage budgeting process for items to be separable. Consumers first choose how much to allocate between groups, then determine how much to allocate within the groups. Following from this, substitution effects of price changes are felt both through expenditure and income effects for items within the same group (Okrent and Alston, 2011). On the other hand, if items are separable *"the compensated effects of price changes in items in different groups are only felt by reallocation of expenditure among groups"* (Eales and Unnevehr ,1988).

Asymmetric seprability implies that the compensated cross-price elasticities in the Slutsky matrix are functions of the income elasticities between the items within the separable group and items outside the separable group. This can be expressed as:

$$\frac{\sigma_{i,k}}{\sigma_{j,k}} = \frac{\epsilon_i}{\epsilon_j} \text{ or equivalently } \sigma_{i,k} = \frac{\epsilon_i}{\epsilon_j} * \sigma_{j,k} \quad (3)$$

Where i and j are goods in separable group g, k is an element not in group g, $\sigma_{i,k}$ is the Allen-Uzawa elasticity of substitution, and ϵ_i is the expenditure elasticity (Eales Wessell, 1999, Moschini, Moro and Green, 1994).

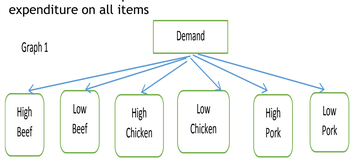
To impose separability, equation 3 replaces the original term in the Slutsky matrix of the estimated demand system. The formula we used to impose these restrictions is:

$$y_{i,k} = \frac{(B_i + w_i(\theta_1 + 1))}{(B_j + w_j(\theta_1 + 1))} * \left(y_{j,k} - w_j w_k(\theta_2 - 1)\right) + w_i w_k(\theta_2 - 1) \quad (4)$$

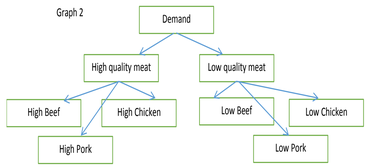
For more detail see Eales and Wessell (1999).

Potential Separability Relationships

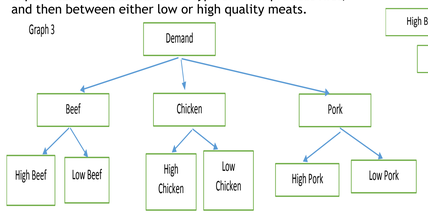
Graph 1. No separability relationships exist between the types or qualities of meats. The demand for each item is a function of the prices of the other items and the total expenditure on all items



Graph 2. High quality meats are separable from low quality meats and low meats are separable from high quality meats. This implies that expenditure is allocated between high and low quality meat first, then to specific meat types within each category.



Graph 3. Beef, Chicken and Pork are separable from each of the other meat types. This implies that expenditure is allocated to the type of meat product first, and then between either low or high quality meats.



Testing for Separability

To test for separability, an unrestricted model and restricted models with the different separability conditions imposed at the mean shares were compared using a likelihood ratio test. The likelihood ratio test statistics were adjusted using the correction factor suggested by Italiar, 1985. Doer and Harkema (1989) found evidence that this size correction factor works well when testing consumer demands. The results are given in table 5.

Table 5: Separability Test Results

	Indianapolis			Seattle		
Hypothesis	LLR Statistic	DF	p-value	LLR Statistic	DF	p-value
High meats separable from low meats	20.00	6	.00277	596.07	6	0.0000
Low meats separable from high meats	457.39	6	0.0000	591.04	6	0.0000
Beef Separable from all other meats	784.61	4	0.0000	115.03	4	0.0000
Chicken separable from all other meats	504.70	4	0.0000	479.88	4	0.0000
Pork Separable from all other meats	358.05	4	0.0000	578.53	4	0.0000

The above are Likelihood Ratio tests, calculated as 2*(LLU-LLR) where LLU is the log-likelihood ratio of the restricted model and LLU is the log-likelihood ratio of the restricted model. The test statistic is distributed Chi-Squared with the degrees of freedom equal to the number of restrictions.
The p-value is the probability of rejecting the null hypothesis that the restricted model is not different from the unrestricted model

Asymmetric separability for meats by type and by quality is rejected for both Indianapolis and Seattle. Our results indicate that consumers jointly make choices on the type and quality of beef, chicken, and pork when making purchase decisions in the Indianapolis and Seattle markets.

Conclusion

We examined the demand for beef, pork and chicken by type and quality in the Indianapolis and Seattle markets during 2008-2010. The data for Indianapolis best fits an AIDS model, while the Seattle data does not satisfy any of the subsets of the general Barton model. We find no indication of separable relationships between individual meat types of quality levels.

Finding differences in meat demand models for Seattle vs. Indianapolis is not surprising. These two markets are very different. The average median household income in Seattle over the time period 2008-2012 was $15,096 higher than that of Indianapolis. 17.5% of the population in Seattle classified themselves as foreign born in 2012 vs. only 4.6% of the population in Indianapolis. Indianapolis had a population in 6,537,334 while that of Seattle was only 634,535 in 2012. (US Census Bureau)

Our separability findings are robust, given our data, the aggregation methods we used, and testing for separability at the mean expenditure shares. Regardless, the following are potential issues to consider: 1) The initial compilation of the data into categories of different types of meats could be aggregating asymmetric separable items and disaggregating non-separable items; 2) The use of linear population growth trends to calculate per capita estimates assumes that there is a steady change in the portion of the city's population shopping at the stores in our sample. This assumption could be false. A change of the population shopping at the sampled stores could results in asymmetric separability relationships being present in specific time periods within the sample; The choice of stores in our sample may be biased towards consumers of income levels, tastes, habits and other characteristics that re not representative of the city's population as a whole. The model specification and lack of asymmetric separability results may be different for the city as a whole. 4) Tests for separability using the Barton demand model could potentially provide different results depending on the choice of expenditure share values. To completely rule out asymmetric separability one needs to test for separability relationships at all possible expenditure share values. One may uncover asymmetric separability relationships using different expenditure share values.

The different demand model specifications for Indianapolis and Seattle demonstrate that researchers cannot assume that similar demand models, and resulting expenditure and cross-price elasticities, apply across different regions. This is a valuable contribution for further research involving meat demands. It is important information for food companies and producers making pricing decisions or when evaluating the decision to expand into different regional markets.

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