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Running Title: Demand for Unobserved Attributes

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Abstract:

We analyze consumers' demand for mint gum accounting for product heterogeneity and unobservable, to the econometrician, flavor quality. We use the control function (CF) approach in the context of a discrete choice logit model in an oligopolistic framework, where price-setting firms endogenously determine prices. We found that when using the control function approach, demand estimators are improved by reducing potential biases generated by endogeneity. We found that gum is price inelastic with respect to price and quality. Implications for the mint oil industry in the Pacific Northwest are cited.

Key Words: Control Function Approach, Quality Differentiation, Unobserved Product Attributes, Demand Estimation, Gum.

JEL: L11, L13, L66.

1. Introduction

Chewing gum is one of the best-performing segments within the confectionery market, and the global market for gum is forecasted to reach $20.7 billion by the year 2015 (GIA, 2011). The industry is characterized by its product innovation, focused on novel and unique flavors, new ingredients, different product shapes, varied colors, and distinctive packaging techniques (GIA, 2011). Typically, gum composition includes a gum base, sweeteners, and a variety of flavors. Flavor is the major source of product differentiation, which is reflected in the high number of products with different flavors available in the market. Across all available gum flavors, mint holds the largest share, accounting for approximately 50% of the total market share (Nielsen, 2005). Mint flavor is obtained from mint oil. Eighty-three percent of all U.S. mint oil (and 50% of all worldwide production) is produced in the Pacific Northwest (Washington, Oregon, and Idaho)[1]. However, the share of U.S. produced mint oil in the gum market has fallen in recent years. Dealers buy cheaper and lower quality oil from China and India and blend these oils with the more expensive, high quality U.S. oil to accommodate gum manufacturer's standards[2]. This has been reflected in the decline in the number of mint plant acres harvested in the U.S. by 37% from 1993 to 2010, and the decline in domestic mint oil prices by 23% (USDA-NASS).

The supply chain of mint oil involves three parties: (1) mint oil producers who sell mint oil to the dealers, (2) mint oil dealers who mix different mint oils to generate the final flavoring oil mixtures, and (3) gum manufacturers who buy the oil mixtures from dealers to produce gum. For each category of mint flavor gum (e.g. double mint, mint splash, or cool mint), the gum

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[1] Information obtained from: http://www.farwestspearmint.org/history.htm

[2] Based on personal communications with Rod Christensen, President of Far West Spearmint Oil Administrative Committee, August 8, 2010.

manufacturer demands a specific mixture of mint oils from the dealer. This specific mint oil mixture is the result of blending mint oils from different qualities, which are measured in terms of the presence of oil components. The mixture of oils from different growing regions used in the final product leads to the lower flavor quality, in terms of strength and duration.[3]

The substitution patterns in consumer demand between high-quality domestically produced oil and low-quality imported oil is important to the U.S. mint oil industry, as its market share has been decreasing with the increase of imports and has been losing negotiating power with gum manufacturers. However, estimation of the elasticity of substitution is difficult because the researcher does not observe differences in the quality of the mint oil used to produce each gum flavor, as each gum recipe is proprietary information of the manufacturing firms.

One alternative is to analyze the consumers' demand for mint gum, accounting for product heterogeneity and unobservable, to the econometrician, product characteristics such as flavor quality. This approach assumes that consumers have a predetermined ranking of flavors based on their own preferences. Thus, consumers know which flavor delivers them the highest utility. Although the differentiation is purely subjective, the differences in flavor profiles for each gum product are real, rather than merely perceived by the consumers. For a discussion of price competition in a setting when product differentiation is purely subjective, see Tremblay, et al., (2002). From the literature on product differentiated oligopolistic models, we know that unobservable product attributes generate endogeneity of prices, leading to biased estimators. The present study considers a control-function approach as a strategy for parameter identification using household-level data.

[3] Typically, mint oil contains menthofuran. This substance reduces palatability. Oils that contain high levels of menthofuran are considered lower quality, whereas oils with lower level of this substance are considered high quality. Personal communication with mint dealer company representative, August 8 2010.

Only a few studies have been conducted on brand choice and products using mint oil as flavoring ingredient, such as in gum and other mint flavored products. For toothpaste, previous studies include Kaya, et al., (2010), Gutierrez (2005), Yang, et al., (2005) and Shin (2008); and for chewing gum, Chung, et al., (1997). All of these studies examine factors that affect brand selection. In general, these studies use discrete choice models with product characteristics and other consumer specific exogenous variables to explain consumer choices, but ignoring the existence of unobservable product characteristics and then the potential endogeneity and bias in the estimated parameters. Toro-Gonzalez et al., (2011), estimate the aggregate demand function for mint-flavored gum in presence of unobserved product attributes based on a nested logit (NL) specification with aggregate market level data and using the "product-market" approach as identification strategy (Berry, 1994) and found that gum has a price inelastic demand, and verify the importance of controlling for unobserved product attributes such as flavor quality when estimating the demand for gum.

The aim of this study is to estimate the individual level demand for mint-flavored gum accounting for the existence of unobservable flavor quality attributes. We use a discrete choice model for gum demand in an oligopoly context, where price-setting firms endogenously determine prices. We also account for the existence of product characteristics unobservable to the researcher, but fully considered by gum manufacturers, when setting prices and by consumers when purchasing the products. However, different from Toro-Gonzalez, et al. (2011), we use the control function approach (Petrin, et al., 2009) as the identification strategy, in the context of a logit model using household information on 2005 grocery store gum purchases.

The article is organized as follows. In the next section, we describe the utility representation and the control function approach as the identification strategy. Next, we describe the empirical model in the context of mint gum. In the subsequent section, we present a description of the dataset used, followed by the estimation results where price and quality elasticity are analyzed. Finally, we discuss implications and conclusions.

2. Empirical Framework

Consider consumer i choosing among j products in market t where the prices are endogenously determined because of the inability of the researcher to observe all the product attributes. The utility that consumer i obtains from product j in market t is specified by:

$$U_{ijt} = V(p_{jt}, x_j; \theta_i) + \varepsilon_{ijt} \qquad (1)$$

$$\varepsilon_{ijt} = \varepsilon_{jt}^1 + \varepsilon_{ijt}^2$$

Where p_{jt} is the price of product j in market t; x_j is a vector of observed exogenous variables that affect the utility derived from product j; θ_i are unobserved parameters that represent the tastes of consumer i. The error term (ε_{ijt}) in the utility function is divided into two parts, ε_{jt}^1 represent all the unobserved product attributes that are correlated with price, and ε_{ijt}^2 is a random term.

Assume the price for each product is correctly specified as a linear function of some observed exogenous variables z_{jt}, plus a separable non-observable term μ_{jt}:

$$p_{jt} = \gamma z_{jt} + \mu_{jt} \qquad (2)$$

where z_{jt} is a vector of observable variables that do not enter the utility directly but do impact the prices (p_{jt}), and the additively separable term (μ_{jt}) represents all the unobserved factors affecting prices, and are independent of the error term ε_{jt}^2 in the utility function.

We assume that prices are correlated with the utility specification error terms (ε_{ijt}), creating endogeneity. The control function approach consists of deriving a proxy variable for ε_{jt}^{1}, such that we account for the unobserved factors affecting p_{jt} (Petrin, 2009). We rely on economic theory to estimate an alternative pricing equation containing information on the unobserved demand factors. This leaves the remaining variation in the endogenous variable independent of the error component ε_{ijt}^{2}, and turning the standard estimation approaches to be consistent (Petrin, et al., 2009). In contrast to the more traditional instrumental variables (IV), the control function approach leaves the endogenous variable in the original specification of the model and adds up a new term (μ_{jt}) that accounts for the relation between the endogenous variable and the error term.

The benefits of this approach is that in order to obtain consistent estimates, one does not have to rely on aggregate data level information, as in the cases of Berry (1994), Berry, et al. (1995), and Nevo (2001), enabling the incorporation of consumer heterogeneity into the analysis.

The utility with the control function for all the j alternatives assuming homogeneous preferences is:

$$U_{ijt} = V\left(p_{jt}, x_j, \theta\right) + \varepsilon_{ijt} \tag{3}$$

$$V\left(p_{jt}, x_j, \theta\right) = x_j\beta - \alpha p_{jt} \tag{4}$$

$$\varepsilon_{ijt} = \lambda\mu_{jt} + \varepsilon_{ijt}^{2} \tag{5}$$

Substituting terms we have:

$$U_{ijt} = x_j\beta - \alpha p_{jt} + \lambda\mu_{jt} + \varepsilon_{ijt}^{2} \tag{6}$$

Where p_{jt} is the price of product j in market t, x_j represents product specific observable characteristics including: flavor, if the product is sugar free, the form of the product, texture, and physical volume or size of the package. Included in the vector x_j are some interactions of the product characteristics with household characteristics such as income, number of members, existence of children and age. The variable μ_{jt} represents the unobserved terms derived as the residuals of the pricing equation with a structural interpretation. That is, all the unobserved factors affecting the price of each product $\theta = (\beta, \alpha)$ are the unobservable parameters of the observable product characteristics, and λ is the parameter that captures the effect of the unobserved product attributes. Assuming ε_{jt}^2 is distributed type I extreme value the model is estimated as a logit model.

The model is estimated in two stages. First, the price is regressed on observed choice characteristics and the instruments (z_{jt}). The residuals of this regression ($\hat{\mu}_{jt}$) are retained and used as a control variable or control function in the next step. Second, the choice model is estimated with the control function μ_{jt} entering as an extra variable in the regression.

Step 1: $$\hat{\gamma} = \left(z_{jt}{}'z_{jt}\right)^{-1} z_{jt}{}'p_{jt} \qquad (7)$$

$$\hat{\mu}_{jt} = p_{jt} - \hat{\gamma} z_{jt}$$

Step 2: $$U_{ijt} = x_j\beta - \alpha p_{jt} + \lambda\hat{\mu}_{jt} + \varepsilon_{ijt}^2 \qquad (8)$$

The control function assumes that the price equation is correctly specified. Hence, the appropriate control function and distribution of ε_{ijt}^2 is a specification issue. We follow Tremblay et al. (1995) to estimate an alternative pricing equation, containing information on the unobserved demand factor. Assume that the profit maximizing firm l in market t faces the following profit function,

$$\pi_{lt} = p_{lt}(q_{lt}, Q_{kt})q_{lt} - C_{lt}(q_{lt}) \qquad (9)$$

where p_{lt} is price received by firm l in market t, q_{lt} is firm l's output, Q_{kt} is the total output of firm l's rivals (i.e., industry output minus q_{lt}), and $C_{lt}(q_{lt})$ is firm l's total cost function. The firm's first-order condition of profit maximization is:

$$\partial\pi_{lt}/\partial q_{lt} = p_{lt} + q_{lt}[\partial p_{lt}/\partial q_{lt} + (\partial p_{lt}/\partial Q_{kt})(\partial Q_{kt}/\partial q_{lt})] - MC_{lt} = 0 \qquad (10)$$

where $\partial Q_{kt}/\partial q_{lt}$ is the firm's conjectural variation, and MC_{lt} is marginal cost. For the empirical estimation, this condition is written as:

$$p_{lt} = MC_{lt} + \varphi q_{lt} \qquad (11)$$

$$\varphi = -[\partial p_{lt}/\partial q_{lt} + (\partial p_{lt}/\partial Q_{kt})(\partial Q_{kt}/\partial q_{lt})]$$

where, the parameter (φ) represents the market power of the firm l in the market t. This rearranged first-order condition is the firm's supply relation and summarizes the actions of the firm under different behavioral assumptions. The market is efficient if price equals marginal cost, which occurs when φ equals zero. Positive and larger values of φ imply a divergence of price from marginal cost and a greather degree of exerted market power or allocative inefficiency. Another way to name the term φq_{jt} is the markup ($M_{jt} = \varphi q_{jt} = p_{jt} - MC_{jt}$). Hence, the pricing equation can be represented as the sum of the marginal cost (MC_{jt}) and the markup (M_{jt}):

$$p_{jt} = MC_{jt} + M_{jt} \qquad (12)$$

Because the marginal cost and the markup are both unobservable variables, we substitute the terms MC_{lt} and M_{lt} for functions of their determinants, z_{lt}^1 and z_{lt}^2 respectively.

$$p_{lt} = \gamma_1 MC_{lt}(z_{lt}^1, v_{lt}^1) + \gamma_2 M_{jl}(z_{lt}^2, v_{lt}^2) \qquad (13)$$

Where $z_{lt} = [z_{lt}^1 \quad z_{lt}^2]'$ and $v_{lt} = [v_{lt}^1 \quad v_{lt}^2]'$ are the observed and unobserved characteristics, respectively; and $\gamma = [\gamma_1 \quad \gamma_2]$ are unobserved parameters. The empirical model for the pricing equation estimation in terms of factors that affect marginal cost and markup is given by equation

(2).

The factors affecting marginal costs (z_{lt}^1), in each market t, are (1) in-state labor cost given by the official minimum wage in each state for the year 2005; (2) transportation costs, or the distance from the production plants as proxies; (3) labor production costs for each product captured by the official minimum wage in the state where the production of each firm was generated; (4) gas prices as a measure of transportation costs and input prices; and (5) indicator variables for each flavor to capture other differences in the production process for each product.

We include three factors affecting the markups (z_{lt}^2) in each market t, the number of products in the market as a measure for the competition[4], and binary variables per firm and brand to capture firms' ability of maintaining markups and the brand advertisement effect.

3. Data

The database consists of 106,496 observations of daily household grocery store purchases of bubble and chewing gum from the AC Nielsen Home-scan survey for 2005[5]. The information was collected in 2,106 counties distributed across the 49 contiguous states. The overall sample consists of 19,702 participant households with fifteen purchases, on average, during the sample period. The minimum purchases for a household is one, and the maximum is 176. Around 24% of the households have between two and five purchases registered in the sample, and approximately 70% of the sample corresponds to households with more than six purchases during 2005.

There are 176 counties in which the recorded sales belong to just one specific product

[4] According to Volpe (2011), "supermarkets utilizing everyday low pricing operate more efficiently than those using other strategies".

[5] USDA Third Party Agreement signed on October 19, 2010.

during all the year. Since we do not have information on the actual product assortment for each market, we use the number of products available at the state level as a proxy variable for production assortment in each county.

We have information on 563 different gum products, nationwide. Out of this number, 116 represent mint-flavored gum. At the state level, the minimum number of products in a given state is 21 and the maximum is 123. However, the actual range of products purchased in a county varies from 1 to 75. Out of the 2,106 counties in the sample, 130 were eliminated because only one observation is reported. Thus, the number of counties is reduced to 1,976, all of them with at least two observations. Each observation is a reported sale of a product, and each product is defined as the combination of gum brand and flavor[6].

Under the assumption that the number of products available at the state level is the same as in each county, we have information for over 32% of the choices. In general, 55% of the total sample is related with counties where the observed number of products with respect to the state variety is lower than 32%, this is 58,665 out of 106,366 total observations. The rest of the 47,701 observations, represent 158 counties across the nation. Recent studies on consumer welfare from new brand introductions by Arnade et al (2011) found substantial regional variation in the distributional effects of new brand introduction. Table 1 presents the descriptive statistics of the main variables in the model.

4. Estimation Results

We first estimate the pricing function to recover the residuals entering the control function in the choice model. The residuals of the initial regression enter the logit model without

[6] This market is not affected by private label strategy as studied recently by Richards et al. (2010).

transformation, that is, the control function is the coefficient λ times the product-market residual (μ_{jt})[7].

Table 2a presents the parameter estimates of the model without the control function variable (first column) and estimates of the model using the control function approach (second column). Without the control function correction, the base price coefficient α is estimated to be 0.652, negative and statistically different from zero. The inclusion of the control function adjusts the estimated price coefficient in the expected way. That is, the absolute value of the coefficient increases to 1.96. This result suggests that the price coefficient has been isolated from some of those unobservable factors affecting the decision. Some other coefficients of the marginal utility are also statistically significant, such as size, sugar-free, and form.

The coefficient of the control function is statistically significant and has the expected positive sign. A positive residual occurs when the observed attributes and other observed factors are not enough to explain the price of the product. This result suggests that the product posses desirable attributes that are not included among the observable product characteristics. The statistical significance of the control function parameter (λ) is then interpretable as a Hausman test for endogeneity. This test evaluates the null hypothesis that $\lambda = 0$ (Imbent, 2007).

In general, with the control function approach, the correction for omitted variables increases the estimated price coefficients for the choice model. Compared with aggregate models, the household-level model incorporates more heterogeneity into the estimates. Comparing the results for mint gum flavored market calculated by Toro-Gonzalez et al. (2011), the price effects under the control function approach are higher. The difference seems to be

[7] Results of the reduced for estimation are presented in Table 2b.

explained by the nature of the data. Their model uses aggregated information over all households in each state. The present study uses disaggregated household level information, increasing the observed heterogeneity. A similar phenomenon was identified in beer studies using disaggregated data. Hausman, Leonard, and Zona (1994), Rojas and Peterson (2008), and Bray, Loomis and Engelen (2009) found evidence that price elasticities across product brands are more elastic than price elasticities obtained by using the whole dataset.

This modeling strategy allows calculating price and quality elasticity by flavor and product. Owing to the relevance of the crop for the Pacific Northwest of the United States, we focus specifically on spearmint-flavored products. The estimated average price elasticity obtained for all gum flavors is -0.306, with a standard deviation of 0.01.

Consumers seem to be less sensitive to changes in quality compared to price. The average quality elasticity is 0.009. That is, if quality increases in 10%, the quantity demanded increases in 0.09% (see Table 3). Price and quality elasticities for 18 spearmint-flavored gum products are presented in Table 4. Price elasticities range between 0.18 and 0.67 show that spearmint gum is price inelastic. In terms of quality elasticity note that the product is very inelastic to changes in quality; however, there is significant variation among products from 0.001 to 0.07. The implications of this finding are very important for mint oil producers, because the empirical evidence on individual consumer preferences supports the existing trend towards the use of lower quality mint oils. Given that consumers are not very sensitive to changes in flavor, then the industry might face an increase in the import mint oils market shares.

Results, on an individual household basis, seem to be negligible as gum purchase represents a minimum portion of household expenditures. However, if we consider total consumption of spearmint gum in the US, we find that changes in mint quality flavor may affect sales up to 180 million dollars yearly. These changes would surely affect the demand for domestic mint oil.

Finally, in spite of the small sensitivity to changes in quality flavor at individual level, we find a positive and statistically significant relation between quality and price was identified, which reflects that consumers have a positive willingness to pay for this attribute.

5. Conclusions

We applied the control function approach to account for endogeneity in discrete choice models. We found evidence that when using the control function approach, demand estimators are improved by reducing potential biases generated by endogeneity. The implementation of this method verifies the importance of unobserved product quality characteristics in price determination. We found that gum is price inelastic with respect to price (-0.306) and quality (0.009).

The implications of this study are that consumers positively value quality but this effect is negligible, if measured for individual gum demand. These results are intuitive since they are aligned with the substitution patterns identified in the use of mint oil. Since consumers are not very sensitive to changes in quality, the incentives of the industry are oriented to reduce costs by buying cheaper oil.

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Table 1. Descriptive Statistics for Variables Used in the Control Function Model for Gum Demand

Variable	Mean	Std. Dev.	Min	Max
Mint Flavor	0.514	0.500	0	1
Spearmint Flavor	0.177	0.382	0	1
Price per Unit (Dollars)	0.825	0.347	0.005	2.89
Size (Ounces)	17.15	17.67	1	380
Sugar-Free	0.586	0.493	0	1
Form	1.587	0.604	1	3
Texture	0.829	0.377	0	1
Minimum Wage (Dollars)	5.481	0.757	2.65	7.35
Distance from Plant (Miles)	793.3	621.5	0	2424
Gas Prices per Gallon (Dollars)	2.178	0.157	1.94	2.61
Household Income (Rank)	19.416	5.642	3	27
Household Size (People)	2.868	1.448	1	9
Age (Rank)	6.480	1.835	1	9
Children Under 18	0.401	0.490	0	1
Total Observations				106,366

Source: AC Nielsen Data.

Table 2a. Parameter Estimates of the Logit and Control Function Model for Gum Demand

Variable	Logit		Control Function	
Price (α)	-0.6520	***	-1.9665	***
	0.0261		0.0477	
Size	-0.0309	***	-0.0228	***
	0.0011		0.0012	
Sugar-Free	1.6970	***	1.8334	***
	0.0170		0.0176	
Form (Piece)	-0.3595	***	-0.3135	***
	0.0162		0.0163	
Income	-0.0004		0.0001	
	0.0015		0.0015	
Household Size	0.0039		0.0054	
	0.0081		0.0082	
Age	0.1192	***	0.1224	***
	0.0046		0.0047	
Children under 18	-0.3497	***	-0.3538	***
	0.0231		0.0233	
Married	-0.0311	**	-0.0265	*
	0.0192		0.0194	
Hispanic	-0.1158	***	-0.1320	***
	0.0267		0.0269	
Control Function (λ)			2.0016	***
			0.0584	
Constant	-0.1940	***	0.6271	***
	0.0705		0.0754	
Observations	87627		87627	
Pseudo R^2	0.1523		0.1627	

Legend: * p<0.05; ** p<0.01; *** p<0.001 (S.E.)

Source: AC Nielsen Data, calculations by the authors.

Table 3b. Parameter Estimates of the Structural Equation for the Control Function

Variables	Coefficients	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Volume	0.012	0.000	53.220	0.000	0.01	0.01
Sugar Free	0.323	106.603	0.000	0.998	-208.62	209.26
Form	-0.060	0.004	-15.920	0.000	-0.07	-0.05
Texture	0.978	105.945	0.010	0.993	-206.67	208.63
Variety in the market	0.000	0.000	5.660	0.000	0.00	0.00
Wage Index	0.014	0.001	10.960	0.000	0.01	0.02
Distance from the plant	0.000	0.000	4.920	0.000	0.00	0.00
Marginal Cost of Labor	-0.008	0.004	-1.840	0.065	-0.02	0.00
Amurol	0.904	108.120	0.010	0.993	-211.01	212.82
Hershey	0.505	213.699	0.000	0.998	-418.34	419.35
Other Producers	0.675	108.135	0.0100	0.995	-211.27	212.62
Gas Price	0.039	0.005	7.3500	0.000	0.03	0.05
Number of obs =						105362
R-squared =						0.5214

Source: AC Nielsen Data, calculations by the authors.

Table 4. Price and Quality Elasticities by Flavor

Flavor	Price	S.E.	Quality	S.E.
Peppermint	-0.359	0.092	0.006	0.007
Spearmint	-0.305	0.055	0.011	0.006
Other mint	-0.295	0.043	0.009	0.005
Fruit	-0.288	0.074	0.009	0.016
Spice	-0.328	0.100	0.007	0.012
Variety	-0.211	0.148	0.010	0.026
Sour	-0.467	0.158	0.005	0.006
Other	-0.273	0.144	0.010	0.018

Source: AC Nielsen Data, calculations by the authors.

Table 5. Price and Quality Elasticities by Product

Name of the Brand	Price Elast.	Quality Elast.
ADAMS FRESHEN-UP C	0.274	0.001
SPRY CS	0.346	0.001
WRIGLEY'S FREEDENT CS	0.67	0.017
CTL BR C	0.256	0.07
CARE*FREE CS	0.292	0.001
STICK*FREE CS	0.307	0.004
CTL BR CS	0.185	0.002
ICE BREAKERS C	0.315	0.016
ADAMS TRIDENT WHITE CS	0.327	0.01
ADAMS TRIDENT CS	0.343	0.008
WRIGLEY'S ORBIT WHITE CS	0.341	0.004
ADAMS DENTYNE ICE CS	0.306	0.009
WRIGLEY'S FREEDENT C	0.359	0.011
WRIGLEY'S ORBIT CS	0.378	0.008
WRIGLEY'S SPEARMINT C	0.251	0.013
WRIGLEY'S ECLIPSE CS	0.295	0.002
WRIGLEY'S EXTRA CS	0.291	0.016
WRIGLEY'S DOUBLEMINT C	0.275	0.018

Source: AC Nielsen Data, calculations by the authors.