International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 11, No. 4, 2023, pp. 207-227

RESPONSES OF CONSUMER AND MANUFACTURER TO THE SALMONELLA OUTBREAK IN THE U.S. PEANUT BUTTER MARKET

Sungtae Eun
Research Fellow in Industrial and Economic Research Division of Jeonbuk Institute, 1696 Kongji Patjwi-ro, Jeonju-si, Jeollabuk-do, 55068, South Korea
Email: steun99@gmail.com, ORCID: 0000-0002-0325-9662

Abstract

This study analyzes the effect of foodborne outbreaks that occurred in 2006 and 2008 in the peanut butter industry across the United States. The objective of this study was to estimate the demand and pricing conduct in the peanut butter industry under the salmonella outbreaks. The study applied a random coefficients multinomial logit demand for differentiated peanut butter brands. With own and cross-price elasticities and cost parameters corresponding to those products' attributes, the study analyzes the effect of a foodborne outbreak on consumers' behavior and manufacturers' pricing performance. Furthermore, this study used the demand estimates to measure the market power of peanut butter brands. Consumers react negatively to price in all cities, but the other taste parameter estimates for calorie, fat, sugar, and protein had a wide distribution, depending on consumers' demographics. For pricing conduct, the cities indicated higher Lerner indices when the city shifted the pricing conduct.
Keyword: C*onsumer behavior, pricing conduct, salmonella outbreak, peanut butter, sentiment score, random coefficient logit model, industrial organization, Lerner index*
JEL Codes: *D11, D12, D47, D91*

1. Introduction

The consumer decision-making process generally involves the following steps: (1) identifying a good, (2) considering alternatives, and (3) making a decision. Consumers and manufacturers are stakeholders in trying to obtain their own benefits in the market. Consumer behavior relates to potential customers' circumstances where they live in, whom they live with, and what they are really aware of their preferences. Manufacturers attempt to convince customers to purchase a good by differentiating products. The differentiation is processed with observable characteristics affecting the demand, such as price, size, and flavor of a product. In addition, the unobservable factors influencing a customer's choice can be various, such as neighbors' opinions and good/bad information about the product from the media. The strategies between the two entities are to increase their utilities upon reasonable consumption and to increase market share with higher profits. This study analyzes the effect of foodborne outbreaks that occurred in 2006 and 2008 in the peanut butter industry across the United States. The peanut butter industry is an interesting case study in the food industry regarding product differentiation and market structure. A simple observation of the evolution of peanut butter prices at the retail and manufacturer's levels and the peanut farm prices' evolution (Figure 1) can signal the potential exercise of market power in this industry. Another exciting feature of this industry is two salmonella outbreaks, as indicated by the vertical lines in Figure 1. The first outbreak was reported in the summer of 2006 and involved two brands produced by ConAgra. The second outbreak occurred in the spring of 2009 and involved brands produced by the Peanut Corporation of America (PCA).

Food safety issues have been a major concern for both public health and the food industry (Gao et al., 2015). The peanut butter industry is a highly concentrated manufacturing industry, and the big three companies J.M. Smucker, Unilever, and ConAgra Foods control more than 90% of the peanut butter market. Peanuts are vulnerable to bacterial infection (Cavallaro et al., 2011), and infected peanuts can be used to produce peanut butter in the absence of good manufacturing practices and unmanaged storage environments. There were two major foodborne outbreaks of the salmonella bacteria. The first outbreak generated the Peter Pan of ConAgra Foods, which brought 628 infected patients across 47 states (Centers for Disease Control and Prevention [CDC], 2020). The second outbreak began with nine deaths and 172 infected patients between November 2008 and April 2009 (CDC, 2020). The PCA's contaminated peanut butter was sold to schools, the military, and nursing institutions, including about 200 food companies (Leighton, 2015). The objective of this study was to estimate the demand and pricing conduct in the peanut butter industry under the salmonella outbreaks: estimating a differentiated demand under a scenario that ignored the salmonella outbreaks and under one that considered the outbreaks. The study applied a random coefficient multinomial logit demand for differentiated peanut butter brands. As noticed of the BLP (Berry, Levinsohn, Pakes) method, this study used the data of two metropolitan areas to estimate the models considered: Chicago and Los Angeles. The rationale was to examine whether these markets in different U.S. regions showed similar behavior on the demand and supply sides. Various studies have been conducted to estimate the demand at the brand level, such as coffee (Gebrehiwot & Daloonpate, 2012; Yohannes et al., 2016), meat (Basarir, 2013), wine (Capitello, 2015), automobile (Moraga-González, 2018), and ready-to-eat cereal (Chidmi & Lopez, 2007). However, this is the first study that incorporates the salmonella outbreaks to estimate consumers' preferences and manufacturers' pricing strategies for different geographical locations. Previous studies dealing with outbreaks mainly focused on the demand side (see, for example, Deodhar & Fletcher,1998; Zhang et al., 1995).

2. Methods and Data

Random Coefficient Logit Model

Berry (1994) analyzed consumer behavior in differentiated goods, and there was a problem of endogeneity. The endogeneity caused by unobserved product characteristics led to misspecification in the analysis. The paper suggested the mean utility to avoid the problem by flipping the utility function. The utility of the consumer by purchasing a good is derived from Eq. (1):

$$U_{ij} = \alpha_i p_j + \beta_i x_j + \varepsilon_{ij} \tag{1}$$

where $i = 1, \dots, n$ indicates the consumer; $j = 1, \dots, J$ indicates the brand; x_j is a vector of the observed product characteristics of brand *j*; p_j is the price of brand *j*; α_i and β_i are taste parameters unique to each consumer; and ε_{ij} is the distribution of consumer preferences around the unobserved product characteristics with a probability density function $f(\varepsilon)$. The indirect utility function is decomposed into two parts in Eqs. (2a) and (2b):

$$a_i = \alpha + \lambda D_i + \gamma v_i \tag{2a}$$

$$\beta_i = \beta + \varphi D_i + \rho v_i \tag{2b}$$

α_i and β_i are to be decomposition into fixed and variable components that change with consumers' observable and unobservable characteristics. D_i denotes observed consumer characteristics, such as demographics, and v_i denotes the unobserved consumer characteristics. To derive the parameter estimates, the BLP method applies specific steps using the market share in Eqs. (3a) and (3b):

$$s_j = \frac{\exp(\delta_j+\mu_{ij})}{1+\sum_{j\in J}\exp(\delta_j+\mu_{ij})} \quad (3a)$$

$$s_0 = \frac{\exp(0)}{1+\sum_{j\in J}\exp(\delta_j+\mu_{ij})} \quad (3b)$$

The market share of outside goods comes from the subtraction from the market share of the choice set: $S_0 = 1 - \sum S_j$. Normalizing the utility of the outside goods to zero and taking a log with the regression, the parameter estimates can be measured.

In the retail industry context, endogeneity appears when there is a correlation between the markup and unobserved costs. The correlation is from unobserved product characteristics, and retail markup endogeneity can be solved using control functions (Hovhannisyan et al., 2014). This study shows how to estimate demand and cost parameters in the differentiated peanut butter market. With own and cross-price elasticities and cost parameters corresponding to those products' attributes, the study analyzes the effect of a foodborne outbreak on consumers' behavior and manufacturers' pricing performance. Furthermore, the paper applies the BLP method by employing two food safety scenarios. The first scenario (hereafter, Model 1) is a full random coefficient logit model (the BLP model) in the absence of the salmonella outbreak; the second one (hereafter, Model 2) also uses the full random coefficient logit model with the food safety variables under the salmonella outbreak. Model 2 includes, r_j, a food safety variable of brand *j*. This study creates the food safety variable using a time dummy variable and develops a sentiment score regarding the salmonella outbreak.

$$\text{Model 1: } U_{ij} = \alpha_i p_j + x_j{}'\beta_i + \xi_j + \varepsilon_{ij} \quad (4a)$$

$$\text{Model 2: } U_{ij} = \alpha_i p_j + x_j{}'\beta_i + \lambda_i r_j + \xi_j + \varepsilon_{ij} \quad (4b)$$

New Empirical Industrial Organization Model

The new empirical industrial organization (NEIO) model needs three elements for estimating competitiveness in an industry: (1) demand specification, (2) cost specification, and (3) competitive interactions (Kadiyali et al., 2001). Under the NEIO, the BLP model is helpful for measuring market power and pricing behavior. Through the full random coefficient model, consumer demand is estimated for peanut butter brands. The demand parameters from the BLP model are then used to compute price-cost markups and recover marginal costs (Berry, 2015). The starting point is manufacturer i, $i = 1, \dots, R$, selling $j = 1, \dots, J$ differentiated products to maximize the profit given by Eq. (5):

$$\pi_i = \sum_{j\in R}(p_j - mc_j)s_j(p)M \quad (5)$$

where p_j is the price of brand j, mc_j is the marginal cost of brand j, $s_j(p)$ is the market share of brand j, and M is the market size. Under the Bertrand-Nash equilibrium, the first-order conditions (FOCs) are given by Eq. (6):

$$\frac{\partial \pi_i}{\partial p_j} = s_j(p) + \sum_{k\in R}(p_k - mc_k)\frac{\partial s_k(p)}{\partial p_j} = 0 \quad (6)$$

The FOCs result in a system of J equations that can be expressed in vector notation as follows in Eq. (7):

$$s(p) + \Omega(p - c) = 0 \quad (7)$$

Solving for the price-cost margins[1] in Eq. (8),

$$\begin{pmatrix} pcm_1 \\ \vdots \\ pcm_J \end{pmatrix} = -\Omega \begin{pmatrix} a_{11} & \cdots & a_{J1} \\ \vdots & \ddots & \vdots \\ a_{1J} & \cdots & a_{JJ} \end{pmatrix}^{-1} \begin{pmatrix} s_1(p) \\ \vdots \\ s_J(p) \end{pmatrix} \quad (8)$$

Market power is the difference between price and marginal cost (White, 2013). The Lerner Index[2] is proposed as an indicator of market power, and it can be calculated by measuring the gap between price and marginal cost (Lerner, 1934) in Eq. (9). The Lerner index is between $0 < L_j < 1$.

$$L_j = \frac{(p_j - mc_j)}{p_j} \quad (9)$$

Assuming that the two firms behave in a collusive way, like a monopolist under joint-profit maximization, the profit maximization problem is set up as if the four brands are owned by one firm. This is implied in Eq. (10):

$$\pi = (p_1 - mc_1)s_1(p)M + (p_2 - mc_2)s_2(p)M + (p_3 - mc_3)s_3(p)M + (p_4 - mc_4)s_4(p)M \quad (10)$$

The implied PCM (Price Cost Margin) is

$$\text{PCM} = p - mc = -T \cdot \Psi^{-1} s(p) \quad (11)$$

where T is a matrix (4 × 4) full of ones and Ψ is a matrix of the first derivatives of the market shares with respect to prices, with $\Psi_{jk} = \frac{\partial s_j}{\partial p_k}$.

For the comparison between alternative models (Bertrand-Nash vs. joint-profit maximization), the likelihood-ratio-based statistics by Vuong (1989) and Rivers and Vuong (2002) are used. Which pricing conduct is suitable for the data depends on Vuong's test. For the selection between alternative models, under the null hypothesis (H_0), the candidate models are asymptotically equivalent. This is implied in Eq. (12):

$$H_0 = \lim_{n \to \infty} \{Q_n^{\text{AM}}(\hat{\alpha}^{\text{AM}}, \hat{\beta}^{\text{AM}}) - Q_n^{\text{AM}}(\hat{\alpha}^{\text{AM}'}, \hat{\beta}^{\text{AM}'})\} = 0 \quad (12)$$

If the alternative model AM is better than the second alternative model AM′,

$$H_1 = \lim_{n \to \infty} \{Q_n^{\text{AM}}(\hat{\alpha}^{\text{AM}}, \hat{\beta}^{\text{AM}}) - Q_n^{\text{AM}}(\hat{\alpha}^{\text{AM}'}, \hat{\beta}^{\text{AM}'})\} < 0 \quad (13)$$

If the second alternative model AM′ is better than the alternative model AM,

$$H_2 = \lim_{n \to \infty} \{Q_n^{\text{AM}}(\hat{\alpha}^{\text{AM}}, \hat{\beta}^{\text{AM}}) - Q_n^{\text{AM}}(\hat{\alpha}^{\text{AM}'}, \hat{\beta}^{\text{AM}'})\} > 0 \quad (14)$$

where Q is the non-nested individual-specific likelihood function that is distinguished by containing parameters $\alpha^{\text{AM}}, \beta^{\text{AM}}$ and $\alpha^{\text{AM}'}, \beta^{\text{AM}'}$. According to Vuong (1989) and Vuong and Rivers (2002), the statistic asymptotically, as in Eq. (15), follows a standard normal distribution:

$$T_n = \frac{\sqrt{n}}{\hat{\sigma}_n^{\text{MM}'}} \{Q_n^{\text{AM}}(\alpha^{\text{AM}}, \beta^{\text{AM}}) - Q_n^{\text{AM}}(\alpha^{\text{AM}'}, \beta^{\text{AM}'})\} \quad (15)$$

where n is the sample size and $\hat{\sigma}$ is the estimated value of the variance of the difference of lack-of-fit between the competing models.

Data

This study selected Chicago and Los Angeles, and the geographical differences allowed for comparing the dissimilarities between these markets in terms of consumer behavior and pricing competition. The sample included 19 peanut butter brands with prices, quantity sold, and product characteristics, such as serving size, calorie, fat, sugar, and protein contents, as in Table 1—the sales data for the 19 peanut butter brands at the manufacturer level for 48 four-week periods. The empirical estimation was to use scanner data from Information Resources, Inc. (IRI). The data consisted of weekly observations on unit sales, unit price, dollar sales, and display features from two U.S. metropolitan areas. To keep the data computationally manageable, the study aggregated the weekly data into four-week periods. The demographic variables were from the U.S. Census Bureau. They included the number of people under 15 years (*under_15*), annual household income (*income*), and age (*age*). The instrumental variables (IVs) were peanut butter prices from other cities and various producer price indices (PPI) for correcting price endogeneity. Moreover, two different demand shock variables were applied to the study to estimate the effect of foodborne outbreaks on consumer behavior and manufacturers' pricing performance. These food safety variables included a time dummy and a sentiment score. The time dummy variable indicated whether peanut butter brand sales occurred during the salmonella outbreak. The other demand shock variable was the sentiment score (Liu & Lopez, 2016), built using the keywords (salmonella, outbreak, recall, safe, recover, protect, etc.) from news articles. The LexisNexis research service was employed to extract articles related to the salmonella outbreak between 2006 and 2009.[3] The sentiment score value was between –1 and +1, which implied how much consumers considered the peanut butter brand positively or negatively. Figure 2 shows the monthly sentiment scores indicating how consumers think of peanut butter brands. After the first salmonella outbreak, the score moved positively because the manufacturer recalled peanut butter products. However, there has been a significant downturn in the second salmonella outbreak since the wide foodborne outbreak happened in the peanut butter industry.[4]

Table 1. Peanut Butter Brands and Nutrition Facts

Manufacturer	Name of Brand	Serving (oz)	Calorie	Fat (g)	Sugar (g)	Protein (g)
J.M. Smucker	Adams	32	190	16	2	8
	Adams No Stir	32	190	16	2	8
	JIF	32	183	15.50	2.9	6.8
	JIF Smooth Sensations	32	200	16	2	6
	JIF To Go	32	186.05	16.37	2.98	6.7
	Laura Scudder	32	190	16	2	8
	Simply JIF	32	178.82	15.06	2.82	6.59
	Smucker	32	190	16	2	8
	Santa Cruz Organic	32	180	16	1	8
Unilever	Skippy	32	190	16	3	7
	Skippy & Carb Options	32	190	17	0.5	7
	Skippy Double Delicious	32	210	15	2	7
	Skippy Squeeze It	32	184.24	16.48	2.91	6.79
	Skippy Squeeze Stix	32	179.20	15.36	3.84	7.68
	Skippy Super Chunk	32	190	16	3	7
	Skippy Natural	32	190	16	3	7
ConAgra Foods	Peter Pan	32	210	17	3	8
	Peter Pan Plus	32	210	17	3	8
	Peter Pan Smart Choice	36	200.20	11	4	8

Source: Each manufacturer provides the nutrition facts of peanut butter. https://www.calorieking.com

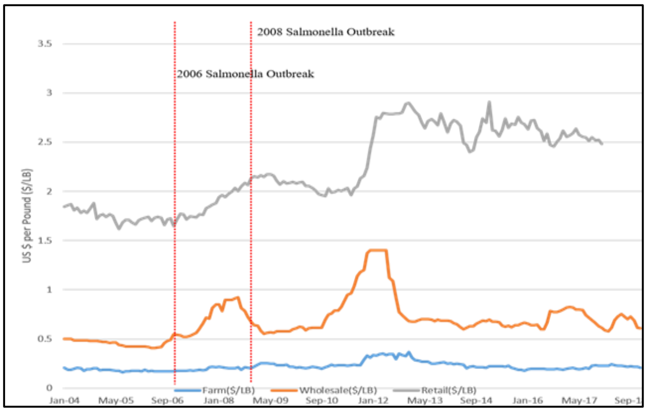


Figure 1. Evolution of the Peanut & Peanut Butter Prices

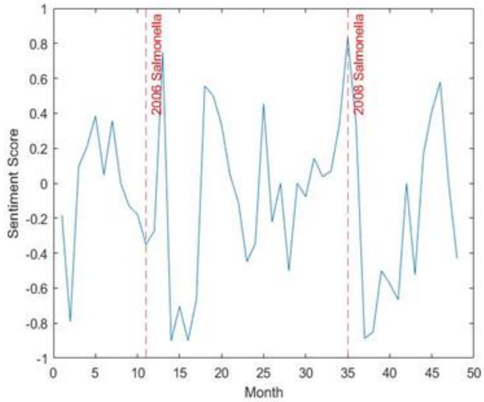
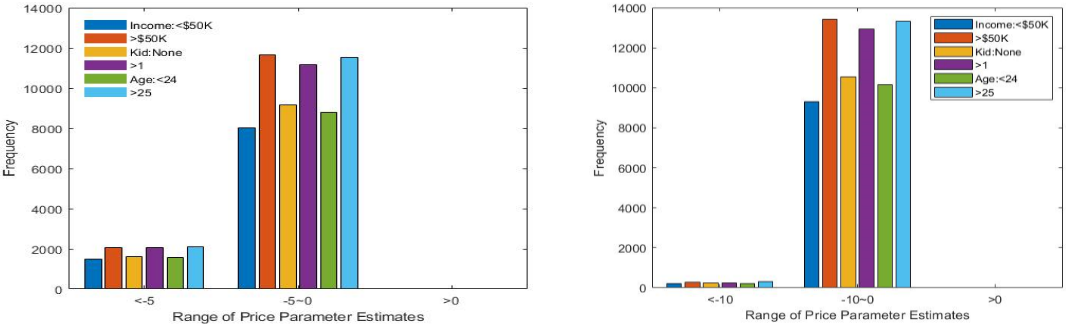


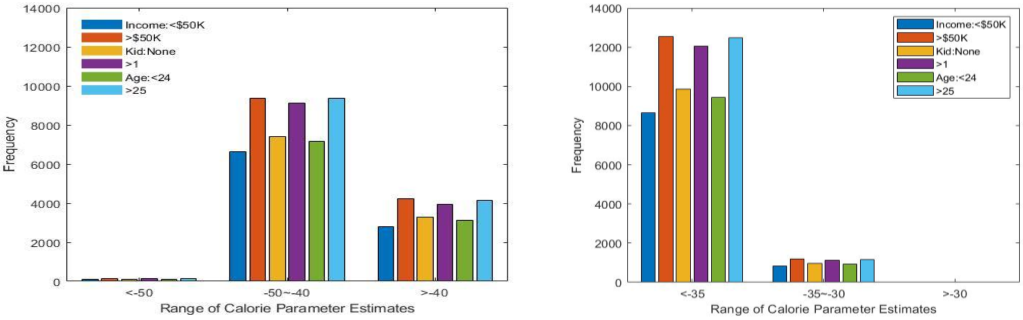
Figure 2. Sentiment Score for Peanut Butter 2006 – 2009

Chicago(demand)



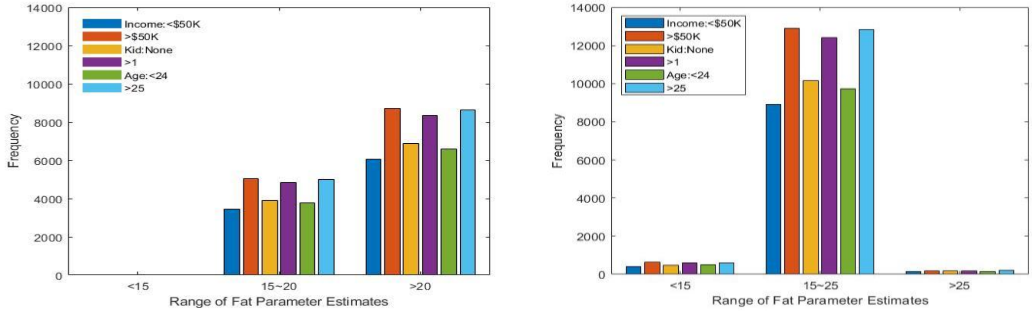
Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 3. Price Parameter Estimates by Demographics in Chicago (Left: Model 1; Right: Model 2)



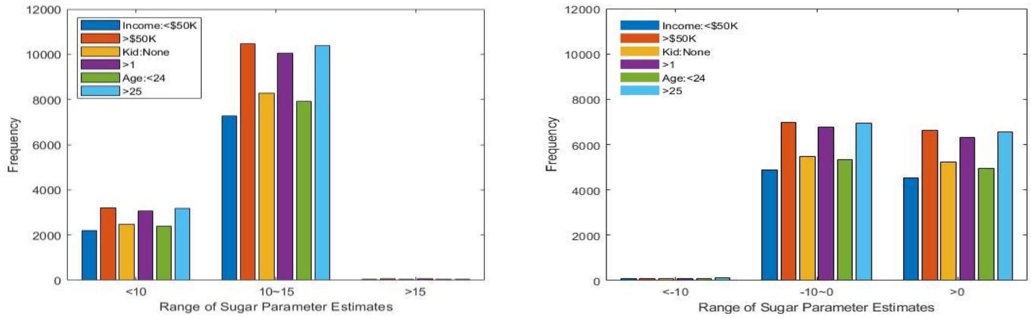
Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 4. Calorie Parameter Estimates by Demographics in Chicago (Left: Model 1; Right: Model 2)



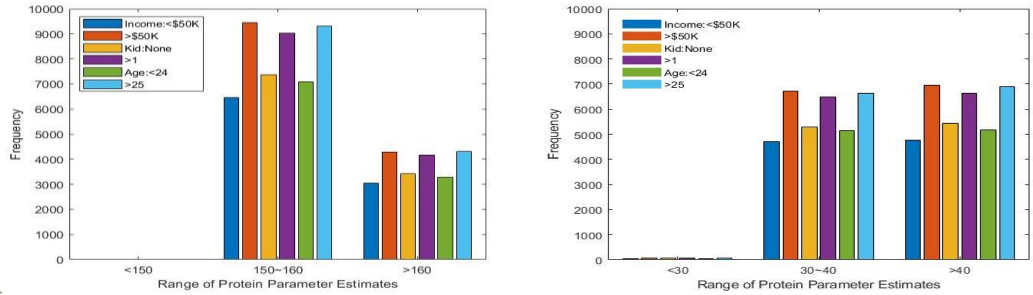
Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 5. Fat Parameter Estimates by Demographics in Chicago (Left: Model 1; Right: Model 2)



Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 6. Sugar Parameter Estimates by Demographics in Chicago (Left: Model 1; Right: Model 2)



Note: Model 1 indicates the model excluding demand shock variables in the absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 7. Protein Parameter Estimates by Demographics in Chicago (Left: Model 1; Right: Model 2)

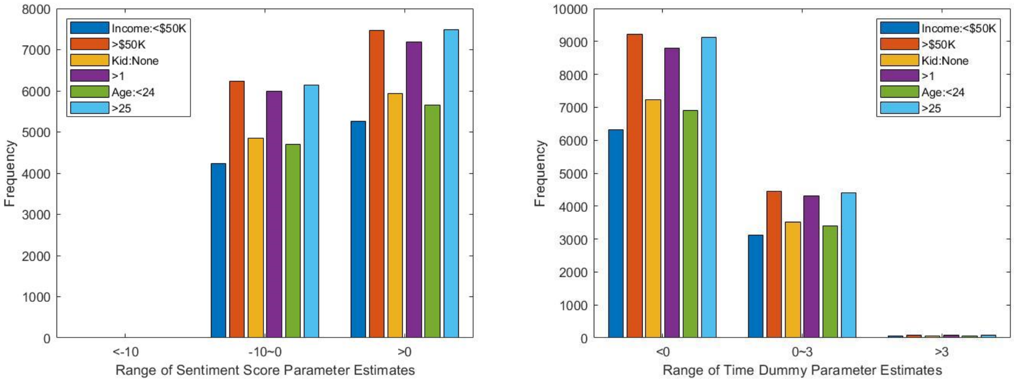


Figure 8. Sentiment Score & Time Dummy Parameter Estimates by Demographics in Chicago

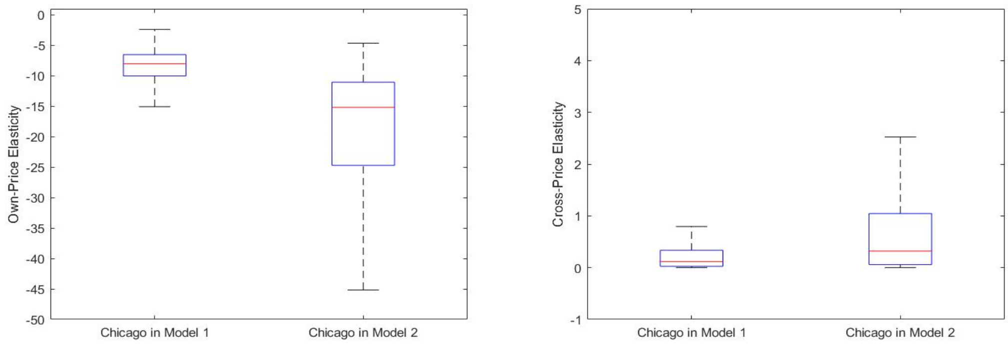
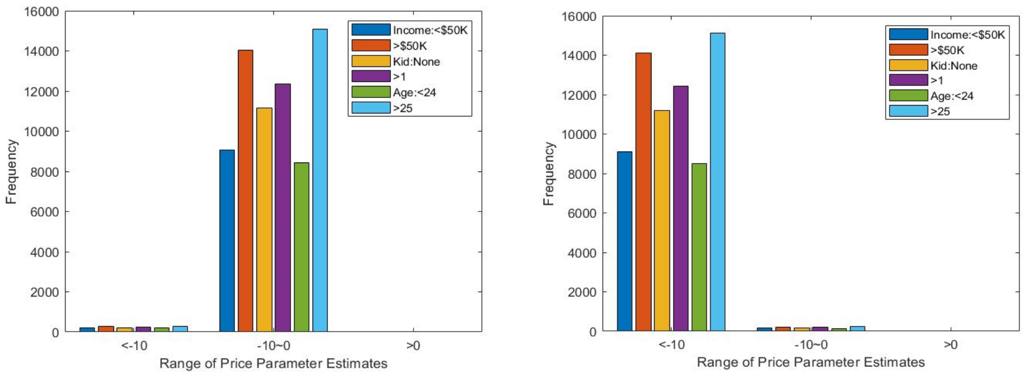


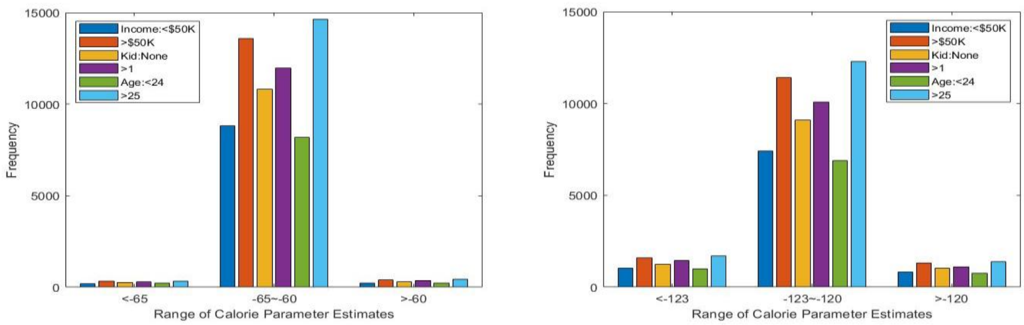
Figure 9. Boxplot for Own-Price Elasticity & Cross-Price Elasticity in Chicago

Los Angeles(demand)



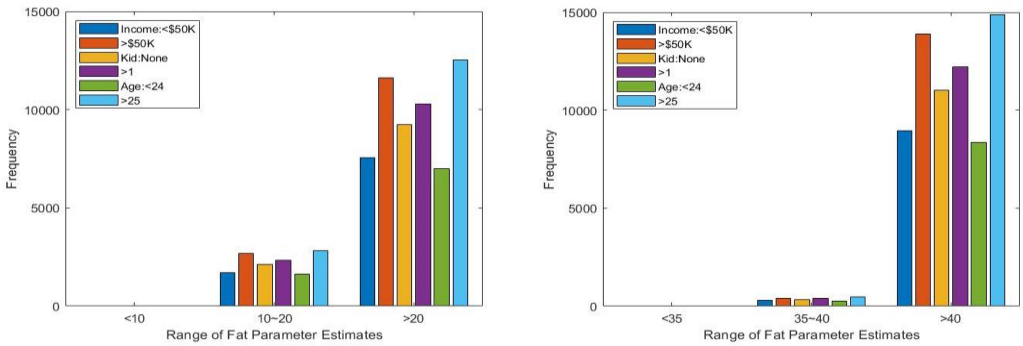
Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 10. Price Parameter Estimates by Demographics in Los Angeles (Left: Model 1; Right: Model 2)



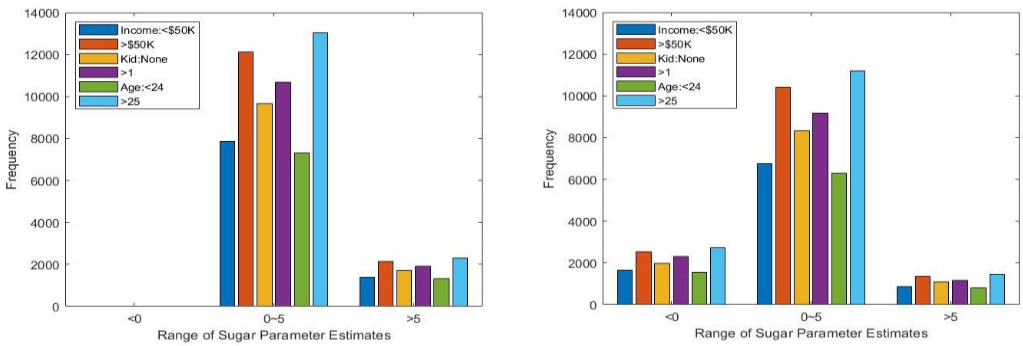
Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 11. Calorie Parameter Estimates by Demographics in Los Angeles (Left: Model 1; Right: Model 2)



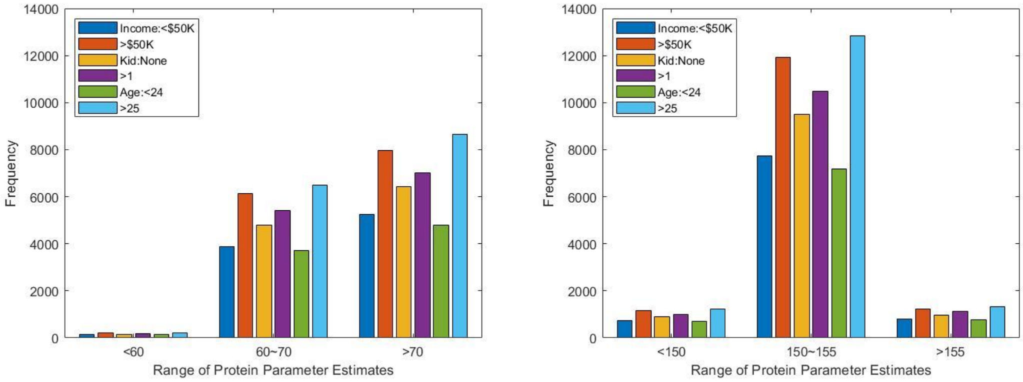
Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 12. Fat Parameter Estimates by Demographics in Los Angeles (Left: Model 1; Right: Model 2)



Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 13. Sugar Parameter Estimates by Demographics in Los Angeles (Left: Model 1; Right: Model 2)



Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. Demographics

Figure 14. Protein Parameter Estimates by Demographics in Los Angeles (Left: Model 1; Right: Model 2)

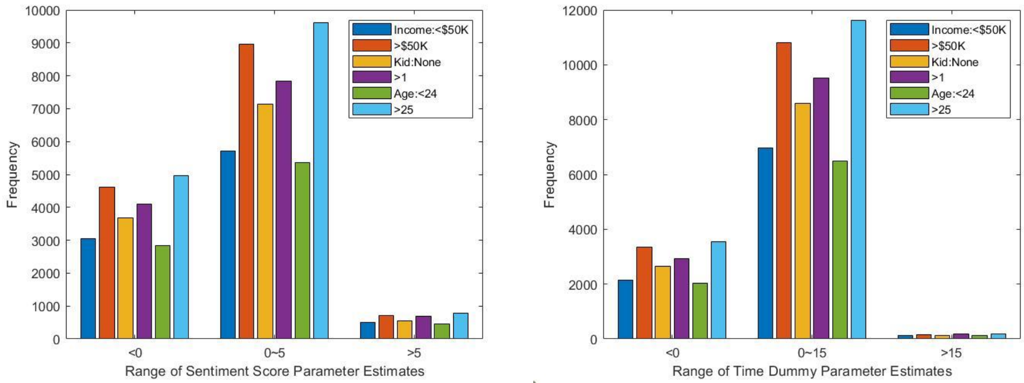


Figure 15. Sentiment Score & Time Dummy Parameter Estimates by Demographics in Los Angeles

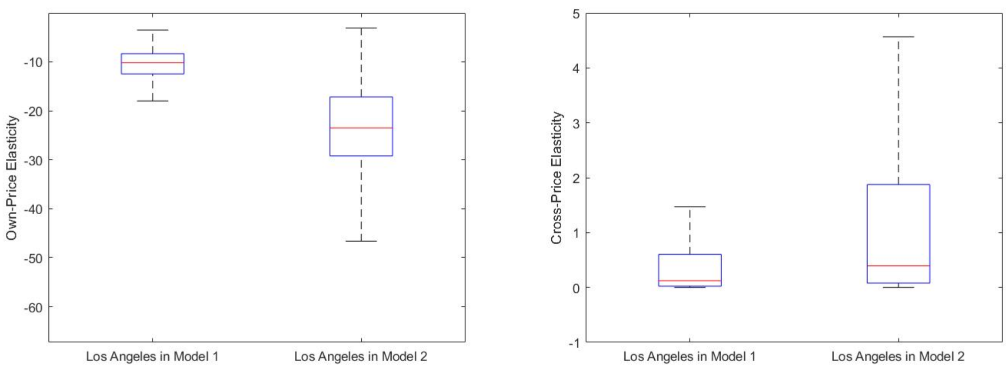


Figure 16. Boxplot for Own-Price Elasticity & Cross-Price Elasticity in Los Angeles

Chicago(supply)

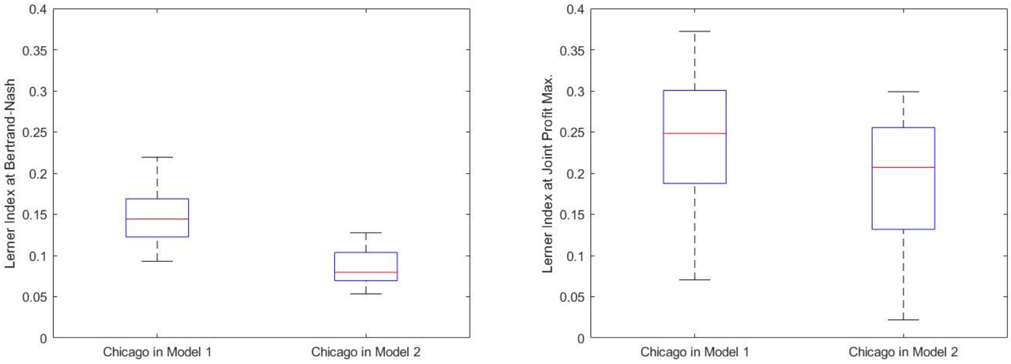


Figure 17. Lerner Index for Peanut Butter Brand in Chicago (Bertrand-Nash vs. Joint Profit Maximization)

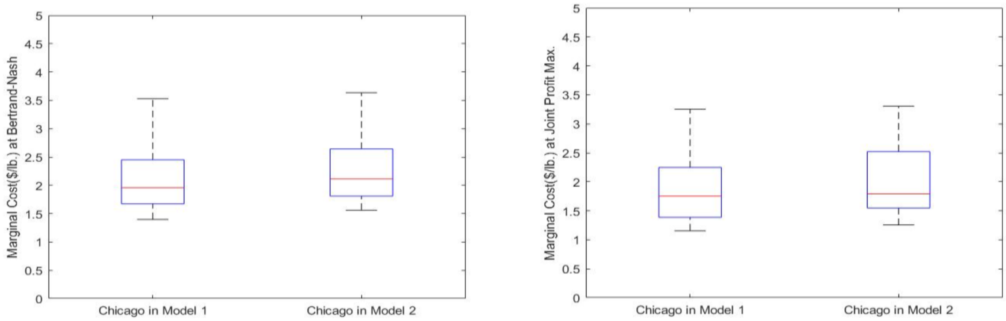


Figure 18. Marginal Cost($/lb.) for Peanut Butter Brand in Chicago (Bertrand-Nash vs. Joint Profit Maximization)

Los Angeles(supply)

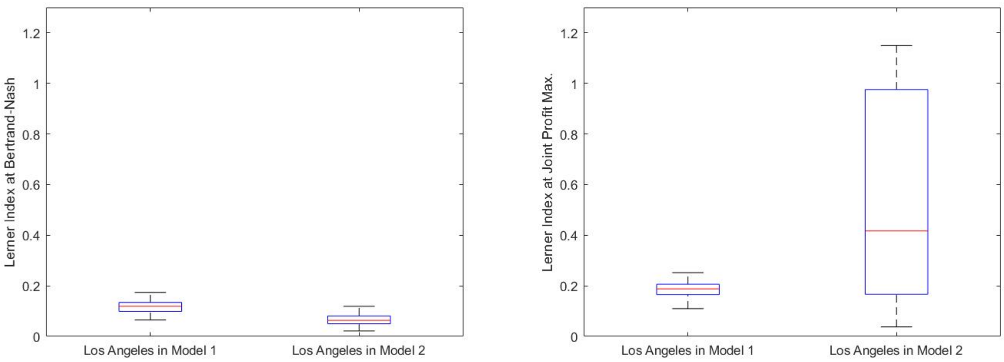


Figure 19. Lerner Index for Peanut Butter Brand in Los Angeles (Bertrand-Nash vs. Joint Profit Maximization)

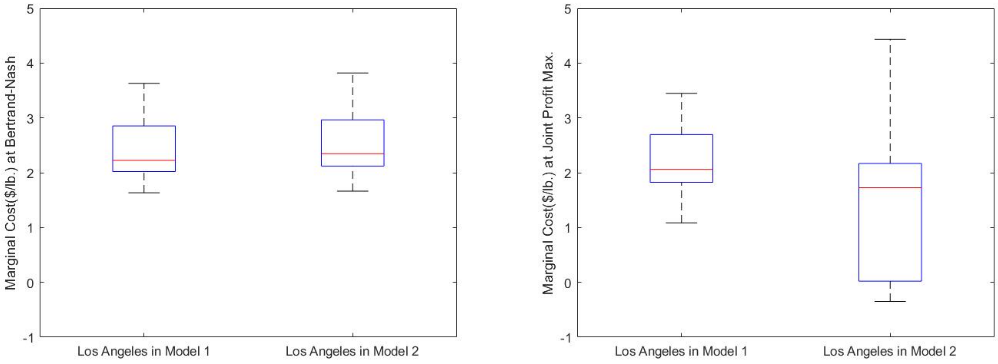


Figure 20. Marginal Cost($/lb.) for Peanut Butter Brand in Los Angeles (Bertrand-Nash vs. Joint Profit Maximization)

3. Demand for The Peanut Butter Industry

3.1. Demand in Chicago

Table 2 presents the estimated demand parameters in Chicago. The upper part describes the mean utility and interaction effects in Model 1, and the lower part provides the mean utility and interaction effects in Model 2. The mean utility in Model 1 was relatively higher in magnitude than in Model 2; it can be interpreted that consumers are less sensitive to the salmonella outbreak. The two price parameters in Models 1 and 2 were negative and statistically significant. The magnitude of the price parameter was smaller in Model 1 than in Model 2, implying that consumers were more price sensitive when the salmonella outbreak was considered. Contrary to sugar, fat, and protein coefficients, the calorie coefficient indicated that this peanut butter brand's attribute did not attract consumers in Chicago. The interactions of price with consumer characteristics were not statistically significant in Model 1. However, in Model 2, the results revealed that the interaction between price and income was negative and statistically significant. As income increased, the price's effect on indirect utility became more negative. The sentiment score variable had a positive and significant effect on the mean valuation utility. This positive perception increased with the number of persons under 15 years old but decreased as income increased. The time dummy variable had a negative and statistically significant effect on mean utility, but the negative impact decreased as income increased.

Figure 3 shows consumers' valuation by demographic variables for Models 1 and 2. The figure indicates that consumers with income over $50K, who were over 25 years old, and more than one child were more price sensitive; this was the same in Models 1 and 2. Figure 4 indicates consumers' calorie valuation by demographic variables. Calorie estimates' distributions were negative in Models 1 and 2, meaning that consumers were not likely to buy peanut butter brands with high calorie content. The interaction with demographic variables indicated that consumers making $50K, who were over 25 years old and had more than one child, were more sensitive to calories in peanut butter brands. The demographic pattern in Figure 5 yields the same conclusion as for calories. The findings show that consumers were more sensitive to the peanut butter brand's ingredients when the salmonella outbreak was considered than when it was ignored. There were the same patterns for the interaction with demographic variables as for calories and fat contents (see Figures 6 and 7). The estimated sentiment score parameter in Figure 8 indicates that the consumers' valuation by demographic categories explains that for people earning over $50K, who were more than 25 years old and had more than one child, the sentiment score's effect was more significant than for the rest. The demand shock variable, the time dummy, in Figure 8 also shows that the demographic pattern is the same as the previously estimated parameter.

Table 2. Demand Parameter Estimates in Chicago

Model 1				
Variable	Mean Utility	Interactions		
		Under_15	Income	Age
Constant	-112.447*** (-110.540)	-0.700 (-0.786)	-0.437* (-1.380)	1.245 (1.171)
Price	-3.196** (-2.425)	-0.384 (-0.245)	-0.174 (-0.081)	-0.089 (-0.028)
Calorie	-36.548*** (-22.511)	-2.174 (-1.169)	-0.648 (-0.935)	-1.178 (-0.576)
Fat	19.524*** (11.126)	1.017 (0.859)	-0.422 (-0.480)	0.248 (0.099)
Sugar	11.539*** (6.120)	-0.406 (-0.145)	0.251 (0.128)	-0.139 (-0.050)
Protein	159.424*** (186.085)	1.032* (1.455)	-0.709** (-2.753)	-0.540 (-0.731)
Model 2				
Variable	Mean Utility	Interactions		
		Under_15	Income	Age
Constant	4.066*** (10.091)	-0.236 (-0.489)	-1.613*** (-6.301)	-0.172 (-0.377)
Price	-4.244*** (-7.598)	0.197 (0.385)	-1.037** (-3.017)	-0.516 (-0.915)
Sentiment Score	0.440** (3.006)	0.500* (1.617)	-1.427*** (-24.630)	0.239 (0.950)
Time Dummy	-0.957*** (-5.130)	0.346 (0.747)	0.641*** (5.194)	-0.253 (-0.812)
Calorie	-39.015*** (-129.418)	0.774** (1.788)	0.593** (1.780)	0.369 (0.600)
Fat	13.990*** (50.384)	1.551** (2.867)	1.158*** (5.436)	0.948** (2.451)
Sugar	2.882*** (8.717)	-0.776* (-1.547)	-1.878*** (-3.655)	-0.244 (-0.228)
Protein	40.164*** (129.448)	-1.842*** (-4.292)	0.532** (2.626)	0.662* (1.446)

Note: Model 1 indicates the model excluding demand shock variables in absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. t-statistics in parentheses (*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level)

Table 3 displays the own-price elasticities in the Chicago market. The cross-price elasticities are too many to display in a single table and are summarized in Figure 9. The own-price elasticities were higher in magnitude when the salmonella outbreak was considered, except for Skippy Squeeze Stix, which was discontinued after 2006. For a given model and given year, the more the brand is differentiated, the more elastic it is. For example, the Skippy Squeeze Stix brand's own-price elasticity was −22.55, while for Jif, it was only −5.11. Across all brands and all years in the study, the salmonella outbreak model displayed more elastic brands than the model without it. As seen from the boxplots in Figure 9, the own-price elasticities for Model 1 were an average of −8.59 with a low interquartile range. In contrast, the salmonella outbreak model showed own-price elasticities averaging approximately −39 with a high interquartile range. For the cross-price elasticities, the results showed smaller figures, in magnitude, averaging 0.342, and a low interquartile range in Model 1. For Model 2, the cross-price elasticities were an average of 1.268 and showed more variation, indicated by a high interquartile range.

Table 3. Estimated Own-Price Elasticities for Peanut Butter Brand in Chicago

Brand	2006		2007		2008		2009	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
ADAMS	-9.523	-47.734	-9.425	-33.083	-10.014	-53.531		
JIF	-5.113	-9.25	-5.695	-10.447	-6.04	-12.565	-6.171	-9.518
JIF To Go	-12.212	-24.543	-12.471	-25.347	-13.06	-40.271	-12.517	-22.388
Simply JIF	-7.235	-13.587	-7.674	-14.953	-8.473	-20.068	-8.577	-14.228
SMUCKERS	-9.19	-34.8	-9.426	-27.21	-10.782	-35.21	-10.427	-33.734
SKIPPY	-5.95	-11.1	-5.347	-10.026	-7.204	-16.104	-6.346	-10.55
SKIPPY Carb Options	-10.19	389.249	-8.979	-1048.54				
SKIPPY Squeeze It	-13.29	-26.11						
SKIPPY Squeeze Stix	-22.546	-19.662						
SKIPPY Super Chunk	-6.587	-12.542	-6.092	-12.084	-8.402	-19.098	-7.962	-13.738
SKIPPY Natural					-10.232	-25.887	-9.004	-14.55
Peter Pan	-6.257	-13.217	-6.82	-16.865	-6.461	-15.165	-7.236	-12.892
Peter Pan Plus					-8.733	-15.818	-7.503	-12.988
Peter Pan Smart Choice	-6.881	-12.496	-6.233	-16.573	-7.336	-19.236	-8.429	-18.267

Note: Model 1 indicates the estimated model in the absence of the salmonella outbreak, and Model 2 displays the estimated model under the salmonella outbreak. The empty cell in the table implies there are no sales of the peanut butter brand.

3.2. Demand in Los Angeles

Table 4 indicates the estimated demand parameters in the Los Angeles market. The upper part presents the mean utility and interaction effect in Model 1, and the lower part displays the demand parameters in Model 2. The estimated price coefficients in the mean utility of Models 1 and 2 were negative and statistically significant. The price estimate in Model 2 was more negative, implying that consumers were more price sensitive when the salmonella outbreak was considered. The calorie coefficient lowered consumers' demand for peanut butter brands, whereas the other product characteristics (fat, sugar, and protein) positively affected the mean utility for both models. The magnitude of the calorie coefficient was more considerable in Model 2 than in Model 1, indicating that consumers were more sensitive to the calorie content when the salmonella outbreak was considered. The interaction effect indicated that income had a negative impact on the effect of the price in Model 1. Unlike Chicago, Los Angeles showed positive coefficients of sentiment score and time dummy that consumers were not likely to be affected by negative news articles about the outbreak.

Table 4. Demand Parameter Estimates in Los Angeles

Model 1				
Variable	Mean Utility	Interactions		
		Under_15	Income	Age
Constant	20.812*** (474.460)	0.430** (2.749)	0.523*** (13.468)	1.003*** (3.785)
Price	-9.776*** (-48.104)	0.686*** (4.606)	-0.140 (-0.699)	1.149** (2.718)
Calorie	-63.654*** (-1341.773)	0.809*** (12.546)	-0.709*** (-7.740)	0.521** (1.926)
Fat	25.273*** (494.873)	-1.047*** (-7.302)	-1.642*** (-18.594)	-0.350 (-1.027)
Sugar	3.689*** (22.509)	0.499*** (7.681)	0.309** (3.075)	-0.630*** (-5.077)
Protein	73.018*** (1611.365)	-2.232*** (-161.937)	-0.522*** (-13.214)	0.405*** (21.994)
Model 2				
Variable	Mean Utility	Interactions		
		Under_15	Income	Age
Constant	54.497*** (405.122)	-0.743** (-2.549)	0.589 (0.852)	1.602*** (3.921)
Price	-14.821*** (-128.623)	0.793 (0.973)	0.690* (1.567)	-0.302 (-0.362)
Sentiment Score	2.054*** (17.377)	-1.835*** (-8.743)	0.650 (0.882)	0.541** (2.146)
Time Dummy	1.117*** (6.759)	-0.754*** (-4.276)	2.872** (2.594)	-0.635* (-1.525)
Calorie	-122.664*** (-1438.435)	0.205 (0.487)	0.210 (0.528)	0.413 (0.824)
Fat	44.969*** (466.097)	-0.360 (-0.905)	-0.974 (-1.105)	-0.696** (-1.691)
Sugar	0.613** (2.784)	-0.077 (-0.231)	0.348 (0.813)	0.781** (1.851)
Protein	152.428*** (1679.995)	-0.825*** (-5.840)	0.127 (0.288)	0.710** (2.409)

Note: Model 1 indicates the model excluding demand shock variables in the absence of the salmonella outbreak. Model 2 indicates the model including 'Sentiment Score' and' Time Dummy' under the salmonella outbreak. t-statistics in parentheses (*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level)

The consumers' assessment by demographic categories is displayed in Figure 10. The figure shows that households with more than $50K a year, who were over 25 years old and had more than one child, were more price sensitive in Model 2 than other households. The rest consumers' valuation for calorie, fat, sugar, and protein by demographic categories from Figures 11, 12, 13, and 14. The estimated calorie parameters were negative in both Models 1 and 2; people were not likely to purchase peanut butter brands regardless of the salmonella outbreak. The estimated fat parameters were positive; consumers were likely to increase demand for more peanut butter brands in Model 2 than in Model 1. Furthermore, the sugar parameters were more negative in Model 2 that consumers were not prone to buy peanut butter brands during the salmonella outbreak. Contrary to sugar, the estimated protein parameters were positive in Models 1 and 2; people were likely to buy peanut butter brands regardless of the foodborne outbreak. For the estimated parameters, consumers' valuation was presented through demographic categories in which consumers earning income over $50K annually, who were over 25 years old and had more than one child, were sensitive to the estimated parameters (calorie, fat, sugar, and protein). The sentiment score and time dummy variables affected consumers' utility positively. The results showed that for some consumers in the Los Angeles market, the sentiment score and the time dummy variables had a positive effect, while they had a negative effect on the utility for others. This result showed the essence of considering consumer heterogeneity when estimating the demand for differentiated goods.

Table 5 indicates the estimated own-price elasticity in Los Angeles, ranging from −19.73 to −6.68 in Model 1 and from −52.34 to −12.83 in Model 2 between 2006 and 2009. Skippy Squeeze Stix was the most highly affected brand (−165%) by the salmonella outbreak in 2006. Peter Pan, Peter Pan Plus, and Peter Pan Smart Choice from ConAgra Foods showed more elastic behavior after the foodborne outbreak in 2006. However, these three peanut butter brands were affected more in the outbreak of 2008. The boxplots in Figure 16 summarize the own- and cross-price elasticity results in the Los Angeles metropolitan area. The left boxplot shows the own-price elasticities, and the right boxplot displays the cross-price elasticities. The mean own-price elasticity was −10.6 in Model 1 and −23.3 in Model 2, implying that consumers were more price sensitive under the salmonella outbreak. The mean cross-price elasticity was 0.461 in Model 1 and 1.510 in Model 2, suggesting that consumers were likely to buy substitutes by the variation.

Table 5. Estimated Own-Price Elasticities for Peanut Butter Brand in Los Angeles

Brand	2006		2007		2008		2009	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
JIF	-8.868	-17.194	-8.311	-20.416	-9.002	-18.493	-9.241	-19.304
JIF To Go	-11.218	-16.601	-11.709	-32.607	-13.914	-32.9	-12.235	-31.87
Laura Scudder	-14.672	-21.029	-12.151	-27.446	-13.687	-27.203	-13.94	-25.885
Simply JIF	-10.519	-21.234	-9.826	-25.862	-10.948	-24.439	-10.717	-24.944
SMUCKERS	-12.96	-28.16						
SKIPPY	-7.226	-12.829	-6.804	-15.141	-8.112	-13.784	-7.699	-15.273
SKIPPY Carb Options	-14.077	-23.475	-10.029	-23.809				
SKIPPY Squeeze It	-16.648	-40.781						
SKIPPY Squeeze Stix	-19.729	-52.345						

SKIPPY Super Chunk	-9.006	-18.604	-8.441	-21.671	-10.066	-22.638	-10.222	-23.332
SKIPPY Natural					-11.23	-24.752	-10.634	-24.355
Peter Pan	-10.741	-21.518	-9.731	-22.842	-10.119	-22.221	-10.935	-24.43
Peter Pan Plus	-10.403	-27.171						
Peter Pan Smart Choice	-8	-21.075	-6.675	-16.713	-8.833	-22.816	-8.799	-23.102

Note: Model 1 indicates the estimated model in the absence of the salmonella outbreak, and Model 2 indicates the estimated model under the salmonella outbreak. The empty cell in the table implies there are no sales of the peanut butter brand.

4. Price Competition in The Peanut Butter Market

This study used the demand estimation results to measure the market power of peanut butter brands, assuming two pricing games: Bertrand-Nash and joint-profit maximization. Specifically, this paper employed the price-cost margin for computing the Lerner index and recovered each brand's marginal cost under the two pricing scenarios (Models 1 and 2) considering the salmonella outbreak. Estimating the market power of an industry and its implications is a crucial issue in today's economy. According to Baker (2017), market power in an industry not only harms the players in the market but also may induce slower overall economic growth and increases economic inequality. Under imperfect competition, firms can set prices well above the marginal cost levels, causing a loss in consumers' welfare, a decrease in labor demand, and a decline in investment (Loecker et al., 2020). A practical question in this study involved the estimation of market power under the demand shocks caused by salmonella outbreaks.

4.1. Supply in Chicago

There are 14 peanut butter brands sold in Chicago, and the Lerner indices and marginal cost ($/lb.) are presented under two different pricing conducts. Each pricing model is estimated under two models (Models 1 and 2). Figure 17 displays the Lerner index's boxplots for peanut butter brands in Chicago under two conducts using two demand models' results. The left boxplot shows that under the Bertrand-Nash game, the Lerner index's maximum value was 22% for Model 1, while it was only 13% for Model 2. For the joint-profit maximization, the Lerner index's maximum value was 37% for Model 1 and only 30% for Model 2. As before, the market power level was lower under the demand shock of salmonella outbreaks, regardless of the pricing conduct considered. The indices showed an increase in the degree of monopoly from the Bertrand-Nash to the joint-profit maximization and a decrease in market power under the foodborne outbreak from Model 1 to Model 2. Figure 18 indicates the marginal cost (in $/lb) under the Bertrand-Nash game and the joint-profit maximization in the absence of the salmonella outbreak and under the salmonella outbreak. The marginal cost was an average of $2.2/lb for Model 1 and $2.36/lb for Model 2 under Bertrand-Nash. The right boxplot shows the marginal cost under the joint-profit maximization, with a mean marginal cost of $1.98/lb for Model 1 and $2.10/lb for Model 2. The marginal cost was higher under the demand shock of salmonella outbreaks.

4.2 Supply in Los Angeles

There are the Lerner indices and the marginal cost (in $/lb) for the Los Angeles market under two pricing conducts. Each pricing market model was estimated in two different models (Models 1 and 2). Figure 19 presents the Lerner index of the peanut butter brand under Bertrand-Nash and joint-profit maximization. The left boxplot shows the Lerner index under the Bertrand-Nash pricing game. The Lerner index ranged from 6% to 20% in Model 1 and from 2% to 14% in Model 2. The right boxplot shows the Lerner index under joint-profit maximization, with an average of 19.1% for Model 1 and an average of 111% for Model 2. This result suggests negative marginal costs in joint-profit maximization under Model 2. Figure 20 presents the marginal cost (in $/lb) for the two pricing models. The left boxplot shows Bertrand-Nash's marginal cost, with an average marginal cost of $2.50/lb for Model 1 and an average of $2.64/lb for Model 2. The right boxplot shows the marginal cost (in $/lb) under joint-profit maximization, averaging $2.31/lb in Model 1 and –$0.07/lb for Model 2. Two cities indicated higher Lerner indices when the city shifted the pricing conduct from Bertrand-Nash to joint-profit maximization. The results also showed lower Lerner indices when the salmonella outbreak was considered. The marginal costs were lower when the manufacturers followed a joint-profit maximization behavior, and they were higher when the salmonella outbreaks were considered.

4.3. Selection of Pricing Conduct

To determine which pricing game was suitable for the data, this study conducted Vuong's test. Table 6 shows Vuong's test results for two cities to compare Bertrand-Nash and joint-profit maximization under two different scenarios (Models 1 and 2). Three out of four cases showed that the join profit maximization game fitted the data better regardless of whether the salmonella outbreak was considered. However, Los Angeles showed the negative marginal cost indicating "fail to reject H_0" under the salmonella outbreak, implying that the suitability for the data was inconclusive. In addition, the negative marginal costs in Los Angeles offered practical evidence to reject the corresponding pricing conduct.

Table 6: Model Comparison Between Bertrand-Nash and Joint Profit Maximization

City	Salmonella outbreak	Models	H_0	H_1	H_2	Tn	Result
Chicago	Model 1	Bertrand-Nash vs. Joint Profit Maximization	Equivalent	Bertrand-Nash better	Joint Profit Maximization better	2.779	Joint Profit Maximization better
	Model 2	Bertrand-Nash vs. Joint Profit Maximization	Equivalent	Bertrand-Nash better	Joint Profit Maximization better	2.866	Joint Profit Maximization better
Los Angeles	Model 1	Bertrand-Nash vs. Joint Profit Maximization	Equivalent	Bertrand-Nash better	Joint Profit Maximization better	10.458	Joint Profit Maximization better
	Model 2	Bertrand-Nash vs. Joint Profit Maximization	Equivalent	Bertrand-Nash better	Joint Profit Maximization better	-0.003	FTR

Note: At a 5% significant level, if Tn<-1.96, H_0 is rejected, H_1 is in favor of; if Tn>1.96, H_0 is rejected, H_2 is in favor of; otherwise, FTR H_0. Model 1 is in the absence of the salmonella outbreak; Model 2 is under the salmonella outbreak.

5. Conclusion and Discussion

This study estimated the brand-level demand for 19 peanut butter brands produced by three manufacturers (J.M. Smucker, Unilever, and ConAgra Foods) sold through Chicago and Los Angeles. The analysis applied the BLP discrete choice model, where the product characteristics were added to consider the differentiation. Moreover, the food safety scenarios (Models 1 and 2) were applied to analyzing consumers' behavior. Model 1 was used to estimate consumers' behavior in the absence of the salmonella outbreak. Model 2 was used to evaluate their behavior under the salmonella outbreak. Moreover, two demand shock variables (sentiment score and time dummy) were employed to estimate demand. By analyzing two metropolitan cities, the study estimated consumers' valuation for the price, calorie, fat, sugar, and protein contents. Consumers reacted negatively to price in all cities, but the other taste parameter estimates for calorie, fat, sugar, and protein had a wide distribution, depending on consumers' demographics. The consumers' assessment in both cities by demographic categories showed that people earning over $50K, who were more than 25 years old and had at least one child, were more sensitive to price and other parameters (calorie, fat, sugar, and protein). The two cities displayed negative own-price elasticities, as expected for Model 1, and more elastic in Model 2. There were also geographical differences: People who lived in Los Angeles were more sensitive to price, whereas those who lived in Chicago were the least sensitive to price in Model 1. However, in Model 2, consumers in Los Angeles were less sensitive to price than in Chicago.

The supply section's empirical results compared the markets under the Bertrand-Nash and the joint-profit maximization games using the demand results from Models 1 and 2. Following the foodborne outbreak, consumers tended to avoid buying the product, affecting the peanut butter brand's market share. Both cities indicated higher Lerner indices when the city shifted the pricing conduct from Bertrand-Nash to joint-profit maximization. The marginal costs were lower when the manufacturers followed a joint-profit maximization behavior, and they were higher when the salmonella outbreaks were considered. Specifically, Los Angeles showed that the Lerner index was higher under joint-profit maximization with a negative marginal cost for Model 2. This implied that there was no practical evidence of the suitability of pricing conduct for the peanut butter market in Los Angeles. This study is one of the few empirical studies that use highly disaggregated data to estimate brand-level demand. Through research on the demand side in the peanut butter industry, this study shows how the behavior of consumers changes in considering the salmonella outbreak or ignoring the outbreak. Future research can also employ demand shock on the supply side and explore how manufacturers build up the marketing strategy in response to the foodborne outbreak. Moreover, the research may include the use of more pricing games on the supply side that extend the pricing behavior of the interactions between manufacturers for improving this kind of research.

References

Baker, J. B. (2017). "Market power in the U.S. economy today." Washington Center for Equitable Growth.

Basarir, A. (2013). "An Almost Ideal Demand System Analysis of Meat Demand in UAE." *Bulgarian Journal of Agricultural Science*. 19(1). 32-39.

Berry, S. T. et al. (1995). "Automobile Prices in Market Equilibrium." *Econometrica*. 63(4). 841-890.

Berry, S. T. & Haile, P. A. (2015). "Identification in Differentiated Product Markets Using Market Level Data." *Econometrica* 82(5). 1749-1797.

Bös, D. (1994). "Pricing and Price Regulation – An Economic Theory for Public Enterprises and Public Utilities." Advanced Textbook in Economics. North-Holland.

Capitello, R. et al. (2015). "Chinese import demand for wine: evidence from econometric estimations." Journal of Wine Research. 26(2). 115-135.

Cavallaro, E. et al. (2011). "Salmonella Typhimurium Infections Associated with Peanut Products." The New England Journal of Medicine. 365(7). 601-610.

Center for Disease Control and Prevention (CDC). (2020). "Typhimurium Infections Lined to Peanut Butter." https://www.cdc.gov/salmonella/2007/peanut-butter-3-7-2007.html

_________ (2020). "Typhimurium Infections Lined to Peanut Butter." https://www.cdc.gov/salmonella/2009/peanut-butter-2008-2009.html

Chidmi, B. & Lopez, R. A. (2007). "Brand-Supermarket Demand for Breakfast Cereals and Retail Competition." *American Journal of Agricultural Economics*. 89(2). 324-337.

Deodhar, S. Y. and Fletcher, S. M. (1998). "Degree of Competition in the U.S. Peanut Butter Industry: A Dynamic Error Correction Approach." *Faculty Series 16725*, University of Georgia.

Gao, Y., Just, D. R., Turvey, C., & Wansink, B. (2015). "Existing Food Habits and Recent Choices Lead to Disregard of Food Safety Announcements." *Canadian Journal of Agricultural Economics*, 63. 491-511.

Gebrehiwot, W. & Daloonpate, A. (2012). "Demand Analysis of Ethiopian Coffee in Japan." *Kasetsart Journal*. 33. 142–151.

Hovhannisyan, V., Stiegert, K. W., & Bozic, M. (2014). "On the Endogeneity of Retail Markups in an Equilibrium Analysis: A Control-Function Approach." *Journal of Agricultural and Resource Economics*. 39(2). 188-200.

Kadiyali, V., Sudhir, K., & Rao, V. R. (2001). "Structural analysis of competitive behavior: New Empirical Industrial Organization methods in marketing. *Int'l Journal of Research in Marketing* 18. 161-186.

Leighton, P. (2015). "Mass Salmonella Poisoning by the Peanut Corporation of America: State-Corporate Crime Involving Food Safety." *Critical Criminology*. 24(1). 75-91.

Lerner, A. P. (1934). "The Concept of Monopoly and the Measurement of Monopoly Power." *The Review of Economic Studies* 1(3). 157-175.

Liu, Y. and Lopez, R. A. (2016). "The Impact of social media conversations on consumer brand choice." *Marketing Letters*. 27(1). 1-13.

Loecker, J. D., Eeckhout, J., & Unger, G. (2020). "The Rise of Market Power and The Macroeconomic Implications." *The Quarterly Journal of Economics* 135(2). 561-644.

Massey, P. (2000). "Market Definition and Market Power in Competition Analysis: Some Practical Issues." *The Economic and Social Review* 31(4). 309-328.

Moraga-González, J. L. and Wildenbeest, M. R. (2018). "Consumer Search and Prices in the Automobile Market." *Tinbergen Institute Discussion Paper*.

Rivers, D. & Vuong, Q. (2002). "Model selection tests for nonlinear dynamic models." *Econometrics Journal* 5. 1-39.

Vuong, Q. H. (1989). "Likelihood Ratio Tests for Model Selection and Non-nested Hypotheses." *Econometrica*. 57(2). 307-333.

White, L. J. (2013). "Chapter 3: Market Power: How Does It Arise? How Is It Measured?". The Oxford Handbook in Managerial Economics. Oxford University Press.

Yohannes et al. (2016). "Substitution in Consumer Demand for Coffee Product Categories in Japan." *Journal of Agricultural Science*. 8(4). 50-59.

Zhang, P. et al. (1995). "Peanut Price Transmission Asymmetry in Peanut Butter." *Agribusiness* 11(1). 13-20.

---

[1] Ω is called the ownership matrix, where Ω_{jk}= 1 if brands j and k are owned by the same manufacturer; otherwise, Ω_{jk}= 0 and $a_{jk} = \frac{\partial s_j}{\partial p_k}$.

[2] If L_j is close to 1, the firm behaves like a monopolist (Massey, 2000). If L_j is close to 0, the firm behaves in line with perfect competition case. L_j is proportional to the inverse of demand elasticity's absolute value (Bös, 1994). This implies that in an imperfectly competitive market firm's market power depends on the elasticity of demand.

[3] This legal research service provides various ways of collecting legal and journalistic documents. The reports are obtained through diverse sources such as newswires and press, newspapers, web-based publications, news transcripts, and magazines and journals from the industries including consumer products, food and beverage, and manufacturing across the United States.

[4] The Peanut Corporation of America (PCA) was a peanut-processing company located in Blakely, GA. The contaminated peanuts from PCM was distributed to institutions like schools, the military, nursing homes and meals used for disaster relief. PCA also sold peanut products to about 200 companies (including Kellogg and Sara Lee) that manufactured cereal, crackers, snack bars, candy, donuts, pet food, etc.