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A Demand Systems Analysis for Cheese Varieties Using a Balanced Panel of US Designated Market Areas over the Period 2018 to 2020

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An Exact Affine Stone Index model is estimated to capture demand interrelationships among Muenster, Mozzarella, Colby, Cheddar, Swiss, other natural, specialty/imported, and processed cheese. A balanced panel constructed from designated market areas and quarterly periods from 2018 to 2020 derived from Nielsen is used. The demand for Muenster, Cheddar, Swiss, and specialty/imported cheese is unitary elastic, while the demand for Mozzarella, Colby, other natural cheese, and processed cheese is inelastic. All varieties are necessities, and substitution relationships are predominant. Demographic characteristics impact the demand for these cheese varieties. Retail pricing strategies designed to maximize total sales are provided.

Key words: cheese demand, Exact Affine Stone Index model, Nielsen Homescan panel data, total sales elasticities

Introduction

The US cheese market size is predicted to grow from $40.73 billion in 2022 to $55.95 billion by 2029, recording a compound annual growth rate of 4.64% over this period (Fortune Business Insights, 2022). The rise in demand for convenient food items like snacks, sandwiches, and other similar products is the primary driver behind the growth of the cheese market in the United States (Fortune Business Insights, 2022). Additionally, restaurants and food chains have launched a diverse range of cheese-based food items and snacks (Fortune Business Insights, 2022). Moreover, natural cheese products, which are made without any additives, are thought to be healthier than processed cheese products, which has led to a notable increase in their consumption in recent years.

US consumption of cheese, on a per capita basis, increased from 35.64 pounds in 1995 to 47.64 pounds in 2021. However, this rise in per capita US consumption of cheese is almost exclusively attributed to natural cheese over processed cheese. Per capita consumption of all natural cheeses rose monotonically from 26.94 pounds in 1995 to 39.40 pounds in 2021, predominantly due to Cheddar and Mozzarella cheese. On the other hand, per capita consumption of processed cheese fell from 8.70 pounds in 1995 to 6.37 pounds in 2013. Since then, per capita consumption of processed

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Researcher(s)' own analyses calculated (or derived) based in part on (i) retail measurement/consumer data from Nielsen Consumer LLC ("NielsenIQ"); (ii) media data from The Nielsen Company (US), LLC ("Nielsen"); and (iii) marketing databases provided through the respective NielsenIQ and the Nielsen Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the Nielsen data are those of the researcher(s) and do not reflect the views of NielsenIQ or Nielsen. Neither NielsenIQ nor Nielsen is responsible for, had any role in, or was involved in analyzing and preparing the results reported herein.

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cheese climbed from 7.36 pounds in 2014 to 8.24 pounds in 2021 (US Department of Agriculture, 2023).

In addition to its expanding demand, cheese also adds $55.4 billion in direct economic impact to the US economy and supports close to 60,000 dairy industry jobs (International Dairy Foods Association, 2021). This background provides the motivation to better understand the factors influencing consumer demand for different cheese categories to enhance the long-term growth and profitability of this sector of the dairy industry. Retail strategies designed to maximize total sales are based in part on the examination of price elasticities. To minimize errors in the estimation of these elasticities, it is necessary to account for interrelationships between natural cheese varieties and processed cheese using more recent market data.

In this light, this study has five objectives: (i) review the literature concerning the demand for various types of cheese varieties; (ii) estimate the demand structure for cheese varieties by accurately accounting for the polynomial degree of real expenditures as well as total expenditure and price endogeneity; (iii) calculate uncompensated and compensated own-price and cross-price elasticities of demand along with expenditure and income elasticities of demand for a granular array of natural cheese varieties and the aggregate categories of specialty/imported cheese and processed cheese; (iv) identify and assess the effects of various demographic characteristics associated with the respective designated market areas (DMAs) that impact the demand for these cheese varieties; and (v) ascertain the change in sales of the entire cheese category with respect to changes in prices of each of the respective cheese products considered in this study, thus providing pricing strategies designed to maximize retail-level sales.

The information gleaned from the empirical findings of this study will be of interest to different stakeholders. Cheese manufacturers and retailers can employ the estimates of price elasticities of demand to design revenue-maximizing pricing strategies as well as inventory management and input procurement plans to adequately respond to price changes of cheese varieties. Additionally, the empirical findings can assist in developing new marketing strategies or revising existing ones to reach specific demographic groups, retain current customers, or add new customers. Another group of interested parties includes policy makers, who can use the empirical findings to design or revise policies to help provide oversight to the cheese industry.

Literature Review

The demand for cheese products has been studied by applying different theoretical frameworks and estimating various empirical models, depending on the objectives of the respective analyses and on the data used. Past studies considered the product forms of various cheese varieties, particularly shredded, grated, sliced, snack, and loaves (Bergtold, Akobundu, and Peterson, 2004; Heien and Wessells, 1988; Heien and Wesseils, 1990; Maynard and Liu, 1999; Maynard, 2000; Arnade, Gopinath, and Pick, 2008; Davis et al., 2011; Bouhlal, 2012). Other studies centered attention on the impact of coupon redemption on household cheese purchases (Dong and Kaiser, 2005); at-home consumption of cheese (Blaylock and Smallwood, 1986; Gould, 1992; Yen and Jones, 1997); impacts of generic advertising on US household cheese purchases (Blaylock and Blisard, 1988; Schmit et al., 2003); and brands (Cotterill and Samson, 2002; Huang, Jones, and Hahn, 2007; Arnade, Gopinath, and Pick, 2007, 2008).

To be consistent with the first objective of this study, we focus the survey on the extant literature exclusively dealing with own-price elasticities, cross-price elasticities, and expenditure (income) elasticities among *specific*, *nonbranded* cheese products as well as on the impacts of sociodemographic variables on purchases of natural cheese, processed cheese, and other types of cheese. Caution should be exercised in comparing estimated elasticities in this study to those from prior studies because of differences in time periods, cheese varieties considered (aggregate or disaggregate), model specifications, and observational units (household level vs. city level).

Attention has been predominantly centered on processed cheese varieties (e.g., snack, sliced, chunk/loaf, shredded, grated, cubed, and imitation cheese, cheese spreads, cream cheese, ricotta cheese, and cottage cheese). In most cases, the demand for these processed cheese varieties, except for cream cheese, was elastic. For the aggregate category of processed cheese, estimated own-price elasticities ranged from −0.99 to −1.73. Natural cheese varieties considered were Cheddar, Colby jack, Monterey, Mozzarella, and Swiss. However, only Bouhlal (2012) investigated the demand for disaggregated natural cheese varieties. For the most part, the demand for these natural cheese varieties was also elastic. For the aggregate category of natural cheese, estimated own-price elasticities varied from −0.64 to −2.15. In general, the own-price elasticities for natural cheese products were greater than the own-price elasticities for processed cheese products.

When reported, income elasticities for processed and natural cheese varieties were generally positive and less than 1, indicative of necessities. However, full-fat processed American cheese, full-fat cottage cheese, processed slices, and processed loaves were identified as inferior goods. Based on the use of demand systems, the respective cheese varieties were substitutes in most cases (Heien and Wessells, 1990; Maynard and Liu, 1999; Cotterill and Samson, 2002; Bergtold, Akobundu, and Peterson, 2004; Huang, Jones, and Hahn, 2007; Chouinard et al., 2010; Davis, Blayney, et al., 2010; Davis, Dong, et al., 2010; Davis et al., 2011; Chahyadi, 2022). Cream cheese was a complement to processed cheese and shredded/grated cheese, and cottage cheese was a complement to most of the other cheese varieties.

Several previous studies also considered the impacts of sociodemographic factors on the demand for the respective cheese varieties. The most prevalent factors included household income; household size; age, race, ethnicity, and education of the household head; region; and age/gender composition of the household. Sociodemographic variables were generally found to be statistically significant determinants of the demand for processed and natural cheese.

Past studies relied on the use of household panel data such as the 1977–1978 Household Food Consumption Survey (Heien and Wessells, 1988; Heien and Wesseils, 1990), Nielsen Marketing Research from March 1991 to March 1992 (Gould, Cornick, and Cox, 1994; Gould and Lin, 1994), and Nielsen Homescan Panel data (Schmit et al., 2002; Arnade, Gopinath, and Pick, 2007; Davis, Blayney, et al., 2010; Davis, Dong, et al., 2010; Davis et al., 2011; Bouhlal, 2012). The principal issue with household panel data is the number of zero observations concerning purchases of cheese products. To address this situation, researchers implemented censored response models such as the censored Almost Ideal Demand System (AIDS), variations of the Tobit model, the Heckman sample selection two-step model, the Shonkwiler and Yen (1999) two-step model, and the censored demand system based on the Amemiya–Tobin model (Dong, Gould, and Kaiser, 2004).

To circumvent censoring issues, Boehm and Babb (1975) constructed a panel dataset from the United Dairy Industry Association of about 55,057 households for more than 45 two-week periods from April 1972 to January 1974 to estimate own-price elasticities for cottage cheese, processed cheese, and American cheese for the United States. Maynard and Liu (1999) and Maynard (2000) aggregated data over households from the Nielsen Homescan panels from calendar years 1996–1998 to form weekly observations to estimate own-price elasticities for various processed cheese products.

Cotterill and Samson (2002) relied on a panel dataset of 33 US cities and quarterly time series from 1988 to 1992 derived from Information Resources, Inc. (IRI) in estimating own-price elasticities for branded American cheese products. Similarly, Bergtold, Akobundu, and Peterson (2004) analyzed a panel of 39 US metropolitan areas derived from IRI over the same period to estimate own-price elasticities of selected varieties of processed cheese. Further, Huang, Jones, and Hahn (2007) constructed a panel of weekly observations from December 30, 2000, to April 21, 2002, across six stores of a supermarket chain located in Columbus, Ohio, to estimate own-price elasticities for national and store brands of shredded, sliced, chunk, snack, and miscellaneous cheese. Additionally, Chouinard et al. (2010) relied on a panel dataset of 23 US cities over the period from January 1, 1997, to December 30, 1998, derived from IRI to estimate own-price elasticities for natural cheese, shredded/grated cheese, cream cheese, and American and other processed cheese.

Despite its burgeoning growth in per capita consumption, few studies in the extant literature have focused on different varieties of natural cheese. Importantly, no studies at present have been conducted using more recent information. Data from past studies have covered the period from 1972 to 2007 only. As such, this analysis extends the current literature in the following ways. First, we base our analysis on the Exact Affine Stone Index (EASI) demand framework that adds to the methodological features of demand systems models used in prior studies while also accommodating unobserved consumer heterogeneity across the cross-sectional units (DMAs) and flexible shapes of Engel curves. Ascertaining the correct shape of Engel curves is important for assessing income effects (Pendakur, 2009; Lewbel and Pendakur, 2009). Finally, the EASI demand model is augmented to include regional fixed effects to address unobserved regional heterogeneity, which can stem from the sociocultural differences across regions.

Second, in contrast to previous studies, this study estimates the EASI demand model, utilizing balanced panel data constructed from DMAs and quarterly periods from 2018 to 2020 derived from Nielsen Homescan data. Detailed information on prices and quantities of a wide spectrum of natural cheese varieties as well as of specialty/imported and processed cheese is provided along with a set of demographic characteristics. While we consider a set of comparable natural cheese varieties and the aggregate category of specialty/imported cheese, as in Bouhlal (2012), we also consider Muenster cheese, which has not been studied previously. Unlike Bouhlal (2012) and others, we do not entertain a granular array of processed cheese products. The primary reasons for this decision are to focus on a set of disaggregated natural cheese varieties that had not been investigated at length previously and because per capita consumption of processed cheese has been relatively stable over time.

Third, the endogeneity in total expenditure and prices is properly accounted for using the approach described by Dhar, Chavas, and Gould (2003) and utilizing Hausman-type instruments for prices. Addressing the endogeneity issue is important; otherwise, inconsistent parameter estimates could lead to flawed demand and policy implications (Hovhannisyan and Bozic, 2017; Hovhannisyan et al., 2020).

Fourth, we ascertain the change in sales of the entire cheese category with respect to changes in prices of each of the respective cheese varieties considered in this study. To the best of our knowledge, this exercise is not only unique in the extant literature concerning cheese products but also provides pricing strategies designed to maximize retail-level sales for cheese.

Model

Linear Approximate EASI (LA-EASI) Demand Model

This analysis uses the linear approximate Exact Affine Stone Index (LA-EASI) demand model developed by Lewbel and Pendakur (2009) to empirically investigate the demand for different cheese varieties. The EASI demand model is preferred over other popular demand systems such as Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980) due to its ability to accommodate arbitrary Engel curve structures and unobserved consumer heterogeneity (Lewbel and Pendakur, 2009). The empirical specification of the EASI demand model is augmented to incorporate region and time fixed effects as well as DMA (hereafter city) demographic characteristics via the method of demographic translation (Pollak and Wales, 1981) and looks as follows:

$$
\begin{aligned}
w_{cit} = \alpha_{i0} + \sum_{j=1}^{N} \gamma_{ij} \ln p_{cjt} + \sum_{l=1}^{L} \beta_{il} y_{ct}^{l} + \sum_{k=1}^{S} \alpha_{ik} D_{ctk} + \sum_{r=1}^{R} \kappa_{ir} Reg_{ctr} \\
+ \sum_{t=1}^{T} \eta_{it} Year_{ct} + u_{cit}, \text{ for any } c = 1,\ldots,C;\ i = 1,\ \ldots,\ N; t = 1,\ldots,T
\end{aligned} \tag{1}
$$

where w_{cit} denotes the budget share of product i in period t for city c; p_{cjt} denotes the price of product j in period t in city c; y_{ct} denotes real expenditures in period t; D_{ctk} denotes proportions reflecting city demographic characteristics concerning gender, age groups, race, ethnicity, educational attainment, employment status, and poverty line; Reg_{ctr} and $Year_{ct}$ are dummy variables accounting for the sociocultural differences across regions and years (region specific and time fixed effects), respectively; α_i, γ_{ij}, and β_{il}, κ_{ir}, and η_{it} are the parameters to be estimated; and u_{cit} is the error term.

The following classical theoretical restrictions of adding-up, homogeneity, and symmetry are put in place on the parameters when estimating the EASI demand model in equation (1): $\sum_i \alpha_{i0} = 1$, $\sum_i \gamma_{ij} = 0$, $\sum_i \beta_{il} = 0$, $\sum_i \alpha_{ik} = 0$, $\sum_i \kappa_{ir} = 0$, $\sum_t \eta_{it} = 0$, for any $j = 1 \ldots N$, and $\gamma_{ij} = \gamma_{ji}$ for any $j \neq i$.

Finally, since we adopt an LA-EASI model to conduct the analysis, y_{ct} is specified as Stone price-deflated real expenditures:

$$y_{ct} = \log\left(x_{ct}\right) - \sum_{j}^{N} w_{cjt} \log\left(p_{cjt}\right), \tag{2}$$

where x_{ct} represents total nominal expenditures. It is noteworthy that in the nonlinear alternatives of the EASI demand model, y_{ct} is the affine transformation of the Stone price-deflated real expenditures. While the Stone price index is—by design—only an approximation of the true expenditure deflator in the linear approximate AIDS (LA-AIDS) model, in the EASI demand model it is the correct deflator of food expenditures (Zhen et al., 2014).

Using the parameter estimates from the LA-EASI demand model, price elasticities of demand and expenditure elasticities are calculated based on the formulas provided by Zhen et al. (2014). In particular, the compensated (Hicksian) price elasticity of demand for product i with respect to the price of product j (e_{ij}^C) is given by

$$e_{ij}^C = \frac{\gamma_{ij}}{w_i} + w_j - \delta_{ij}, \text{ for any } i, j = 1, \ldots, N, \tag{3}$$

where δ_{ij} is the Kronecker delta, taking on the value of 1 if $i = j$, and 0 otherwise. The expenditure elasticity is given by

$$\boldsymbol{E} = \left(diag\left(\boldsymbol{W}\right)\right)^{-1}\left[\left(\boldsymbol{I}_N + \boldsymbol{BP}'\right)^{-1}\boldsymbol{B}\right] + \boldsymbol{1}_N, \tag{4}$$

where $\boldsymbol{E}$ denotes the $(N \times 1)$ vector of expenditure elasticities, $\boldsymbol{W}$ denotes the $(N \times 1)$ vector of budget shares, $\boldsymbol{I}_N$ denotes an $(N \times 8)$ identity matrix, $\boldsymbol{B}$ denotes an $(N \times 1)$ vector with the ith element given by $\sum_{l=1}^{L} \beta_{il} l y^{l-1}$, $\boldsymbol{P}$ is the $(N \times 1)$ vector of logarithmic prices, and $\boldsymbol{1}_N$ is the $(N \times 1)$ vector of ones. The uncompensated (Marshallian) price elasticities (e_{ij}^U) can be computed using the Slutsky equation with the already computed compensated price elasticity (e_{ij}^C) and expenditure elasticity (e_i) as follows:

$$e_{ij}^U = e_{ij}^C - e_i w_j. \tag{5}$$

Owing to the law of demand, own-price elasticities are expected to be negative, while compensated cross-price elasticities are expected to possess a positive sign, given that cheese varieties have been shown to be substitutes for each other. Expenditure and income elasticities are anticipated to be positive since cheese varieties are hypothesized to be normal goods.

Total Expenditure and Price Endogeneity Issues

When using the EASI demand model, two empirical issues related to total expenditure and price endogeneity need to be addressed. The endogeneity of total expenditure arises because of simultaneity bias, where real expenditures appear on both the righthand and lefthand sides of the budget share equations. Following Dhar, Chavas, and Gould (2003), we address this endogeneity issue by augmenting the EASI demand system with the following reduced-form real expenditure equation:

$$(6) \qquad y_{ct} = \mu_0 + \sum_{r=1}^{R} \varphi_r Reg_r + \sum_{t=1}^{T} \delta_t Year_t + \sigma_{ct} \ln\_medhhinc_{ct} + \varepsilon_{ct},$$

where Reg_r is the region and is incorporated into the model as a dummy variable; $Year_t$ denotes time and is included in the model as a dummy variable; $\ln\_medhhinc_{ct}$ denotes median household income in logarithmic form and is used as an instrument for real expenditures; μ_0, φ_r, δ_t, and σ_{ct} are parameters to be estimated; and ε_{ct} is the error term. Income elasticities can be obtained by multiplying expenditure elasticities from equation (4) by the coefficient of $\ln\_medhhinc$ (σ_{ct}).

The unit values used in place of prices also may be endogenous because of the simultaneity bias attributed to the fact that price and quantity are determined jointly by the interaction of demand and supply. Additionally, measurement error may be present in the Homescan data. (Zhen et al., 2014). To address the price endogeneity issue, we impute prices for each designated market area as an average of corresponding prices from adjacent market areas (Hausman, 1997).[1] This approach hypothesizes that the prices from adjacent market areas reflect cheese manufacturing, wholesaling, and retail costs (i.e., supply side shocks) (Zhen et al., 2014). As such, the following reduced-form price equations are appended to the EASI demand system:

$$(7) \qquad p_{cjt} = \psi_0 + \sum_{r=1}^{R} \nu_r Reg_r + \sum_{t=1}^{T} \rho_t Year_t + \tau \bar{p}_{cjt} + \omega_{ct},$$

where p_{cjt} is the endogenous price, $\overline{p}_{cjt}$ is the Hausman-type price instruments, and ω_{ct} is the error term. The presence of endogeneity in total expenditure and prices is ascertained based on a test introduced by Durbin (1954), Wu (1973), and Hausman (1978) known as the DWH test (for details, see Dhar, Chavas, and Gould, 2003). According to the null hypothesis of the DWH test, total expenditure and prices are exogenous with the test statistic following a $\chi^2(g)$ distribution, with g specifying the number of potentially endogenous variables.

Data

This study employs city-level balanced panel quarterly data from the Nielsen Homescan panels (Nielsen at the Kilts Center for Marketing, 2021) covering the period from January 1, 2018, through December 31, 2020.[2] Nielsen Homescan panels are nationally representative longitudinal survey of households in which participating households are equipped with handheld scanners to scan and track all of their consumer packaged goods purchases at any store for a given time period for their at-home consumption. These data contain detailed information on retail food purchases and household sociodemographic characteristics.

For the present analysis, the city-level quarterly panel data contain 2,460 observations (205 designated market areas times 4 quarters for 3 years) concerning prices and quantities of the following eight cheese varieties: Muenster, Mozzarella, Colby, Cheddar, Swiss, remaining natural cheese, specialty/imported cheese, and processed cheese. The quantities purchased of every cheese variety in ounces are aggregated for each city across all quarters and years. Since Nielsen Homescan panel data do not report prices directly, unit values (hereafter prices), computed as total expenditure divided by quantity purchased and measured in dollars per ounce, are used as proxies for prices. These price-quantity data are supplemented with city-level demographic information obtained from

[1] The relevant data for supply factors as price instruments were unavailable for the cheese varieties considered.

[2] The data were aggregated from the household level to designated market areas (city level) due to the high degree of censoring present for the cheese varieties considered.

Table 1. Descriptive Statistics and Description of Quantities and Prices of Cheese Varieties and Demographic Characteristics (N = 2,460)

Variable	Description	Mean	Std. Dev.
Quantities (oz)			
q_mu	Muenster	223.43	381.78
q_mo	Mozzarella	2,644.41	4,040.05
q_co	Colby	181.69	253.51
q_ch	Cheddar	3,997.50	4,941.72
q_sw	Swiss	862.49	1,190.48
q_rn	Remaining natural	2,449.46	2,901.25
q_si	Specialty/Imported	1,933.87	2,801.22
q_pr	Processed	24,915.08	28,832.21
Prices ($/oz)			
p_mu	Muenster	0.2911	0.0508
p_mo	Mozzarella	0.2711	0.0272
p_co	Colby	0.2611	0.0665
p_ch	Cheddar	0.2852	0.0310
p_sw	Swiss	0.3099	0.0454
p_rn	Remaining natural	0.2938	0.0336
p_si	Specialty/Imported	0.4401	0.0598
p_pr	Processed	0.2132	0.0219
Demographic variables			
Median_hh_inc ($)	Median household income	58,695	11,936
Male	Proportion of male city population	0.492	0.0103
Female	Proportion of female city population	0.508	0.0103
Age_24_and_below	Proportion of city population aged 24 and below	0.3262	0.0335
Age_25-59	Proportion of city population aged 25–59	0.4466	0.0241
Age_60_above	Proportion of city population aged 60 and above	0.2272	0.0350
White	Proportion of city population, White	0.7711	0.1302
Black	Proportion of city population, Black	0.1237	0.1259
Asian	Proportion of city population, Asian	0.0305	0.0307
Other race	Proportion of city population, other races	0.0748	0.0532
Hispanic	Proportion of city population, Hispanic	0.1332	0.1644
Non-Hispanic	Proportion of city population, Non-Hispanic	0.8668	0.1644
Less_than_highschool	Proportion of city population with less than high school education	0.1041	0.0454
High_school	Proportion of city population with high school education	0.2795	0.0546
Some_college	Proportion of city population with some college education	0.3083	0.0392
Bachelor_or_higher	Proportion of city population with bachelorâĂŹs or higher degree	0.308	0.0779
Employed	Proportion of city population, employed	0.9507	0.0158
Unemployed	Proportion of city population, unemployed	0.0493	0.0158
Below_poverty	Proportion of city population below the poverty line	0.1412	0.0396
East	Proportion of city population residing in the East	0.2894	0.4536
Central	Proportion of city population residing in the Central region	0.522	0.4996
West	Proportion of city population residing in the West	0.1886	0.3913

Notes: Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business as well as data from the American Community Survey, 2018–2020. City population refers to the population within the 205 respective designated market areas associated with the Nielsen Homescan panels.

the American Community Survey (2020). This information discusses proportions of population in terms of median household income, gender, age groups, race, ethnicity, educational attainment, employment status, and poverty line by city.

Table 1 reports descriptive statistics of the variables used in the analysis. Based on the average quantities of the cheese varieties considered, processed cheese is the most popular variety (24,915 oz), followed by Cheddar (3,998 oz), Mozzarella (2,644 oz), remaining natural cheese (2,449 oz), specialty/imported cheese (1,934 oz), Swiss (862 oz), Muenster (223 oz), and Colby (182 oz). According to the results associated with average prices, the highest-priced cheese variety is specialty/imported cheese ($0.44/oz), followed by Swiss ($0.31/oz), remaining natural cheese, Muenster, and Cheddar (about $0.29/oz for each), Mozzarella ($0.27/oz), Colby ($0.26/oz), and processed cheese ($0.21/oz).

The remaining demographic variables included in the analysis are expressed as proportions of population except for city median household income. On average, city median household income is $58,695. The gender variable consists of two categories, with males accounting for 49.2% and females accounting for 50.8% of city populations on average. The variable pertaining to age consists of three categories with the average proportion of city populations aged 24 and below (almost 33%), from 25 to 59 (almost 45%), and 60 and above (almost 23%). The race variable consists of four categories with average proportions as follows: White (77%), Black (12%), Asian (3%), and other races (7%). On average, roughly 13% of city populations is Hispanic.

Educational attainment is represented by four categories: less than high school, high school, some college, and bachelor's or higher degree. On average, slightly more than 60% of each city's population have at least some college education, and about 95% are employed. Only about 14% are reported to be below the poverty line, on average. The region of residence variable is disaggregated into three categories: East (29%), Central (52%), and West (19%). The delineation of regions is consistent from the American Community Survey American Community Survey (2020).

Empirical Results

The LA-EASI demand model for eight cheese varieties, along with the reduced-form expenditure and price equations, is estimated using the full information maximum likelihood (FIML) approach and the MODEL procedure in SAS (SAS Institute, Inc., 2016). Tacitly, we assume that the eight cheese products considered are weakly separable from other food and nonfood products. The demand equation for processed cheese was omitted during the estimation to sidestep the singularity of the variance–covariance matrix of disturbance terms since budget shares add up to 1 in the EASI demand model. However, the parameters of the dropped budget share equation are then recovered using the theoretical restrictions of adding-up, homogeneity, and symmetry.

To determine the appropriate degree of the real expenditure polynomial function, we first estimate a linear EASI demand model, after which the degree is increased one at a time and a log-likelihood ratio test is conducted to measure the incremental change in the explanatory power of more general models. According to the χ^2 test statistic from the likelihood ratio tests for various degrees of real expenditures (up to the septic/seventh degree) and the associated p-values of effectively 0 presented in Table 2, the septic LA-EASI demand model is best supported by the data. As such, the rest of the analysis is predicated on the septic LA-EASI demand model specification.

Considering the DWH χ^2 statistic of 462.46 and its associated p-value of virtually 0, the null hypothesis that total expenditure and prices are exogenous is rejected. Additionally, the first-stage F-statistics and the associated p-values of virtually 0 provide further evidence of price instruments satisfying the relevance criterion. Finally, based on χ^2 tests, region and time fixed effects significantly enhance the explanatory power of the EASI model. While the results from the reduced-form expenditure and price equations are not reported here for brevity purposes (they are available upon request), the parameter estimates of the instruments used are statistically significant

Table 2. Diagnostic Tests for the EASI Model

Hypotheses	Likelihood Ratio Test Statistic	p-Value
EASI model specification tests		
(i) Quadratic vs. linear EASI model, (χ^2 test)	111.74	0
(ii) Cubic vs. quadratic EASI model, (χ^2 test)	54.3	0
(iii) Quartic vs. cubic EASI model, (χ^2 test)	54.96	0
(iv) Quintic vs. quartic EASI model, (χ^2 test)	48.74	0
(v) Sextic vs. quintic EASI model, (χ^2 test)	20.96	0.004
(vi) Septic vs. sextic EASI model, (χ^2 test)	18.86	0.009
Cheese prices and expenditures are exogenous (DWH test), (χ^2 test)	462.46	0
First-stage regression for instrument relevance, total expenditures, (F-test)	236.48	0
First-stage regression for instrument relevance, price of Muenster, (F-test)	9.83	0
First-stage regression for instrument relevance, price of Mozzarella, (F-test)	54.26	0
First-stage regression for instrument relevance, price of Colby, (F-test)	10.52	0
First-stage regression for instrument relevance, price of Cheddar, (F-test)	107.82	0
First-stage regression for instrument relevance, price of Swiss, (F-test)	27.9	0
First-stage regression for instrument relevance, price of Remaining natural, (F-test)	29.79	0
First-stage regression for instrument relevance, price of Specialty/Imported, (F-test)	35.91	0
First-stage regression for instrument relevance, price of Processed, (F-test)	80.83	0
Unobserved regional heterogeneity has no significant impact on cheese demand, (χ^2 test)	1,771.88	0
Time fixed effects have no significant impact on cheese demand, (χ^2 test)	26.48	0.023

Notes: Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

and are consistent with economic theory, suggesting positive relationships between prices and the supply-side shocks, as represented by price instruments.

Table 3 reports parameter estimates and standard errors from the LA-EASI demand model budget share equations at the three conventional significance levels of 1%, 5%, and 10%. Per the estimation results, the budget shares for Muenster, remaining natural cheese, and specialty imported cheese are higher for males, while the budget shares for Cheddar and processed cheese are higher for females. Relative to people aged 60 and above, those aged 24 and below allot higher shares of their cheese expenditures to Cheddar and lower shares of their cheese expenditures to Swiss and specialty/imported cheese. At the same time, compared to people aged 60 and above, those aged between 25 and 59 allot higher shares of their cheese expenditures to Cheddar and processed cheese and lower shares of their cheese expenditures to Muenster, Mozzarella, and specialty/imported cheese.

Compared to Americans of other races, white Americans have higher budget shares for Muenster, Cheddar, and Swiss and lower budget shares for Colby and remaining natural cheese. Compared to Americans of other races, Black Americans have higher budget shares for Cheddar and Swiss and lower budget shares for Mozzarella and Colby. Compared to Americans of other races, Asians have higher budget shares for Mozzarella, Cheddar, and Swiss and lower budget shares for processed cheese. Hispanics have higher budget shares for Muenster, Mozzarella, Swiss, and specialty/imported cheese than non-Hispanic individuals. However, non-Hispanic individuals have higher budget shares for processed cheese than Hispanic individuals.

Compared to people with a bachelor's degree or higher, people with less than a high school education tend to allocate higher shares of their cheese expenditures to Cheddar, and lower shares of their cheese expenditures to Muenster, Mozzarella, Colby, Swiss, and remaining natural cheese. In comparison to people with a bachelor's degree or higher, people with a high school education tend

Table 3. Parameter Estimates and Standard Errors from the EASI Budget Share Equations

Parameters	Muenster	Mozzarella	Colby	Cheddar	Swiss	Remaining Natural	Specialty/ Imported	Processed
Intercept (α_{i0})	0.0052***	0.0892***	0.0015	0.1591***	0.0334***	0.1032***	0.0941***	0.5145***
	(0.0010)	(0.0049)	(0.0016)	(0.0045)	(0.0018)	(0.0044)	(0.0034)	(0.0098)
Muenster price (γ_{1i})	−0.0002	0.0004	−0.0007	0.0003	−0.0006	0.0017	−0.0008	−0.0001
	(0.0014)	(0.0015)	(0.0013)	(0.0013)	(0.0006)	(0.0017)	(0.0009)	(0.0013)
Mozzarella price (γ_{2i})		0.0278***	−0.0021	0.0011	0.0055**	0.0057	−0.0109***	−0.0276***
		(0.0070)	(0.0025)	(0.0047)	(0.0022)	(0.0057)	(0.0035)	(0.0067)
Colby price (γ_{3i})			0.0010	0.0040*	−0.0005	−0.0014	0.0016	−0.0019
			(0.0029)	(0.0022)	(0.0014)	(0.0026)	(0.0016)	(0.0023)
Cheddar price (γ_{4i})				−0.0005	−0.0047*	−0.0005	0.0146***	−0.0142**
				(0.0083)	(0.0026)	(0.0067)	(0.0044)	(0.0072)
Swiss price (γ_{5i})					0.0003	0.0051*	0.0014	−0.0065**
					(0.0016)	(0.0026)	(0.0018)	(0.0028)
Remaining natural price (γ_{6i})						0.0135	0.0051	−0.0293***
						(0.0086)	(0.0041)	(0.0070)
Specialty/imported price (γ_{7i})							−0.0027	−0.0084
							(0.0043)	(0.0053)
Processed price (γ_{8i})								0.0879***
								(0.0156)
Real expenditure (β_{i1})	0.0014***	0.0095***	0.0016*	−0.0120***	−0.0017	−0.0043	0.0051**	0.0005
	(0.0005)	(0.0019)	(0.0009)	(0.0029)	(0.0011)	(0.0026)	(0.0023)	(0.0043)
Real expenditure (β_{i2})	−0.0001	−0.0007	0.0002	−0.0025	−0.0001	0.0020	0.0001	0.0012
	(0.0002)	(0.0010)	(0.0004)	(0.0017)	(0.0006)	(0.0013)	(0.0012)	(0.0026)
Real expenditure (β_{i3})	−0.0001	−0.0007	−0.0003	0.0011	0.0002	−0.0004	−0.0002	0.0004
	(0.0001)	(0.0007)	(0.0003)	(0.0011)	(0.0004)	(0.0010)	(0.0008)	(0.0016)
Real expenditure (β_{i4})	0.00004	−6.75E-6	−0.0001	0.0004	−0.0001	−0.0006	0.0002	0.0001
	(0.0001)	(0.0003)	(0.0001)	(0.0006)	(0.0002)	(0.0004)	(0.0004)	(0.0008)
Real expenditure (β_{i5})	1.378E-6	0.0001	0.00002	−0.00003	4.79E-6	−0.00001	0.00002	−0.0001
	(0.00002)	(0.0001)	(0.00003)	(0.0001)	(0.00004)	(0.0001)	(0.0001)	(0.0002)
Real expenditure (β_{i6})	−3.54E-6	0.00002	6.963E-6	−0.00003	1.668E-6	0.00004	−0.00002	−0.00002
	(6.625E-6)	(0.000028)	(0.000014)	(0.000058)	(0.000017)	(0.000039)	(0.000037)	(0.000078)
Real expenditure (β_{i7})	−3.87E-7	1.764E-6	4.407E-7	−3.05E-6	−1.28E-7	4.428E-6	−2.64E-6	−4.21E-7
	(7.113E-7)	(2.486E-6)	(1.415E-6)	(5.765E-6)	(1.689E-6)	(3.426E-6)	(3.578E-6)	(7.568E-6)

Table 3 continued. Parameter Estimates and Standard Errors from the EASI Budget Share Equations

Parameters	Muenster	Mozzarella	Colby	Cheddar	Swiss	Remaining Natural	Specialty/ Imported	Processed
Male	0.0007***	0.0016	0.0002	−0.0040***	0.0006*	0.0058***	0.0018**	−0.0068***
	(0.0001)	(0.0007)	(0.0003)	(0.0010)	(0.0004)	(0.0009)	(0.0007)	(0.0016)
Age_24_and_below	−0.0001	−0.0010	0.0002	0.0030**	−0.0019***	0.0008	−0.0042***	0.0031*
	(0.0002)	(0.0007)	(0.0003)	(0.0013)	(0.0004)	(0.0011)	(0.0008)	(0.0017)
Age_25-59	−0.0004**	−0.0044***	0.00002	0.0039***	−0.0004	−0.0022*	−0.0030***	0.0065***
	(0.0002)	(0.0007)	(0.0003)	(0.0012)	(0.0004)	(0.0011)	(0.0008)	(0.0017)
White	0.0008**	−0.0019	−0.0024***	0.0073**	0.0027**	−0.0050**	0.0006	−0.0021
	(0.0004)	(0.0023)	(0.0008)	(0.0033)	(0.0012)	(0.0025)	(0.0017)	(0.0052)
Black	0.0012*	−0.0056**	−0.0032***	0.0079**	0.0022**	−0.0008	0.0033*	−0.0051
	(0.0004)	(0.0022)	(0.0007)	(0.0032)	(0.0011)	(0.0027)	(0.0018)	(0.0050)
Asian	0.0001	0.0029***	−0.0009*	0.0038**	0.0014**	−0.0016	0.0021*	−0.0077***
	(0.0002)	(0.0011)	(0.0005)	(0.0017)	(0.0006)	(0.0016)	(0.0011)	(0.0028)
Hispanic	0.0020***	0.0036***	0.0007	−0.0034*	0.0022***	0.0017	0.0088***	−0.0156***
	(0.000210)	(0.00113)	(0.000461)	(0.00192)	(0.000660)	(0.00144)	(0.00109)	(0.00282)
Less_than_highschool	−0.0010***	−0.0035***	−0.0011**	0.0063***	−0.0021***	−0.0029**	0.0019*	0.0024
	(0.0002)	(0.0011)	(0.0005)	(0.0018)	(0.0006)	(0.0014)	(0.0011)	(0.0027)
High_school	−0.0003*	0.0005	0.0016***	−0.0040***	0.0004	0.0004	−0.0060***	0.0074***
	(0.0002)	(0.0008)	(0.0003)	(0.0013)	(0.0004)	(0.0010)	(0.0009)	(0.0018)
Some_college	−0.0002	0.0017***	−0.00004	0.0069***	−0.0009***	−0.0001	−0.0055***	−0.0018
	(0.0002)	(0.0006)	(0.0003)	(0.0009)	(0.0003)	(0.0008)	(0.0007)	(0.0015)
Employed	0.0002	−0.0023***	−0.0005*	0.0051***	0.0006	0.0033***	0.0004	−0.0067***
	(0.0002)	(0.0007)	(0.0003)	(0.0012)	(0.0004)	(0.0010)	(0.0007)	(0.0017)
Below_poverty	0.0004	−0.0026**	−0.0006	−0.0003	0.0008	−0.0012	0.0008	0.0027
	(0.0002)	(0.0010)	(0.0005)	(0.0017)	(0.0006)	(0.0014)	(0.0010)	(0.0025)
Region fixed effects								
East	0.0021	−0.0024	0.0016	−0.0118*	0.0010	−0.0247***	−0.0021	0.0362***
	(0.0017)	(0.0055)	(0.0026)	(0.0064)	(0.0025)	(0.0059)	(0.0044)	(0.0098)
Central	0.0002	−0.0273***	0.0078***	−0.0496***	−0.0079***	−0.0217***	−0.0210***	0.1195***
	(0.0013)	(0.0060)	(0.0019)	(0.0052)	(0.0021)	(0.0054)	(0.0039)	(0.0113)
Time fixed effects								
Year_2018	0.0001	−0.0005	0.0006	−0.0060*	−0.0031**	−0.0056	−0.0013	0.0157**
	(0.0007)	(0.0032)	(0.0011)	(0.0035)	(0.0013)	(0.0034)	(0.0026)	(0.0064)
Year_2019	−0.0002	−0.0053*	−0.0001	0.0010	−0.0027**	−0.0044*	−0.0001	0.0118**
	(0.0004)	(0.0027)	(0.0009)	(0.0027)	(0.0011)	(0.0025)	(0.0020)	(0.0056)

Notes: Values in parentheses are the standard errors as reported by PROC MODEL (SAS statistical software). Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level, respectively. Seasonality, captured using the quarterly indicator variables, was not a statistically significant factor and therefore was not included in the final estimation of the demand system. Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

to allocate higher shares of their cheese expenditures to Colby and processed cheese and lower shares of their cheese expenditures to Cheddar and specialty/imported cheese. People with some college education tend to allocate higher shares of their cheese expenditures to Mozzarella and Cheddar and lower shares of their cheese expenditures to Swiss and specialty/imported cheese compared with people with a bachelor's degree or higher.

The budget shares for Cheddar and remaining natural cheese are higher for those who are employed, while those who are unemployed have higher budget shares for Mozzarella and processed cheese. Those who are above the poverty line allocate higher budget shares for Mozzarella. Compared with city populations located in the West, city populations located in the East have higher budget shares for processed cheese but lower budget shares for remaining natural cheese varieties. At the same time, city populations located in the Central region have higher budget shares for Colby and processed cheese, but lower for Mozzarella, Cheddar, Swiss, remaining natural cheese, and specialty/imported cheese relative to city populations located in the West. Finally, budget shares for processed cheese are higher in 2018 and 2019 relative to 2020, but the reverse is true for Swiss.

We calculate two sets of demand elasticities using the parameter estimates from the LA-EASI demand model: compensated (Hicksian) and uncompensated (Marshallian). Table 4 presents uncompensated (Marshallian) own-price, cross-price, expenditure, and income elasticities of demand computed at the sample means using the parameter estimates from the EASI demand model. As anticipated, all uncompensated own-price elasticities of demand are negative and statistically significant. The uncompensated own-price elasticities of Muenster (−1.0310), Cheddar (−0.9922), Swiss (−0.9883), and specialty/imported cheese (−1.0380) suggest a virtually unitary elastic demand, while the uncompensated own-price elasticity estimates of Mozzarella (−0.6223), Colby (−0.8382), remaining natural cheese (−0.8323), and processed cheese (−0.8537) reveal inelastic demands for these cheese varieties. Our estimates of own-price elasticities contrast with those reported in the extant literature, which suggested elastic demands for cheese varieties.

All the estimated expenditure elasticities are positive and statistically significant, as expected. According to the expenditure elasticities, Muenster (1.2290), Mozzarella (1.1315), Colby (1.2691), specialty/imported cheese (1.0615), and processed cheese (1.0009) are more responsive to changes in cheese expenditures, while Cheddar (0.9043), Swiss (0.9362), and remaining natural cheese (0.9474) are less responsive to changes in cheese expenditures. Our results for natural cheese varieties such as Muenster, Mozzarella, and Colby align with findings from Davis, Blayney, et al. (2010) and Davis, Dong, et al. (2010).

Consistent with our expectations and with the literature, all estimates of income elasticities are positive and statistically significant. In particular, the positive signs and magnitude of income elasticity estimates of Muenster (0.6669), Mozzarella (0.6140), Colby (0.6887), Cheddar (0.4907), Swiss (0.5080), remaining natural cheese (0.5141), specialty/imported cheese (0.5760), and processed cheese (0.5431) indicate that these cheese varieties not only are normal goods but are also necessities. These results compare favorably with those from Bouhlal (2012) and Gould and Lin (1994).

Table 5 reports the compensated (Hicksian) own-price elasticity and cross-price elasticity of demand computed at the sample means. As expected, all compensated own-price elasticities of demand of Muenster (−1.0238), Mozzarella (−0.5410), Colby (−0.8304), Cheddar (−0.8788), Swiss (−0.9629), remaining natural cheese (−0.7541), specialty/imported cheese (−0.9505), and processed cheese (−0.2546) are negative and statistically significant.

Consistent with our expectations, out of 56 compensated cross-price elasticities, 28 are positive and statistically significant, indicating a net substitutability relationship between the cheese varieties considered, 12 are positive but not statistically significant, and 16 are negative but not statistically significant. Hence, no statistically significant complementary relationships are evident. Interestingly, processed cheese is a substitute for specialty/imported cheese and all natural cheese varieties except

Table 4. Uncompensated (Marshallian) Price, Expenditure, and Income Elasticity Estimates and Associated Standard Errors from the EASI Demand System

Cheese Variety	Muenster	Mozzarella	Colby	Cheddar	Swiss	Remaining Natural	Specialty/ Imported	Processed	Expenditure	Income
Muenster	−1.0310***	0.0452	−0.1176	0.0180	−0.1154	0.2732	−0.1468	−0.1546	1.2290***	0.6669***
	(0.2449)	(0.2618)	(0.2113)	(0.2255)	(0.1082)	(0.2891)	(0.1597)	(0.2190)	(0.0234)	(0.0285)
Mozzarella	0.0043	−0.6223***	−0.0297	−0.0015	0.0735**	0.0691	−0.1625***	−0.4624***	1.1315***	0.6140***
	(0.0215)	(0.0980)	(0.0352)	(0.0658)	(0.0303)	(0.0795)	(0.0491)	(0.0927)	(0.0248)	(0.0263)
Colby	−0.1133	−0.3583	−0.8382*	0.6122*	−0.0940	−0.2520	0.2375	−0.4630	1.2691***	0.6887***
	(0.2032)	(0.4121)	(0.4707)	(0.3625)	(0.2248)	(0.4156)	(0.2562)	(0.3737)	(0.0268)	(0.0295)
Cheddar	0.0028	0.0155	0.0322*	−0.9922***	−0.0346*	0.0038	0.1244***	−0.0562	0.9043***	0.4907***
	(0.0106)	(0.0377)	(0.0177)	(0.0661)	(0.0207)	(0.0531)	(0.0347)	(0.0577)	(0.0301)	(0.0210)
Swiss	−0.0234	0.2087***	−0.0192	−0.1639*	−0.9883***	0.1942**	0.0567	−0.2009**	0.9362***	0.5080***
	(0.0235)	(0.0803)	(0.0508)	(0.0957)	(0.0570)	(0.0975)	(0.0664)	(0.1014)	(0.0213)	(0.0217)
Remaining natural	0.0212	0.0734	−0.0168	0.0004	0.0635**	−0.8323***	0.0667	−0.3234***	0.9474***	0.5141***
	(0.0207)	(0.2891)	(0.0309)	(0.0807)	(0.0320)	(0.1047)	(0.0492)	(0.0846)	(0.0341)	(0.0220)
Specialty/ imported	−0.0095	−0.1366***	0.0189	0.1695***	0.0153	0.0573	−1.0380***	−0.1384**	1.0615***	0.5760***
	(0.0114)	(0.0428)	(0.0190)	(0.0528)	(0.0218)	(0.0492)	(0.0520)	(0.0637)	(0.0335)	(0.0246)
Processed	−0.0002	−0.0461***	−0.0031	−0.0239**	−0.0109**	−0.0490***	−0.0141	−0.8537***	1.0009***	0.5431***
	(0.0022)	(0.0111)	(0.0038)	(0.0121)	(0.0046)	(0.0117)	(0.0088)	(0.0261)	(0.1587)	(0.0232)

Notes: Elasticities are calculated at the sample means. Values in parentheses are the standard errors as reported by PROC MODEL (SAS statistical software). Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level, respectively. Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

Table 5. Compensated (Hicksian) Price Elasticity Estimates and Associated Standard Errors from the EASI Demand System

Cheese Variety	Muenster	Mozzarella	Colby	Cheddar	Swiss	Remaining Natural	Specialty/ Imported	Processed
Muenster	−1.0238***	0.1335	−0.1101	0.1722	−0.0821	0.3747	−0.0455	0.5811***
	(0.2449)	(0.2618)	(0.2113)	(0.2255)	(0.1082)	(0.2891)	(0.1597)	(0.2190)
Mozzarella	0.0110	−0.5410***	−0.0228	0.1405**	0.1041***	0.1625**	−0.0692	0.2149**
	(0.0215)	(0.0980)	(0.0352)	(0.0658)	(0.0303)	(0.0795)	(0.0491)	(0.0927)
Colby	−0.1058	−0.2671	−0.8304*	0.7714**	−0.0596	−0.1473	0.3421	0.2967
	(0.2032)	(0.4121)	(0.4707)	(0.3625)	(0.2248)	(0.4156)	(0.2562)	(0.3737)
Cheddar	0.0081	0.0805**	0.0377**	−0.8788***	−0.0101	0.0784	0.1989***	0.4852***
	(0.0106)	(0.0377)	(0.0177)	(0.0661)	(0.0207)	(0.0531)	(0.0347)	(0.0577)
Swiss	−0.0179	0.2760***	−0.0135	−0.0465	−0.9629***	0.2714***	0.1339**	0.3594***
	(0.0235)	(0.0803)	(0.0508)	(0.0957)	(0.0570)	(0.0975)	(0.0664)	(0.1014)
Remaining natural	0.0268	0.1414**	−0.0109	0.1192	0.0892***	−0.7541***	0.1448***	0.2437***
	(0.0207)	(0.0692)	(0.0309)	(0.0807)	(0.0320)	(0.1047)	(0.0492)	(0.0846)
Specialty/imported	−0.0033	−0.0603	0.0254	0.3027***	0.0440**	0.1449***	−0.9505***	0.4970***
	(0.0114)	(0.0428)	(0.0190)	(0.0528)	(0.0218)	(0.0492)	(0.0520)	(0.0637)
Processed	0.0057***	0.0258**	0.0030	0.1017***	0.0163***	0.0336***	0.0685***	−0.2546***
	(0.0022)	(0.011)	(0.0038)	(0.0121)	(0.0046)	(0.0117)	(0.0088)	(0.0261)

Notes: Elasticities are calculated at the sample means. Values in parentheses are the standard errors as reported by PROC MODEL (SAS statistical software). Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level, respectively. Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

for Colby. Additionally, specialty/imported cheese is a substitute for Cheddar, Swiss, remaining natural cheese, and processed cheese. The weakest net substitutability relationship is observed between the processed cheese and Muenster (0.0057), while the strongest net substitutability relationship is present between Colby and Cheddar (0.7714). Overall, our empirical findings are in alignment with those from Bouhlal (2012); Davis, Blayney, et al. (2010); and Davis, Dong, et al., (2010), who reported substitutability relationships among natural cheese varieties as well as between natural cheese varieties and processed cheese.

Finally, using the average values for prices and quantities as well as the compensated elasticity estimates from this study, we compute the elasticity of total cheese sales with respect to the prices of cheese varieties.[3] Following Dharmasena and Capps (2014), the total sales for the cheese industry is defined as

$$TS = \sum p_i q_i, \tag{8}$$

where p_i and q_i are the price and quantity of cheese variety i, respectively. Hence, the elasticity of total sales with respect to the price of cheese variety i is given by

$$E_{TS} = \frac{1}{p_i}\left(S_i\left(1 + e_{ii}^C\right) + \sum S_j e_{ji}^C\right)\frac{TS}{p_i}, \tag{9}$$

where E_{TS} is the elasticity of total sales with respect to the price of cheese variety, p_i is the price of cheese variety i, S_i is the sales of cheese variety i, e_{ii}^C is the compensated own-price elasticity of cheese variety i, S_j is the sales of cheese variety j, e_{ji}^C is the compensated cross-price elasticity of demand for cheese variety j with respect to the price of cheese variety i, and *TS* is total sales. The computed elasticities of total sales with respect to price are 0.0058 for Muenster, 0.0744 for Mozzarella, 0.0059 for Colby, 0.1270 for Cheddar, 0.0216 for Swiss, 0.0687 for remaining natural cheese, 0.0442 for specialty/imported cheese, and 0.5936 for processed cheese. Hence, to increase total sales of the entire cheese category, our findings suggest raising the prices of the cheese varieties considered, particularly processed cheese.

Summary, Implications, and Recommendations for Future Research

Using city-level balanced panel data derived from the Nielsen Homescan panels from 2018 through 2020, we estimate a fixed-effects LA-EASI model to empirically investigate the demand for a wide spectrum of cheese varieties. Our empirical findings ascertain that the septic (seventh) degree LA-EASI model provides the best fit of the data. Also, demand for Muenster, Cheddar, Swiss, and specialty/imported cheese is found to be unitary elastic, while that for Mozzarella, Colby, remaining natural cheese, and processed cheese is inelastic. This result suggests that manufacturers and retailers of Mozzarella, Colby, remaining natural cheese, and processed cheese should raise their prices in order to maximize total revenue in the short run, all other factors invariant. Based on the estimated income elasticities, cheese varieties are labeled as necessities. This finding implies that with increases in income, the consumption of all cheeses is also expected to grow, but by less proportionally. Per the estimated compensated cross-price elasticities, substitutability relationships are ascertained among various cheese varieties, implying that they are direct competitors for each other. This useful information can be utilized by cheese manufacturers to facilitate their input procurement and inventory management decisions in response to changes in the prices of competing cheese varieties.

Demographic characteristics emerge as statistically significant factors influencing the demand for cheese varieties. Information regarding the demographic characteristics can assist cheese

[3] One reviewer suggested that because we do not analyze interrelationships with noncheese products, our results concerning the elasticity of total cheese sales with respect to prices of the cheese varieties considered are likely to be biased. We assume that this bias is negligible.

manufacturers and retailers in designing marketing strategies targeting specific demographic groups to expand beyond their traditional customer base.

The computed elasticities of total sales with respect to cheese prices are of significance to cheese manufacturers and retailers in designing pricing strategies geared toward increasing total sales in the cheese industry as well as to policy makers in their efforts to provide oversight to the cheese industry. In particular, the estimated total sales elasticities reveal that increases in the prices of any cheese variety considered result in an increase in total sales, with the most notable increase in total sales associated with a change in the price of processed cheese.

Future work could benefit from the use of price instruments developed from data associated with the costs of manufacturers. Additionally, future research is recommended to conduct a more disaggregated analysis of processed cheese. Finally, future work replicating the analysis at the household level, taking into consideration a high degree of censoring, may be done as well as a check of the robustness of our results.

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