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RESEARCH ARTICLE

A Micro-perspective Analysis of the Demand for Greek and Non-Greek Yogurt in the United States Over Calendar Years 2018 to 2020

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Abstract
Using the Heckman framework, we develop profiles of households who purchase Greek yogurt and non-Greek yogurt and estimate own-price, cross-price, and income elasticities of demand. Attention is centered on the impacts of age, race, education, and ethnicity of the household head, household income, household size, region, the presence of children, and prices of Greek yogurt and non-Greek yogurt. This analysis rests on data acquired from Nielsen pertaining to 164,484 households over calendar years 2018–2020. Own-price elasticities are estimated to be −1.36 for Greek yogurt and −0.70 for non-Greek yogurt. Additionally, these yogurt products are not only substitutes but also necessities.

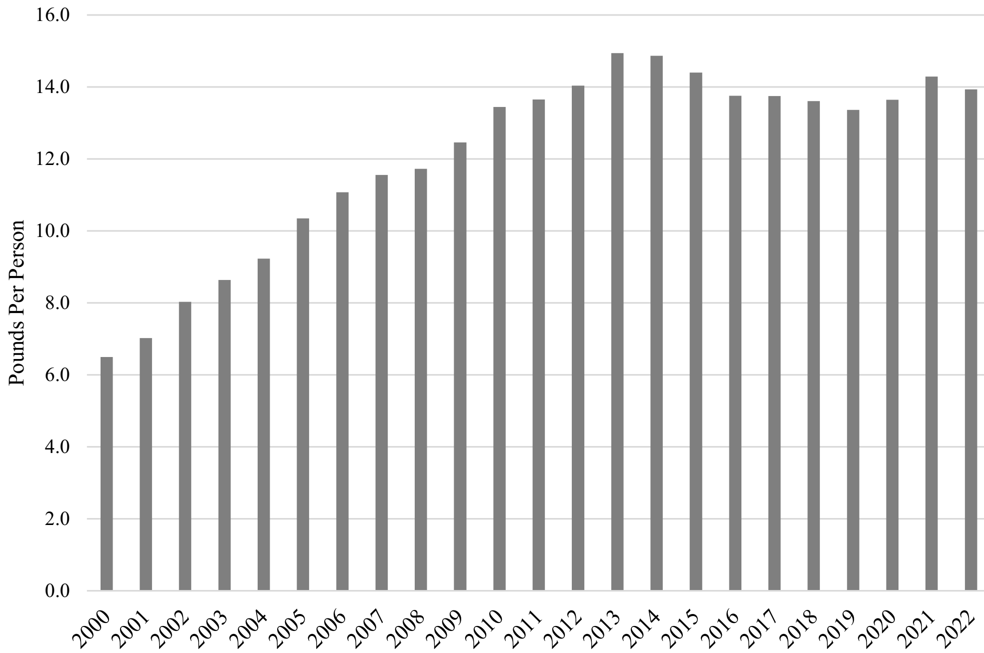
Keywords: NielsenIQ; Greek Yogurt; non-Greek Yogurt; Heckman maximum likelihood estimator; sample selection bias; probit analysis; household demand analysis

JEL classifications: C20; D12

Introduction
Yogurt has been one of the most popular dairy products worldwide with considerable consumer acceptability due to its perceived health and nutrition benefits (Weerathilake et al., 2014). Yogurt often is recommended to individuals with lactose intolerance as well as gastrointestinal disorders such as inflammatory bowel disease and irritable bowel disease. As well, yogurt aids in immune function and weight control (Lourens-Hattingh and Viljoen, 2001; McKinley, 2005).

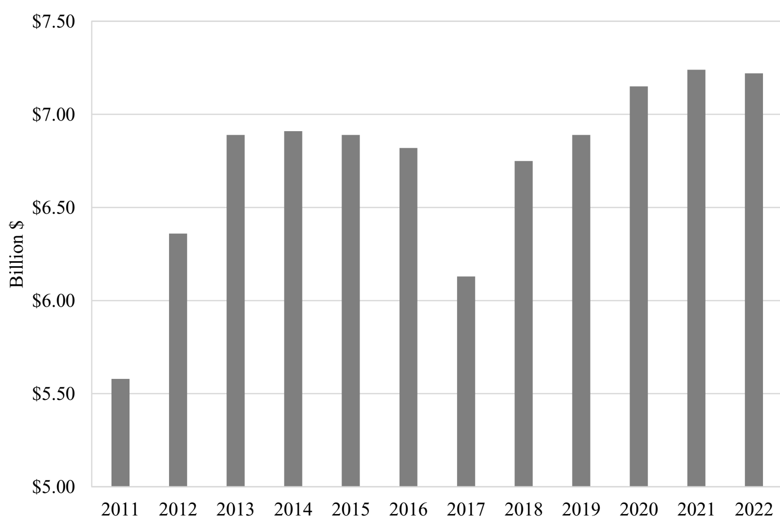
As exhibited in Fig. 1, yogurt rose monotonically from 6.5 pounds to 14.9 pounds from 2000 to 2014. However, from 2015 to 2022 per capita consumption of yogurt leveled off, ranging between 13.4 pounds to 14.4 pounds (Economic Research Service, USDA, 2024). As shown in Fig. 2, the market value of yogurt in the United States rose from $5.58 billion to $7.24 billion over the past decade, tantamount to roughly a 30 percent increase, despite the drop that occurred in 2017 (Shahbandeh, 2022a). Currently close to 180 companies are involved, directly or indirectly, with yogurt production industry in the United States. Combined, these companies provide employment opportunities for about 10,000 workers (IBIS*World*, 2021).

Greek yogurt also is known as strained yogurt. Through the straining process, the excess watery whey is removed, which gives the yogurt a much thicker and creamier consistency. TV chef Graham Kerr – "The Galloping Gourmet" – touted strained yogurt on his show as early as 1990, long before anyone had heard of Greek yogurt, and the first commercial strained yogurt appeared on the shelves of U.S. grocery stores in 2001 (Andrews, 2017).



Source: Economic Research Service, U.S. Department of Agriculture, https://www.ers.usda.gov/data-products/dairy-data/dairy-data/, Dairy products: Per capita consumption, United States (annual).

Figure 1. Per capita consumption of yogurt in pounds, 2000 to 2022.



Source: Shahbandeh (2022a).

Figure 2. Market value of yogurt in the United States in billion dollars, 2011 to 2022.

Greek yogurt sales have experienced tremendous growth over the past ten years, from $391 million in 2010 to close to $3.7 billion currently. Further, Greek yogurt presently accounts for approximately 51% of the U.S. yogurt market share, up from almost a 0% market share in 2001 (Shahbandeh, 2022b). The Greek yogurt market size is projected to grow at a compound annual growth rate of 10.9% from 2020 to 2027 (Allied Market Research, 2020).

Greek yogurt and non-Greek yogurt unequivocally are of importance not only to the U.S. economy but also to the health of Americans. Moreover, the demographic landscape of the U.S. population has been changing over time. In this light, we wish to ascertain which socio-demographic factors are drivers associated with the decision to purchase Greek and non-Greek yogurt and with the amounts purchased. To adapt to the changing needs of households and to keep up to date measures concerning the sensitivity of households to changes in prices and income, this research provides requisite information to producers, processors, marketers, and retailers to enhance opportunities to enhance their agri-business activities.

Yet relatively few economic studies are evident in the literature dealing specifically with ***separate*** demand analyses for these yogurt products. Moreover, previous findings do not reflect current economic conditions as well as changes in consumer tastes and preferences and thus may arguably be considered obsolete. Consequently, stakeholders in the yogurt industry cannot rely on past estimates of own-price and income elasticities or impacts of socio-demographic variables. To fill this research void, the objectives of this study are threefold: (1) to develop profiles of households who purchase Greek yogurt and non-Greek yogurt; (2) to investigate the socioeconomic determinants of the demand by U.S. households for these yogurt products; and (3) to estimate own-price, cross-price, and income elasticities of demand for stakeholders in the yogurt industry.

This analysis rests on data acquired from Nielsen pertaining to 164,484 households over calendar years 2018–2020. We utilize the Heckman sample selection model to carry out the respective objectives. The probit models and the conditional demand models inherent with the Heckman framework center attention on economic and socio-demographic factors as explanatory variables, including age, race, education, and ethnicity of the household head, household income, household size, region/designated market area, the presence of children, and prices of Greek yogurt and non-Greek yogurt. From this analysis, industry stakeholders will have a better understanding of households who are most likely to purchase Greek yogurt and non-Greek yogurt. This information can then be used in developing new or revising existing marketing strategies to reach specific socio-demographic groups to retain current customers and perhaps to add new customers. Estimated own-price, cross-price, and income elasticity estimates gleaned from this analysis can be used by yogurt manufacturers and by retailers in formulating optimal pricing strategies to maximize revenue.

Literature review

The demand for yogurt has been studied applying different theoretical frameworks and estimating various empirical models, depending on the nature of the respective analyses and on the data used. As exhibited in Table 1, various studies have focused primarily on yogurt without reference to Greek yogurt or to non-Greek yogurt. Additionally, past studies have considered the demand for yogurt by product forms, specifically refrigerated yogurt, frozen yogurt, drinkable yogurt, and flavored yogurt as well as by brand, particularly Chobani, Dannon, Yoplait, and private label. Without reference to brand, the demand for the aggregate category of yogurt has been estimated to be elastic, except for the studies by Boehm and Babb (1975) and Chouinard et al. (2010). The own-price elasticities for yogurt by brand have varied considerably as follows – Chobani (−2,64 to −6.84); Dannon (−0.35 to −5.48); Yoplait (−0.37 to −5.65); Private Label (−0.19 to −6.15). Most of the demand studies summarized in Table 1 were conducted using a demand systems approach.

Table 1. Selected prior studies from the economic literature dealing with yogurt

Researcher(s)	Category	Data	Model	Own-Price Elasticity
Boehm and Babb (1975)	Yogurt	United Dairy Industry Association–United States	Quantity-Dependent Log Single-Equation	−0.36 short run; −0.51 long run
Maynard and Veeramani (2003)	Frozen Yogurt	Weekly observations for calendar years 1996 to 1998	Differential Demand System	Elastic, no specific value reported
Davis et al. (2010a)	Refrigerated Yogurt Frozen Yogurt Drinkable Yogurt	Roughly 6,000 households during Calendar Year 2005 from the Nielsen Homescan Panel	Three-Equation Seemingly Unrelated Regression (SUR)	−1.01 −2.03 −1.10
Davis et al. (2010b)	Refrigerated Yogurt Frozen Yogurt Drinkable Yogurt	63,601 households during calendar year 2007 from the Nielsen Homescan Panel	Censored AIDS	−1.19 −1.26 −1.73
Davis et al. (2011)	Refrigerated Yogurt Frozen Yogurt	63,601 households during calendar year 2007 from the Nielsen Homescan Panel	Amemiya-Tobin Censored Demand System	−0.92 −1.18
Chouinard et al. (2010)	Flavored Yogurt	Weekly data from Information Resources, Inc. (IRI) from 23 U.S. cities	Variation of the AIDS	−0.77
Villas-Boas (2007)	Dannon Yoplait Private Label	Data from a Midwestern urban area from June 1991 to June 1993	Random Coefficients Discrete Choice	−5.48 −5.65 −6.15
Mehta et. al. (2010)	Dannon Yoplait Private Label	Nielsen scanner data from Sioux Falls, South Dakota over the period 1986 to 1988	Hanemann Discrete/Continuous Models	−0.60 −0.66 −0.85
Robinson (2017)	Chobani Dannon Yoplait Stonyfield Private Label	Weekly data from Nielsen for the United States from January 2009 to December 2011	Five-Equation Seemingly Unrelated Regression (SUR)	−2.64 −1.43 −0.37 −0.86 −0.19
Mohammed and Murova (2019)	Chobani Dannon Yoplait Private Label	Weekly data from 27 retailers collected from IRI over the period 2008 to 2011 located in Eau Claire, Wisconsin and Pittsfield, Massachusetts	Quadratic Almost Ideal Demand System (QUAIDS)	−6.84 −0.35 −1.62 −3.43

Notably, only a few prior studies have conducted separate demand analyses for Greek yogurt and non-Greek yogurt. Dharmasena et al. (2014) analyzed U.S. household demand for Greek yogurt and non-Greek yogurt along with other dairy products using the 2010 Nielsen Homescan Panel. Based on the estimation of a censored QUAIDS model involving 61,440 households, own-price elasticities for Greek yogurt and non-Greek yogurt were estimated to be −0.12 and −0.22, respectively. Their cross-price elasticities were positive, indicative of substitutes. The income elasticities for Greek yogurt and non-Greek yogurt were estimated to be 0.35 and 0.20, respectively, indicative of necessities. Key demographic factors affecting these demands were household income, age, and education of the female head of household, region, race, ethnicity, and presence/absence of children.

Keller (2018) estimated probit models only of household purchases of: (1) yogurt; (2) Greek yogurt only; (3) non-Greek yogurt only; and (4) both Greek and non-Greek yogurt. This research utilized the Nielsen Homescan Panel for calendar year 2015 only. Socio-demographic factors considered were household income, household size, region, age and presence of children, race, and education and age of the household head.

Gao and Capps (2023) investigated demand interrelationships for eight dairy categories, including Greek yogurt and non-Greek yogurt, as well as for margarine and plant-based milk alternatives using the QUAIDS and the Barten Synthetic Model, based on monthly data derived from Nielsen covering the period January 2010 to November 2015. Estimated own-price elasticities for non-Greek yogurt ranged from −1.42 and −1.63 and estimated own-price elasticities for Greek yogurt ranged from −1.97 to −2.25. Income elasticities for these products were estimated to be in the interval 0.23 to 0.50, indicative of necessities. Greek yogurt and non-Greek yogurt were revealed to be substitutes.

In sum, while there have been several research studies dealing with the demand for yogurt in the United States dating back to the 1970s, few studies have centered attention on partitioning yogurt into separate Greek and non-Greek yogurt categories. In our study, we use data acquired from Nielsen pertaining to 164,484 panel households across the United States for calendar years 2018 to 2020.[1] Hence, our study reflects more recent market conditions of the yogurt category compared to previous studies. Additionally, we conduct separate analyses of Greek and non-Greek yogurt using a variation of the Heckman model to mitigate observed zero purchase values. We provide separate probit models dealing with the likelihood of purchasing Greek yogurt and non-Greek yogurt as well as separate conditional demand models for these distinct yogurt products. On this basis, our study subsequently adds to the literature concerning household demand for Greek yogurt and non-Greek yogurt. As such, we provide a comprehensive overview of the yogurt market in the United States.

Model development

Not all households purchase Greek or non-Greek yogurt in each calendar year of the sample period. For these households, the expenditures expressed in dollars and the quantities purchased expressed in ounces (with standardization) are zero. To deal with this censoring issue, we rely on the sample selection model of Heckman (1976, 1979). Consistent with the first stage of Heckman two-step estimation procedure, we employ a probit model or selection equation (choice model) to develop profiles of U.S. households who purchase Greek or non-Greek yogurt.

The probit models in this analysis are binary choice models, where the dependent variables take on two values – 0 when no expenditure is made for Greek yogurt or non-Greek yogurt and 1 when any expenditure for these yogurt products is made by household *i*. Keller (2018) centered attention on the decision to purchase Greek yogurt only and non-Greek yogurt only as well as the decision to purchase *both* Greek yogurt and non-Greek yogurt. To differentiate our work from Keller (2018), we are concerned with the decision to purchase Greek yogurt or not and the decision to purchase non-Greek yogurt or not. Our sample covers calendar years 2018 to 2020, while the sample in Keller (2018) dealt with calendar year 2015 only.

We provide details of the probit model for yogurt product j ($j = 1$ for Greek yogurt and $j = 2$ for non-Greek yogurt) as follows:

$$y_{ij} = \boldsymbol{x}_i^{'}\boldsymbol{\beta} + u_{1ij} \tag{1}$$

[1]At the time this analysis was conducted, the data from 2018 to 2020 was the most recent data available to academic subscribers of the Nielsen Homescan Panel database.

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$$y_{ij} = 1 \text{ if yogurt product purchase j was made by household } i$$

$$y_{ij} = 0 \text{ if no yogurt product purchase j was made by household } i$$

and

$$\Pr\left(y_{ij} = 1 \mid \boldsymbol{x}_i^{'}\right) = \Phi(\boldsymbol{x}_i^{'}\boldsymbol{\beta}), \tag{2}$$

where Φ is the cumulative distribution function (CDF) of the standard normal distribution; $\boldsymbol{x}_i^{'}$ is a column vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of parameters associated with the explanatory variables, and e_i is the random error.

Socio-demographic factors were considered in previous studies of yogurt demand including household size, age, and education of the female head of household, the presence of children, race, region, and household income. Boehm and Babb (1975) ascertained that regional differences were evident concerning yogurt consumption. Kepner, Knutson, and Nichols (1978) noted that the typical yogurt consumer was female; college-educated; from the Pacific, Northeast, and Mid-Atlantic regions; resided in a household with relatively high income; and was between ages 13–19 or 35–44. Davis, Blayney et al. (2010a), Davis, Dong et al. (2010b), and Davis et al. (2011) analyzed the impacts of household size, education of the female head of household, region, race, ethnicity, presence of children, household income and marital status on the demand for refrigerated yogurt, frozen yogurt, and drinkable yogurt. As such, past research supports the contention that the influence of socio-demographic variables should be considered.

Additionally, Hill and Lynchehaun (2002), Peterson and Buse (1975), and Dharmasena, Okrent, and Capps (2014) identified various cultural and socioeconomic factors influencing household preferences including age, ethnicity, household income, household size, education, presence of children, region, and race. We hypothesize that age is inversely related to the decision to purchase Greek and non-Greek yogurt, and households located in the Pacific, Northeast, and Mid-Atlantic regions are more likely to purchase Greek and non-Greek yogurt relative to other regions. Moreover, based on the work by Keller (2018), we expect household income to be positively linked to the decision to purchase Greek and non-Greek yogurt, but household size to be negatively related to the decision to purchase these yogurt products. Moreover, we expect the presence of children to be negatively associated with the likelihood of purchasing these yogurt products.

In agreement with Keller (2018), we expect key regions associated with the likelihood of purchasing Greek yogurt to be the New England, the Middle Atlantic, and the South Atlantic regions. Further, consistent with the finding of Kepner, Knutson, and Nichols (1978) and because education level often is positively associated with health consciousness (Alviola and Capps, 2010), we hypothesize that college-educated households are more likely to purchase Greek and non-Greek yogurt relative to non-college-educated households. Finally, we hypothesize that prices of Greek yogurt and non-Greek yogurt also influence the purchase decision of these products.

Operationally, the decision to purchase either Greek or non-Greek yogurt is defined in equation (3) as:

$$\begin{aligned} y_{ij} = f_{ij}(&\mathrm{Age_{i,}, HS_i, HI_i, CD_i, PC_i, BL_i, WC_{,} OR_{i,} HC_{i,}, Pacific_i, ESC_i, MA_i, MN_i, NE_{i,} SA_i,} \\ &\mathrm{WNC_i, WSC_{i,} Panel\_Year\_2019_i, Panel\_Year\_2020_i, PG_i, PNG_{i,} DMA_{ik}}) +, u_{1ij}, \end{aligned} \tag{3}$$

where $i = 1 \ldots .164{,}484$ households, $j = 1$ (Greek yogurt), $j = 2$ (non-Greek yogurt), and $k = 1, \ldots 205$ (designated market areas (DMAs)). The explanatory variables are explicitly listed as follows: (1) HS = $\mathrm{Household\_size_i}$; (2) HI = $\mathrm{Household\_income_i}$; (3) CD = $\mathrm{College\_degree_i}$, (4) PC = $\mathrm{Presence\_Children_i}$, (5) OR = $\mathrm{Other\_Races_{i,}}$ (6) Bl = $\mathrm{Black_i}$, (7) WC = $\mathrm{White/Caucasian_i}$, (8) HC = $\mathrm{Hispanic_{i,}}$ (9) PC = $\mathrm{Pacific_i}$, (10) ESC = $\mathrm{East\_South\_Central_i}$, (11) MA = $\mathrm{Mid\_Atlantic_i}$, (12) MN = $\mathrm{Mountain_i}$, (13) NE = $\mathrm{New\_England_{i,}}$ (14) SA = $\mathrm{South\_Atlantic_i}$, (15) WNC = $\mathrm{West\_North\_Central_i}$, (16) WSC = $\mathrm{West\_South\_Central_{i,}}$ (17) PG = $\mathrm{Price\_Greek\_Yogurt_i}$, (18) PNG = $\mathrm{Price\_Non\text{-}Greek\_Yogurt_{i,}}$ and (19) DMA = Designated Market Areas.

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DMAs are a group of counties and zip codes that form a particular geographic area. In this analysis, the number of DMAs[2] was 205. Their use provides a more granular decomposition of geographical areas within the broader nine Census regions previously mentioned. We allow for the possibility that DMAs within the same region (or even the same state such as Texas) to have different preferences for Greek yogurt and non-Greek yogurt. Further, we add panel years as dummy variables in the analysis to isolate differences among the respective calendar years, particularly differences between 2018 and 2020 as well as between 2019 and 2020. The COVID pandemic was initiated in the United States in March 2020. Age of the household head, household size, household income, and the prices of the yogurt products are continuous variables, while the remaining explanatory variables are indicator or dummy variables.

To avoid the dummy variable trap, the reference categories for the indicator variables are Asian (race), East North Central (region), panel year 2018 (Panel Year), and New York city (DMA). Additionally, we use inflation-adjusted or real values of household income as well as prices of the respective yogurt products. The dependent variable and the explanatory variables in the probit specifications are defined explicitly in Table 2.

Marginal effects associated with the two probit models provide insight as to how changes in the right-hand side variables affect the probability of purchasing Greek yogurt and non-Greek yogurt. Because the marginal effects vary from observation to observation, they are calculated at the sample means for each of the explanatory variables in the probit model.

From the probit analysis, let $Z_{ij} = 1$ if household i purchases yogurt product j and 0 otherwise. Then, we can write the probability of purchasing Greek yogurt or non-Greek yogurt and the probability of not purchasing Greek yogurt or non-Greek yogurt as:

$$\Pr(Z_{ij} = 1) = \Phi(\boldsymbol{x}_{ij}^{'}\boldsymbol{\beta}) \text{ and } \Pr\left(Z_j = 0\right) = 1 - \Phi(\boldsymbol{x}_{ij}^{'}\boldsymbol{\beta}), \tag{4}$$

where $i = 1,,.164{,}484$; $j = 1, 2, and\ \boldsymbol{x}_{i_i}{}'$ is the vector of previously mentioned explanatory variables in equation (3). Following Heckman, we form the Inverse Mills Ratio (IMR), defined as

$$\widehat{IMR}_{ij} = \begin{cases} \frac{\varphi\left(x_{ij}^{'}\beta\right)}{\Phi\left(x_i^{'}\beta\right)}, & if\ Z_{ij} = 1 \\ \frac{\varphi\left(x_{ij}^{'}\beta\right)}{1-\Phi\left(x_{ij}^{'}\beta\right)}, & if\ Z_{ij} = 0 \end{cases} \tag{5}$$

where ϕ is the probability density function (pf) of the standard normal distribution and Φ is the CDF of the standard normal distribution.

In the second stage of the Heckman model, let Q_{ij} denote the quantity of yogurt product j purchased (in ounces) by household i, and let $\boldsymbol{w}_{ij}^{'}$ correspond to the vector of explanatory variables in the model specification. The exclusion restriction in the Heckman model states that there must be at least one variable which appears with a non-zero coefficient in the selection (probit) equation but does not appear in the conditional demand equation (Puhani, 2000). In this study, we include DMAs in the first stage but not in the second stage to satisfy the exclusion restriction Otherwise, $\boldsymbol{w}_{ij}{}'$ and $\boldsymbol{x}_{ij}{}'$ are the same set of explanatory variables. In the second stage, we only consider the conditional demands for Greek yogurt and for non-Greek yogurt. That is, we only use the non-zero amounts purchased of these products as the dependent variables. We then may write the household conditional demand functions as:

$$E\left[Q_{ij}|Z_{ij} = 1\right] = \boldsymbol{w}_{ij}^{'}\gamma_j + \alpha\frac{\varphi(\boldsymbol{x}_{ij}^{'}\boldsymbol{\beta})}{\Phi(\boldsymbol{x}_{ij}^{'}\boldsymbol{\beta}))} = \boldsymbol{w}_i^{'}\gamma_j + \alpha\widehat{IMR}_{ij} + u_{2ij}. \tag{6}$$

[2]A list of the respective DMAs is available from the authors upon request.

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Table 2. Description and descriptive statistics of the dependent variables and explanatory variables included the analysis[1]

Variable	Definition	Mean
Age	Age of the household head	60
Asian	1 if the race of the household head is Asian, 0 otherwise *(Reference/Base Category)*	0.0394
Black	1 if the race of the household head is Black, 0 otherwise	0.1124
White/Caucasian	1 if the race of the household head is White/Caucasian, 0 otherwise	0.7966
Other Races	1 if the race of the household head is neither white, black, nor Asian, 0 otherwise	0.0516
East_North_Central	1 if the household is located in the East North Central region, 0 otherwise (*Reference/Base Category*)	0.1742
East_South_Central	1 if the household is located in the East South Central region, 0 otherwise	0.0639
Mid-Atlantic	1 if the household is located in the Mid-Atlantic region, 0 otherwise	0.1251
Mountain	1 if the household is located in the Mountain region, 0 otherwise	0.0741
Pacific	1 if the household is located in the Pacific region, 0 otherwise	0.1126
New_England	1 if the household is located in the New England region, 0 otherwise	0.0464
South_Atlantic	1 if the household is located in the South Atlantic region, 0 otherwise	0.2127
West_North_Central	1 if the household is located in the West North Central region, 0 otherwise	0.0806
West_South_Central	1 if the household is located in the West South-Central region, 0 otherwise	0.1103
Hispanic	1 if the household head is Hispanic, 0 otherwise	0.0743
College_degree	1 if the household head earned a college degree, 0 otherwise	0.4627
Household_income	Household income	$65,745
Household_size	Number of members in the household	2.50
Presence_Children	1 if children are present in the household, 0 otherwise	0.2229
Price_Greek_Yogurt	Unit value of Greek yogurt ($/ounce)	0.1755
Price_non_Greek_Yogurt	Unit value of non-Greek yogurt ($/ounce)	0.1391
Purch_Greek_Yogurt	1 if Greek yogurt is purchased by the household, 0 otherwise (*Dependent Variable in the Probit Model)*	0.2500
Purch_non_Greek_Yogurt	1 if non-Greek yogurt is purchased by the household, 0 otherwise (*Dependent Variable in the Probit Model)*	0.7724
Calendar_Year_2018	1 if calendar year = 2018, 0 otherwise *Reference/Base Category)*	0.3355
Calendar_Year_2019	1 if calendar year = 2019, 0 otherwise	0.3364
Calendar_Year_2020	1 if calendar year = 2020, 0 otherwise	0.3282

[1]Because of the large number of designated market areas (205), we do not report their means. This information is available from the authors upon request.

In equation 6, γ_j are parameters associated with the explanatory variables included in the conditional demand equations, β are parameters associated with the explanatory variables in the probit equations, and α is the parameter associated with the IMR included in the conditional demand functions. The existence/non-existence of sample selection bias rests on simply testing $H_0: \alpha = 0$.

We rely on the maximum likelihood (ML) estimator (also known as the full information maximum likelihood approach) in estimating the Heckman model. We estimate both the probit

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model and the conditional demand model for each type of yogurt simultaneously assuming that $u_{1ij} \sim N(0, \sigma_j)$, $u_{2ij} \sim N(0, 1)$, and the correlation $(u_{1ij}, u_{2ij}) = \rho_j$. The ML estimation procedure is done using Stata 15 (Stata Corp, 2017). σ_j and ρ_j are additional parameters to be estimated in conjunction with the ML procedure.

The ML procedure yields consistent and more efficient estimates than the two-step method especially if there is non-zero correlation between the error terms u_{1ij} and u_{2ij}. Previous empirical works such as those of Nelson (1984), Stolzenberg and Relles (1990) and Nawata (1993, 1994) provide evidence that the greater the correlation between u_{1ij} and u_{2ij}, the greater the superiority of the maximum likelihood estimator over the two-step estimator in terms of efficiency. With respect to the conditional demand functions, the number of observations is vastly different for Greek yogurt and for non-Greek yogurt. Consequently, we could not estimate the conditional demand functions jointly.

Following Saha et al. (1997), the estimated marginal effect of a change in any explanatory variable k (discrete or non-discrete) for household i and yogurt product j in the conditional demand functions can be written as:

$$\widehat{ME}_{ijk} = \frac{dE[log\,(Q_{ij})|Z_ij = 1]}{dw_{ijk}} = \gamma_{jk} + \alpha \frac{d}{dw_{ijk}}(\widehat{IMR}_{ij}) \tag{7}$$

$$\widehat{ME}_{ijk} = \gamma_{jk} - \alpha\hat{\boldsymbol{\beta}}_{jk}\left\{\boldsymbol{x}_{ij}^{'}\boldsymbol{\beta} * \widehat{IMR}_{ij} + \left(\widehat{IMR}_{ij}\right)^2\right\} \tag{8}$$

If α is not statistically different from zero, then no sample selection bias is evident, and γ_{jk} represents the appropriate marginal effect. Hence the significance, sign, and magnitude of the estimated parameter α embedded in equation (8) is very important in the calculation of appropriate marginal effects. To properly assess the impacts of explanatory variables, we implement equation (8) derived by Saha et al. (1997).

We expect the own-price elasticities of Greek yogurt and non-Greek to be negative in accord with economic theory. We also expect the demand for these yogurt products to be elastic. This hypothesis is consistent with the findings of Gao and Capps (2023) but not with the findings of Dharmasena, Okrent, and Capps (2014). Consistent with past studies, we expect the cross-price elasticity of Greek yogurt with respect to non-Greek yogurt and vice versa to be positive, indicative of substitutes. As well, we expect the income elasticity of demand for the respective yogurt products to be positive and smaller than 1, suggesting that Greek yogurt and non-Greek yogurt are necessities. Additionally, we entertain similar hypotheses concerning the socio-demographic factors in the conditional demand functions as previously discussed with the respective probit models.

Data

As previously mentioned, the source of data for this analysis is the NielsenIQ, formerly known as the Nielsen Homescan Panel, pertaining to 164,484 households for calendar years 2018–2020. These data constitute a national panel of households wherein transactions of purchases from all retail outlets for the panel households are recorded daily over the calendar year. These data therefore provide information associated with expenditures (expressed in dollars) and quantities purchased (volume) of Greek and non-Greek yogurt (standardized as ounces) as well as socio-demographic characteristics of each household. Like Davis, Dong, Blayney, and Owens (2010b) and Davis, Yen, Dong, and Blayney (2011), the data are aggregated over each calendar year to determine annual expenditures and volume for each of the respective households. Importantly, the NielsenIQ data refer only to at-home purchases of Greek and non-Greek yogurt in the United States.

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Prices of Greek and non-Greek yogurt are imputed as the ratio of expenditure to volume and are expressed as dollars per ounce. These unit value measures are considered as proxies for the prices of Greek and non-Greek yogurt. The construction of unit values is consistent with the methodology proposed by Deaton (1987). Indeed, as pointed out by Deaton (1988, 1990, 1997), bias associated with the use of unit values may occur. The bias is attributed to quality variation and reporting errors in expenditures and/or quantities (measurement errors). Deaton (1988) suggested that the bias associated with quality variation makes the demand for a commodity appear to be more elastic, overstating the response of quantity to changes in price. We operate on the assumption that this bias is negligible.

For households not purchasing Greek and non-Greek yogurt, it is not possible to calculate their imputed values directly. Missing imputed values for those households who did not purchase these yogurt products are generated via auxiliary regressions in which observed unit values for each of the two respective products are regressed as a function of household income, household size, the region as well as the DMA where the household is located. In this analysis, we use dummy variables for 9 regions and 205 DMAs in the auxiliary regressions. Except for DMAs, these instrument variables have been used extensively in prior studies to not only obtain values of missing prices but also to deal with price endogeneity issues (Alviola and Capps, 2010; Dharmasena and Capps, 2012, 2014; Kyureghian et al., 2011).

To ensure that the imputed prices of Greek and non-Greek yogurt are greater than zero, we employ a semi-logarithmic functional form. That is, the dependent variables in these auxiliary regressions correspond to the logarithm of observed Greek and non-Greek unit values. The parameters estimated from these auxiliary regressions are subsequently used to impute prices for observations associated with missing observations using the exponential transformation. Details associated with the auxiliary regressions for Greek and non-Greek yogurt are available from the authors upon request.

Across the sample of 164,484 households, on average, the price of Greek yogurt is 17.55 cents/ounce, and the price of non-Greek yogurt is 13.91 cents/ounce. As such, in our sample, the average price of Greek yogurt is 1.3 times the average price of non-Greek yogurt. The correlation between the respective prices is 0.1155. The number of households who purchase Greek and non-Greek yogurts during the three-year period is 41,120 and 127,042, respectively. Hence, the market penetration or percentage of households purchasing Greek and non-Greek yogurts is 25 and 77%, respectively. Of note, 21% of households purchase no yogurt at all, and 23% of households purchase both Greek and non-Greek yogurt.

In Table 2, we summarize the descriptive statistics (mean values only) for the sample of households included in our analysis. The average age of the household head in our sample is 60. On average, household size is 2.5, and household income is $65,745. About 46% of the sample earned a college degree, and slightly more than 7% are of Hispanic ethnicity. About 77% of our sample have no children living in the household. Further, roughly 80% of the sample is White/Caucasian, 11% are Black, and about 4% are Asian.

About 17% of the sample of households are located in the East North Central region (Illinois, Michigan, Ohio, and Wisconsin), 6% are located in the East South-Central region (Alabama, Kentucky, Mississippi, and Tennessee), 13% are located in the Mid-Atlantic region New Jersey, New York, and Pennsylvania), 7% are located in the Mountain region (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming), 5% are located in the New England region (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont), 21% are located in the South Atlantic (Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, District of Columbia, and West Virginia), 8% are located in the West North Central region (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota), 11% are located in the West South-Central region (Arkansas, Louisiana, Oklahoma, and Texas), and 11% were located in the Pacific region (Alaska, California, Hawaii, Oregon, and Washington).

Table 3. Representativeness of the 2018–2020 NielsenIQ Data to the U.S. Population According to the 2021 U.S. Census Bureau

Socio-Demographic Characteristic	2021 U.S. Census Bureau	Sample of 164,484 Useable Observations 2018-2020 Nielsen Data
White	77.10%	79.66%
Black	12.90%	11.24%
Asian	4.20%	3.94%
Other	5.80%	5.16%
Average Household Size	2.59	2.50
Median Age of Household Head	52	60
East North Central Region	14.70%	17.42%
East South-Central Region	6.13%	6.39%
Mid-Atlantic Region	12.52%	12.51%
Mountain Region	7.67%	7.41%
New England Region	4.74%	4.64%
Pacific Region	15.12%	11.28%
South Atlantic Region	20.43%	21.27%
West North Central Region	6.68%	8.06%
West South-Central Region	12.02%	11.03%
Median Household Income	$69,021	$65,000
Hispanic	12.50%	7.43%
Not Hispanic	87.50%	92.57%
Less Than High School Education	8.00%	1.68%
High School Graduate	25.74%	22.51%
Some College	16.03%	29.53%
College Graduate	34.86%	31.77%
Post College	15.37%	14.51%
Absence Of Children	67.20%	77.71%
Presence of Children	32.80%	22.29%

Source: U.S. Census Bureau, Current Population Survey, 2022 Annual Social and Economic Supplement (CPS ASEC), https://www.census.gov/main/www/cprs.html.

To demonstrate the representativeness of our sample to the U.S. population, as exhibited in Table 3, we compare the socio-demographic characteristics of our sample with population statistics provided by the U.S. Census Bureau for 2021 (U.S. Census Bureau, Current Population Survey, 2022 Annual Social and Economic Supplement). The median income for 2021 reported by the U.S. Census Bureau is $69,021, close to the median income of our study of $65, 000. As well, the average household size for 2021 as reported by the U.S. Census Bureau is 2.59, also very close to our average household size of 2.50. Further, similar percentages by race and region are evident. Moreover, the percentage of households whose head earned a college degree is 46% in our sample, close to 50% for 2021 as reported by the U.S. Census Bureau. However, the percentage of Hispanic households in our sample is 7.43%, less than the 12.50% for 2021 as reported by the U.S. Census

Bureau. The percentage of households without children in our sample is 77.71%, more than the 67.20% of households without children as reported by the U.S. Census Bureau. The median age of the household head in our sample is 60, while the median age reported by the U.S. Census Bureau is 52. Nevertheless, we maintain our sample is representative of the socio-demographic and marketing landscape of the United States, lending to the external validity of this analysis.

Empirical results

For the probit models and the conditional demand function models, the level of statistical significance chosen is set at 0.05. We report the empirical results initially for Greek yogurt, and then for non-Greek yogurt. Specifically, we use the probit models to gain insight into the profile of households who purchase Greek yogurt and non-Greek. The maximum likelihood parameter estimates, standard errors, and associated p-values of the respective explanatory variables in the respective probit models are exhibited in Tables 4 and 5. Because of the numerous DMAs (205), we exclude this information to conform to space limitations. The details associated with these parameter estimates, standard errors, and p-values are available from the authors upon request. In addition, we report the marginal effects for the socio-demographic binary variables as well as for the continuous variables associated with the decision to purchase Greek yogurt and non-Greek yogurt for at-home consumption in Tables 4 and 5.

We also rely on prediction-success tables to validate the binary choices models for Greek and non-Greek yogurt. These tables are standard practice in the evaluation of binary choices models (Pindyck and Rubinfeld, 1998). To formulate a prediction-success table, it is necessary to employ a decision rule for correct classifications of outcomes. Conventionally, if the predicted probability is ≤ 0.5, then the predicted outcome is $Y_i = 0$ (the household is predicted not to purchase). On the other hand, if the predicted probability is >0.5, then the predicted outcome is $Y_i = 1$ (the household is predicted to purchase). Maddala (1983) and Pindyck and Rubinfeld (1998) support this contention. However, Park and Capps (1997) point out that the appropriate cutoff may not necessarily be 0.5. Arguments have been made for the decision rule to be the ratio of the number of observations (households for which $Y_i = 1$) to the total number of observations. We adopt this decision rule in deriving the prediction-success tables.

Empirical results from the probit model for Greek yogurt

All estimated coefficients statistically different from zero are in bold. The key drivers associated with the decision to purchase Greek yogurt for at-home consumption are age, race, and education of the household head, household size, real household income, real prices of Greek yogurt and non-Greek yogurt, the DMA in which the household is located, and calendar year. Hispanic origin, the presence of children, and the region in which the household is located are not statistically significant determinants of the decision to purchase Greek yogurt. The lack of significance of the estimated coefficients pertaining to region likely is attributed the presence of the DMA variables. From Keller (2018), statistically significant determinants of the decision to purchase Greek yogurt were household income, household size, region, race, and presence of children. Our results align with Keller (2018) concerning household income, household size, and race only.

As expected, household income and education of the household head are positively linked to the decision to purchase Greek yogurt for at-home consumption. Age of the household head and household size are negatively linked to the decision to purchase Greek yogurt. Relative to Asian households, White/Caucasian households are more likely to purchase Greek yogurt, but Black households are less likely to do so. The decision to purchase Greek yogurt is negatively related to the price of Greek yogurt but positively related to the price of non-Greek yogurt. The location of the household by DMA but not by region is a key factor affecting the likelihood of purchasing

Table 4. Maximum Likelihood parameter estimates, standard errors, and p-values associated with the estimation of the probit model for Greek yogurt[1]

Variable	Coefficient	Std. Error	p-value	Marginal Effects
Constant	−2.9345	0.1878	**0.000**	
LOG(REAL_HOUSEHOLD_INCOME)	0.1631	0.0056	**0.000**	0.1774[2]
HOUSEHOLD_SIZE	−0.0080	0.0039	**0.041**	−0.0022
PACIFIC	0.2041	0.1494	0.172	0.0555
NEW_ENGLAND	−0.0344	0.0982	0.726	−0.0094
MID_ATLANTIC	0.0218	0.0810	0.788	0.0076
MOUNTAIN	0.1478	0.1139	0.194	0.0402
WEST_NORTH_CENTRAL	−0.0134	0.0464	0.773	−0.0036
WEST_SOUTH_CENTRAL	−0.1493	0.0973	0.125	−0.0406
SOUTH_ATLANTIC	0.0193	0.0637	0.762	0.0053
EAST_SOUTH_CENTRAL	0.0019	0.0480	0.969	0.0005
CALENDAR_YEAR_2019	−0.1159	0.0084	**0.000**	−0.0315
CALENDAR_YEAR_2020	−0.1173	0.0085	**0.000**	−0.0319
COLLEGE_DEGREE	0.1675	0.0073	**0.000**	0.0456
AGE_OF_HOUSEHOLD_HEAD	−0.0026	0.0003	**0.000**	−0.0007
PRESENCE_CHILDREN	−0.0324	0.0121	0.341	−0.0088
WHITE_CAUCASIAN	0.1059	0.0180	**0.000**	0.0288
BLACK	−0.1520	0.0207	**0.000**	−0.0414
OTHER_RACES	0.0026	0.0285	0.914	0.0007
HISPANIC	0.0155	0.0146	0.287	0.0042
LOG(REAL_PRICE_GREEK_YOGURT)	−0.7379	0.0338	**0.000**	−0.8027[2]
LOG(REAL_PRICE_NON_GREEK_YOGURT)	0.5026	0.0087	**0.000**	0.5468[2]
McFadden R-squared	0.0538			
LR statistic	9,953.33			
Prob(LR statistic)	0.0000			
Obs with Dep = 0	123,364	164,484		
Obs with Dep = 1	41,120			

Note: Bold p-values indicate statistical significance at the 0.05 level. The sample size is 164,484 households.
Source: From the use of the econometric software package Stata 15.
[1]Because of the numerous DMAs (205), we exclude this information in Table 3 to conform to space limitation. The details associated with the parameter estimates, standard errors, and p-values of the DMA indicator variables are available from the authors upon request.
[2]These elasticities refer to the percentage change in the probability of purchasing Greek yogurt due to a one percent change in real household income, in the real price of Greek yogurt, and the real price of non-Greek yogurt.

Greek yogurt. Relative to calendar 2018, the likelihood of purchasing Greek yogurt is lower in calendar years 2019 and 2020.

As the household head ages each year, the probability of purchasing Greek yogurt is lower by 0.07%. For household heads that earned a college degree, the probability of purchasing Greek yogurt is higher by 4.56% relative to household heads who did not earn a college degree. For each increase in household size, the likelihood of purchasing Greek yogurt for at-home consumption

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Table 5. Maximum Likelihood parameter estimates, standard errors, and p-values associated with the estimation of the probit model for non-Greek yogurt[1]

Variable	Coefficient	Std. Error	p-value	Marginal Effects
constant	−0.5977	0.1679	**0.000**	
LOG(REAL_HOUSEHOLD_INCOME)	0.1001	0.0051	**0.000**	0.0353[2]
HOUSEHOLD_SIZE	0.0735	0.0041	**0.000**	0.0200
PACIFIC	0.6302	0.1414	**0.000**	0.1715
NEW_ENGLAND	0.1571	0.0915	0.086	0.0427
MID_ATLANTIC	0.0383	0.0697	0.583	0.0104
MOUNTAIN	0.3110	0.1022	**0.002**	0.0846
WEST_NORTH_CENTRAL	0.0371	0.0399	0.351	0.0109
WEST_SOUTH_CENTRAL	0.0373	0.0795	0.639	0.0109
SOUTH_ATLANTIC	0.0400	0.0526	0.448	0.0109
EAST_SOUTH_CENTRAL	0.0228	0.0406	0.575	0.0062
CALENDAR_YEAR_2019	−0.1379	0.0084	**0.000**	−0.0375
CALENDAR_YEAR_2020	−0.1849	0.0085	**0.000**	−0.0503
COLLEGE_DEGREE	0.0952	0.0073	**0.000**	0.0259
AGE_OF_HOUSEHOLD_HEAD	−0.0046	0.0003	**0.000**	−0.0013
PRESENCE_CHILDREN	0.1549	0.0127	**0.000**	0.0422
WHITE_CAUCASIAN	0.1418	0.0184	**0.000**	0.0386
BLACK	−0.1688	0.0204	**0.000**	−0.0459
OTHER_RACES	0.0372	0.0203	0.121	0.0101
HISPANIC	−0.0066	0.0148	0.656	−0.0018
LOG(REAL_PRICE_GREEK_YOGURT)	0.0225	0.0386	0.560	0.0079[2]
LOG(REAL_PRICE_NON_GREEK_YOGURT)	−0.0454	0.0083	**0.000**	−0.0160[2]
McFadden R-squared	0.0438			
LR statistic	7,736.53			
Prob(LR statistic)	0.0000			
Obs with Dep = 0	37,442	164,484		
Obs with Dep = 1	127.042			

Note: Bold p-values indicate statistical significance at the 0.05 level. The sample size is 164,484 households.
Source: From the use of the econometric software package Stata 15.
[1]Because of the numerous DMAs (205), we exclude this information in Table 5 to conform to space limitation. The details associated with the parameter estimates, standard errors, and p-values of the DMA indicator variables are available from the authors upon request.
[2]These elasticities refer to the percentage change in the probability of purchasing non-Greek yogurt due to a one percent change in real household income, in the real price of Greek yogurt, and the real price of non-Greek yogurt.

falls by roughly 0.22%. Relative to Asians, the likelihood of purchasing Greek yogurt is lower by 4.14% for Black households, but higher by 2.88% for White/Caucasian households. Relative to calendar year 2018, households are less likely to purchase Greek yogurt by 3.15% in calendar year 2019 and by 3.19% in calendar year 2020, the year associated with the beginning of the COVID-19 pandemic in March 2020.

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We also report the elasticity or the percentage change in the probability of purchasing Greek yogurt attributed to a 1 percent change in the respective continuous variables (except for age and household size) in the probit model. The elasticity is always the product of the marginal effect times the ratio of the relevant continuous explanatory variable to the dependent variable. Calculated at the sample means, if household income increases by 1 percent, the probability of purchasing Greek yogurt for at-home consumption increases by 0.18%. If the price of Greek yogurt changes by 1 percent, the probability of purchasing Greek yogurt changes by 0.80% in the opposite direction. Further, if the price of non-Greek yogurt changes by 1 percent, the probability of purchasing Greek yogurt changes by 0.55% in the same direction.

Roughly 25% of the sample households purchase Greek yogurt for at-home consumption. Hence, in the derivation of the prediction-success of the probit model, the cutoff probability for classification purposes is 0.25. That is, we predict that household i will purchase Greek yogurt if the probability of doing so exceeds 0.25. In agreement with Greene (2012, p. 658), "in general any prediction rule will make two types of errors; it will incorrectly classify zeros as one and ones as zeros." For binary choice models, to the best of our knowledge, no benchmark exists regarding correct classifications. Using the cutoff probability of 0.25, the probit model for Greek yogurt correctly classifies the decision to not make purchases with 58.93% accuracy (72,702 out of 123,364), and the probit model correctly classifies the decision to make purchases with 66.02% accuracy (27,149 out of 41,120). Overall, the model correctly classifies all decisions 99,851 out of 164,484 times, with 60.71% accuracy.

Empirical results from the probit model for non-Greek yogurt

All estimated coefficients statistically different from zero are in bold. The factors affecting the decision to purchase non-Greek yogurt for at-home consumption are age, race, and education of the household head, presence of children, household size, real household income, region, and DMA in which the household is located, calendar year, and the real price of non-Greek yogurt. Hispanic origin and the real price of Greek yogurt are not statistically significant determinants of the decision to purchase non-Greek yogurt. From Keller (2018), statistically significant determinants of the decision to purchase non-Greek yogurt were household income, household size, region, race, and presence of children. Our results agree with Keller (2018) concerning household income, household size, and race only.

As the price of non-Greek yogurt increases, the likelihood of purchasing non-Greek yogurt for at-home consumption decreases as expected. Moreover, the decision to purchase non-Greek yogurt is positively linked to real household income and to household size. The older the head of household, the lower the likelihood of purchasing non-Greek yogurt, like the situation for Greek yogurt. Compared to Asian households, White/Caucasian households are more likely to purchase non-Greek yogurt, while Black households are less likely to do so.

Households whose head earned a college degree are more likely to purchase non-Greek yogurt relative to households whose heads do not have a college degree. As well, households with children are more likely to purchase non-Greek yogurt relative to households without children. Recall that the presence of children is not a factor in determining purchase of Greek yogurt. The likelihood of purchasing non-Greek yogurt is statistically the same for Hispanic and non-Hispanic households.

Relative to the East North Central region, households located in the Pacific and Mountain regions are more likely to purchase non-Greek yogurt. The likelihood of purchasing non-Greek yogurt is statistically the same for households located in East South-Central, Mid Atlantic, New England, South Atlantic, West North Central and West South-Central regions compared to households located in the East North Central region. Relative to calendar year 2018, households are less likely to purchase non-Greek yogurt in calendar years 2019 and 2020 just like the situation for Greek yogurt.

As the household head ages each year, the probability of purchasing non-Greek yogurt is lower by 0.13%. For household heads that earned a college degree, the probability of purchasing non-Greek yogurt is higher by 2.59% relative to household heads who did not earn a college degree. For each increase in household size, the likelihood of purchasing non-Greek yogurt for at-home consumption rises by 2.00%. Relative to Asians, the likelihood of purchasing non-Greek yogurt is lower by 4.59% for Black households, but higher by 3.86% for White/Caucasian households. Relative to households located in the East North Central region, households located in the Pacific and Mountain regions are more likely to purchase non-Greek yogurt by 17.15% and 8.46%, respectively. For households with children, the likelihood of purchasing non-Greek yogurt is higher by 4.22% relative to households without children. Relative to calendar year 2018, households are less likely to purchase non-Greek yogurt by 3.75% in calendar year 2019 and by 5.03% in calendar year 2020.

Calculated at the sample means, if household income increases by 1 percent, the probability of purchasing non-Greek yogurt for at-home consumption increases by nearly 0.04%. If the price of non-Greek yogurt changes by 1 percent, the probability of purchasing non-Greek yogurt changes by slightly less than 0.02% in the opposite direction. These elasticities concerning the probability of purchasing non-Greek yogurt are much lower than the corresponding elasticities for Greek yogurt.

Roughly 77% of the sample households purchase non-Greek yogurt for at-home consumption. Hence, in the derivation of the prediction-success of the probit model, the cutoff probability for classification purposes is 0.77. Using the cutoff probability, the probit model for non-Greek yogurt correctly classifies the decision to not make purchases with 64.57% accuracy (14,175 out of 37,442), and the probit model correctly classifies the decision to make purchases with 55.95% accuracy (71,080 out of 127,042). Overall, the model correctly classifies all decisions 95,255 out of 164,484 times, with 57.91% accuracy.

Subsequently, we rely on the conditional demand functions to determine the impact of socioeconomic determinants on the amount purchased of these yogurt products and to provide own-price, cross-price, and income elasticities of demand. As to specification, real household income, the real price of Greek yogurt and the real price of non-Greek also are expressed in logarithms. The maximum likelihood parameter estimates, standard errors, and associated p-values of the respective explanatory variables in the respective conditional demand models are exhibited in Table 6 and 7.

The sample of observations for the conditional demand function for Greek yogurt includes 41,120 households. On average, the number of ounces purchased of Greek yogurt for at-home consumption is 171.25. The sample of observations for the conditional demand function for non-Greek yogurt includes 127,042 households. On average, the number of ounces purchased of non-Greek yogurt for at-home consumption is 431.76 ounces.

The dependent variables in the conditional demand functions correspond to the logarithm of the number of ounces purchased by households of Greek yogurt and non-Greek yogurt over the period 2018 to 2020. Because the respective dependent variables entail a logarithmic transformation, the percentage change associated with the marginal effect for any dummy variable corresponding to a socio-demographic factor c is given as (exp(c)-1) *100, following Halvorsen and Palmquist (1980).

Empirical results from the conditional demand function for Greek yogurt

As exhibited in Table 6, the correlation of the error terms of the probit model and the conditional demand function for Greek yogurt is −0.3655, significantly different from zero. The goodness-of-fit statistic, R^2 is 0.0531, and the standard error of the regression is 1.3435. The explanatory variables associated with the quantity of Greek yogurt purchased for at-home consumption are

Table 6. Maximum Likelihood parameter estimates, standard errors, and p-values associated with the estimation of the conditional demand model for Greek yogurt

Variable	Heckman Second-Stage Coefficient	Std. Error	*p*-value	Coefficient Adjustment for Sample Selection Basis
constant	1.2219	0.1949	**0.000**	
Age	0.0035	0.0006	**0.000**	0.0025
White/Caucasian	0.0531	0.0302	**0.097**	0.0925
Black	−0.0253	0.0385	**0.051**	−0.0819
Other	0.0490	0.0437	0.262	0.0499
Hispanic	0.0239	0.0261	0.359	0.0297
Household Size	−0.0213	0.0074	**0.004**	−0.0242
LOG(Real_Household Income)	0.0666	0.0119	**0.000**	0.1272
South_Atlantic	0.0959	0.0213	**0.000**	0.1031
East_South_Central	0.0436	0.0335	0.193	0.0443
Mid_Atlantic	0.1762	0.0238	**0.000**	0.1843
Mountain	0.0638	0.0271	**0.018**	0.1188
New England	0.2083	0.0309	**0.000**	0.1955
Pacific	0.1400	0.0241	**0.000**	0.2159
West_North_Central	−0.0040	0.0288	0.891	−0.0089
West_South_Central	−0.0283	0.0265	0.285	−0.0838
LOG(Real_Price_Greek_Yogurt)	−1.0866	0.0433	**0.000**	−1.3610
LOG(Real_Price_non-Greek_Yogurt)	0.1619	0.0220	**0.000**	0.3488
College_Degree	0.0708	0.0144	**0.000**	0.1332
Presence_children	0.0047	0.0221	0.833	0.0004
Inverse Mills Ratio (IMR)	−0.4911	0.0393	**0.000**	
Calendar_year_2019	0.1320	0.0159	**0.000**	0.0889
Calendar_year_2020	0.1666	0.0160	**0.000**	0.1230
R-squared	0.0531			
Standard error of the regression	1.3435			

Note: Bold p-values indicate statistical significance at the 0.05 level. The sample size is 41,120 households.
Source: Use of the econometrics package Stata 15.

region, household size, real household income, age and education of the household head, real prices of Greek yogurt non-Greek yogurt, and calendar year.

Importantly, the estimated coefficient associated with the inverse Mills ratio is statistically different from zero, indicating the presence of sample selection bias. To properly assess the impacts of explanatory variables, we implement equation (8) derived by Saha, Capps, and Byrne (1997). The coefficients adjusted for sample selection bias are also exhibited in Table 6. For each increase (decrease) in household size, the amount of Greek yogurt purchased for at-home consumption rises (decreases) by 0.0242 ounces. As the household head ages each year, the

Table 7. Maximum Likelihood parameter estimates, standard errors, and p-values associated with the estimation of the conditional demand model for non-Greek yogurt

Variable	Heckman Second-Stage Coefficient	Std. Error	p-value	Coefficient Adjusted for Sample Selection Bias
Constant	2.6281	0.1349	**0.000**	
Age	0.0030	0.0004	**0.000**	0.0006
White/Caucasian	0.1546	0.0213	**0.000**	0.2286
Black	−0.0740	0.0244	**0.002**	−0.1619
Other	0.0605	0.0281	**0.031**	0.0799
Hispanic	−0.0750	0.0168	**0.000**	−0.0784
Household Size	0.0550	0.0046	**0.000**	0.0933
LOG(Real_Household Income)	0.0742	0.0064	**0.000**	0.1263
South_Atlantic	−0.0645	0.0132	**0.000**	−0.0437
East_South_Central	−0.1202	0.0191	**0.000**	−0.1084
Mid_Atlantic	0.0688	0.0151	**0.000**	0.0887
Mountain	0.0125	0.0176	0.477	0.1745
New England	0.1369	0.0208	**0.000**	0.2186
Pacific	0.0161	0.0157	0.306	0.3443
West_North_Central	−0.0586	0.0172	**0.000**	−0.0392
West_South_Central	−0.1609	0.0158	**0.000**	−0.1414
LOG(Real_Price_Greek_Yogurt)	0.0814	0.0413	**0.049**	0.0932
LOG(Real_Price_non-Greek_Yogurt)	−0.6790	0.0085	**0.000**	−0.7027
College_Degree	0.0834	0.0086	**0.000**	0.1330
Presence_children	0.0501	0.0141	**0.000**	0.1308
Inverse Mills Ratio (IMR)	−1.1626	0.0142	**0.000**	
Calendar_year_2019	−0.0473	0.0099	**0.000**	−0.1191
Calendar_year_2020	−0.0488	0.0100	**0.000**	−0.1451
R-squared	0.0931			
Standard error of the regression	1.5090			

Note: Bold p-values indicate statistical significance at the 0.05 level. The sample size is 127.042 households.
Source: Use of the econometrics package Stata 15.

amount of Greek yogurt purchased rises by 0.0025 ounces per year. This result likely is attributed to heightened awareness of improving health status as we age.

Accordingly, for households who earned a college degree, the amount of Greek yogurt purchased for at-home consumption is higher by 14.2% relative to households without a college degree. For household heads of Hispanic ethnicity, the volume of Greek yogurt purchased is higher by 3.0% relative to household heads of non-Hispanic ethnicity. Relative to Asian households, the quantity purchased of Greek yogurt is lower by 7.9% for Black households, but higher by 9.7% for White/Caucasian households. The impact of the presence/absence of children on the quantity purchased of Greek yogurt is not statistically different from zero.

Relative to the East North Central region, households located in the Mid-Atlantic, Mountain, New England, Pacific, and South Atlantic purchase more Greek yogurt by 20.2%, 12.6%, 21.6%, 24.1%, and 10.9%, respectively. On the other hand, no statistically significant differences are evident concerning the quantities of Greek yogurt purchased among households located in the West North Central, West South Central, East South-Central regions relative to households located in the East North Central region.

Recall that the likelihood to purchase Greek yogurt declined in 2019 and 2020 relative to 2018, But once the decision is made to purchase Greek yogurt, the amount bought rose by 9.3% in 2019 and 13.1% in 2020 relative to 2018.

The own-price elasticity of demand for Greek yogurt to be −1.36, lower than the own-price elasticities of −1.97 and −2.25 reported by Gao and Capps (2023) but higher than the own-price elasticity of −0.12 reported by Dharmasena, Okrent, and Capps (2014). As well, we estimate the cross-price elasticity of Greek yogurt and non-Greek yogurt to be 0.35. In agreement with Gao and Capps (2023), we find that the respective yogurt products indeed are substitutes. Further, we estimate the income elasticity of Greek yogurt to be 0.13, indicative of a necessity. This estimate is lower than the income elasticities of 0.23 and 0.50 reported by Gao and Capps (2023) and the income elasticity of 0.35 reported by Dharmasena, Okrent, and Capps (2014).

Empirical Results from the Conditional Demand Function for Non-Greek Yogurt

As exhibited in Table 7, the correlation of the error terms of the probit model and the conditional demand function for non-Greek yogurt is −0.7705, significantly different from zero. The goodness-of-fit statistic, R^2 is 0.0931, and the standard error of the regression is 1.5090. The determinants associated with the quantity of non-Greek yogurt purchased for at-home consumption are age, education, race, and ethnicity of the household head, region, real household income, household size, calendar year, presence of children, and real prices of Greek yogurt and non-Greek yogurt.

Like the situation for Greek yogurt, the estimated coefficient associated with the inverse Mills ratio is statistically different from zero, indicating the presence of sample selection bias. Again, to properly assess the impacts of explanatory variables, we implement equation (8) derived by Saha, Capps, and Byrne (1997). The coefficients adjusted for sample selection bias are also exhibited in Table 7.

For each increase/decrease in household size, the amount of non-Greek yogurt purchased for at-home consumption rises/decreases by 0.0933 ounces. As the household head ages each year, the amount of non-Greek yogurt purchased rises by 0.0006 ounces per year.

For households who earned a college degree, the amount of non-Greek yogurt purchased for at-home consumption is higher by 14.2% relative to households without a college degree. For household heads of Hispanic ethnicity, the volume of non-Greek yogurt purchased is lower by 7.5% relative to household heads of non-Hispanic ethnicity. Recall that in the case of Greek yogurt, no significant difference between in quantity purchased is evident between Hispanic and non-Hispanic households.

Relative to Asian households, the quantity purchased of non-Greek yogurt is lower by 14.9% for Black households, but higher by 25.7% for White/Caucasian households and higher by 8.3% for other races households. For households with children, the quantity of non-Greek yogurt is higher by 14.0% relative to households without children. This result is different compared to the case of Greek yogurt wherein the presence of children is not a statistically significant factor.

The volume of non-Greek yogurt purchased is lower by 11.2% in calendar year 2019 and by 13.5% in calendar year 2020, respectively relative to calendar year 2018. This finding is different from the situation for Greek yogurt, suggesting that a gradual shift in demand away from non-Greek yogurt to Greek yogurt is taking place.

Relative to the East North Central region, households located in the Mid-Atlantic, Mountain, New England, and Pacific purchase regions more non-Greek yogurt by 9.3%, 19.1%, 24.4%, and 41.1%, respectively. On the other hand, households located in the East South Central, West North Central, West South Central and South Atlantic regions purchase less non-Greek yogurt by 10.3%, 3.8%, 13.2% and 4.3% than households located in the East North Central region.

The own-price elasticity of demand for non-Greek yogurt to be −0.70, much smaller than the own-price elasticities of −1.42 and −1.63 reported by Gao and Capps (2023), but higher than the own-price elasticity of −0.20 reported by Dharmasena, Okrent, and Capps (2014). Unlike the situation for Greek yogurt, the demand for non-Greek yogurt is inelastic. As well, we estimate the cross-price elasticity of demand for the yogurt products to be 0.09, much lower than the cross-price elasticity of 0.35 reported in the conditional demand function for Greek yogurt. Nevertheless, in accord with previous studies, substitution between Greek yogurt and non-Greek yogurt is evident. Further, the income elasticity of non-Greek yogurt is identical to the income elasticity of Greek yogurt at 0.13. Thus, we support the claim that Greek yogurt and non-Greek yogurt are necessities. Once again, this estimate is lower than the income elasticity of 0.42 reported Gao and Capps (2023) and the income elasticity of 0.20 reported by Dharmasena, Okrent, and Capps (2014).

Concluding remarks

The purposes of this study are to develop separate profiles of households who purchase Greek yogurt and non-Greek yogurt, to investigate the socioeconomic determinants of the demand for Greek and non-Greek yogurt by U.S. households, and to estimate their own-price, cross-price, and income elasticities of demand. The source of data for this analysis is the NielsenIQ pertaining to 164,484 households for calendar years 2018 to 2020.

The major takeaways from this analysis are as follows. First, we identify U.S. households who make the decision to purchase Greek yogurt and non-Greek yogurt. Wealthier households, households with fewer members, household head(s) with a college degree, younger households, and White/Caucasian comprise the profile of households who purchase Greek yogurt. On the other hand, wealthier households, households with more members, household head(s) with a college degree, younger households, households with children, White/Caucasian households, and households located in the Pacific, New England, and Mountain regions of the United States comprise the profile of households who purchase non-Greek yogurt. Thus, our research assists industry stakeholders in developing a coordinated program of marketing and outreach efforts not only to maintain but also to increase market exposure for Greek yogurt and non-Greek yogurt. These efforts should target wealthier households, college-educated households, younger households, and White/Caucasian households.

Second, we provide the impacts of household socioeconomic factors associated with purchasing the respective yogurt products. To illustrate, the elasticities with respect to income and price concerning the probability of purchasing non-Greek yogurt are much lower than the corresponding elasticities for Greek yogurt. Additionally, the real price of non-Greek yogurt affects the decision to purchase Greek yogurt, but the real price of Greek yogurt does not affect the decision to purchase non-Greek yogurt.

Third, based on the conditional demand analyses, the own-price elasticities of demand for Greek yogurt and non-Greek yogurt are estimated to be −1.36 and −0.70, respectively. Given the elastic demand for Greek yogurt, the optimal pricing policy for manufacturers to maximize retail sales in the short run is to lower prices for Greek yogurt from a competitive intelligence standpoint. On the other hand, given the inelastic demand for non-Greek, the optimal pricing strategy to maximize sales is to raise prices for non-Greek yogurt.

Fourth, based on cross-price elasticities, we provide evidence that substitution between Greek yogurt and non-Greek yogurt is evident. Consequently, caution should be exercised concerning efforts to expand the entire yogurt category due to market cannibalism between Greek and non-Greek yogurt. Further, the income elasticities of Greek yogurt and non-Greek yogurt are nearly identical, on the order of 0.13. Thus, Greek yogurt and non-Greek yogurt are necessities. Changes in household income are not likely to have sizeable impacts on at-home consumption of these yogurt products.

Fifth, based on socio-demographic factors, the quantities purchased of non-Greek yogurt are lower for Hispanics compared to non-Hispanics. However, ethnicity is not a statistically significant factor associated with purchases of Greek yogurt. The quantities purchased of Greek yogurt are higher by 9% for White/Caucasian households, but the quantities purchased of non-Greek yogurt are higher by 23% for White/Caucasian households. The quantities purchased of Greek yogurt are lower by 8% for Black households, but the quantities purchased of non-Greek yogurt are lower by 16% for Black households.

Regional differences in the quantities purchased of Greek and non-Greek yogurt also are evident. Quantities purchased of Greek yogurt are highest in the Pacific, New England, and Mid-Atlantic regions, while quantities purchased of non-Greek yogurt are highest in the Pacific, New England, and Mountain regions. The quantities purchased of both products are higher by 13% for college-educated household head(s) relative to households with less education. Households with children purchase 13% more non-Greek yogurt than households without children. But the presence of children is not a statistically significant factor associated with purchases of Greek yogurt.

Finally, quantities purchased of Greek yogurt are higher by 9 and 12% in 2019 and 2020, respectively, relative to 2018. This result suggests that purchases of Greek yogurt are rising over time. On the other hand, quantities of non-Greek yogurt are lower by 12 and 15% in 2019 and 2020, respectively, relative to 2018. This finding suggests that purchases of non-Greek yogurt are falling over time.

As far as limitations, our study does not consider away-from-home purchases of Greek yogurt or non-Greek yogurt. The NielsenIQ data pertain exclusively to at-home purchases made by households from grocery stores, convenience stores, supercenters, drugstores, and mass merchandisers. In addition, given that the data correspond to annual values without attention to monthly or quarterly values, we forego considering the impact of seasonality on these respective yogurt products. Further, our work can be extended to include various brands of Greek yogurt and non-Greek yogurt, particularly Chobani, Dannon, and Yoplait. To capture interrelationships among Greek yogurt and non-Greek yogurt along with other dairy products, a demand systems analysis could be used to provide information on own-price, cross-price, and expenditure elasticities at the household level. Despite these limitations, our study nevertheless adds to the body of literature by providing a micro-perspective analysis concerning the propensity to purchase Greek and non-Greek yogurt as well as factors affecting household demand for these products in the United States over calendar years 2018 to 2020. This study then provides a baseline for future studies using updated household information in subsequent calendar years.

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