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US Household Purchases of Dairy Milk and Plant-Based Milk Alternatives

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US household purchases of fluid dairy milk and plant-based milk alternatives are investigated using household-level data from the 2018 National Consumer Panel. About 58.5% of all households bought only dairy milk and 4.4% bought only plant-based products over the course of that year. Another 37.1% switched between the two types of products, buying dairy milk on most shopping occasions and plant-based products on a smaller number of occasions. Dairy milk will not likely lose out to plant-based products anytime soon given these purchase patterns; rather, the two products may coexist, with plant-based options playing a minor role.

Key words: household food purchases, household scanner data, interpurchase time, milk, plant-based milk alternatives, product choice

Introduction

US households are buying less fluid dairy milk and more plant-based milk alternatives (Badruddoza, Carlson, and McCluskey, 2020; Stewart et al., 2020). Sales of plant-based alternatives reached 9.2% of the combined retail dairy milk and nondairy milk alternatives market on a volume (gallons) basis in the first half of 2020 (Dairy Management Inc., 2020). Almond-based products are the most popular (Dairy Management Inc., 2019). Other varieties include oat, cashew, coconut, walnut, hemp, soy, and rice-based options, among still others.

About 90% of individuals do not consume enough dairy products to satisfy recommendations in the *Dietary Guidelines for Americans, 2020–2025*.[1] A shift in demand away from dairy milk in favor of plant-based products could reduce dairy farmer sales as well as further widen the gap between recommended and actual diets. Only soy beverages fortified with calcium, which account for less than 10% of all US sales of plant-based milk alternatives, are nutritionally comparable enough to dairy milk to be considered a dairy equivalent.[2]

US per capita consumption of fluid dairy milk has been trending downward since the mid-1940s and fell at a faster rate in the 2010s than it had during any previous decade.[3] Plant-based alternatives contributed to this faster rate of decline (Stewart et al., 2020), but over 90% of US households still buy dairy milk, including most buyers of plant-based alternatives (Stewart et al., 2020).

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[1] The *Dietary Guidelines for Americans* are issued every 5 years by the US Department of Agriculture and the US Department of Health and Human Services to provide evidence-based nutrition information and advice.

[2] Soy-based products represent about 10% of the plant-based alternatives market (Dairy Management Inc., 2019), including nonfortified versions. In general, Chalupa-Krebzdak, Long, and Bohrer (2018) argue that plant-based alternatives contain less protein, have reduced calcium availability, and higher glycemic index values.

[3] US per capita fluid dairy milk consumption fell by 7.4% between 1950 and 1959, 8.4% in the 1960s, 9.9% in the 1970s, 5.4% in the 1980s, 10.9% in the 1990s, 7.9% in the 2000s, and 20.2% in the 2010s (US Department of Agriculture, 2021a).

In this study, we investigate the market for dairy milk and plant-based milk alternatives by asking how often US households buy one of these products and the extent to which they switch between them when making purchases. Dairy milk is the traditional product, meaning that most households have long bought it and are familiar with it. However, after trying a plant-based option, households may largely transition away from dairy milk. Alternatively, they may continue to buy dairy milk on most shopping occasions. Households can include a variety of members with their own preferences. A single individual might be allergic to dairy products or prefer plant-based products for their taste while other household members prefer dairy. It is also possible that multiple household members use plant-based products for only one purpose and dairy for all others. Members of a household might put plant-based products in coffee, for example, but consume dairy milk with cereal and as a standalone beverage. In this case, the ability of plant-based alternatives to grow market share at dairy farmers' expense would be much more limited; rather, the two products would likely coexist, with plant-based products a niche option.

An integrated purchase frequency and product choice model is introduced to analyze how frequently households buy both types of products and what marketing variables and household characteristics influence their choices. The model is estimated using panel data provided by Information Resources Inc. (IRI). Researchers are increasingly taking advantage of such data in which the daily grocery purchases of thousands of households are observed over months or years. An aspect of the model is that it uses the Dirichlet distribution to incorporate households' past purchase histories and explain behaviors like repeat buying and switching between products.

Literature Review

A growing body of research examines competition between traditional animal products and emerging plant-based alternatives. In the case of dairy milk and plant-based milk alternatives, Dharmasena and Capps (2014) used household-level scanner data from 2008 to estimate a demand system for soy-based products, white dairy milk, and flavored dairy milk. Soy-based products and both types of dairy milk were found to be price substitutes.

Dairy and plant-based products offer consumers distinct sets of attributes and, as such, it is unsurprising that buyers of them exhibit different characteristics themselves. Higher income, college-educated households without children exhibit a greater demand for plant-based products (Dharmasena and Capps, 2014). Larger, non-Hispanic white households with children, by contrast, exhibit a greater demand for dairy milk (Dharmasena and Capps, 2014; Stewart, Dong, and Carlson, 2012; Dong, Chung, and Kaiser, 2004; Schmit et al., 2002).

A few recent studies investigated the extent to which sales of plant-based alternatives have impacted dairy milk sales. Badruddoza, Carlson, and McCluskey (2020) used scanner data from 2009–2018 with information on the quantities sold and prices charged by stores at the UPC level. These retailer-level data do not include information on the characteristics of purchasing households. They estimated a model to test whether sales of milk-type products are driven in part by a "bandwagon effect," which occurs when consumers derive greater utility from products perceived to be fashionable. Findings confirmed that consumers value products more as they gain popularity, but only up to a point. The amount of utility derived from a product decreases after a threshold is reached, suggesting that sales could suffer from an "anti-bandwagon effect" if plant-based alternatives one day become popular enough.

In another study,Stewart et al. (2020) used household-level scanner data from 2013–2017 and found that weekly dairy milk purchases declined 12% from about 0.41 gallons to 0.36 gallons per household per week over those 4 years. Total US retail sales were further estimated for each week of each year by aggregating individual households' purchases. Their estimation of a time series model using those aggregated data revealed that every purchase of a plant-based product could be taking an equal-sized sale away from dairy suppliers (i.e., the rate of replacement may be about 1:1). Even so, growth in sales of plant-based options over 2013–2017 was only one-fifth the size of the decrease in dairy milk sales, which suggests that plant-based milk alternatives are contributing to—but not a primary driver of—declining dairy milk sales.

Overall, existing research finds that plant-based alternatives are reducing Americans' dairy milk consumption (Badruddoza, Carlson, and McCluskey, 2020; Stewart et al., 2020). Buyers of these two types of products also differ (Schmit et al., 2002; Dong, Chung, and Kaiser, 2004; Stewart, Dong, and Carlson, 2012; Dharmasena and Capps, 2014). However, we cannot simply separate them along economic and demographic lines, since over 90% of all US households still buy dairy milk at least once a year, including those that buy plant-based alternatives (Stewart et al., 2020). This leaves many important questions unanswered. It would be good to know how buying plant-based products affects the likelihood that a household continues to buy dairy milk. Are households likely to stick with plant-based alternatives after trying them? Just how much do such behaviors vary across households? Below, we propose a model for investigating US household purchases of dairy and plant-based milk alternatives. Unlike previous studies, this model—which is estimated with microlevel panel data—allows us to examine behaviors like repeat buying and product switching.

A Model of Households' Milk Shopping Behavior

Pioneering research by Jeuland, Bass, and Wright (1980) and Goodhardt, Ehrenberg, and Chatfield (1984) developed a framework for studying household purchases of frequently bought goods. One expression is developed for how frequently households buy such products and another for their choice among competing options whenever a purchase is made. The two expressions are then combined to obtain measures of phenomena of interest, such as repeat buying and product switching. This framework has been widely applied in marketing sciences. Applications and extensions include Meyer-Waarden and Benavent (2006); Dawes, Meyer-Waarden, and Driesener (2015); Jacobs, Donkers, and Fok (2016); and Fujak et al. (2018).

Interpurchase Time

We develop first an expression for how frequently households buy a particular product. Suppose, for example, that we have data on household purchases over 1 year or, equivalently, 365 days. Moreover, suppose that a household made purchases on the 15th, 100th, 199th, 250th, and 300th days of observation. The full set of interpurchase times for that household (i.e., the duration of time between two occasions) would be 15 or more days, 85 days, 99 days, 51 days, and 50 days. These are nonnegative numbers and, indeed, we can see that interpurchase time is the reciprocal of purchase frequency. The duration of time between the first and second purchase is 85 days, meaning that the household shopped for a milk-type product 1 out of 85 days during that particular period. Anything that increases interpurchase times implies less frequent purchases and anything that decreases interpurchase times implies more frequent purchases. An increase in household size, for example, might be associated with an increased rate of consumption, so we would expect an additional household member to decrease interpurchase times. We also note that interpurchase time is left-censored for our first observation since the household's last purchase before that one was made outside the range of the data (e.g., it was made before data collection began).

Researchers studying purchase frequency have proposed several approaches based on different assumptions about the distribution of interpurchase times. One approach uses the Gamma distribution, which can take on a variety of shapes for experiments involving nonnegative outcomes. It also accounts for inventory effects. The probability that a household makes a purchase increases with the amount of time elapsed since its last purchase.[4] Herniter (1971), for example, assumed that interpurchase time is an Erlang process, which is a special case of the Gamma distribution. Herniter

[4] If households store some amount of a product as inventory, the likelihood that they make another purchase should be smallest just after they shopped and increase over time (Jeuland, Bass, and Wright, 1980, p. 259)

chose this specification after examining interpurchase time histograms for frequently bought items, including laundry detergent, that were right-skewed. Other distribution choices, such as the Poisson, can be found in Jain and Vilcassim (1991). However, unlike the Gamma, the Poisson cannot account for inventory effects.[5]

Following Herniter (1971), we assume that interpurchase time is a Gamma-distributed random variable with probability density function (pdf):

$$(1) \qquad f\left(d_{it}\right) = \frac{\left(\frac{k}{\lambda_{it}}\right)^{k}}{\Gamma(k)} {d_{it}}^{k-1} e^{-\frac{k}{\lambda_{it}} d_{it}},$$

where d_{it} denotes the time between two purchases by household i, λ_{it} and k are parameters with $\lambda_{it} > 0$, and $\Gamma(\cdot)$ is the Gamma function. The mean and variance of interpurchase time are $\mathrm{E}\left(d_{it}\right) = \lambda_{it}$ and $V\left(d_{it}\right) = \frac{{\lambda_{it}}^{2}}{k}$, respectively. Moreover, the probability that household i makes a purchase at time $t = 1, 2, 3, \ldots, T_i$ is

$$(2) \qquad f\left(d_{i1}\right) = \frac{1 - F\left(d_{i1}\right)}{\lambda_{i1}} = \frac{1}{\lambda_{i1}} - \frac{\gamma_{i1}\left(k, \frac{k d_{i1}}{\lambda_{i1}}\right)}{\lambda_{i1}\Gamma(k)}$$

when $t = 1$ and

$$(3) \qquad f\left(d_{it}\right) = \frac{\left(\frac{k}{\lambda_{it}}\right)^{k}}{\Gamma(k)} d_{it}^{k-1} e^{-\frac{k}{\lambda_{it}} d_{it}}$$

when $t = 2, 3, \ldots, T_i$. Equation (2) is derived following Cox (1962) since the first interpurchase time is left-censored. The function $\gamma_{it}(k, \frac{k d_{it}}{\lambda_{it}})$ is the incomplete Gamma distribution, and the variable T_i is the total number of purchases made by i. The cumulative density function (cdf) of d_{it} is

$$(4) \qquad F\left(d_{it}\right) = \int_{0}^{d_{it}} f(d_{it}) dd_{it} = \frac{\left(\frac{k}{\lambda_{it}}\right)^{k}}{\Gamma(k)} \gamma_{it}\left(k, \frac{k d_{it}}{\lambda_{it}}\right).$$

Additionally, we allow marketing and economic environmental variables to influence interpurchase times. We do so by parameterizing λ_{it} as

$$(5) \qquad \lambda_{it} = e^{\boldsymbol{X}_{it}\boldsymbol{\beta}},$$

where $\boldsymbol{\beta}$ is a vector of parameters to be estimated and $\boldsymbol{X}_{it}$ is a matrix of marketing and household variables influencing d_{it} including prices, household size, and household income. We use an exponential function in equation (5) to guarantee that λ_{it} is positive, as required by the Gamma distribution defined in equation (1).

Finally, the logarithm of the likelihood for household i is

$$(6) \qquad \ln L_i = \ln\left[\frac{1}{\lambda_{i1}} - \frac{\gamma_{i1}\left(k, \frac{k d_{i1}}{\lambda_{i1}}\right)}{\lambda_{i1}\Gamma(k)}\right] + \sum_{t=2}^{T_i} \ln\left[\frac{\left(\frac{k}{\lambda_{it}}\right)^{k}}{\Gamma(k)} {d_{it}}^{k-1} e^{-\frac{k}{\lambda_{it}} d_{it}}\right]$$

and the log-likelihood for a total of N households is

$$(7) \qquad \ln L = \sum_{i=1}^{N} \ln L_i.$$

We use a maximum likelihood procedure to obtain parameter estimates.

[5] The Poisson probability that a household makes a purchase is constant and independent of the amount of time elapsed since its last purchase (Jeuland, Bass, and Wright, 1980, p. 259).

Household Purchase Choice

Aside from purchase frequency, another key aspect of a household's shopping behavior is, when it does so, which option the household chooses. Many competing products, each differentiated by salient attributes (e.g., brand or type of ingredients) may be available. While researchers generally allow the level of utility derived through consumption and a household's ultimate choice among the products to depend on age, education, and other demographic characteristics, researchers should also try to account for each household's own past purchase history. In the parlance of the marketing sciences, Jeuland, Bass, and Wright (1980); Guadagni and Little (1983); and Goodhardt, Ehrenberg, and Chatfield (1984) argue that households may exhibit loyalty to particular products to the extent that they form the habit of repeatedly buying them over time.

A few approaches have been developed for modeling a household's choice among competing products in a framework that accounts for their past purchase history. One approach, developed by Guadagni and Little (1983), calculates a weighted average of each household's past purchases to define a "loyalty" variable. This variable can be included among other explanatory variables in a multinomial logit model. Another approach, promoted by Jeuland, Bass, and Wright (1980) and Goodhardt, Ehrenberg, and Chatfield (1984), uses a Dirichlet choice model. A key advantage of this approach is that expressions for repeat buying and product switching have been developed.[6]

Following Jeuland, Bass, and Wright (1980), Ehrenberg (1988), and Fader (1993), we develop a choice model with the Dirichlet distribution. The distribution's pdf is

$$(8) \qquad D(\rho_{i1t}, \rho_{i2t}, \ldots, \rho_{iJt}) = \frac{\Gamma(\delta_{i1t} + \delta_{i2t} + \cdots + \delta_{iJt})}{\Gamma(\delta_{i1t})\Gamma(\delta_{i2t})\ldots\Gamma(\delta_{iJt})}\rho_{i1t}^{\delta_{i1t}-1}\rho_{i2t}^{\delta_{i2t}-1}\ldots\rho_{iJt}^{\delta_{iJt}-1},$$

where $\Gamma(\cdot)$ is the Gamma function, $\delta_{i1t}, \delta_{i2t}, \ldots, \delta_{iJt}$ are positive parameters that indicate the relative level of a household's preference over each option, and

$$(9) \qquad \rho_{ijt} = \frac{\delta_{ijt}}{\sum_{j=1}^{J}\delta_{ijt}}$$

is the probability that household i chooses option j at time t. Thus, $\sum_{j=1}^{J}\rho_{ijt} = 1$.

The Dirichlet choice model can be extended to capture a household's past purchase history by updating the probabilities in equation (9) at time t using a household's observed choices from time 1 through time $t-1$ (Fader and Lattin, 1993). First, define y_{ijr} as household i's choice history, and let $y_{ijr} = 1$ if i chose option j at time r and 0 otherwise. Next, define a new Dirichlet distribution with parameters $\delta_{i1t} + \sum_{r=1}^{t-1} y_{i1r}, \delta_{i2} + \sum_{r=1}^{t-1} y_{i2r}, \ldots, \delta_{iJt} + \sum_{r=1}^{t-1} y_{iJr}$. The probability that household i chooses option j at time t is now

$$(10) \qquad \mathrm{E}\left(\rho_{ijt} \mid y_{ijt}\right) = \frac{\delta_{ijt} + \sum_{r=1}^{t-1} y_{ijr}}{\sum_{j=1}^{J}\left(\delta_{ijt} + \sum_{r=1}^{t-1} y_{ijr}\right)} = \frac{\delta_{ijt} + \sum_{r=1}^{t-1} y_{ijr}}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t - 1},$$

where $t-1$ is the total number of purchases by household i through time $t-1$. Note that $\sum_{j=1}^{J}\left(\sum_{r=1}^{t-1} y_{ijr}\right) = \sum_{r=1}^{t-1} y_{i1r} + \sum_{r=1}^{t-1} y_{i2r} + \ldots + \sum_{r=1}^{t-1} y_{iJr} = t-1$. Unlike the expected choice probabilities in equation (9), those in equation (10) vary across households according to their specific purchase history, y_{ijr}. In other words, the model allows for heterogeneity through $\sum_{r=1}^{t-1} y_{ijr}$, the observed household purchase history.

In order to additionally allow for household heterogeneity due to differences in income and demographic characteristics as well as the influence of marketing variables, we follow Dong and Stewart (2012) and parameterize δ_{ijt} as

$$(11) \qquad \delta_{ijt} = e^{\mathbf{Z}_{it}\boldsymbol{\alpha}_j + \mathbf{W}_{ijt}\boldsymbol{\theta}_j} > 0,$$

[6] Much like Guadagni and Little's (1983) approach, the Dirichlet choice model can also be used to create a loyalty variable. This variable can then be included in a multinomial logit model among other explanatory variables. See, for example, Fader (1993), Fader and Lattin (1993), and Dong and Stewart (2012).

where $\boldsymbol{Z}_{it}$ is a matrix of household variables that may influence the probability that a household chooses any of the j options defined by δ_{ijt} and $\boldsymbol{\alpha}_j$ is a vector of parameters to be estimated. Variables like age, income, and household size can be included in $\boldsymbol{Z}_{it}$, as past studies and economic theory suggest. $\boldsymbol{W}_{ijt}$ in equation (11) is a matrix of marketing variables facing household i. These could include prices, seasonality, and other variables. $\boldsymbol{\theta}_j$ is a vector of parameters to be estimated. The exponential specification of equation (11) guarantees that δ_{ijt} is positive, which is a requirement of the Dirichlet model.

Finally, applying this model to the current research question, our expression for the probability that household i chooses option j when shopping for a milk and/or milk alternative at time t becomes

$$(12) \qquad P_{ijt} = \frac{\delta_{ijt} + \sum_{l=1}^{t-1} y_{ijr}}{\sum_{j=1}^{J}\left(\delta_{ijt} + t - 1\right)} \text{ for } j = 1,2,3,$$

where we assume that the household has three choices: (i) buying only dairy milk ($j = 1$), (ii) buying only a plant-based alternative ($j = 2$), and (iii) buying both products ($j = 3$). The logarithm of the likelihood for household i is then

$$(13) \qquad \ln L_i = \sum_{j=1}^{J}\sum_{t=1}^{T_i}\left(y_{ijt}\ln P_{ijt}\right) = \sum_{j=1}^{J}\sum_{t=1}^{T_i}\left(y_{ijt}\ln\frac{\delta_{ijt} + \sum_{r=1}^{t-1} y_{ijr}}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t - 1}\right),$$

where T_i is the total number milk and milk alternative product purchases made by household i. The log-likelihood for a total of N households is

$$(14) \qquad \ln L = \sum_{i=1}^{N}\ln L_i.$$

We use a maximum likelihood procedure obtain parameter estimates.

Expressions of Interest

We have thus far developed models for the frequency with which households buy products as well as their choice among competing options whenever they make a purchase. Next, we generate measures of purchase frequency, option choice, repeat buying, and product switching using results from those two models and equations (1), (5), (11), and (12). Our approach notably assumes that a household's choice among competing options is independent of the length of time since its last purchase conditional on our explanatory variables. Jeuland, Bass, and Wright (1980) and other past studies also assume independence, as methods that allow for dependence have not been developed.[7]

Interpurchase Time and Purchase Frequency

The expected interpurchase time for household i at time t is

$$(15) \qquad \mathrm{E}\left(d_{it}\right) = \lambda_{it} = e^{\boldsymbol{X}_{it}\boldsymbol{\beta}},$$

and the expected purchase frequency is the inverse of the expected interpurchase time:

$$(16) \qquad \mathrm{E}\left(R_{it}\right) = 1/\lambda_{it} = 1/e^{\boldsymbol{X}_{it}\boldsymbol{\beta}}.$$

[7] The formulas become intractable if independence is not assumed.

Option Choice

The expected probability that household i chooses option j at time t is

$$\text{(17)} \qquad \mathrm{E}\left(P_{ijt}\right) = \mathrm{E}\left(R_{it}P_{ijt}\right)/\mathrm{E}\left(R_{it}\right) = \left(\frac{1}{\lambda_{it}}\frac{\delta_{ijt} + \sum_{r=1}^{t-1} y_{ijr}}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t - 1}\right) / \left(\frac{1}{\lambda_{it}}\right) = \frac{\delta_{ijt} + \sum_{r=1}^{t-1} y_{ijr}}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t - 1},$$

where $\mathrm{E}(\cdot)$ is the expectation operator and R_{it} and P_{ijt} are independent.

Switching between Products and Repeating Buying

Also of key interest in this study is a household's decision to switch between different types of products versus buying the same product on consecutive purchase occasions. To capture these phenomena, we follow Jeuland, Bass, and Wright (1980) and derive the expected probability of switching to option j_2 at time t conditional on previously choosing option j_1 at time $t-1$ as

$$\text{(18)} \qquad \mathrm{E}\left(P_{ij_1t}P_{ij_2t} \mid j_1\right) = \mathrm{E}\left(P_{ij_1t}P_{ij_2t}\right)/\mathrm{E}\left(P_{ij_1t}\right) = \left(1 - \frac{1}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t}\right)\frac{\delta_{ij_2t} + \sum_{r=1}^{t-1} y_{ij_2r}}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t - 1}$$

and the expected probability of again choosing option j_1 at time t conditional on choosing option j_1 at time $t-1$ (repeat buying) as

$$\text{(19)} \qquad \mathrm{E}\left(P_{ij_1t}P_{ij_1t} \mid j_1\right) = \frac{1}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t} + \left(1 - \frac{1}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t}\right)\frac{\delta_{ij_1t} + \sum_{r=1}^{t-1} y_{ij_1r}}{\sum_{j=1}^{J}\left(\delta_{ijt}\right) + t - 1}.$$

Interested readers can find expressions for other phenomena of interest—like unconditional switching and unconditional repeat buying—in Jeuland, Bass, and Wright (1980).

Elasticities or marginal effects can be calculated either analytically or numerically for all explanatory variables in equations (15)–(19).

Data

Household purchase panel data, such as IRI's National Consumer Panel (NCP), contain the information for estimating our model. The NCP is an operational joint venture owned by IRI and The Nielsen Company (Muth et al., 2016). The NCP data used in this study were collected in 2018 and contain information on 52,168 households that provided data for 12 full months and bought at least one dairy milk and/or plant-based milk alternative during that year. Each household recorded its food purchases after shopping occasions at retail food stores (e.g., supermarkets, supercenters, and warehouse club stores). We also observed the dates when those purchases were made.

We identified each NCP household's purchases of dairy milk and plant-based alternatives. Moreover, because we aim to capture the impact that the different types of alternatives are collectively having on households' total purchases of dairy milk, we defined both product categories broadly. Dairy milk includes whole, reduced-fat, low-fat, and skim options as well as flavored milks, acidophilus milk, and buttermilk. Plant-based alternatives include options made with almonds, cashews, soybeans, rice, oats, and other plants as well as options made from multiple plants, such as almonds and coconut. Both product categories include refrigerated and unrefrigerated products as well as organic and conventional options. Behaviors like repeat buying and product switching may vary between buyers of organic and conventional products or between buyers of refrigerated and unrefrigerated ones. The results of our study represent an average of such behaviors across buyers of all types of products within the two product categories.

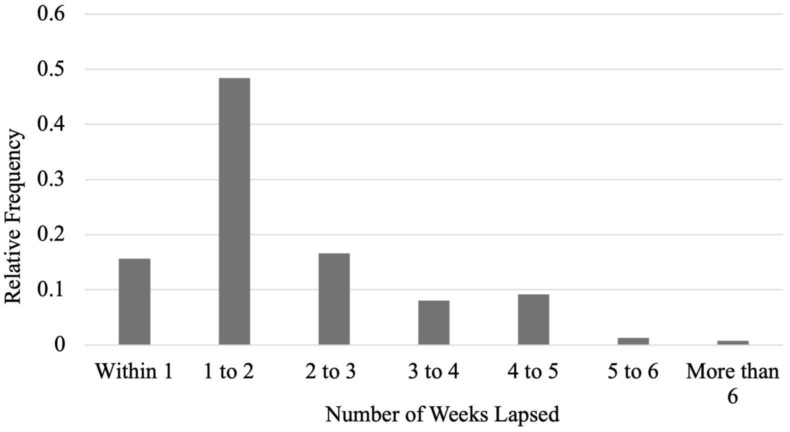

Figure 1. Time Elapsed between US Households' Purchases of a Milk-Type Product over 1 Year, 2018 (N = 52,168)

Notes: Data are from the National Consumer Panel (NCP), an operational joint venture owned by IRI and The Nielsen Company. Participating households report their food purchases at retail stores. Milk-type products are defined to include both dairy milk and plant-based milk alternatives.

Table 1. Number of Times that a Panel of US Households Chose Dairy Milk, a Plant-Based Milk Alternative, and Both Products When Making a Purchase

	Households that Purchased Only Dairy Milk (N= 30,533)	Households that Purchased Only Plant-Based Products (N = 2,297)	Households that Purchased Both Types of Products at Least Once (N = 19,338)	Total (N= 52,168)
Purchase occasions involving only dairy milk	657,345		319,330	976,675
Purchase occasions involving only plant-based products		26,126	96,128	122,254
Purchase occasions involving both types of products			46,328	46,328
Total	657,345	26,126	461,786	1,145,257

Notes: The National Consumer Panel (NCP) is an operational joint venture owned by IRI and The Nielsen Company. Participating households report their food purchases at retail stores. The data used in this study were collected in 2018 and include 1,145,257 purchase occasions by 52,168 NCP households.

Across all 52,168 households, we identified 1,145,257 purchase occasions (i.e., days when one or more milk-type products were purchased). About 64% of these events occurred within 2 weeks of a previous purchase by the same household. However, consistent with the Gamma distribution, the data are skewed to the right, with a substantial number of purchases occurring as many as 4–5 weeks afterward (Figure 1).

As for which types of products households bought when making a purchase, we find that, among all 52,168 NCP households, 30,533 (58.5%) bought only dairy milk during 2018 (Table 1). Purchase occasions by these households represent 657,345 (57.4%) of all purchase occasions by all households. We observe no instances of product switching among them. All of these purchases followed a previous purchase of dairy milk or, alternatively, were the household's first purchase occasion of the year.

A small share of all households bought only plant-based alternatives and never purchased dairy milk. Among all 52,168 NCP households, 2,297 (4.4%) did so. Purchase occasions by these

Table 2. Average Number of Purchases Broken out by Choice Made among Households that Reported Buying Both Dairy Milk and Plant-Based Milk Alternatives

Behavior Observed	Average Number of Times Behavior Observed
Bought the same product as on the previous occasion	15.99
Repeat purchase of dairy milk	2.48
Repeat purchase of plant-based product	12.90
Repeat purchase of both types of products	0.62
Bought a different product than on the previous occasion	6.89
Household's first observed purchase	1.00
Total number of purchase occasions	23.88

Notes: The National Consumer Panel (NCP) is an operational joint venture owned by IRI and The Nielsen Company. Participating households report their food purchases at retail stores. The data used in this study were collected in 2018 and include 19,338 NCP households that bought both dairy milk and plant-based milk alternatives at least once over the course of that year.

households represent 26,126 (2.3%) of all purchase occasions by all households. We also observe no instances of product switching among this group.

Many more households bought both types of products at some point during the year. Among all 52,168 NCP households in our data, 19,338 (37.1%) did so. Purchase occasions by these households represent 461,786 (40.3%) of all purchase occasions by all households. Among those 461,786 purchase occasions, 319,330 (69.2%) involved the purchase of only dairy milk, 96,128 (20.8%) involved the purchase of only plant-based products, and 46,328 (10%) involved the purchase of both types of products.

Plant-based alternatives could replace dairy milk if US households transition away from dairy products after they begin to purchase plant-based products. In Table 2, we take a closer look at the 37.1% of all households in our sample that bought both types of products at least once over the course of 2018. On average, this group of consumers reported 23.88 purchase occasions. These occasions include one initial purchase for which we lack information about the previous occasion. However, for all subsequent purchase occasions, we can determine whether the households repeated their previous choice. On average, households switched choices 6.89 times and repeated their previous choice 15.99 times, including 12.9 repeat purchases of only dairy milk, 2.48 repeat purchases of only plant-based products, and 0.62 repeat purchases of both products. These households do not stick with one type of product. Many instances of repeat buying and product switching can be seen among them although, on average, their demand for dairy milk exceeds that for plant-based products.

How often US households buy a milk-type product as well as their choices between dairy and plant-based alternatives are hypothesized to depend on several factors. Specifically, following Schmit et al. (2002); Dong, Chung, and Kaiser (2004); Stewart, Dong, and Carlson (2012); and Dharmasena and Capps (2014), we hypothesize that a household's income, demographic characteristics, region of residence, seasonality, and prices all determine these shopping behaviors (Table 3). Among a household's demographic characteristics, we include a count of the number of members (*HHSIZE*) along with three binary indicator variables—*KID*05, *KID*0612, and *KID*1318—for whether any of those members are aged up to 5 years old, 6–12 years, and 13–18 years, respectively. "Conflicts of interest" are more likely to occur within larger households because different individuals may have different tastes and preferences. Larger households may also consume more milk-type products overall and, holding HHSIZE constant, those with children may consume a still greater amount (e.g., Schmit et al., 2002; Stewart, Dong, and Carlson, 2012). We also include the binary indicator variables, *BLACK* and *ASIAN*, for whether the household head belongs to these racial groups as well as another binary indicator variable, *HISPANIC*, for whether they are of Hispanic origin. Individuals who identify as Hispanic can belong to any racial group. Notably, we take the inverse of *HHISIZE* as well as the natural logarithm of our age and income variables to

Table 3. Explanatory Variables

Variable	Description	Included in Equation[a]	Mean	Std. Dev.
Intercept	Intercept	I, C	1.00	0.00
HHSIZE	Household size (number)		2.46	1.31
INCOME	Household income ($1,000)		66.9	36.8
AGE	Age of household head		55.9	13.6
COLLEGE	=1 if household head completed college	I, C	0.55	0.50
EMPLOYED	=1 if household head is employed	I, C	0.73	0.44
HISPANIC	=1 if household is Hispanic	I, C	0.08	0.28
BLACK	=1 if household is Black	I, C	0.10	0.30
ASIAN	=1 if household is Asian	I, C	0.03	0.18
*KID*05	=1 if household has children aged up to 5	I, C	0.07	0.26
*KID*0612	=1 if household has children aged 6–12	I, C	0.12	0.32
*KID*1318	=1 if household has children aged 13–18	I, C	0.13	0.34
PACIFIC	=1 if household resides in the Midwest	I, C	0.12	0.33
MOUNTAIN	=1 if household resides in the Northeast	I, C	0.08	0.26
SOUTHEAST	=1 if household resides in the South	I, C	0.25	0.43
MIDATLANTIC	=1 if household resides in the Northeast	I, C	0.15	0.36
NEWENGLAND	=1 if household resides in the South	I, C	0.05	0.21
SPRING	=1 if purchase was in the spring	I, C	0.26	0.14
SUMMER	=1 if purchase was in the summer	I, C	0.25	0.13
FALL	=1 if purchase was in in the fall	I, C	0.24	0.14
PRICE	Average price of dairy and alternatives ($/gallon)	I	4.50	2.60
COWPRICE	Average price of dairy milk ($/gallon)	C	3.27	0.53
PLANTPRICE	Average price of milk alternatives ($/gallon)	C	6.11	0.32

Notes: Means are for 52,168 households that participated in the National Consumer Panel (NCP) in 2018 and bought one or both products under study at least once. Participating households report their food purchases at retail stores. Household head is assumed to be the adult female if one is present. Product prices are the weekly average price paid by all households that made a purchase in the same region of the United States as the household.
[a] I and C represent interpurchase time and choice equations, respectively.

allow for a nonlinear relationship between these variables and our dependent variables, as some past studies also do (e.g., Dong, Chung, and Kaiser, 2004; Stewart, Dong, and Carlson, 2012).

Instead of the prices that individual households reported paying for products, we calculated and included in our analysis measures of weekly, regional-average prices.[8] Separate price variables were created to measure the price of all milk-type products, only dairy milk, and only plant-based products. To define these variables, we first divided the US into five geographic regions. Using IRI-provided sample weights, we then summed the purchases of NCP households within each of those five regions during each of the 52 weeks of 2018.[9] Finally, we calculated unit values by dividing household aggregate expenditures during each week and region by the aggregate quantities those same households bought in gallons. *PRICE* is the unit price paid for all milk-type products obtained by summing household purchases of both dairy and plant-based options. *COWPRICE* and *PLANTPRICE* are the unit prices obtained by exclusively summing household purchases of dairy and plant-based options, respectively. All three variables take on 260 different values (i.e., 52 weeks $\times$ 5 regions).

[8] Including weekly, regional-average prices in our models instead of the prices that individual households reported paying should help minimize any potential bias due to price endogeneity.
[9] IRI provides sample weights for obtaining US population-level estimates of food product demand.

Model Estimation and Results

Using our 2018 NCP data on US household purchases of dairy milk and plant-based alternatives, we separately estimated the above purchase frequency and choice models using GAUSS software and a maximum likelihood estimation (MLE) routine that employs the optimization procedure developed by Berndt et al. (1974).

Overall, the data appear to fit the models well (Table 4). Likelihood ratio tests confirmed at a 1% significance level that both models performed better than restricted models in which we set all coefficients on all explanatory variables equal to 0 (see Table 4 notes for calculations).[10] For the interpurchase time model, we further estimated McFadden's (1974) pseudo-R^2 statistic to be 0.168, which is reasonable for a cross-sectional analysis of household food demand. For the choice model, by contrast, we compared predicted purchase choices based on the model with each household's actual choices and found the model to correctly predict 90.34% of all purchase choices (1,034,578 out of 1,145,257).

Finally, we calculated elasticity estimates for all independent variables (Table 5). This was done by differentiating equations (15)–(18) with respect to the models' explanatory variables one at a time, evaluating those expressions for all 1,145,257 purchase observations, grouping our results by household to calculate one full set of average effects for each of our 52,168 NCP participants and, finally, calculating the average of those values.[11]

Interpurchase Time and Purchase Frequency

Results show that larger, non-Hispanic white households with children and an older head of household buy milk-type products more frequently, whereas those with more income and an employed head of household do so less frequently (Table 5, first set of columns).[12] Consider, for example, the median household for which average interpurchase time was 19.2 days in 2018. Increasing the age of the household head by 25%, from 40 years to 50 years, would decrease expected interpurchase time by 4.65% ($25 \times -0.186\%$), from 19.2 days to 18.3 days or, equivalently, increase the number of days per year the household bought a milk-type product from 19.0 ($365 \div 19.2$) to 19.9 ($365 \div 18.3$) occasions. By contrast, a 10% increase in the combined retail price of milk and milk alternatives would extend interpurchase time by 0.81%.

A Household's Choice among All Available Options

Dairy milk is the traditional product, and 58.5% of NCP households exclusively chose it over plant-based alternatives during 2018 (Table 1). Moreover, the model results show that larger, non-Hispanic white households with an older head of household and children are more likely to do so on any given shopping occasion (Table 5, second set of columns). These are the same characteristics associated with buying milk-type products more frequently (Table 5, first set of columns). In other words, households exhibiting these characteristics are an important market segment and are most loyal to dairy milk.

Plant-based alternatives are an emerging product. Only 4.4% of NCP households bought plant-based alternatives exclusively throughout 2018 (Table 1). Characteristics associated with doing so on any given shopping occasion include being a smaller, younger, college-educated household without children (Table 5, second set of columns). Raising a household's income by 10% increases its likelihood of buying only a plant-based product on a given purchase occasion by 0.03 percentage points.

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[10] We additionally performed some robustness checks. For example, when specifying our empirical models, we take the inverse of *HHISIZE* as well as the natural logarithms of *AGE* and *INCOME*. Both models were re-estimated after imposing linear relationships between our dependent variables and all explanatory variables. Our results, including measures of model fit, were not significantly affected.

[11] This includes explanatory variables that enter our models nonlinearly (*AGE*, *INCOME*, and *HHSIZE*).

[12] Our model indicates that Hispanic, non-Hispanic Black, and non-Hispanic Asian households all shop less frequently than the control group, which consists largely of non-Hispanic White households.

Table 4. Parameter Estimates

		Product Choice		
Variable	**Interpurchase Time**	**Dairy Only**	**Plant-Based Only**	**Both**
Intercept	2.7497**	−0.9046**	−0.9873**	−1.1164**
	(0.0096)	(0.3727)	(0.3733)	(0.3981)
1/*HHSIZE*	0.4455**	−1.1921**	−0.4064**	−1.4567**
	(0.0017)	(0.0463)	(0.0507)	(0.0584)
ln(*INCOME*)	0.0142**	0.0648**	0.1713**	0.1849**
	(0.0006)	(0.0152)	(0.0176)	(0.0185)
ln(*AGE*)	−0.1862**	−0.0173	−0.7704**	−0.7625**
	(0.0018)	(0.0415)	(0.0483)	(0.0508)
COLLEGE	0.0031**	−0.1823**	0.1531**	0.0616**
	(0.0008)	(0.0188)	(0.0228)	(0.0237)
EMPLOYED	0.0561**	−0.0508**	0.0183	−0.0178
	(0.0008)	(0.0200)	(0.0240)	(0.0247)
HISPANIC	0.1125**	0.1004**	0.4317**	0.3342**
	(0.0014)	(0.0298)	(0.0358)	(0.0361)
BLACK	0.3286**	−0.0970**	0.4297**	0.0730
	(0.0015)	(0.0300)	(0.0345)	(0.0382)
ASIAN	0.0982**	0.1336**	0.5615**	0.2117**
	(0.0020)	(0.0431)	(0.0488)	(0.0544)
KID05	−0.1192**	0.0492**	−0.1446**	0.0283
	(0.0015)	(0.0337)	(0.0433)	(0.0410)
KID0612	−0.0161**	0.0307**	−0.1197**	−0.0275
	(0.0012)	(0.0283)	(0.0362)	(0.0345)
KID1318	−0.0524**	0.1493**	−0.0467	0.0576
	(0.0011)	(0.0263)	(0.0338)	(0.0327)
PACIFIC	0.0492**	−0.2635**	0.2191**	0.0224
	(0.0012)	(0.0492)	(0.0527)	(0.0554)
MOUNTAIN	0.0243**	−0.1634**	0.2144**	0.0639
	(0.0014)	(0.0365)	(0.0419)	(0.0430)
SOUTHEAST	0.0135**	−0.1300**	0.0653	0.0028
	(0.0009)	(0.0305)	(0.0366)	(0.0376)
MIDATLANTIC	−0.0368**	−0.0961	0.0983	0.0941
	(0.0010)	(0.0488)	(0.0579)	(0.0593)
NEWENGLAND	−0.0963**	−0.2067**	0.1680**	0.1890
	(0.0016)	(0.0574)	(0.0659)	(0.0679)
COWPRICE	–	0.0288	0.1213**	0.0495
		(0.0355)	(0.0412)	(0.0419)
PLANTPRICE	–	0.1338**	−0.0686	−0.0514
		(0.0535)	(0.0451)	(0.0491)
SPRING	0.1280**	−0.2315**	0.0956**	0.3184**
	(0.0029)	(0.0264)	(0.0231)	(0.0240)
SUMMER	0.2335**	−0.1416**	0.3382**	0.5958**
	(0.0026)	(0.0315)	(0.0259)	(0.0269)
FALL	0.2664**	0.2182**	0.3488**	0.7359**
	(0.0024)	(0.0336)	(0.0294)	(0.0298)
PRICE	0.0179**	–	–	–
	(0.0001)			
Θ	0.9853**	–	–	–
	(0.0002)			
p-value (LR)	< 0.01		< 0.01	
Performance	*Pseudo-R^2 = 0.168*		*Percentage correctly predicted = 93.4%*	

Notes: Parameter estimates are for 1,145,257 purchase decisions. The log-likelihood value is $-4,216,200.92$ for the full interpurchase time model with 22 parameters and $-5,067,599.52$ for the restricted model with two parameters: LR $= 2(-4,216,200.92 - (-5,067,599.52)) = 1,702,797.2 > \chi^2(20) = 37.57$. The log-likelihood value is $-331,625.33$ for the full choice model with 66 parameters and $-375,465.49$ for the restricted model with three parameters: LR $= 2(-331,625.33 - (-375,465.49)) = 87,680.32$ $> \chi^2(63) = 94.42$. Using the log-likelihood values reported in note a of this table, the size-corrected pseudo-R^2 value for the interpurchase time model is $1 - \frac{-4216200.92-(22-2)}{-5067599.52} = 0.168$. Double asterisks (**) indicate significance at the 5% level.

Table 5. Elasticity Estimates

Variable	Interpurchase Time	Unconditional Probability of Choosing: Dairy	Unconditional Probability of Choosing: Plant-Based	Unconditional Probability of Choosing: Both	Probability of Choosing Conditional on Previously Making a Different Choice: Dairy	Probability of Choosing Conditional on Previously Making a Different Choice: Plant-Based
Household variables						
HHSIZE	−0.236**	0.008**	−0.014**	0.006**	0.027**	−0.004**
INCOME	0.014**	−0.005**	0.003**	0.002**	−0.001	0.002**
AGE	−0.186**	0.031**	−0.020**	−0.012**	0.015**	−0.014**
COLLEGE	0.001	−0.061**	0.047**	0.014	−0.045**	0.037**
EMPLOYED	0.004	−0.011**	0.012	−0.001	−0.009**	0.008
HISPANIC	0.008**	−0.060**	0.048**	0.012	−0.031**	0.055**
BLACK	0.027**	−0.076**	0.103**	−0.028**	−0.049**	0.090**
ASIAN	0.007**	−0.057**	0.091**	−0.034**	−0.027**	0.092**
*KID*05	−0.008**	0.023**	−0.039**	0.016	0.016**	−0.031**
*KID*0612	−0.001**	0.023**	−0.027**	0.003	0.015**	−0.022**
*KID*1318	−0.004**	0.032**	−0.033**	0.003	0.028**	−0.021**
PACIFIC	0.004**	−0.080**	0.077**	0.004	−0.060**	0.059**
MOUNTAIN	0.002**	−0.064**	0.060**	0.005	−0.046**	0.048**
SOUTHEAST	0.001**	−0.036**	0.029**	0.007	−0.028**	0.020**
MIDATLANTIC	−0.003**	−0.041**	0.021	0.020	−0.029**	0.018
NEWENGLAND	−0.006**	−0.080**	0.036	0.044	−0.057**	0.031**
Marketing variables						
COWPRICE	–	−0.010**	0.009	0.001	−0.001	0.007**
PLANTPRICE	–	0.047**	−0.034**	−0.013**	0.052**	−0.019**
SPRING	0.009**	−0.091**	0.003	0.087**	−0.064**	0.008
*SU*MMER	0.018**	−0.121**	0.010	0.111**	−0.079**	0.026**
FALL	0.021**	−0.071**	−0.035**	0.106**	−0.034**	−0.003
PRICE	0.081**	–	–	–	–	–
Probability point change given an additional purchase in history ($\sum y$)						
Own purchase		0.096**	0.373**	0.401**	0.192**	0.273**
Other purchase		−0.339**	−0.062**	−0.034**	−0.098**	−0.017**

Notes: Elasticity estimates for the continuous variables are percentage changes in interpurchase time and percentage point changes in the choice probabilities given a 1% change in the variable. Those for the dummy (binary) variables are percentage changes in interpurchase time and percentage point changes in the choice probabilities when the variable equals 1 versus 0. Double asterisks (**) indicate significance at the 5% level.

About 37.1% of households in the NCP data bought both dairy milk and a plant-based product at least once at some point during 2018 (Table 1). Purchasers include households that bought dairy milk on some shopping occasions and plant-based products on others. Analysis of the panel data model reveals that having more income increases the probability that a household buys both types of products on the same shopping occasion (Table 5, second set of columns). Results on other variables are mixed. Variables for the presence of children are statistically insignificant, while those for a household's race are not consistently positive or negative in sign.

Despite the importance of income and demographic characteristics, we also find that household choices are swayed by prices. Higher retail prices for either type of product discourage households from choosing only that product (Table 5, second set of columns). A 10% increase in dairy milk's retail price decreases the likelihood that a household buys only that product on a given shopping occasion by 0.1 percentage points.

A household's past purchase history is a significant predictor of its current and future choices. The bottom of Table 5 (second set of columns) shows the impact of having made each choice one additional time in the past on (i) the likelihood of making that same choice again and (ii) the likelihood of making a different choice. Having bought dairy milk one additional time in the past increases a household's likelihood of exclusively buying it on a given shopping occasion by 0.096 percentage points. By contrast, having bought a plant-based product once more increases a household's likelihood of choosing only that product by 0.373 percentage points. The impact is notably larger for plant-based alternatives. These are a newer product category and, unlike dairy milk, some households may be unfamiliar with them. However, the more a household has tried the newer product, the more likely it is to buy that product again in the future. Experience with the newer product may reduce unfamiliarity, which, in turn, may cause the effect of past purchase history to be much larger for the newer product than the traditional one.

Switching between Products

More households may try plant-based products over time, but will they switch between them and dairy milk or will they mostly transition away from dairy toward plant-based products? To address this question more formally than in the earlier examination of the raw data, we further calculated two probabilities: the likelihood that a household buys only dairy milk after not doing so on the previous purchase occasion and the likelihood that it buys only a plant-based product after not doing so on the previous purchase occasion. These probabilities are found to be 0.70 and 0.10, respectively. In other words, the household is more likely to buy dairy than plant-based products, regardless of its previous purchase choice.[13]

While households are more likely to choose dairy milk over plant-based products on most purchase occasions, the exact probabilities vary across households. In the third set of columns in Table 5, we examine how each of the above two probabilities changes with our model's explanatory variables. Not surprisingly, we find that larger, non-Hispanic white households with an older household head and children are more likely than other households to switch back to dairy milk after previously making a different choice. Notably, these are again the same factors associated with purchasing milk-type products more frequently (Table 5, first set of columns) and being a more loyal buyer of dairy milk (Table 5, second set of columns).

We also continue to find that past purchase history is a significant determinant of current and future behavior. Increasing the number of past occasions when a household bought only dairy milk by 1 increases the probability that it will switch back to only dairy milk after having previously made a different choice by 0.192 percentage points (Table 5, third set of columns). By contrast, increasing the number of past occasions when a household bought only plant-based products by 1 increases the probability that it will switch back to only plant-based products after having previously made a different choice by 0.273 percentage points. Thus, past purchase history is again found to have the largest effect on the newer product category, as discussed above.

Conclusions

Most Americans do not consume enough dairy products to meet recommendations. According to the federal *Dietary Guidelines for Americans, 2020–2025*, individuals should consume 2 to 3 one-cup equivalents of fluid milk and other dairy products per day.[14] From the mid-1980s through the 2000s, US dairy intake averaged between 1.52 and 1.57 one-cup equivalents per person per day as increases in cheese consumption were generally sufficient to offset decreases in milk drinking (US

[13] There is additionally the probability that they will buy both products on their next shopping occasion.

[14] Recommendations vary with an individual's age, gender, and level of physical activity. Consuming 1 cup of dairy milk, 1 cup of fortified soy beverage, 1 cup of yogurt, 1½ounces of natural cheese, or 2 ounces of processed cheese contributes a 1-cup equivalent toward meeting daily dairy recommendations.

Department of Agriculture, 2021a). Cheese consumption has been increasing due to its widespread use in commercially prepared foods, such as frozen pizza, as well as the popularity of cheese-rich Italian and Tex Mex cuisines (Bentley, 2014). However, given the accelerated rate at which per capita fluid milk consumption fell in the 2010s, US dairy intake was less than 1.5 one-cup equivalents per person per day in both 2018 and 2019 (US Department of Agriculture, 2021a).

Previous research shows that rising sales of plant-based milk alternatives contributed to the accelerated rate at which US per capita dairy milk consumption decreased during the 2010s (Stewart et al., 2020). In this study, consistent with past research, including Schmit et al. (2002); Dong, Chung, and Kaiser (2004); Stewart, Dong, and Carlson (2012); and Dharmasena and Capps (2014), we find that larger, non-Hispanic white households with children and an older head of household exhibit a greater level of demand for dairy products, whereas younger, college-educated households without children are most likely to choose plant-based products. Additionally, we find that US households do not generally transition away from buying dairy products after they try plant-based products. In our 2018 data, 58.5% of all households bought only dairy milk and 4.4% bought only plant-based products over the course of 2018. Another 37.1% bought both products at least once. These households tend to switch between buying dairy milk on most shopping occasions and plant-based products on a smaller number of occasions. Dairy milk will not likely lose out to plant-based products anytime soon given these purchase patterns; rather, it is much more likely that the two products will coexist, with plant-based options playing a minority role.

The dairy industry is working to grow dairy product sales through nutrition education, research, and collaborative efforts with the food industry. Funding for these promotional efforts is made possible through checkoff programs. Farmers contribute $0.15 per 100 pounds of milk they commercially market,[15] while fluid milk processors contribute $0.20 per 100 pounds they sell in consumer-type packages.[16] A better understanding of dairy's competitive position could help the industry to further improve how it markets and promotes dairy products.

In this study, we broadly define both dairy milk and plant-based alternatives to capture the impact that the alternatives are collectively having on total dairy milk sales. We also use household-level data collected over a single year. Future research could investigate the extent to which behaviors like repeat buying and product switching vary among buyers of specific types of products (e.g., organic vs. conventional products and soy- vs. almond-based products). Future research might also investigate what motivates a household to start trying plant-based products in the first place. Working with several years of data, for example, it might be possible to include explanatory variables that capture the effects of advertising on household choices.

Questions about the nature and extent of competition between traditional animal products and plant-based alternatives are not unique to dairy milk. Recent studies compare consumer preferences for plant-based meat products and beef (Van Loo, Caputo, and Lusk, 2020). Future research could use panel data and the model outlined in this study to expand on that body of research by further characterizing household purchase behavior with respect to meats and meat alternatives.

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[15] Dairy farmers contribute to the National Dairy Promotion and Research Program (US Department of Agriculture, 2021b).

[16] Fluid milk processors contribute to the National Fluid Milk Processor Promotion Program (US Department of Agriculture, 2021c).

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