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Abstract

The continued penetration of plant-based beverages in fluid milk markets appears to have reinforced the ongoing decline in the U.S. per capita consumption of fluid cow milk. In this study, we focus on how demographic variables and consumers' opinions about climate change impact the preference for plant-based beverages. This study also explores the competition in fluid milk markets. To this end, we utilized sales data from the Nielsen retail scanner dataset and employed a random-coefficients logit model. Results show that consumers' belief in the human role in climate change is positively correlated with their preference for plant-based beverages. Non-whites show a higher preference for plant-based beverages. The average own-price elasticities of plant-based beverages were found to be higher than those of a manufacturers brand and private label cow milk and lower than those of organic and lactose-free cow milk. Plant-based beverages are found to be close substitutes for each other but are less substitutable with milk types. The results suggest that the price-cost markup percentages associated with plant-based beverages are higher than those of private label cow milk and lower than those of organic and lactose-free cow milk, indicating a significant market power for the firms producing them.

Keywords: Plant-based beverages, fluid milk, environmental sustainability, random-coefficients logit

JEL code: D10, D40, L10

*Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.The conclusions drawn from the NielsenIQ data are those of the researcher(s) and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

1. Introduction

Cow milk and derivative products are great sources of protein (Vanga and Raghavan, 2018) and other nutrients, thus, is considered an important constituent of the American diet (USDA, 2020, Dietary Guidelines for American 2020-2025). But there has been a great shift in the consumption of fluid cow milk in recent decades, decreasing by more than 25 percent from 2000 to 2018, while the consumption of cheese and yogurt has increased severalfold during the same time (ERS, 2021). As consumers are increasingly health-and-environment-conscious and are adopting healthy and sustainable diets, the demand for different specialty "milks," such as low- and reduced-fat milk and lactose-free milk, that are perceived to be healthy and environmentally friendly is increasing. Even more recently, demand for non-dairy plant-based beverages (which are often called *mylk* or simply plant-based milk)[1] is rising and establishing its strong presence in the fluid milk market. Thus, in this study, we employed random coefficients logit model (Berry, Levinsohn, and Pakes, 1995; hereafter BLP) to the sales data of cow milk and plant-based beverages to study the demand and competition in the fluid milk market. Furthermore, this study also explores how consumers' opinion about the human role in climate change impacts the preference for plant-based substitutes.

The dollar sales of plant-based beverages account for 14 percent of all retail milk (Wolf, Malone, and McFadden, 2020). As seen in Figure 1A (in the appendix), plant-based beverages are forecasted to increase their sales in the American market. From 2017 to 2018 alone, sales increased by 9 percent (GFI, 2020). This rapid increase in the consumption of plant-based beverages has been often considered as one of the causes of the global dairy crisis (Irfan, 2018;

[1] Some plant-based beverage brands have labeled their brand as "mylk," and Clay et al. (2020) have used this term in their paper. Without an adjective, hereon we use "milk" for cow based or dairy milk, and use "beverages" for plant-based beverages, unless noted otherwise.

Barrett and Higgins, 2020). It has also created some policy debate.[2] Dairy farmers oppose plant-based beverages being called "milk,"[3] as in "soy milk" or "coconut milk," depending on what they are made of. The Food and Drug Administration (FDA) defines plant-based beverages as "imitation milk" that physically looks like cow milk. Likewise, in Europe, plant-based beverages are not allowed to be called milk except for almond milk and coconut milk.[4] Nonetheless, the fluid milk manufacturing industry in the Census of Manufacturers now includes both cow and plant-based beverages. Moreover, it is likely that both types of beverages are part of the same market, termed herein as the fluid milk market.

Growing demand for lactose-free beverages and low-calorie beverage options (McCarthy et al., 2017) and the increasing vegan lifestyle among American consumers (Makinen et al., 2016) are reported to be major drivers of plant-based beverage demand. In addition, due to milk-protein related allergy and lactose intolerance (Crittenden and Bennet, 2005), demand is rising for plant-based beverages (McCarthy et al., 2017). However, Clark et al. (2016) did not find dairy products to be "unhealthy" or to have an impact on mortality, stroke, colorectal cancer, and coronary heart disease, although consumption of cow milk is positively correlated with diabetes.

From a sustainability perspective, cow milk is considered a water guzzler, requiring almost twice as much water to produce one cup, compared to almond milk, the worst performer in the plant-based beverage category (see Table 1). Because cows emit methane gas, a powerful greenhouse gas (GHG), during the digestion (and manure decomposition processes), a unit of milk constitutes a high carbon footprint compared to plant-based alternatives. A plant-based

[2] For example, Wisconsin Senator Tammy Baldwin sponsored the DAIRY PRIDE (Defending Against Imitations and Replacements of Yogurt, milk, and cheese to Promote Regular Intake of Dairy Every day) Act to prohibit the use of words like milk, cheese, or yogurt for plant-based products.
[3] Accessed from https://www.agweb.com/article/dairy-farmers-press-against-labeling-nut-milk on 1/30/2021.
[4] Accessed from https://www.bbc.com/news/business-40274645 on 1/20/2021.

beverage is the best alternative for those who care about sustainability and animal welfare (Bir et al., 2019; Sabate and Soret, 2014; Haas et al., 2019). In Clark et al.'s (2016) comparison of the environmental impacts of plant-based and animal-based foods, dairy products almost always underperformed in terms of environmental sustainability compared to a plant-based diet. Mintel (2020) reported that environmental concerns are one of the major factors determining consumers' decisions to purchase plant-based beverages.

Understanding consumer behavior with respect to choices of plant-based beverages is important to identify the drivers of consumption decisions, and it provides bedrock information to ascertain the impact on the competitiveness of cow milk. Given the health and environmental advantages of plant-based beverages over cow milk, demand for these products is rising, while the demand for cow milk continues to drop. This dynamic also gives further insight into the ongoing dairy crisis, which some claim to be the result of the growth in plant-based milk's market share (Irfan, 2018; Barrett and Higgins, 2020). Although there are many studies on the demand study of fluid milk using BLP demand model (for example Lopez and Lopez (2009) studied the several differentiated milk products in Boston, Li, Lopez, and Yang (2018) studied energy-milk price transmission, and Liu et al (2020) focused on local milk) there are very few studies considering plant-based beverages and cow milk in the same study. Stewart et al. (2020) found that these two categories of beverages are close substitutes and plant-based beverages are accelerating the decline in the demand for cow milk. Using the vector autoregressive (VAR) model, Stewart et al. (2020) also found that plant-based beverages partially caused the decline in the demand for cow milk. Dharmasena and Capps (2014) used the Tobit model to study the demand for flavored cow milk, white milk, and soy milk and found that soy milk and cow milk are competitive with each other but that the demand for dairy alternatives is driven by several demographics like education, employment, age, race, and ethnicity. Okrent and MacEwan (2014) applying the Linear Approximate-Almost Ideal Demand System (LA-AIDS) model to several non-alcoholic beverages in a demand study, concluded that demand for plant-based beverages (and energy drinks) was driven mostly by demographic variables. Most of the studies to date considering types of milk and its plant-based substitutes use classical demand models like AIDS that are based on product space and do not allow a higher degree of product differentiation.

Studies show that awareness of environmental sustainability positively relates to buying "green" products that have a smaller carbon footprint. Statista (2019) reported that 56 percent of U.S. consumers changed the products and services they use because of concern about climate change. McCarthy et al. (2017), in a survey-based study, found that consumers' perception of lower environmental impact affects their consumption of plant-based beverages. There are, however, few studies that relate the environmental sustainability-related variables and preference for plant-based beverages. One of the major reasons for this is the lack of reliable data that includes information on opinions about environmental sustainability.

This overview justifies including plant-based beverages in a demand study of milk, with a focus on climate change beliefs. This paper attempts to fill this research gap on how climate-change opinions are related to preferences for plant-based beverages. This study also explores how other demographic variables, such as income and race, might impact the preference for plant-based beverages. Adding to the literature, this study uses a random coefficients logit model to explore the competitiveness of plant-based beverage types and different types of milk. This model solves the dimensionality problem that arises in other classical demand models used in previous studies by Okrent and MacEwan (2014) and Dharmasena and Capps (2014). Unlike many other studies related to shifting diet and climate change that are focused on meat, this study focuses on milk and its substitutes.

Results show that there is a positive correlation between plant-based beverages and a consumer’s belief that climate change is caused by human activities. White Americans are found to show a lower preference for plant-based milk as compared to the other ethnic groups. The results show that the own-price elasticity for plant-based beverages is higher than that of private label cow milk and manufacturers brand (MB) milk, while it is lower than that of organic and lactose-free cow milk. The estimated cross-price elasticities show higher substitutability of plant-based beverages with other plant-based beverages. For example, the soy-based beverage is a strong substitute for the almond-based beverage. Interestingly, this study reveals low substitutability of plant-based beverages with other milk types sharing common features as plant-based beverages like lactose-free milk.

There are some potential limitations in this study. This study only covers metropolitan areas; the preference for plant-based beverages in non-metropolitan areas could be different from metropolitan areas. Furthermore, there could be some selection bias with the stores that are considered in the study. The next one is that the data on consumers' opinions about the human role in climate change is from the survey which sometimes is fraught with noise. Health is also a potential factor that drives the demand for plant-based beverages, which could be a topic for future research.

The rest of the article has the following order. The next section highlights the relevant literature which is followed in the third section by the empirical model. The fourth section discusses the data and estimation strategy, followed by results and discussion. Finally, the sixth section concludes and proposes future avenues of study related to the demand for plant-based beverages and competition in fluid milk markets.

2. Relevant literature

2.1. Plant-based beverages

Plant-based beverages have a very long history. They used to be a good source of milk-like beverages in regions that have an insufficient supply of cow milk. But recently, the rapidly changing dietary habits of American consumers have increased demand for plant-based beverages as it is perceived to be a healthier and more sustainable alternative to cow milk. Plant-based beverages are formed by grinding the source (nuts, seeds, grains, pseudo-cereal, and legumes) and dissolving it in water. The suspension thus formed is treated thermally and enzymatically to make it stable, microbe-free, and good-tasting (Makinen et al., 2015). Since plant-based milk lacks many of the micronutrients found in cow milk, it is often fortified with several micronutrients and vitamins (Sethi, Tyagi, and Anurag, 2016). However, plant-based beverages are rich in some compounds not found in cow milk. For example, soy milk is rich in isoflavones, almond milk is rich in alpha tocopherol and arabinose, and rice milk is rich in phytosterols. These compounds have several beneficial health features, such as antioxidants and anti-carcinogenic and cholesterol-reducing properties (Sethi, Tyagi, and Anurag, 2016).

Except in cases of milk-protein allergy and a vegan diet, nutritionally, one can find comparable cow-milk alternatives to plant-based beverages. For example, for those who are looking for a low-calorie beverage, fat-free milk products have fewer calories than plant-based alternatives. If consumers are looking for lactose-free beverages, there is also lactose-free cow milk. However, the environmental impact of cow milk has always been higher than almost all plant-based substitutes. Obviously, from the perspective of animal welfare, consumers always find cow milk to be less humanely produced than plant-based milk. Thus, for consumers looking for milk (or milk-like) beverages that are environmentally sustainable and produced humanely, plant-based beverages could be a great alternative.

2.2.Climate change and food consumer behavior

Although the efficiency of dairy production has improved significantly (Capper, Cady, and Bauman, 2009), livestock is one of the major contributors to greenhouse gas emissions. The excreta decomposition and belching processes in ruminants produce methane, which is a very strong GHG. Thus, cow milk (and meat) is considered an important contributor to climate change. Globally, livestock (mostly ruminants) contribute almost 15 percent of anthropogenic emissions (Gerber et al., 2013). Comparing cow milk and plant-based beverages, the carbon footprint for cow milk is 2.5 to 4 times higher than that of plant-based milk. As freshwater has been increasingly depleted due to agricultural practices, cow milk is considered unsustainable, since it requires 628 liters of freshwater to produce a glass of milk, whereas around 370 liters of water are required to produce the same amount of almond milk. Almond plantations, in the Californian context, require more water than any other crops, but the water requirement is even less for other types of plant-based beverages. The comparison of the carbon footprint and water requirements to produce cow milk and other plant-based milk is shown in Table 1.

Studies have shown that changing consumer behavior toward a more plant-based diet would be crucial in limiting GHG emissions (Gerber et al., 2013; Joyce et al., 2012; Stehfest et al., 2009; Pimentel and Pimentel, 2003). Stehfest et al. (2009) have shown that a low-meat diet offers the double benefits of better health and mitigation of GHG emissions. Consumers can play a role by making more sustainable diet choices that take into account various factors, for example, their beliefs about climate change. However, the findings on consumer beliefs about climate change and willingness to shift toward a more sustainable diet are divided.

A sense of shared responsibility among consumers regarding climate change could move their dietary behavior toward sometimes consuming foods perceived to be environmentally sustainable (Wells, Ponting, and Peattie, 2011). A study by Kotchen, Boyle, and Leiserowitz (2013) found that consumers are willing to pay around $80 annually to reduce greenhouse gas emissions through different policy tools. More specifically, they found that stronger belief in global warming was correlated with a willingness to pay a carbon tax. A study in Finland showed that consumers concerned about climate change would choose a sustainable diet. Korkola, Hugg, and Jaakkola (2014) used a survey to show that consumers with a medium concern about climate change increased their Climate-Friendly Diet Score (CFDS)[5] by 0.51 points. One study in England showed that self-identification as a pro-environmentalist has a positive linkage with climate-friendly eating and shopping behavior (Whitemarsh and O'Neill, 2010). Makiniemi and Vainio (2013) concluded that increasing the moral concern about climate change could help consumers adopt climate-friendly diets. In a Dutch study, de Boer, Schosler, and Boersema (2013) found that consumers who care for nature valued the idea of meat-free meals more positively. Related to this, studies have shown several degrees of willingness to pay for products labeled as environmentally sustainable (Yu, Gao, and Zeng, 2014; Van Loo et al., 2015). Consumers were found to pay 40 percent more for "green" vegetables and meat in China (Yu, Gao, Zeng, 2014). Likewise, using an eye-tracking tool, Van Loo et al. (2015) found a

[5] In this study, the CFDS range from -14 to 14, where a higher value indicates a more climate-friendly diet.

positive willingness to pay for sustainability attributes of coffee. Sustainability in this study was defined based on the organic production process, fair trade, and low impact on the rainforest.

On the other hand, some other studies argue that consumers are not flexible in shifting their dietary habits to protect the environment mostly due to the taste and tradition associated with the animal-based diet (de Bakker and Dagevos, 2012) and lack of awareness about the role of livestock in climate change. Macdiarmid, Douglas, and Campbell (2016), in a qualitative study, found that consumers are reluctant to change their dietary habits to reduce GHG emissions, mostly because they lack the awareness of the connection between diet and climate change.

Table 1: Carbon footprint and water requirement for milks by their source

	Carbon footprint (Kg CO2 eq/liter)	Water requirement (liter/liter)
Cow milk	3.2	628
Almond milk	0.7	371
Soy milk	1	28
Rice milk	1.2	270

Source: Poore and Nemecek (2018); Haake (2019)

3. Empirical Model

This study uses consumer choices model based on the BLP random coefficients logit demand model. The random coefficient logit model has advantages over many other demand-based models (like AIDS) since it is based on the characteristics space and, thus, readily considers product characteristics. Besides, this model solves the dimensionality problem that arises when estimating the demand for a differentiated product, like milk (Lopez and Lopez, 2009). Huang, Rojas, and Bass (2008) have found that the random coefficients logit model produces less biased estimates as compared to classical demand models like AIDS, if the model is incorrectly specified.

3.1. Model of consumer behavior

Following Berry, Levisohn, and Pakes (1995), the indirect utility of consumer i (i=1……….n) from consuming one unit of milk product j (j=0…..J) be given by, [6]

$$U_{ij} = \alpha_i P_j + \beta_i x_j + \varepsilon_{ij} , \qquad (1)$$

where P_j is price of brand j, and x_j indicates vector of observed brand characteristics, such as plant-based beverage dummy, organic dummy, fat percentage, lactose-free dummy, and gallon-package type. If consumers do not purchase the from the list of brands, then it is assumed that they purchase the outside goods; therefore, j=0. α_i and β_i are consumer-specific taste parameters. ε_{ij} is stochastic error term which is assumed i.i.d and has type I extreme value distribution.

Assuming $\alpha_i$and β_i to be,

$$\alpha_i = \alpha + \gamma D_i + \delta \nu_i \qquad (2)$$

$$\beta_i = \beta + \rho D_i + \varphi \nu_i \qquad (3)$$

where D_i indicates observed consumer characteristics, and ν_i denotes unobserved consumer characteristics. $\alpha, \beta, \gamma, \rho, \delta$, and φ are fixed parameters. Plugging α_i and β_i back into (1) yields,

$$U_{ij} = \delta_j + \mu_{ij} + \varepsilon_{ij,} \qquad (4)$$

where, δ_j denotes the mean utility, which is common across all consumers, and μ_{ij} are deviations in the mean utility that vary across the consumers and are given by:

$$\delta_j = \alpha \, P_j + \beta x_j \qquad (5)$$

$$\mu_{ij} = \gamma D_i P_j + \rho D_i x_j + \delta \nu_i P_j + \varphi \nu_i x_j \ . \qquad (6)$$

[6] To keep it simple, we omitted the time and city (market) subscripts that we subsequently used in the estimation.

Now, the probability of a consumer choosing product j in the market is given by:

$$s_{ij} = \frac{\exp\left(\delta_{jm}+\mu_{ijm}\right)}{\sum_{r=1}^{J}\exp\left(\delta_{r}+\mu_{ir}\right)} \quad . \qquad (7)$$

This probability, if aggregated over consumers, yields the market share of brand j as:

$$S_j = \frac{1}{ns}\sum_{i=1}^{ns}\frac{\exp\left(\delta_{j}+\mu_{ij}\right)}{1+\sum_{r=1}^{J}\exp\left(\delta_{r}+\mu_{ir}\right)} \quad . \qquad (8)$$

(9) and (10) give own and cross-price elasticities, respectively:

$$\eta_{jj} = \frac{\partial S_j P_j}{\partial P_j S_j} = -\frac{P_j}{S_j}\int \alpha_i s_{ij}\left(1-s_{ij}\right) dP_D(D)dP_v(v) \qquad (9)$$

$$\eta_{jk} = \frac{\partial S_j P_k}{\partial P_k S_j} = -\frac{P_k}{S_j}\int \alpha_i s_{ij} s_{ik}\, dP_D(D)dP_v(v) \qquad (10)$$

Unlike elasticities from the logit model (Berry, 1994),[7] the elasticities from the random-coefficients logit model are not highly impacted by the price of the product. This is also one of the reasons why this model is more plausible in estimating the elasticities as compared to the logit model.

3.2. Model of supply and market equilibrium

Following Nevo (2001), the profit function for a firm is given by:

$$\pi_l = \sum_{j\epsilon k(l)}\left(P_j - c_j\right)M * s_j \ , \qquad (11)$$

where, c_j is the marginal cost for brand j, M is market size, and s_j is the market share of brand j.

Assuming that firms would compete on price and follow the Bertrand Nash equilibrium, the first order condition is given by:

[7] Own and cross-price elasticities from the logit model are given by $e_{jk} = -\alpha P_j\left(1-s_j\right)\ if\ j=k$ and $e_{jk} = -\alpha P_k(s_k)\ if\ j \neq k$, respectively. As most of the time the share is quite low (the average is 0.005 in this study), the elasticity would be highly impacted by the price such that a higher price would lead to higher elasticity.

$$s_j + \left[\sum_{h\epsilon k(l)} (p_{h-} c_h) \frac{\partial s_h}{\partial P_j}\right] = 0 \quad . \qquad (12)$$

Where, *h* denotes the product produced in firm *l*.

Rearranging this generates a series of equations for each firm as follows:

$$P_j - c_j = \Delta^{-1} s_j \quad , \qquad (13)$$

which is a price cost margin, and $\Delta = -I * \frac{\partial s_h}{\partial P_j}$. Again, *I* is a matrix whose elements are 1 if the products are produced in the same firm and 0 otherwise. s_j is the market share for product j. Equation (13) would give the marginal cost.

$$P_j - (\Delta^{-1}) s_j = c_j \quad . \qquad (14)$$

Finally, the Lerner index or percent markups over marginal cost is given by:

$$L_j = \frac{P_j - c_j}{P_j} \, , \qquad (15)$$

where the brand-level c_j is computed via equation (14) and P_j is observed. Thus, (15) measures oligopoly power at the product-brand level, which we use to compare between plant-based beverages and other types of cow milk.

4. Data and estimation strategy

4.1. Data

The primary source of data is the Nielsen Retail Scanner dataset, which provides the sales data for the milk brands for each UPC (Universal Product Code) at the store level for each week. To include wide geographic variation, we have used nine designated market areas (DMA) across the country representing the largest DMA (based on the number of stores in the sample) from each geographical division of the country. The geographical divisions of the US along with the DMAs are shown in Figure 2A (in the appendix). The sales data at the store level are aggregated to the DMA level for each four-week period. Milk (both dairy and plant-based beverages) from other brands and milk sold in other stores that are not under study are defined as outside goods.

This assumption would allow the consumers to choose none of the brands considered in the study (Nevo, 2000).

Following Nevo (2000) (also applied by Chen et al (2019) in energy drinks demand study and by Bonnano, Huang, and Liu (2015) in yogurt demand study), the potential market size is defined as the national per capita milk consumption in four-week period times the population of the DMA. The annual per capita consumption of fluid milk in 2017 and 2018 was 149 and 145 pounds, respectively (ERS, 2021)[8]. We also included the per capita consumption of the plant-based beverages in the study.[9] Thus, the market share for each product is calculated by dividing the sales volume of each product by the market size. The market share of the outside good is thus (1-sum of shares of all products in the study).[10]

The unit price ($ per gallon) of the product is calculated by dividing total sales revenue for each product by the total sales volume in the market. The price of MB milk is comparable with that used by Liu et al (2020). Using the similar method, they calculated the price of MB milk in New England region to be 4.24 $/gallon while we calculated it to be 4.5 $/gallon in Boston (see Table 2A). We have included different brands of cow milk and plant-based beverages.[11] There are a couple of organic milk brands (Horizon Organic and Organic Valley), some cow milk brands from the major national processor (Deans), one lactose-free cow milk

[8] The reliable data on per capita consumption of milk and plant-based beverages at the DMA (or corresponding state) level is not available. So, we used the per capita consumption of cow milk at the national level to create the market size.

[9] Stewart (2020) estimated per household plant-based beverages consumption to be 0.038 gallons. To estimate the per capita plant-based beverages consumption, we used the household size of 2.53 persons.

[10] This calculation of market share assumes that most of the sales of milk and its substitutes in the store occur from the sample stores, thus the market share of the products calculated here is assumed to be equal to the actual share. Conversely, the results in this study are based on the store samples which are assumed to be representative of the market.

[11] Following the restrictions imposed in the contract with the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business, we did not reveal the brand names and price at the UPC level in the study.

brand (Lactaid), one private label milk brand, three soy-based beverage brands (Silk, private label, and 8th Continent), one almond-based beverage brand (Almond breeze), and one rice-based brand (Rice Dream).

The products are defined as a combination of brand, fat percent, and size of the container. As done by Liu et al. (2020) and Lopez and Lopez (2009), the milk categories mentioned above will distinguish between fat-free (0%), reduced-fat (2%), low-fat (1%), and whole milk (3.5%). Most cow milk brands have two container sizes: 64 oz and 128 oz, while the plant-based beverage brands are mostly sold in 64-oz containers. Organic brands and lactose-free milk brands are not sold in one-gallon sizes but rather in 96-oz containers. Thus, this study assumes that large and small-sized packaging represents different products. Further, the plant-based beverages are categorized as original and flavored, which allows us to define the product for plant-based beverages based on flavor. So, following this, private label 2% fat milk sold in a 1-gallon container, private label whole milk sold in a 1-gallon container, private label whole milk sold in a half-gallon container, for example, are considered three different products in the study. Altogether, this study has 50 product types in this study.

We aggregated the sales data by four-week period and include the years 2017 and 2018 in the study. There are 26 four-year periods (13 from each year). The market is defined as a combination of DMA*time, as done by Nevo (2001). Thus, there are 234 markets (26*9). Those observations corresponding to those brands that appeared only occasionally in the market were dropped. Finally, we had 9,376 observations (product market) used in the estimation of the final model.

4.2.Estimation strategy and identification

The nested fixed-point algorithm is used in the estimation, which is part of the generalized method of moments (GMM) developed by BLP and used in similar models thereafter. This algorithm can be used to construct the moment conditions for both the demand and supply sides and to estimate the demand and supply sides.

The demographic data comes from the CPS March supplement by sampling 500 observations from each DMA, randomly. Reynaert and Verboven (2014), using Monte Carlo, simulation, have shown that increasing the number of random draws would decrease the bias of the estimates. They found fewer biased estimates when the samples were increased from 50 to 200. Since there are 234 markets, the total number of demographic observations is 117,000 (234*500). We have used annual household income (in thousand dollars) and race (white or not) from this dataset. The percentages of people believing that climate change is due to human activities in each DMAs are from the Yale Project on Climate Change Communication and the George Mason Center for Climate Change Opinion (Howe et al., 2015). Table 1A (in the appendix) shows the average population that believes that climate change is due to human activities across the DMAs considered in the study. This dataset, which is widely used in studying the geographical variation in opinion about climate change, has data for 2016 and 2018. Since this study comprises 2017 and 2018, we used the simple average of 2016 and 2018 to generate climate change opinion data across the DMAs for 2017. For all the samples, we randomly assigned the belief about climate change that varies by year and DMAs. To capture the impacts of unobserved consumer characteristics, we followed Nevo (2000) to generate unobservable variables that follow the standard normal distribution $N(0, 1)$. These demographic (observed and unobserved) characteristics will help to estimate the predicted market share of the products using equation (8). This model defines error terms as deviations from mean utilities. These error terms from the model are interacted with the instrumental variables to form an objective function to be minimized using GMM. We follow the estimation process from Vincent (2015).

The potential endogeneity of the price that arises due to the association between the unobserved (to the researcher) product characteristics and price, both of which could impact consumer preference, is solved by using the instrumental variable approach. The instrumental variables we used in the model are cost shifters (Nevo, 2001) and brand-specific prices from other markets, also known as the Hausman instrument (Hausman, 1996). The idea behind using the Hausman instrument is that prices in the other markets are correlated with the price in the given market through the same cost of production, but they are not correlated with the demand shocks in that market. The cost shifters used are farm price of milk, price of soybeans, price of rice, hay price, and price of almonds, and were extracted from the National Agricultural Statistical Service (NASS) of the United States Department of Agriculture (USDA). We have also used retail wage as an instrumental variable, which is excerpted from the Bureau of Labor Statistics (BLS). Likewise, the price of diesel fuel is also used as an instrumental variable, which we downloaded from the Environmental Protection Agency (EPA). These instrumental variables have been widely used in the related literature (Liu et al., 2020; Nevo, 2001). The validity of the instruments is shown through the logit demand models.

The market share for the brands is quite low—on average 0.5 percent because of the various product differentiation variables used to create brands. The average price is 6.559 $/gallon. Nearly one-fifth (19.5 percent) of the brands used in the model are plant-based, while

17.7 percent of the brands are lactose-free dairy products, and 27.3 percent are organic brands. The average fat percentage in the milk brands is 1.6. Almost 36 percent of the products have a gallon-size container.

Table 2: Descriptive statistics (N=9,736)

Variables	Mean	Standard Deviation	Minimum	Maximum
Market share	0.005	0.016	9.84e-08	0.169
Price ($/oz)	6.559	2.105	2.104	13.035
Plant-based (1/0)	0.195	0.396	0	1
Lactose-free (1/0)	0.177	0.382	0	1
Fat (%)	1.604	1.201	0	3.5
Organic (1/0)	0.273	0.445	0	1
Gallon size (1/0)	0.357	0.479	0	1

5. Results and discussion

Table 3 presents the logit demand estimation results, which are based on linear models using OLS and Instrumental Variable (IV) approach. The logit demand model used here was developed by Berry (1994). This model is given by:

$$ln\left(\frac{S_{jt}}{S_{0t}}\right) = \alpha_0 + \alpha_1 Price_{jt} + \alpha_2 Plant\_based_{jt} + \alpha_3 X_{jt} + \Psi_{jt} \qquad (16),$$

where S_{jt} and S_{0t} are market share of brand *j* at market *t* and market share of the outside good at market *t*, respectively.

Both simple linear models use DMA fixed effects and four-week fixed effects. As expected, the coefficients for price have negative signs. The first stage F-statistics reported in the IV approach suggest that the instruments are valid. Strong adjusted R-squared values also suggest the strength of the model.

Table 3: Linear models by OLS and IV approach for logit demand model

	Linear model-OLS		Linear model-IV	
	Coefficients	SE	Coefficient	SE
Price	-0.715***	0.090	-0.491***	0.123
Plant-based	-1.141***	0.212	-1.464***	0.369
Lactose-free milk	0.464	0.352	-0.305	0.424
Fat	0.346***	0.061	0.349***	0.054
Organic	0.174	0.350	-0.735	0.511
Gallon package	-0.835**	0.290	-0.452***	0.233
Constant	-2.041***	0.682	-4.053***	0.724
DMA Fixed effects	YES		YES	
4-week fixed effects	YES		YES	
First stage F statistics			1004.80	
R-squared	0.526			
Centered R-squared			0.546	
Number of observations	9,736		9,736	

*** and ** indicate less than 1% and less than 10% level of significance, respectively. The standard errors are clustered at DMA level.

The negative coefficient of *price* suggests that increasing the price would decrease the mean utility. Likewise, the interpretation for the negative coefficient corresponding to plant-based beverage would also suggest a similar meaning. The implication of this has been discussed in the random coefficient logit model. The linear model based on OLS and IV estimation approach is used to show the strength of the instrumental variables used.

After this, we used the random coefficients logit model developed by BLP (1995). Table 4 presents the full model using the random coefficients logit model, which produced some interesting results. Expectedly, the coefficient corresponding to the price is negative—which means a negative mean utility of price. The histogram plot of these coefficients is shown in

Figure 3A (in the appendix). The coefficient of the plant-based beverage dummy is negative, perhaps due to the unwillingness to accept the plant-based beverages by the mainstream consumers due to some perceived unappealing attributes (Maniken et al., 2015; Wansink et al., 2005). Many consumers do not find plant-based beverages gustatorily appealing because they are 'chalky' (Durand et al. 2003) and 'beany' (Chambers et al 2006). Most of the plant-based beverages are nutritionally poor compared to cow milk, which would make them less preferable to many consumers (Vanga and Raghavan, 2018). The negative coefficient could also be because of the less familiarity with plant-based beverages by the potential consumers, as shown in a study in Austria that found that the product image of plant-based beverages is worse than cow milk's (Haas et al., 2019). Related to this, Tonsor, Lusk, Scroeder (2021) also found a poor product image of the products associated with plant-based protein. Thus, this result indicates that even though the market share of plant-based beverages is rising rapidly, there still are many demand challenges faced by plant-based milk manufacturers.

The coefficient for fat percentage has a significant positive impact on the mean utility, a finding that is in line with Liu et al. (2020), who found a positive correlation between whole milk and mean utility. The organic and lactose-free attributes of cow milk have a negative and significant impact, similar to the findings of Lopez and Lopez (2009). The package size has an insignificant positive effect on the mean utility.

The interactions between plant-based beverage and demographic variables show some interesting results. The belief that climate change is due to human activities is correlated positively with plant-based beverage preference[12]. The total derivative of the model w.r.t *climate change opinion* would give a monotonic relationship between climate change opinion and plant-

[12] The interpretation of this result must be made with caution because the survey data could be fraught with noise and results certain degree of error.

based milk. Although there are not many studies related to this, some of the extant studies suggest that consumers who believe in climate change are more likely to shift toward foods that are deemed sustainable. Almost all these studies focus on meat products and the findings were mostly shown in stated preference models. This result is consistent with McCarthy et al. (2017), who also found that people who consume only plant-based beverages do so because they care about the environment and animal welfare and are following veganism. This result also accords with the findings of Kotchen, Boyle, Leiserowitz (2013) and Korkola, Hugg, and Jaakkola (2014). Whites show less preference for plant-based milk; this estimate is self-intuitive as non-whites are more likely to experience lactose intolerance (Swagerty, Walling, and Klein, 2002). This finding is similar to that of Okrent and McEwan (2014), who showed that demographic variables like race are more important in defining the preference for plant-based beverages. The coefficient from the interaction between price and race (i.e., whites) shows that white people are not price-sensitive; the price parameter is positively correlated with the white dummy variable. Nevo (2001) also showed that some demographic variables are not price sensitive. For example, a family with children was not price-sensitive to ready-to-eat cereal.

The analogous equations for equations (2) and (3) are given by:

Price: $\alpha_i = -0.914 + 0.801\ Climate\ change + 0.050\ Income + 0.202\ White - 0.1054\ Unob$

Plant based: $\beta_i = -8.061 + 0.115\ Climate\ change + 0.011\ Income - 1.921\ White + 2.663\ Unob$

Table 4: Coefficient estimates from the random-coefficients logit demand model

Variables	Estimates	Standard errors
Product characteristics		
Price ($/gallon)	-0.914**	0.418
Plant-based (1/0)	-8.061***	1.905
Lactose-free milk (1/0)	-1.478**	0.775
Fat (%)	0.313***	0.018
Organic (1/0)	-2.288***	0.626
Size (Gallon=1)	0.073	0.111
Consumer characteristics		
Climate change belief	0.005	0.141
Annual income ($1000)	-0.001	0.050
White	-4.094***	1.672
Interactions		
Climate change belief x Plant-based	0.115***	0.057
Annual income x Plant-based	0.011	0.022
White x Plant-based	-1.921***	0.560
Unobserved x Plant-based	2.663	5.267
Climate change belief x Price	0.081	0.185
Annual income x Price	0.005	0.057
White x Price	0.202***	0.020
Unobserved x Price	-0.105	0.177
Constant	-3.417***	1.022
DMA fixed effect	YES	
4-Week fixed effect	YES	
Number of observations	9,736	
Number of markets	234	

*, ** and *** indicate less than 10, 5, and 1 percent level of significance, respectively.

Table 5 shows the estimated own- and cross-price elasticities for selected product types. The selected plant-based beverages are regular (unflavored) while the selected cow milk types are whole milk (3.5%) in a 1-gallon-size container. Expectedly, the own-price elasticities of all products are negative. The own-price elasticities for organic and lactose-free cow milk brands are highest (in absolute terms), followed by the own-price elasticities for plant-based beverage brands. The own-price elasticities of MB and private label brands are lower among the listed brands. The own-price elasticities of plant-based beverages are comparable to what Okrent and MacEwan (2014) found. They estimated the own-price elasticities for almond-based and soy-based beverages to be -2.14. However, Dharmasena and Capps (2014) estimated the price elasticity for soy-based beverages to be -1.68, which is lower than what we estimated in this study. Okrent and MacEwan (2014) used the LA-AIDS model, while Dharmasena and Capps (2014) used the Tobit econometric model to estimate the elasticities. Andreyeva, Long, Brownell (2010) reviewed the own-price elasticities of various categories of foods including milk and reported a wide range of elasticities of milk which were mostly inelastic (-0.75 to -1.22). However, the studies at the brand level (for example Liu et al 2020; Lopez and Lopez, 2008) are reported to be elastic. Liu et al (2020) estimated the own-price elasticities which range from -4.330 to -2.806. Likewise, Lopez and Lopez (2008) estimated elasticities to be -8.65 to -1.89.

The estimated cross-price elasticities show some interesting results. It is worth highlighting that the consumers would respond to an increase in the price of one plant-based beverage type by increasing the demand for other plant-based beverages indicating higher substitutability with the other plant-based beverages. For example, a 1% increase in increase in the price of Almond Breeze would result in a 0.63% increase in the demand for Rice Dream. Although plant-based beverages share some common attributes with lactose-free milk, there is a limited substitution of soy-and almond-based beverages towards lactose free milk. However, a higher estimate of cross-price elasticity of rice-based beverage with respect to lactose-free milk shows some degree of substitution with each other. Consistent with Lopez and Lopez (2009), increase in the price of private label milk brands, consumers respond by shifting to other milk types. In the Italian yogurt market, Bonanno (2013) also found higher cross-price elasticities of plain yogurt types with respect to other yogurt types compared to flavored yogurt types.

Table 5: Estimated own and cross price elasticity of selected product types

1% rise in price of→	8th Continent	Almond Breeze	Rice Dream	Lactaid	Horizon Organic	Dean MB	Private Label
Plant-based beverages							
8th Continent	-2.815	0.6143	0.0226	0.0010	0.0000	0.0021	0.0121
Almond Breeze	0.2111	-2.4362	0.0269	0.0011	0.0022	0.0023	0.0103
Rice Dream	0.0777	0.6302	-3.777	0.0243	0.0011	0.0022	0.0124
Cow milk							
Lactaid	0.0073	0.0072	0.0237	-3.5512	0.0007	0.0048	0.0232
Horizon Organic	0.0017	0.0071	0.0004	0.0026	-3.626	0.0045	0.0146
Dean MB	0.0018	0.0079	0.0003	0.0032	0.0024	-2.3344	0.0191
Private Label	0.0019	0.0074	0.0003	0.0032	0.0024	0.0047	-1.377

Note: '1% percent increase in the price of' is shown by rows and 'percentage change in the quantity demanded' is shown by columns.

Table 6 highlights the average of the estimated own-price elasticity, price, Lerner index, markup, and marginal cost (MC) of different plant-based beverages and cow milk types. Appendix 2A shows the result for all DMAs. The rice-based beverage is the most expensive among the plant-based beverages. The price of organic milk and lactose-free milk is higher than almond- and soy-based beverages. The boxplot for the Lerner indices across different categories of milk and plant-based substitutes is shown in Figure 4A (in the appendix). Overall, the Lerner index for plant-based beverages is less than that for lactose-free and organic cow milk brands and more than that of private labels and MB. Rice-based beverage brands have the lowest Lerner index among the plant-based beverages, while those based on almond have the highest Lerner indices. The Lerner index for private label milk brands is the highest among the categories of milk and plant-based substitutes, followed by the MB. This is consistent with previous findings

(Liu et al. (2020) for fluid milk, Meza and Sudhir (2005), and Chidmi and Lopez (2007) for ready-to-eat cereals) where studies have found that most basic brands have a higher mark-up percentage. The boxplot for the marginal costs of types of plant-based beverages and cow milk is shown in Figure 5A. Rice-based beverages have the highest marginal costs among the three plant-based beverages. The marginal cost of lactose-free milk and organic milk is highest among the cow milk types. This could be due to the high cost of production of organic milk and the high processing cost for lactose-free milk. This further explains the lower Lerner indices for these milk types.

Table 6: Average own price elasticity, Lerner index, markup, and marginal cost of types of plant-based beverages and cow milk

Beverage types	Own price elasticity	Price ($/gal)	Lerner Index	P-MC ($/gal)	MC ($/gal)
Plant-based beverages					
Soy based	-2.934	6.444	0.343	2.199	4.245
Almond based	-2.504	6.238	0.400	2.493	3.744
Rice based	-3.792	8.215	0.264	2.166	6.049
Cow milk					
Lactose-free	-3.814	7.805	0.263	2.049	5.756
Organic	-4.033	8.314	0.254	2.069	6.245
MB	-2.501	4.851	0.411	1.932	2.919
Private label	-1.830	3.781	0.592	2.074	1.707

Note: Due to the contract agreement with Nielsen, author(s) is(are) not allowed to disclose brand name and price together. Thus, we report the average of estimates for different broad product categories.

6. Conclusion

Consumers' health and environmental sustainability issues are driving a new food movement around the globe. The market is getting flooded with food brands with health and sustainability claims. In the fluid milk market, plant-based beverages are increasing their presence and are perceived to be environmentally sustainable alternatives to cow milk because of the less carbon footprint associated with them. Several studies have claimed that shifting toward a more plant-based diet would help in mitigating GHGs and thus, lessen the impact of climate change. But there are very few studies that explore the relationship between the consumers' beliefs about climate change and their choice of plant-based products. Employing a random coefficients logit model and utilizing the Nielsen retail scanner data, we explored how demographic variables and beliefs about the role of humans in climate change are correlated with the preference for plant-based beverages. Apart from this, we also explored competition in the fluid milk market considering plant-based beverages a part of it.

Results suggest a positive association between consumers' belief in the role of human activities in climate change and their preference for plant-based milk. Non-white consumers are found to show a preference for plant-based beverages. Consistent with the previous findings, we found a lower (absolute value) own price elasticity for private label milk brands. On average, the own-price elasticity of plant-based beverage is lower than that of organic cow milk and lactose-free cow milk and higher than that of MB and private label milk brands. The estimated cross-price elasticities corresponding to plant-based beverages with respect to other plant-based beverages suggest high substitutability between them, such as almond- and soy-based beverages are strong substitutes of each other, while the substitutability between plant-based beverages and lactose-free, organic, and reduced-fat cow milk brands is low. Estimated Lerner indices suggest a higher percentage markup for private-and MB-label milk brands followed by plant-based beverages and the lowest percentage for organic and lactose-free cow milk. The estimated marginal cost for organic and lactose-free milk is higher than that of plant-based beverages (except for rice beverages) while the marginal cost for private label and manufacturers brand is the lowest.

Overall, this study provides a window into the implications of penetration of plant-based products that have been designated by some as the food for the future, for reasons such as an alternative to deal with climate change. As now plant-based beverages have captured 14% of the retail fluid milk market, their penetration into the meat markets now stands at one percent but it is likely to gain further momentum as plant-based products did with fluid milk a decade ago and as it is ongoing in processed dairy products like cheese.

The study has some limitations. The first concern is about the data source itself, which only covers some stores in some major cities across the country. There could be some biases in the selection of the stores within the cities. This study does not encompass the non-metropolitan areas of the U.S. where the demand for milk could be different from that in the metropolitan regions. Likewise, this study uses consumer opinion about the human role in climate change as a proxy for concern about the environment. A more comprehensive measure of the consumers' perception toward environmental sustainability or climate change could be used in future research to explore how the environmentally sustainable attitudes of consumers would drive demand for milk and its plant-based substitutes. Health is another equally important and potential factor driving demand for plant-based beverages. Future research also should focus on how consumers' health concerns might be driving the demand for plant-based beverages that are perceived as healthy alternatives to dairy milk.

References

Andreyeva, T., Long, M. W., & Brownell, K. D. (2010). The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food. *American Journal of Public Health*, 100(2), 216-222.

Barrett, R. and Higgins, D. (2020). Americans love soda, fancy water and fake milk. Can the dairy industry keep up? Accessed online at 12/2/2020 from https://www.jsonline.com/in-depth/news/special-reports/dairy-crisis/2019/08/28/milk-vs-almond-soy-oat-milk-water-and-soda-how-can-dairy-compete-with-alternative-products/2141547001/.

Berry, S. T. (1994). Estimating discrete-choice models of product differentiation. *The RAND Journal of Economics*, 25(2), 242-262.

Berry, S., Levinsohn, J., & Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica: Journal of the Econometric Society*, 841-890.

Bir, C., Widmar, N. O., Wolf, C., & Delgado, M. S. (2019). Traditional attributes moo-ve over for some consumer segments: Relative ranking of fluid milk attributes. *Appetite*, *134*, 162-171.

Bonanno, A. (2013). Functional foods as differentiated products: the Italian yogurt market. *European Review of Agricultural Economics*, *40*(1), 45-71.

Bonanno, A., Huang, R., & Liu, Y. (2015). Simulating welfare effects of the European nutrition and health claims' regulation: the Italian yogurt market. *European review of agricultural economics*, *42*(3), 499-533.

Capper, J. L., Cady, R. A., & Bauman, D. E. (2009). The environmental impact of dairy production: 1944 compared with 2007. *Journal of Animal Science*, *87*(6), 2160-2167.

Chambers IV, E., Jenkins, A., and McGuire B. (2006). Flavor properties of plain soymilk. *Journal of Sensory Studies*, *21*(2), 165-179.

Chen, X., Liu, Y., Jaenicke, E. C., & Rabinowitz, A. N. (2019). New concerns on caffeine consumption and the impact of potential regulations: The case of energy drinks. *Food Policy*, *87*, 101746.

Chidmi, B., & Lopez, R. A. (2007). Brand-supermarket demand for breakfast cereals and retail competition. *American Journal of Agricultural Economics*, *89*(2), 324-337.

Clark, M. A., Springmann, M., Hill, J., & Tilman, D. (2019). Multiple health and environmental impacts of foods. *Proceedings of the National Academy of Sciences*, *116*(46), 23357-23362.

Clay, N., Sexton, A. E., Garnett, T., & Lorimer, J. (2020). Palatable disruption: the politics of plant milk. *Agriculture and Human Values*, 1-18.

Crittenden, R. G., & Bennett, L. E. (2005). Cow's milk allergy: a complex disorder. *Journal of the American College of Nutrition*, *24*(sup6), 582S-591S.

De Bakker, E., & Dagevos, H. (2012). Reducing meat consumption in today's consumer society: questioning the citizen-consumer gap. *Journal of Agricultural and Environmental Ethics*, *25*(6), 877-894.

De Boer, J., Schösler, H., & Boersema, J. J. (2013). Climate change and meat eating: an inconvenient couple?. *Journal of Environmental Psychology*, *33*, 1-8.

Dharmasena, S., & Capps Jr, O. (2014). Unraveling demand for dairy-alternative beverages in the United States: The case of soymilk. *Agricultural and Resource Economics Review*, *43*(1203-2016-95531), 140-157.

Durand, A., Franks, G. V., & Hosken, R. W. (2003). Particle sizes and stability of UHT bovine, cereal and grain milks. *Food Hydrocolloids*, *17*(5), 671-678.

ERS (2021). Dairy data. Accessed online on 2/1/2021 from https://www.ers.usda.gov/data-products/dairy-data/.

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., ... & Tempio, G. (2013). Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO).

GFI. (2020). Plant based market overview. Assessed online on 11/19/2020 from https://www.gfi.org/marketresearch.

Grandview Research (2019). Dairy alternative market size, share, industry trend report 2019-2025. Accessed online on 1/20/2021 from https://www.grandviewresearch.com/industry-analysis/dairy-alternatives-market.

Haake, D. (2019). Which milk has the smallest impact on the planet? Accessed online on 11/28/2020 from https://blog.datawrapper.de/cow-milk-and-vegan-milk-alternatives/

Haas, R., Schnepps, A., Pichler, A., & Meixner, O. (2019). Cow milk versus plant-based milk substitutes: A comparison of product image and motivational structure of consumption. *Sustainability*, *11*(18), 5046.

Hausman, J. A. (1996). Valuation of new goods under perfect and imperfect competition. In *The Economics of New Goods* (pp. 207-248). University of Chicago Press.

Howe, P. D., Mildenberger, M., Marlon, J. R., & Leiserowitz, A. (2015). Geographic variation in opinions on climate change at state and local scales in the USA. *Nature Climate Change*, *5*(6), 596-603.

Huang, D., Rojas, C., & Bass, F. (2008). What happens when demand is estimated with a misspecified model?. *The Journal of Industrial Economics*, *56*(4), 809-839.

Irfan, U. (2018). "Fake milk": why the dairy industry is boiling over plant-based milks. Accessed online on 12/2/20 from https://www.vox.com/2018/8/31/17760738/almond-milk-dairy-soy-oat-labeling-fda.

Joyce, A., Dixon, S., Comfort, J., & Hallett, J. (2012). Reducing the environmental impact of dietary choice: Perspectives from a behavioral and social change approach. *Journal of Environmental and Public Health*, *2012*.

Korkala, E. A., Hugg, T. T., & Jaakkola, J. J. (2014). Awareness of climate change and the dietary choices of young adults in Finland: a population-based cross-sectional study. *PloS One*, *9*(5), e97480.

Kotchen, M. J., Boyle, K. J., & Leiserowitz, A. A. (2013). Willingness-to-pay and policy-instrument choice for climate-change policy in the United States. *Energy Policy*, *55*, 617-625.

Lea, E., & Worsley, A. (2008). Australian consumers' food-related environmental beliefs and behaviours. *Appetite*, *50*(2-3), 207-214.

Liu, Y., Chen, X., Rabinowitz, A. N., & Campbell, B. (2020). Demand, challenges, and marketing strategies in the retail promotion of local brand milk. *Agricultural Economics*, *51*(5), 655-668.

Lopez, E., & Lopez, R. A. (2009). Demand for differentiated milk products: implications for price competition. *Agribusiness: An International Journal*, *25*(4), 453-465.

Macdiarmid, J. I., Douglas, F., & Campbell, J. (2016). Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite*, *96*, 487-493.

Mäkinen, O. E., Wanhalinna, V., Zannini, E., & Arendt, E. K. (2016). Foods for special dietary needs: Non-dairy plant-based milk substitutes and fermented dairy-type products. *Critical Reviews in Food Science and Nutrition*, *56*(3), 339-349.

Mäkiniemi, J. P., & Vainio, A. (2013). Moral intensity and climate-friendly food choices. *Appetite*, *66*, 54-61.

McCarthy, K. S., Parker, M., Ameerally, A., Drake, S. L., & Drake, M. A. (2017). Drivers of choice for fluid milk versus plant-based alternatives: What are consumer perceptions of fluid milk? *Journal of Dairy Science*, *100*(8), 6125-6138.

Nevo, A. (2000). A practitioner's guide to estimation of random-coefficients logit models of demand. *Journal of Economics & Management Strategy*, *9*(4), 513-548.

Nevo, A. (2001). Measuring market power in the ready-to-eat cereal industry. *Econometrica*, 69(2), 307-342.

Okrent, A. M., & MacEwan, J. P. (2014). The effects of prices, advertising, expenditures, and demographics on demand for nonalcoholic beverages. *Agricultural and Resource Economics Review*, 43(1203-2016-95524), 31-52.

Pimentel, D., & Pimentel, M. (2003). Sustainability of meat-based and plant-based diets and the environment. *The American Journal of Clinical Nutrition*, *78*(3), 660S-663S.

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987-992.

Reynaert, M., & Verboven, F. (2014). Improving the performance of random coefficients demand models: the role of optimal instruments. *Journal of Econometrics*, *179*(1), 83-98.

Sabate, J., & Soret, S. (2014). Sustainability of plant-based diets: back to the future. *The American Journal of Clinical Nutrition*, *100*(suppl_1), 476S-482S.

Sethi, S., Tyagi, S. K., & Anurag, R. K. (2016). Plant-based milk alternatives an emerging segment of functional beverages: a review. *Journal of Food Science and Technology*, *53*(9), 3408-3423.

Statista (2019). Share of the consumers worldwide who have changed the products and services they use due to the concern about climate change in 2019. Accessed online on 2/9/2019 from https://www.statista.com/statistics/1106653/change-made-consumer-bevaviour-concern-climate-change-worldwide/#:~:text=Change%20made%20to%20consumer%20behavior%20due%20to%20concern%20about%20climate%20change%20worldwide%202019&text=According%20to%20a%20survey%20from,to%20concern%20about%20climate%20change.

Stehfest, E., Bouwman, L., Van Vuuren, D. P., Den Elzen, M. G., Eickhout, B., & Kabat, P. (2009). Climate benefits of changing diet. *Climatic Change*, *95*(1), 83-102.

Stewart, H. (2020). Plant-based products replacing cow's milk, but the impact is small. Amber Waves. Accessed online on 3/28/2021 from https://www.ers.usda.gov/amber-waves/2020/december/plant-based-products-replacing-cow-s-milk-but-the-impact-is-small/.

Stewart, H., Kuchler, F., Cessna, J., & Hahn, W. (2020). Are Plant-Based Analogues Replacing Cow's Milk in the American Diet?. *Journal of Agricultural and Applied Economics*, 1-18.

Swagerty Jr, D. L., Walling, A., & Klein, R. M. (2002). Lactose intolerance. *American Family Physician*, *65*(9), 1845.

Tonsor, G. T., Lusk, J. L., and Schroeder, T. C. (2021). Impacts of new plant-based protein alternatives on US beef demand. Assessed online on 3/23/2021 from https://agmanager.info/livestock-meat/meat-demand/meat-demand-research-studies/impact-new-plant-based-protein-0

U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 2020-2025. 9th Edition. December 2020. Accessed online on 1/17/2021 from https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf

Van Loo, E. J., Caputo, V., Nayga Jr, R. M., Seo, H. S., Zhang, B., & Verbeke, W. (2015). Sustainability labels on coffee: Consumer preferences, willingness-to-pay and visual attention to attributes. *Ecological Economics*, *118*, 215-225.

Vanga, S. K., & Raghavan, V. (2018). How well do plant-based alternatives fare nutritionally compared to cow's milk? *Journal of Food Science and Technology*, *55*(1), 10-20.

Vincent, D. W. (2015). The Berry–Levinsohn–Pakes estimator of the random-coefficients logit demand model. *The Stata Journal*, 15(3), 854-880.

Wansink, B., Sonka, S., Goldsmith, P., Chiriboga, J., & Eren, N. (2005). Increasing the acceptance of soy-based foods. *Journal of International Food & Agribusiness Marketing*, *17*(1), 35-55.

Wells, V. K., Ponting, C. A., & Peattie, K. (2011). Behavior and climate change: Consumer perceptions of responsibility. *Journal of Marketing Management*, *27*(7-8), 808-833.

Whitmarsh, L., & O'Neill, S. (2010). Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. *Journal of Environmental Psychology*, *30*(3), 305-314.

Wolf, C. A., Malone, T., & McFadden, B. R. (2020). Beverage milk consumption patterns in the United States: Who is substituting from dairy to plant-based beverages? *Journal of Dairy Science*.

Li, X., Lopez, R., & Yang, S. (2018). Energy-milk price transmission at the product brand level. *Agricultural Economics*, *49*(3), 289-299.

Yu, X., Gao, Z., & Zeng, Y. (2014). Willingness to pay for the "Green Food" in China. *Food Policy*, *45*, 80-87.

Appendix

Table 1A: Percentage of people who believe climate change is due to human behavior across DMAs

Division	DMA	Believe climate change is due to human activities	
		2017	2018
New England	Boston	62	64
Middle Atlantic	New York	61	63
East North Central	Chicago	55	57
West North Central	Minneapolis	56	58
South Central	Atlanta	61.5	64
East South Central	Nashville	61.5	64
West South Central	Houston	57.5	59
Mountain	Denver	52	54
Pacific	Los Angeles	57.5	59

Note: The data covers the years 2016 and 2018. For year 2017, we took a simple average of 2016 and 2018. The data is retrieved from https://climatecommunication.yale.edu/visualizations-data/ycom-us-2016/?est=human&type=value&geo=cbsa

Table 2A: Estimated own-price elasticity, price, Lerner index, and markup for beverage types across DMAs

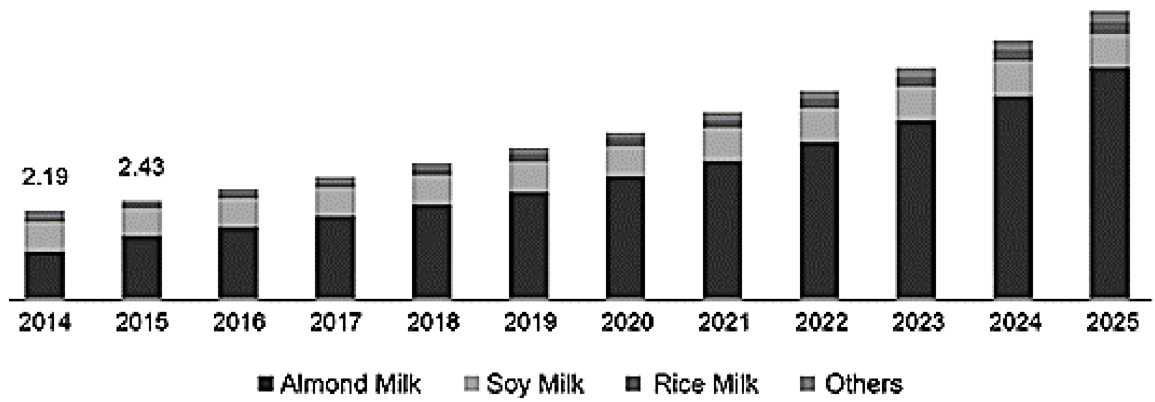
Beverage types	DMA	Own price elasticity	Price ($/gal)	Lerner Index	P-MC ($/gal)	MC ($/gal)
Soy bev	Boston	-2.977	6.395	0.338	2.154	4.240
Almond bev	Boston	-2.182	5.977	0.459	2.744	3.233
Rice bev	Boston	-3.475	7.283	0.288	2.096	5.187
Lactose free milk	Boston	-3.427	7.177	0.293	2.095	5.082
Organic	Boston	-3.878	8.623	0.265	2.138	6.485
MB milk	Boston	-2.171	4.540	0.473	2.092	2.448
Private Label milk	Boston	-1.773	3.785	0.618	2.152	1.633
Soy bev	NYC	-3.160	7.102	0.321	2.254	4.848
Almond bev	NYC	-2.342	6.839	0.427	2.923	3.916
Rice bev	NYC	-3.748	8.294	0.267	2.213	6.081
Lactose free milk	NYC	-3.666	8.020	0.274	2.186	5.834
Organic milk	NYC	-4.197	9.061	0.243	2.159	6.903
MB milk	NYC	-2.394	5.178	0.426	2.162	3.016
Private Label milk	NYC	-2.127	4.633	0.511	2.180	2.453
Soy bev	Chicago	-2.847	6.460	0.352	2.272	3.490
Almond bev	Chicago	-2.409	6.486	0.416	2.696	3.790
Rice bev	Chicago	-4.230	9.696	0.239	2.294	7.402
Lactose free milk	Chicago	-3.725	8.112	0.269	2.177	5.935
Organic milk	Chicago	-3.932	8.487	0.260	2.160	6.327
MB milk	Chicago	-2.011	4.290	0.521	2.068	2.223
Private Label milk	Chicago	-1.747	3.925	0.652	2.248	1.676
Soy bev	Minneapolis	-2.870	6.373	0.352	2.225	4.148
Almond bev	Minneapolis	-2.551	6.605	0.392	2.591	4.014
Rice bev	Minneapolis	-3.971	8.562	0.252	2.156	6.405
Lactose free milk	Minneapolis	-3.542	7.622	0.283	2.152	5.470
Organic milk	Minneapolis	-3.887	8.455	0.263	2.175	6.280
MB milk	Minneapolis	-3.221	7.093	0.311	2.202	4.891
Private Label milk	Minneapolis	-1.498	3.357	0.698	2.248	1.108
Soy bev	Atlanta	-3.190	6.052	0.322	1.919	4.133
Almond bev	Atlanta	-2.482	6.069	0.403	2.446	3.622
Rice bev	Atlanta	-3.534	7.190	0.283	2.034	5.156
Lactose free milk	Atlanta	-3.694	7.801	0.272	2.133	5.667

Organic milk	Atlanta	-4.107	8.328	0.250	2.058	6.270
MB milk	Atlanta	-2.376	5.091	0.447	2.134	2.957
Private Label milk	Atlanta	-1.805	3.703	0.604	2.057	1.646
Soy bev	Nashville	-2.015	5.679	0.501	2.821	2.858
Almond bev	Nashville	-2.433	5.799	0.412	2.386	3.412
Rice bev	Nashville					

Table 2A continued…

Lactose free milk	Nashville	-3.391	7.783	0.304	2.354	5.429
Organic milk	Nashville	-3.447	7.849	0.327	2.419	5.430
MB milk	Nashville	-2.987	6.092	0.350	2.033	4.058
Private Label milk	Nashville	-1.687	3.529	0.636	2.120	1.409
Soy bev	Houston	-2.781	6.217	0.361	2.237	3.980
Almond bev	Houston	-2.373	5.997	0.422	2.528	3.469
Rice bev	Houston					
Lactose free milk	Houston	-3.432	7.371	0.292	2.148	5.223
Organic milk	Houston	-3.695	7.933	0.276	2.150	5.783
MB milk	Houston	-2.128	4.676	0.489	2.199	2.477
Private Label milk	Houston	-1.537	3.408	0.710	2.229	1.179
Soy bev	Denver	-2.793	6.006	0.358	2.148	3.858
Almond bev	Denver	-2.369	6.009	0.422	2.537	3.472
Rice bev	Denver					
Lactose free milk	Denver	-3.951	8.062	0.253	2.041	6.021
Organic milk	Denver	-4.051	8.166	0.250	2.019	6.148
MB milk	Denver	-2.101	4.232	0.488	2.012	2.220
Private Label milk	Denver	-1.737	3.609	0.637	2.093	1.517
Soy bev	Los Angeles	-4.004	6.435	0.251	1.606	4.829
Almond bev	Los Angeles	-3.246	6.358	0.308	1.960	4.398
Rice bev	Los Angeles	-4.680	7.404	0.214	1.582	5.822
Lactose free milk	Los Angeles	-5.266	8.199	0.190	1.558	6.641
Organic milk	Los Angeles	-5.944	9.169	0.171	1.543	7.626
MB milk	Los Angeles	-3.521	5.437	0.287	1.545	3.892
Private Label milk	Los Angeles	-2.522	4.080	0.428	1.627	2.452

Note: The blank space means that the product was not used in the analysis either because we dropped the sales data due to a rare appearance of Rice based milk or because of no reporting of sales in those DMAs. The author(s) is(are) not allowed to disclose the brand and price together, so the table shows the estimates for categories of plant-based beverages and cow milk across 9 DMAs.



Source: Grandview research (2019).

Figure 1A: 2014-2017 sales data and 2018-2025 projected sales data of plant-based beverages (in billion dollars)

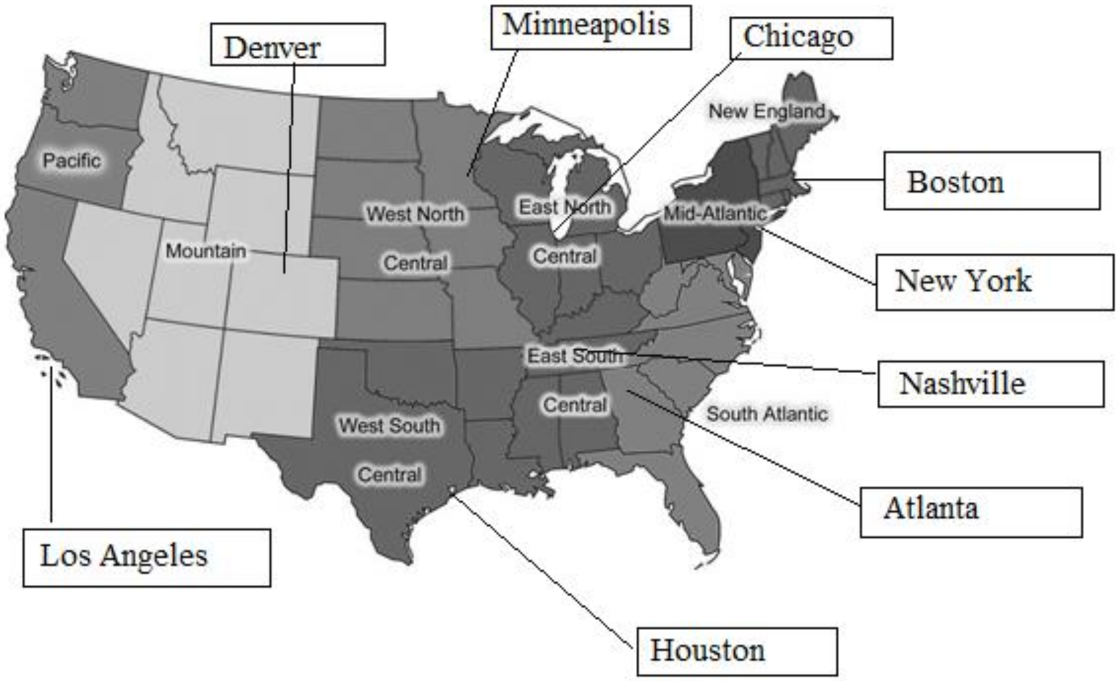


Figure 2A: Location of the nine Designated Markets Areas (DMAs) and respective census divisions

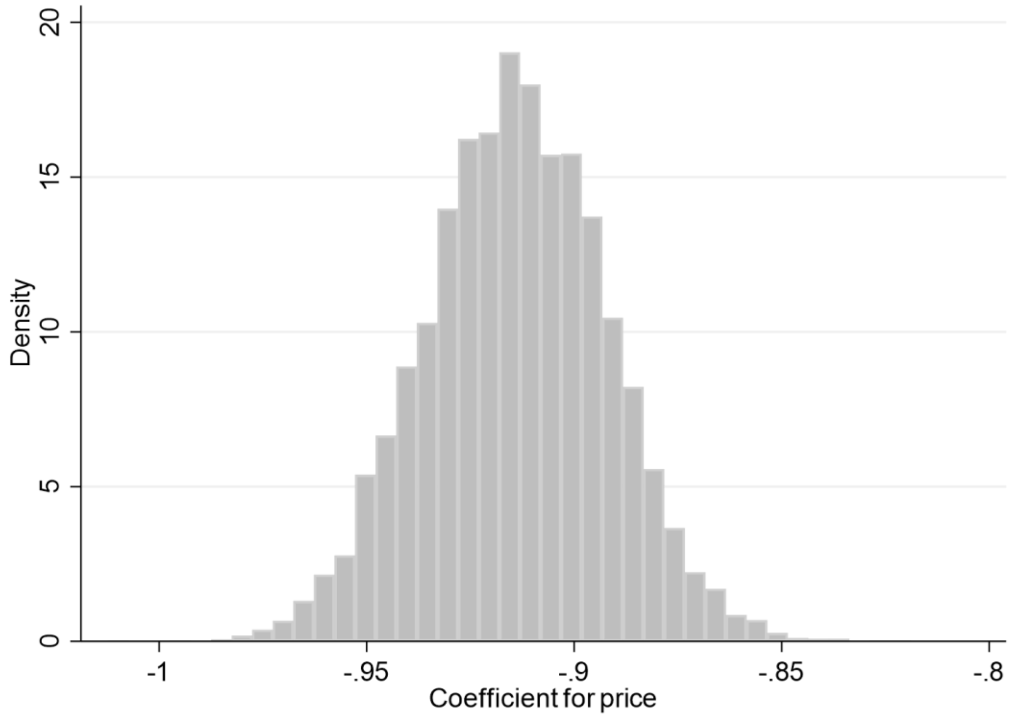


Figure 3A: Histogram plots of the estimated price coefficient

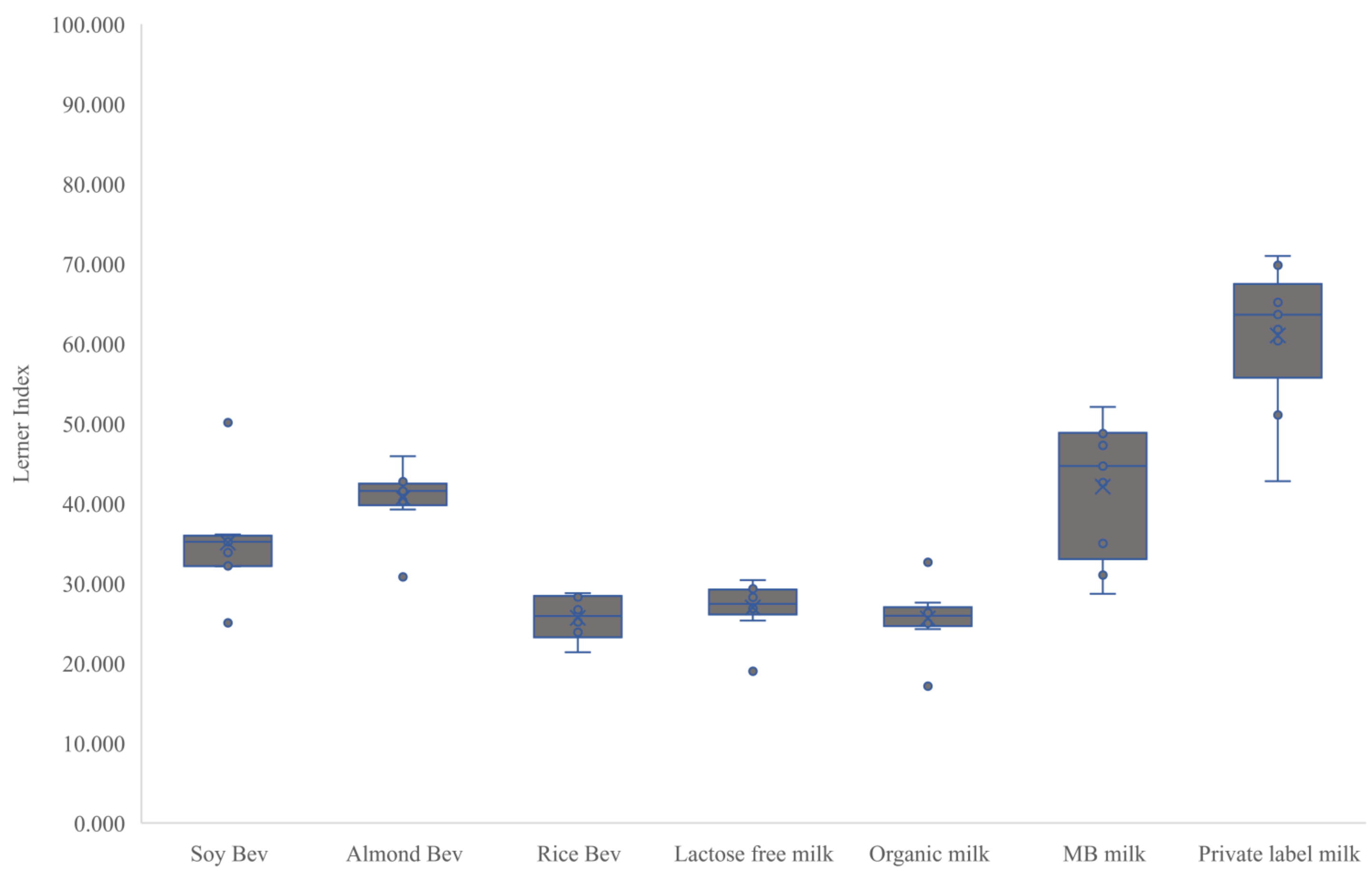


Figure 4A: Box plots of estimated Lerner indices (Markup percentage) of types of plant-based beverages and cow milk

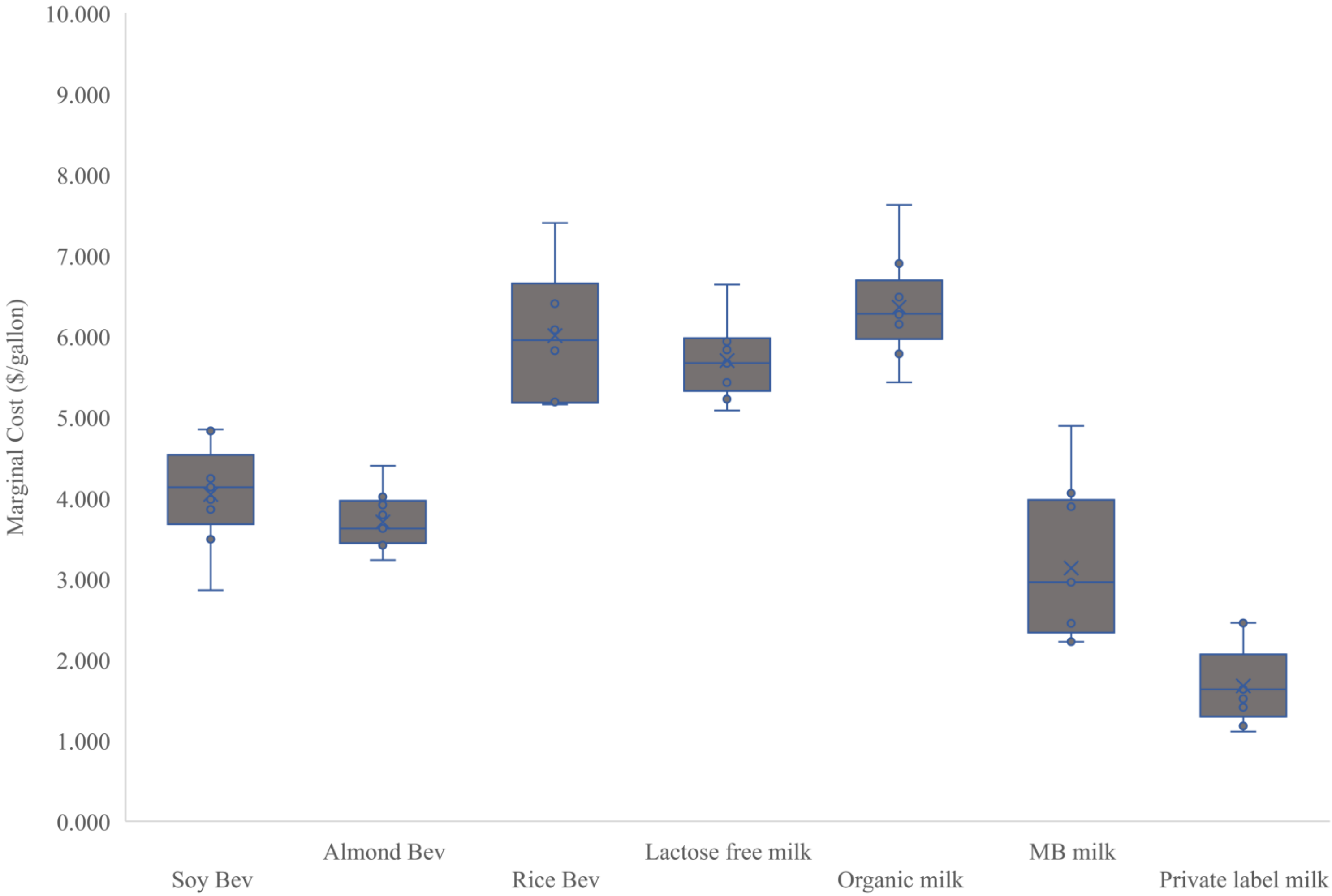


Figure 5A: Box plots of estimated marginal costs ($/gal) of types of plant-based beverages and cow milk