PRICE ELASTICITY OF THE DEMAND FOR PLANT-BASED MILK IN THE MIDDLE ATLANTIC DIVISION

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AERES HOGESCHOOL

Preface

I have written this study to fulfil the graduation requirements for my bachelor studies at Aeres University of Applied Sciences in Dronten. I have specifically chosen to review and estimate price elasticity of demand for plant-based milk, because I am intrigued by the growth of plant-based food and beverages categories and because I am interested to see how growth will accelerate when scale and efficiencies could result in lower retail prices.

Initially, I would like to thank professor Anom for sharing his knowledge and expertise and providing prompt and detailed feedback. I also want to thank Laura Qiu for helping me come up with research subjects and questions.

Reinier Oosterwijk
Almere, August 2020

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Summary

Both plant-based and dairy milk has been a deeply integrated nutrient source for cultures across the world. Although dairy milk provides essential nutritious value, plant-based milk could serve as a nutrient, more environmentally friendly, and fewer saturated fat containing substitute to dairy milk. Basic economic principles indicate that demand would increase if prices of plant-based milk reduce. Price elasticity of demand estimates could help to quantify the potential effects of pricing policy to promote plant-based milk as a substitute for dairy milk. As a result, the objective was to identify the price elasticity of demand for plant-based milk beverages to predict the impact of pricing policies to improve public health and diets in the US Middle Atlantic division.

In this study, quantitative data analysis was conducted using consumer expenditure, and Nielsen point-of-sale and consumer panel data. A Linear Approximation of the Almost Ideal Demand System was utilized to derive own and cross-price elasticities of 7 milk categories, namely dairy, almond, soy, coconut, rice, blends, and oat milk, where after appropriate cross-price elasticity values were used to predict the effect of a sales tax extension on public health.

In all, the results indicated that milk demand is elastic, which suggests that an increase in milk beverage prices could lead to increases in the demand for other goods. In specific, the own-price elasticities of the various milk categories were estimated to be between -1.53 and -3.19. In addition, the cross-price elasticity estimates implied that plant-based milk behaves as substitutes for dairy milk. In accordance with these findings, the estimated effects of an extension of sales tax to dairy milk beverages on public health were calculated, which were estimated to be modest, as some health benefits were partly offset by unintended effects.

In conclusion, the impact of price elasticity of demand for plant-based milk on public health in the United States Middle Atlantic division is inadequate to justify a sales extension on dairy milk. In the short term, governmental institutions could utilize the estimated own and cross-price elasticity values in this study to evaluate and potentially redesign existing policies. In the long-term, governments should carefully study unintended cross-elasticity effects and changes across a range of nutrients associated with a dairy milk tax. In a like matter, governmental institutions should explore how other interventions, that have proven to be effective to prevent and reduce health risks, could complement a sales tax extension.

1. Introduction

Both plant-based and dairy milk has been consumed for thousands of years and has grown to an indispensable and deeply integrated nutrient source for cultures across the world (Bennett, McMahon, & Muehlhoff, 2013). Due to globalization and liberalization, milk has become the most traded agricultural commodity in the world with an annual global production of 522 million tons in 2018, of which 82% originates from cattle (FAO, 2019). Demand is expected to grow by 22% in the next decade driven by urbanisation and increasing wealth in emerging economies (Cronin & McMahon, 2017; Ohlan, 2014).

Despite positive growth projections, external factors are significantly impacting the milk sector and slowing down growth and consumption in historically strong sales markets (Cronin & McMahon, 2017; Ohlan, 2014). Particularly, health, safety and environmental trends have initiated a shift in consumer purchasing behaviour requiring governments to assess existing policies to safeguard the public interest (Shankar, 2017). Indeed, milk products have historically been produced below the actual social costs through governmental subsidies and other privileged policies (Erba & Novakovic, 1995). In other words, governments have been sustaining artificially high demand through their policies, as price along with taste and convenience have traditionally been the three major influencing purchasing factors for food (Ohlan, 2014). Increasingly, governments are, therefore, evaluating the effectiveness of existing policies and redesigning policies to positively influence public health and diets (Antonelli, Dembska, Maughan, Pedrotti, & Recanati, 2019).

Plant-based milk could serve as a nutrient, more environmentally friendly, and fewer saturated fat containing substitute to dairy milk, however, retail prices of plant-based milk are significantly higher, partly because the category does not benefit from the same efficiencies and scale compared to dairy milk (Nemecek & Poore, 2018). Illustratively, retail plant-based milk sales only represent one-eleventh of total fluid milk retail sales in the US in 2018, even though the category is undergoing double-digit growth (Cahill, Gleadall, Lane, & O'Dochartaigh, 2019; Nielsen, 2019).

Basic economic principles define the relationship between supply and demand of a good or service as a determent of price under the law of supply and demand. Demand increases when prices decrease and vice versa. Policymakers could, therefore, improve public health and diets through pricing policies that incentivize healthier food demand (Connor, et al., 2018).

Price elasticity of demand, which is an economic measure of the change in quantity demanded in relation to price fluctuations, can expose the relationship between consumer demand and pricing and can help to quantify the effectiveness and impact of pricing policy (Regmi & Seale Jr, 2010). A clear understanding of pricing characteristics for plant-based milk products will not solely benefit governmental institutions for policymaking, but other stakeholders as well, as their business models transition from lean and agile towards scale and cost efficiencies (Baker, Marn, & Zawada, 2010).

Resultantly, the objective of this study is to identify the price elasticity of demand for plant-based milk in the US Middle Atlantic division, enabling governmental institutions to predict the impact of pricing policies to improve public health and diets. Research indicates that pricing policies could significantly impact purchasing behaviour, especially among low-income groups, however, there is no clear evidence that public health improves through pricing policies (Blakely, et al., 2013). Results from the study could, therefore, be used in the redesign and evaluation of current pricing policies related to (plant-based) milk consumption, and the potential improvement of public health and diets in the Middle Atlantic division.

1.1 Transition towards plant-based diets

In the fast-moving consumer good (FMCG) industry, consumer trends are constantly influencing the business model. As channel landscape and consumer behaviours shift, FMCG brands face great pressure to continue to perform and deliver positive financial results. In order to understand how these trends impact plant-based milk retail sales, both industry-wide as well as category-specific trends are provided.

1.1.1 Industry-wide trends

In general, three major industry-wide trends can be identified, namely health and well-being, safety and transparency, and sustainability and ethic, of which high-level overviews are given below.

In general, food and beverage categories are evolving, as consumers are increasingly committed to a healthier lifestyle and make purchasing decisions based on the label, health perception and ingredients of food and beverage products (Kelly, Kopka, Küpper, & Moulton, 2018; Bucher, Duncanson, Labbe, Murawski, & van der Horst, 2018). In fact, food is no longer just for nutrition, it must also offer added value for mental and physical health and holistic well-being. In accordance, consumers are purchasing increased volumes of food and beverages that are perceived to be healthy. In the future, consumers will increasingly focus on plant-based foods, as plant-based fats and protein benefit from a superlative health perception as shown in figure 1. It may, therefore, be clear that plant-based protein sources will have a growing importance in the retail landscape in the coming years and beyond (Alam, Hoque, & Nahid, 2018; Garnett, Lorimer, & Sexton, 2019).

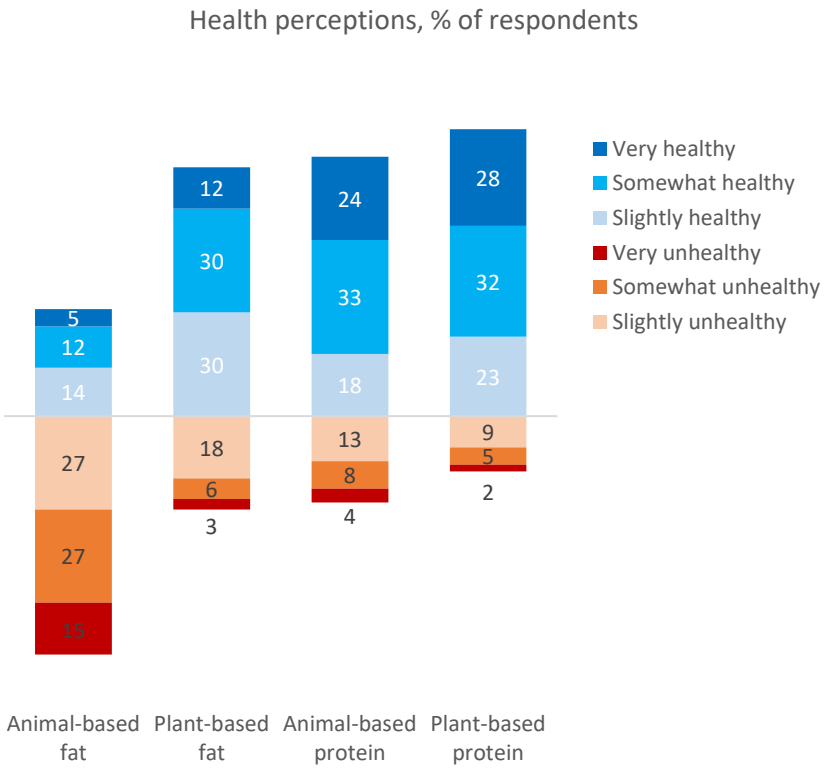

Figure 1: Consumer perceive plant-based fat and protein healthier than animal-based fat and protein (Adams, Paula, Schnitzlein, & Vasconcellos, 2019; Armbrecht, Hughes, Kress, & Mattfeldt-Beman, 2014).

In line with health, consumers are now also progressively making purchasing decisions based on a food category's transparency towards sustainability, social impact and safety. 80% of consumers would like to know the product ingredients, manufacturing processes and the sourcing practices of what they purchase (Boland, Kriege-Steffen, Lohscheidt, Schneider, & Stolze, 2010). In some situations, absence, shortage or disinformation may severely disturb or negatively impact how a consumer perceives a product (category), which ultimately affects purchasing behaviour (Nielsen, 2018). In the last decade, consumers have very consciously been distancing from non-transparent large-scale industrial food processing, which pushed consumers towards food and beverage companies that express ethical values, social consciousness, corporate transparency and sustainability efforts (Adams, Maluf, Meilhac, Paula, & Ramirez, 2019; Boland, et al., 2010).

At last, the popularity of terms as vegetarian, vegan and dairy-free have increased by 22% YOY in 10 years' time, mostly driven by environmental, principal or ethical beliefs (Bashi, McCullough, Ong, & Ramirez, 2019; Joshi & Rahman, 2015). Because greenhouse gas emissions as well as land, water and energy usage of plant-based products are significantly lower relative to their animal-based peers, plant-based products have gained popularity among environmentally conscious consumers (Nemecek & Poore, 2018). In a world where sustainability efforts are gradually becoming a critical purchasing decision criterion, consumers are increasingly deciding to substitute animal-based products for alternative proteins, including plant-based options, to reduce their environmental footprint (Kelly, et al., 2018; Bucher, et al., 2018).

1.1.2 Category specific trends

In economically developed countries, consumer awareness for alternative protein is growing rapidly (Bashi, et al., 2019; Joshi & Rahman, 2015). In these economies, animal-based food and beverages have traditionally been the main source of protein, however, animal-based protein sources are now making way for alternative protein sources, including plant-based milk beverages (Adams, et al., 2019; Hekkert, Kalfagianni, Negro, & Tziva, 2020). In all, three category-specific trends can be identified that currently reshape and redefine the milk aisle.

Initially, consumers have grown more interest in plant-based milk alternatives, which has lead to increase availability and variety of plant-based milk brands at retail outlets. In the last 12 months, 41% of consumers have tried plant-based milk brands, of which 70% continued to purchase the brand after trying it for the first time. Interestingly, 48% of these consumers now purchase both brands, while 24% stick to the new and only 28% remain loyal to their original milk brand (Adams, et al., 2019; Hekkert, et al., 2020). Due to increased awareness, variety and availability, the plant-based milk category now represents the most mature, furthest developed and highest volume plant-based retail category in the US (Cameron & O'Neill, 2019; Nielsen, 2019).

In addition, small and medium-sized enterprises (SMEs) in the milk aisle have gained momentum and have been able to win valuable and relatively loyal customers, especially through their leaner operation models and shorter go-to-market cycles. Due to the dependency of large milk brands on size, scale and efficiencies, these organizations are less successful in responding to consumer trends (Nejati, Nejatian, Zarei, & Zanjirchi, 2018). In all, SMEs have been responsible for 3.8% ($1.1B) of category growth, while private label and large milk brands have declined by -2.5% ($1.4B) and -1.3% ($1B) between 2015 and 2018. In spite of that, animal-based milk innovations have been outperforming the rest of the market and have also achieved rapid share growth (Adams, et al., 2019; Nielsen, 2019).

At last, purchasing behaviour in the milk aisle is increasingly highly segregated based on age, channel and value preferences. As shown in figure 2, millennials are almost twice as likely as other age groups to shop dairy at natural 'premium' retailers, whose assortment is focused on health and 'all natural'. In contrast, older age groups tend to shop at either traditional retailers as well as discount grocers (Adams, et al., 2019; Ameerally, Drake, Drake, McCarthy, & Parker, 2017). Interestingly, millennials perceive name branded products to be the more valuable options instead of baby boomers and generation X, who generally purely assess value from an economic perspective and choose the cheapest available option (Kelly, et al., 2018; Bucher, et al., 2018). In online shopping, the channel segmentation between millennials and generation Xers is also clearly visible, as almost 20% of the 18 to 34-year-old consumers purchase dairy products online compared to only 4% in the age group of 55-64 (Ameerally, et al., 2017).

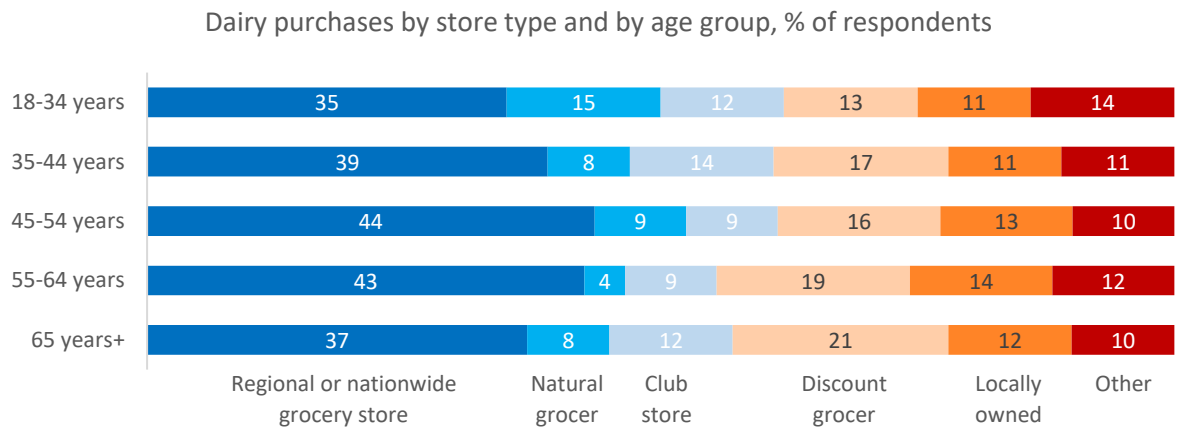

Figure 2: Consumers in different age groups tend to purchase dairy products in different types of retailers and favour other value propositions (Adams, et al., 2019; Ameerally, et al., 2017).

1.2 Consumption of dairy and plant-based milk

In terms of consumption, the retail milk category can be broken down into two categories, namely dairy milk, which include animal-based protein milk and lactose-reduced or -free milk, and plant-based milk, which collectively generate $18B in annual retail sales. 87.9% represent dairy milk sales, of which 8.0% are lactose-reduced and -free milk sales, and the remainder are plant-based milk sales (Nielsen, 2018). YOY, the dairy milk category has declined by 2%, while plant-based milk sales have grown by 9% in 2018 (Cameron & O'Neill, 2019; Nielsen, 2019). In the paragraphs below, further detail will be provided about the breakdown of sales (growth) in both categories.

1.2.1 Dairy milk

Annually, consumers spend about $10.8B on animal-based milk throughout retail outlets in the US (Nielsen, 2018). Both from a dollar as well as a volume standpoint, animal-based milk is the second perishable category in food retail (Nielsen, 2018). Due to the recent market developments, which have been discussed previously, the dairy milk industry has been undergoing turbulent times, which has led to a decline of 2.7% in unit sales (Kelly et al., 2018; Nielsen, 2019). Resultantly, retail milk prices have come under pressure, resulting in an even steeper sales dollar decline of 6.0%. As shown in figure 3, none of the animal-based milk segments have been able to grow dollar sales nor unit sales, except for the whole milk category, which grew unit sales by 1.5% (Nielsen, 2018). In the shift towards healthier diets, consumers are increasingly interested in fuller fat options, which clarifies the marginal unit sales growth of whole milk and the steep decline in both dollar and unit sales of fat-free and low-fat milk (Cronin & McMahon, 2017; Bhavadharini, et al., 2020; Borruso, Gold, Javetski, & Staples, 2019).

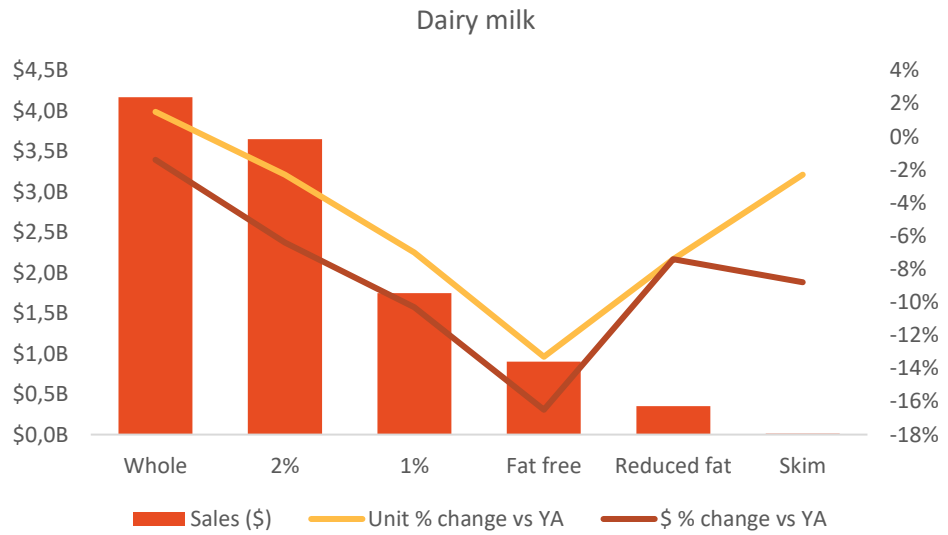

Figure 3: Nielsen, Traditional milk category, Sales ($), Unit % change vs YA, $ % change vs YA, Total U.S. All Outlets Combined (xAOC), 52W ended June 30, 2018 (Nielsen, 2018).

In addition, lactose-reduced or -free milk is also captured as dairy milk sales. Individuals with an impaired ability to digest lactose are submitted to either plant-based milk or lactose-reduced or -free milk when it comes to dairy milk cravings. In 2018, lactose-reduced and -free milk made up for 'only' $1.1B retail sales, however, the expectation is that the category will continue to grow by 7.6% YOY (Nielsen, 2018). As lactose-reduced and -free milk offers the same essential nutrients as dairy milk, but at a lower price than plant-based alternatives, the popularity of these lactose-reduced and -free products is increasing, especially among Southeast-Asian consumers, who are considered to be price conscious and are genetically 98%-100% likely to be lactose-intolerant (Bruins, Dekker, & Koenders, 2019). As shown in figure 4, the lactose-reduced or -free category can be broken down similarly to the dairy milk section, of which 2% milk is the quickest mover. In all segments, but the skimmed lactose-reduced and -free milk, both the dollar sales as well as the unit sales increased. In contrast to the dairy and plant-based milk, dollar sales growth has even outpaced unit sales growth in the lactose-reduced and -free category, which implies that retail prices have slightly increased (Nielsen, 2018).

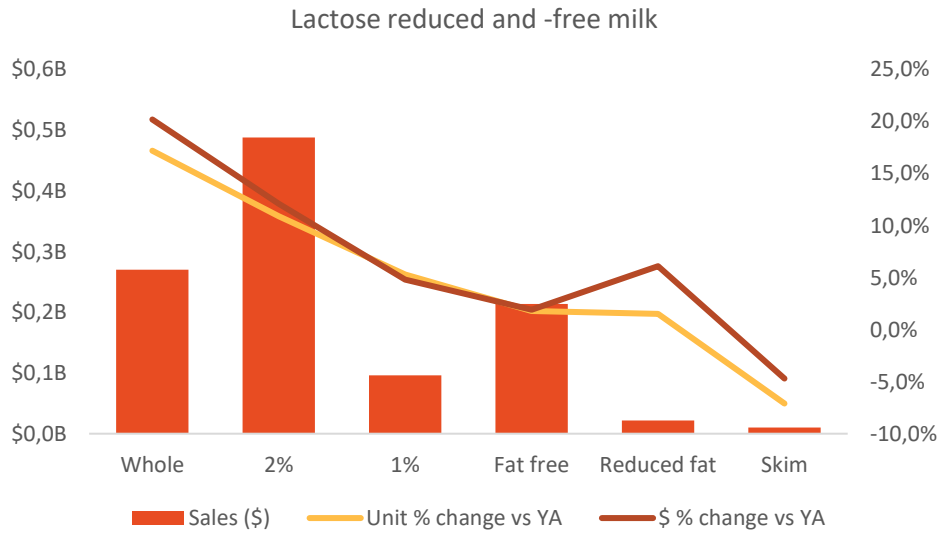

Figure 4: Nielsen, Lactose-reduced and -free milk category, Sales ($), Unit % change vs YA, $ % change vs YA, Total U.S. All Outlets Combined (xAOC), 52W ended June 30, 2018 (Nielsen, 2018).

1.2.2 Plant-based milk

In total, plant-based milk sales represent 40% of the total plant-based food and beverage retail sales and 12% of total dollar sales of retail milk (Cameron & O'Neill, 2019; Nielsen, 2019). Plant-based milk retail sales have been growing at a CAGR of 9% and now represent $1.8B in retail sales in the US (Nielsen, 2018). Refrigerated plant-based milk account for 89.5% of total dollar sales and shelf-stable plant-based milk sales for the remaining 10.5%. In these two retail sections, almond milk represents the lion share of the plant-based milk sales, followed by soy and coconut, which collectively make up for 85% of the total plant-based milk sales as shown in figure 5. Both the unit sales as well as the dollar sales were up for plant-based milk throughout 2018, except for soy, which was down by -8.9%. Particularly, blends and oat milk have been undergoing spectacular growth, however, dollar sales are still relatively low at this point (Nielsen, 2018). Also, the plant-based milk category has been attaining growth primarily through increases in velocity, which has been up by 7% YOY, rather than distribution growth (Cameron & O'Neill, 2019; Nielsen, 2019).

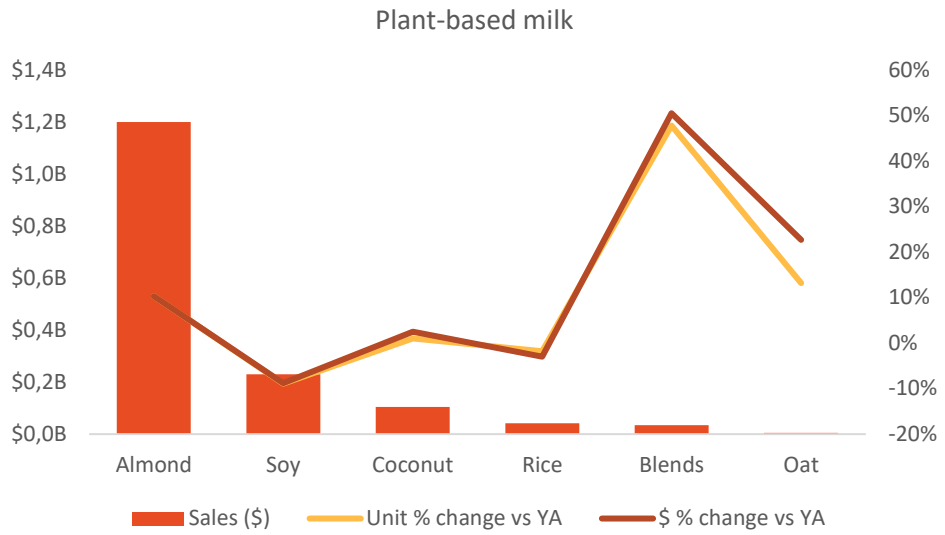

Figure 5: Nielsen, Plant-based milk category, Sales ($), Unit % change vs YA, $ % change vs YA, Nielsen, Total U.S. All Outlets Combined (xAOC), 52W ended June 30, 2018 (Nielsen, 2018).

1.3 Demographics of dairy and plant-based milk purchasers

As the plant-based milk category grows and the dairy aisle evolves, consumer demographics insights gain importance for stakeholders in the plant-based and dairy industry, as these insights allow them to align consumer demand against supply. During the transition from dairy towards plant-based milk, stakeholders must understand what consumers purchase plant-based milk and utilize these insights to develop effective strategies. Income, age, ethnicity, and lifestyle represent important demographic measures for stakeholders and will, therefore, be discussed with regards to the dairy and plant-based milk category.

1.3.1 Income

Initially, the aggregated household income of dairy and plant-based milk purchasers are discussed. Relative to dairy consumers, plant-based consumers over-index in higher-income categories, namely in income categories with an aggregated household income of more than $70.000 (Cameron & O'Neill, 2019; Appelhans, Crane, French, Tangney, & Wang, 2019). Individuals in these relatively high-income categories have statistically higher disposable incomes compared to lower-income brackets. In combination with plant-based milk's price perception, this could clarify why price-conscious consumers in lower aggregated household income brackets tend to stick to cheaper animal-based dairy (Ahmed, Khan, & Samad, 2016). In accordance with this assumption, figure 6 shows that plant-based milk under-indexes in the lowest aggregated income categories, but especially in aggregated household incomes lower than $30.000 (Nielsen, 2019).

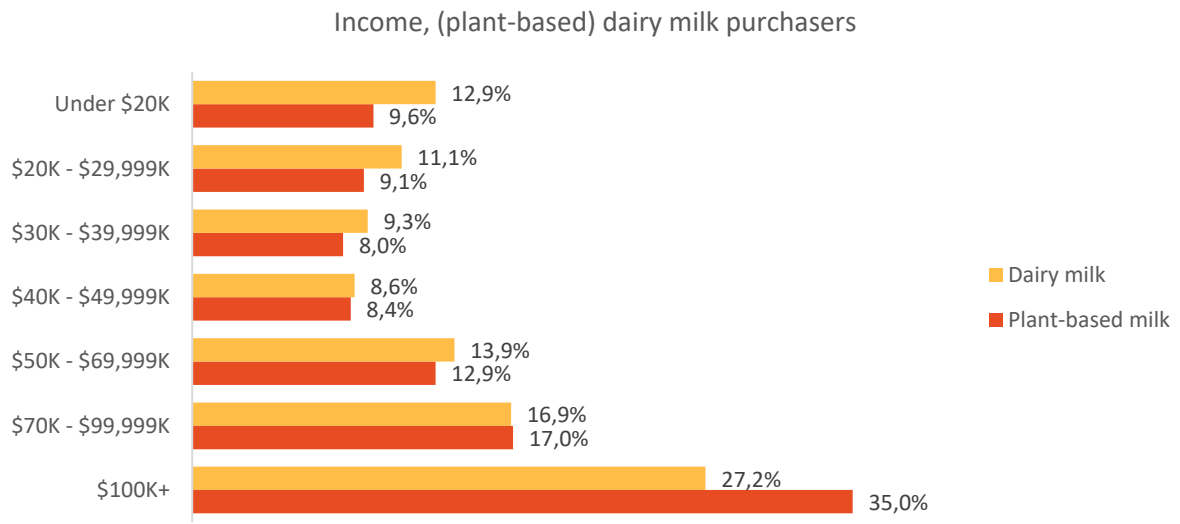

Figure 6: Nielsen Homescan, Total milk category, Household Income Aggregated, 52W ended March 31, 2019 (Nielsen, 2019).

1.3.2 Ethnicity

In addition to aggregated household income, the ethnicity of plant-based and milk purchasers will be discussed. As shown in figure 7, the dairy and plant-based milk category show overlap and similarities in terms of household ethnicity, which displays the percentage of dairy or plant-based milk purchasers among various ethnic groups (Nielsen, 2019). Interestingly, Asian ethnic groups are underrepresented in the lactose-free plant-based milk category, even though lactose-intolerance is twice as likely among Asian cultures compared to Caucasians (Leitner, Merin, & Silanikove, 2015). Caucasians are also slightly underrepresented among plant-based milk purchasers, but at the same time African Americans and other ethnic groups represent a relatively large ethnic share (Nielsen, 2019).

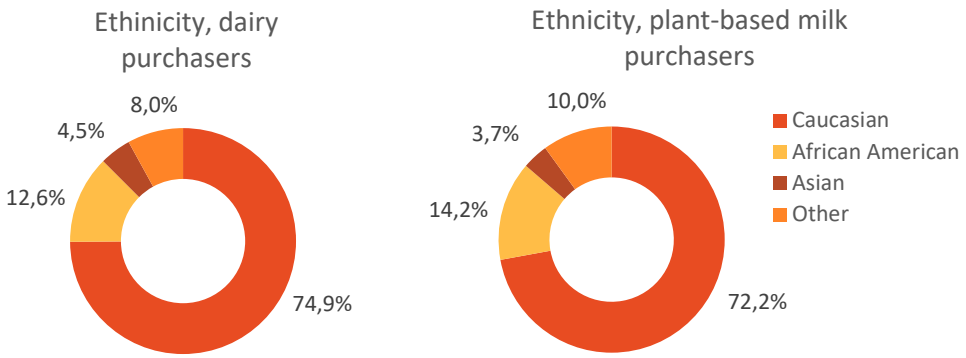

Figure 7: Nielsen Homescan, Total milk category, Household Ethnicity, 52W ended March 31, 2019 (Nielsen, 2019).

1.3.3 Age

In the dairy aisle, consumers are highly segmented based on channel and age preferences (Carpenter & Yoon, 2011). In figure 8, (plant-based) milk purchasers are broken down by gender and age. As shown, millennials, but specifically females under 35 to 54 years old, over-index on plant-based milk purchases, while plant-based milk is substantially underperforming among older age groups (Nielsen, 2019). In contrast, the male age curve of a male plant-based milk buyer is much more consistent and aligned to the average male dairy milk purchaser, potentially because men are less health-conscious relative to women (Brønnum-Hansen, Jeune, & Oksuzyan, 2010). A similarity that both the female as well as the male curve have in common is that dairy milk significantly outperforms plant-based milk in the 65+ years age category. In this age category, male and female consumers are almost twice as likely to purchase dairy milk instead of plant-based milk. At the other end, a similar observation can be made for plant-based milk in the age category under 35 years old. Plant-based milk, therefore, is more likely to be purchased by millennials, but specifically by female millennials, while baby boomers tend to stick to dairy milk (Nielsen, 2019).

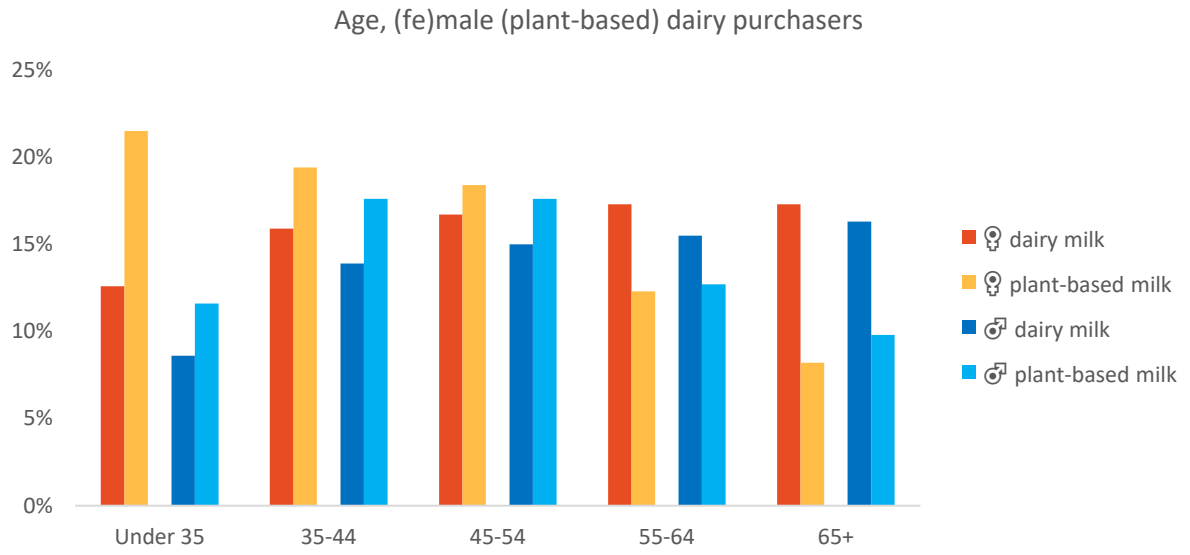

Figure 8: Nielsen Homescan, Total milk category, Female Head of Household Age Aggregated, 52W ended March 31, 2019 (Nielsen, 2019).

1.3.4 Lifestyle

Between dairy and plant-based milk consumers, there are significant differences among the various lifestyle categories. 60.8% of plant-based milk consumers live in urban areas, which include urban cores, cosmopolitan centres, and suburban spreads. In contrast, dairy milk purchasers are overrepresented in rural regions, which cover modest working towns, comfortable country, and rural living. 56.9% of the total dairy milk purchasers live in rural areas versus 43.1% in urban environments. Particularly in urban cores and plain rural environments, the gap between the percentage of plant-based milk and dairy milk purchasers is significant and can be up to 12% (Croney, Cummins, & Widmar, 2015; Nielsen, 2019).

1.4 Policy framework for sustainable food consumption

In total, 71% of all deaths globally can be associated with non-communicable diseases (NCDs), also known as chronic diseases, which are caused by physiological, genetic, behaviours and environmental factors (Afshin, et al., 2019). A large portion of these deaths relate to food-related chronic diseases and are caused by a misbalance in diet, nutrition, and physical activity, which make these diseases largely preventable (Waxman, 2004). Intergovernmental institutions, such as the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO), consult and advise national authorities to implement policies to fight food-related chronic diseases and to promote healthier and sustainable food consumption (WHO, n.d.). Intergovernmental institutions however do not possess legislative powers, which makes them dependant on national authorities for the implementation and execution of the proposed measures (FAO, 2017). Initiatives to improve public health have been, but are not limited to, implementing pricing policies, as these directly affect consumer demand, and can be achieved through specific excise, which is a fixed amount of tax on a specific quantity of the taxed good, value-added tax, when taxes are levied over the added value that stakeholders have created, and ad-valorem excise, which is a percentage of tax levied over the gross value at the point of sale (Albert, et al., 2016; Garnett & Gonzalez Fischer, 2016; Breda, Calvert, Galea, Jewell, & Mantingh, 2015).

In the US, food-related diseases, as obesity, overweight, and diabetes, are increasingly having far-reaching negative economic and social effects (Batz, Hoffman, & Maculloch, 2015). Intensive measurements must be taken to stop further escalation of these issues and therefore the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA) are influencing consumer purchasing behaviour and consumer demand through (pricing) policies and legislative actions (Breneman, et al., 2009). In recent years, legislation relating to national nutrition rating systems and labelling have been sharpened to make consumers more knowledgeable about their food purchases. Both food service operators as well as retailers are now legally required to display calorie count and nutritional value in restaurants or on front of package (FOP) labels, while regulations regarding health claims have become stricter to protect consumers from (misleading) unsubstantiated (health) statements (Cash, et al., 2014; Richards & Sindelar, 2013). In addition, the USDA actively influences consumer demand and public health through Supplemental Nutrition Assistance Program (SNAP), which supports nearly 50M low- and no-income participants through financial premiums and benefits (Eicher-Miller, Maulding, & Rivera, 2019). Besides attempts to influence consumer purchasing behaviour, multiple acts have passed the Congress to aid food producers through financial incentives (FAO, 1998). Before 1996, deficiency payments, which are direct government payments, were offered to guarantee farmers' incomes. After 1996, there have been multiple acts, including the 1996 Farm Act and the 2018 Federal Agricultural Improvement and Reform (FAIR), which reduced government intervention in the agriculture sector and replaced deficiency payments for compensatory payments. Regardless of this change, the sector has remained highly dependent on the support given by the federal government to maintain (inter)national competitiveness (US Senate, 1996). Presently, hundreds of thousands of farmers, growing anything from oat to corn, still benefit and are financially dependent on these financial premiums and benefits to provide access to reliable, consistent, and safe food supply at artificially low prices (FAO, 1998).

In terms of milk consumption, both the FAO as well as the WHO recommend to include dairy milk or other dairy products in a diet, as these products significantly contribute to the required nutrient intake of calcium, magnesium, protein among other essential nutrients, provided that diets are properly balanced (Bennett et al., 2013). Besides essential nutrients, dairy milk contains a relatively

high content of saturated fats, which should only represent 10% of the daily calorie intake according to the USDA. In practice, the average intake of saturated fats of Americans is higher than the recommended daily intake, especially among age groups between 1 and 30 years old. In line with this, the USDA recommends two strategies to reduce the intake of saturated through dairy milk, namely to consider consuming fat-free, low-fat milk or plant-based milk or to either reduce the frequency or the portions of dairy milk consumption (US Department of Agriculture, US Department of Health and Human Services, 2015). Besides influencing the demand side, the USDA and the FDA have made structural changes on the supply side. In 2014, the Congress reorganized the dairy policy in the Agricultural Act and launched the Margin Protection Plan (MMP) as a financial protection measure for farmers against increasing volatility in milk and feed prices, but also to strengthen the industry for increasing international exposure (Cessna, MacDonald, & Mosheim, 2016). FAIR, which is the overarching program of the MMP, also offers financial incentives to farmers with selected plant-based milk commodities, however, plant-based milk is not marketed and pushed as actively as dairy milk through state-level marketing programs and (inter)national food aid programs among other programs (Blayney & Manchester, 2001). In contrast to dairy milk, no policies are currently being considered or implemented that would incentivize consumer demand for plant-based milk (Blayney & Normile, 2017).

1.5 Price elasticity and food consumption

Pricing directly influences consumption and is therefore a critical variable when influencing the demanded quantity. If a product is overpriced, this may result in under consumption of the good, while having an undervalued product in the market could encourage overconsumption, which could both have an undesirable societal effect from a health, environmental or people standpoint (Kilroy, MacKenzie, & Manacek, 2015; Ellickson & Misra, 2006). Price elasticity of demand is an economic measure that estimates the impact of a price change on the purchased or demanded quantity (Regmi & Seale Jr, 2010). Businesses and governmental institutions can use price elasticity of demand to determine an effective pricing strategy for their product(s), but also to identify effective fiscal policies (Klapdor, Kullmann, Mark, & Sundararajan, 2017; Ellickson & Misra, 2006). As shown in the equation below, price elasticity of demand can be calculated by dividing the percentage change in demanded or purchased quantity by the percentage price change (Jones, Marshall, & Sands, 2014). Based on the outcome of the equation, the products (in)elasticity can be determined.

$$\text{Price elasticity of demand} = \frac{\%\ \Delta \text{ in quantity demanded}}{\%\ \Delta \text{ in price}}$$

If the outcome of the equation is less than 1, the demand is inelastic, which implies that the percentage change in quantity demanded is smaller than the percentage price change thus positively influencing dollar sales (Jones, et al., 2014). Relative price inelasticity occurs when quantity demanded doesn't in- or decrease as quickly as price does, while perfect inelasticity exists when the quantity demanded is not affected by price at all. A representative example of a (relatively) inelastic product is gasoline, which consumers continue to purchase in more or less the same quantity regardless of the height of a price in- or decrease (Regmi & Seale Jr, 2010).

If the outcome of the equation is greater than 1, the demand is elastic, which entails that the percentage change in quantity demanded is greater than the percentage price change thus resulting in a net negative result on dollar sales (Jones, et al., 2014). Relative price elasticity is when the demand in- or decrease outpaces the price in- or decrease. Perfect elasticity occurs in situations where a relatively minor price change triggers a very large change in quantity demanded. In this category, consumers either have alternatives or have no meaningful (emotional) attachment to the product and can therefore easily swap to substitutes (Regmi & Seale Jr, 2010).

If the outcome of the equation is exactly 1, the demand is unit elastic, which suggests that the percentage change in quantity demanded is equal and proportional to the percentage price change (Jones, et al., 2014). Regardless of the height of the percentage price change, the quantity demanded will change by the exact same percentage. In monopolistic situations, unit elasticity frequently occurs, as consumers have no substitutes and are dependent on the product or service that the monopolist offers (Regmi & Seale Jr, 2010).

In addition, two distinct types of price elasticities can be recognized, namely own price elasticity and cross-price elasticity. Own price elasticities of demand predict the percentage change in quantity demanded for the item under consideration. Cross elasticity of demand however is an economic concept that measures the responsiveness in the quantity demanded of one good when the price for another good changes. Cross elasticity of demand can be calculated by taking the percentage change in the quantity demanded of one good and dividing it by the percentage change in the price of the other good (Lechene, 2001). In both cases, the elasticity measures a demand response with income and all prices, except that under consideration, held constant (Okrent & Alston, 2012).

In practice, governmental institutions are increasingly considering fiscal policies to reduce unhealthy food and beverage consumption due to by increasing (health care) costs that are associated with consumption of unhealthy food and beverages, information asymmetry in food and beverage marketing, and the financial necessity to support those who experience negative effects of unhealthy food and beverage consumption (Colchero, Hernández-Ávila, Rivera-Dommarco, Salgado, & Unar-Munguía, 2015). Although several countries, including France, Denmark and Finland, have implemented taxes on unhealthy food and beverages, there are no clear scientific publications that provide any evidence for the effectiveness of taxation of unhealthy food and beverage purchases (Colchero, Guerrero-López, & Unar-Munguía, 2017). Institutions can therefore solely utilize price elasticity of demand to obtain preliminary results to predict the effectiveness of fiscal policies on consumer demand until scientific literature becomes available.

Previous price elasticity studies have proven that food demand is generally inelastic, which suggests that the percentage change of the quantity demanded is greater than the percentage change in price, and ranges between 0.27 to 0.81 depending on the category (Andreyeva, Brownell, & Long, 2010). Interestingly, sugar-sweetened beverages, which include (plant-based) milk, show greater sensitivity to price change and therefore have a higher absolute price elasticity of demand value relative to other food categories (Colchero et al., 2015). In the dairy milk category, which is the most studied category aside from meat with 26 estimates, elasticity levels even differ for different types of milk and per study. In this instance, 2% milk is inelastic at -0.025, while price elasticity for reduced-fat milk is even more inelastic at -0.049 (Blayney, Davis, Dong, & Owens, 2012). In line with these findings, other studies also find milk to be an inelastic good (Akobundu, Bergtold, & Peterson, 2004; Allcott, Lockwood, & Taubinsky, 2019; Huang, 1993).

In American diets, milk is among the three major saturated fat sources (Krebs-Smith & Reedy, 2010). Implementing (pricing) policy could actively encourage consumers to substitute relatively saturated fat-rich milk for less or saturated fat-free products that could contribute to reducing food-related chronic diseases (Andreyeva et al., 2010). Presently, 27% of the non-plant-based retail milk customers do not consider plant-based milk, because plant-based milk does not offer the same value as dairy milk from a monetary standpoint, which underlines the importance of value perception in the retail milk category (Adams et al., 2019; Ameerally, et al., 2017)). Research also indicates that price elasticity of demand among low-income populations is more elastic, namely 1.2 against 0.66, which proves that dairy milk consumption would substantially reduce when dairy milk prices increase. Intervention as well as laboratory research settings also underline that lowering the price of healthier foods and increasing the price of less healthy alternatives could shift consumer purchases toward healthier food options (Andreyeva et al., 2010). Pricing policy could, therefore, have a substantial impact on consumer demand for plant-based milk.

1.6 Research objective

In this thesis, the research objective is to the objective is to estimate the price elasticity of demand to predict the impact of pricing policies on public health in the Middle Atlantic division. Presently, no price elasticity of demand studies have been conducted specifically for plant-based milk beverages. Resultantly, the impact of a price in- or decrease on the quantity demanded of plant-based milk beverages is undefined and therefore the relationship between consumer demand and retail price of plant-based milk has not been clarified. Price elasticity of demand estimates could contribute to quantifying the impact of pricing policies on consumer demand for plant-based milk beverages, which is how this thesis adds to existing literature. Results from the study could be used in the redesign and evaluation of current pricing policies related to (plant-based) milk beverage consumption, and the potential improvement of public health and diets in the Middle Atlantic division. In order to conduct research leading towards the research objective, the following question was formulated:
What is the impact of price elasticity of demand for plant-based milk on public health in the United States Middle Atlantic division?

In order to answer the main question, the following three sub-questions were identified:
What is the own-price elasticity of demand for plant-based milk beverages?
What is the cross elasticity of demand for plant-based milk and dairy milk beverages?
What is the effect of sales tax on dairy milk to improve public health and diets through plant-based milk consumption?

2. Research methodology

Presently, the impact of a price in- or decrease on the quantity demanded of plant-based milk beverages is undefined and therefore the relationship between consumer demand, the retail price of plant-based milk, and public health has not been clarified.

In this study, the objective is therefore to identify the price elasticity of demand for plant-based milk beverages to predict the impact of pricing policies to improve public health and diets in the Middle Atlantic division. Based on the price elasticity of demand for plant-based milk beverages, estimates can be made to predict the impact of a price in- or decrease on the quantity purchased. Indirectly, price elasticity of demand estimates could contribute to quantifying the impact of pricing policies on consumer demand for plant-based milk beverages, which is how this thesis adds to existing literature. Results from the study could be used in the redesign and evaluation of current pricing policies related to (plant-based) milk beverage consumption, and the potential improvement of public health and diets in the Middle Atlantic division.

Resultantly, the following main question is defined:
What is the impact of price elasticity of demand for plant-based milk on public health in the United States Middle Atlantic division?

In order to answer the main question, the following three sub-questions were identified:
What is the own-price elasticity of demand for plant-based milk beverages?
What is the cross elasticity of demand for plant-based milk and dairy milk beverages?
What is the effect of sales tax on dairy milk to improve public health and diets through plant-based milk consumption?

2.1 Data analysis

In this study, the sub-questions were answered through quantitative data analysis. Data for these sub-questions were obtained through two sources, namely consumer expenditure from the US Bureau of Labor Statistics and Nielsen point-of-sale and consumer panel data. Below are brief explanations of both data sources:

Consumer expenditure surveys (CES) are published by the US Bureau of Labor Statistics to provide household information on income and expenditures as well as household characteristics and socio-demographic data of household members in the US (US Bureau of Labor Statistics, n.d.). Consumer expenditure data consists of estimates that are derived from two cross-sectional nationally representative surveys, namely interview surveys and diary surveys. Interview surveys are conducted quarterly and are designed to collect data on large and recurring expenditures, e.g. rent and utilities. In contrast to interview surveys, diary surveys are conducted weekly and give insights into small, frequently purchased items, such as food and clothing purchases (US Bureau of Labor Statistics, n.d.). Beverage and food expenditures and socio-demographic variables are included per region, division, and area. In this study, the 2018 publication, which is the most recent CES focused on the Middle Atlantic division, is utilized to measure E total household expenditures on beverages and food, h variables at household and municipality level, and h and m the number of households and municipalities.

Nielsen is a paid service that provides both point-of-sale and demographic data to its customers through licenses that are granted per product category (Nielsen, n.d.). Nielsen collects its point-of-

sale data directly from retailers across the United States and offers comprehensive information on market shares, competitive sales volumes, and insights in pricing, distribution, merchandising, and promotion. Before being published, Nielsen checks the validity of the data (Nielsen, n.d.). Nielsen also captures weekly purchase data on household level through panellists who scan their purchases using a handheld scanner at unique product code level, which allows insight into geographical and demographic characteristics of the household (Nielsen, n.d.). Nielsen users can filter data on various criteria, including geographical area and price metrics (Nielsen, n.d.). In this study, point-of-sale and Homescan data, focused on the Middle Atlantic division, from calendar year 2018 is utilized to measure p_{jt} the price for food or beverage j at municipality level in wave t.

2.2 Empirical model

In order to estimate a demand system for plant-based milk beverages, the Linear Approximation of the Almost Ideal Demand System (LA/AIDS), developed and used by Deaton and Muelbauer, was utilized (Deaton & Muellbauer, 1980). In this linear model, the Laspeyres index was included as suggested by Moschini to obtain linear parameters, but also to avoid simultaneity, which occurs when two events happen at the same time (Moschini, 1995). In the equation, the dependent variable was the share of the beverage category expenditure relative to the total expenditures on food and beverages, recognizable as i. In total, the demand system consisted of 7 equations, one for each group of (plant-based) milk beverages, namely dairy, almond, soy, coconut, rice, blends, and oat milk. A composite numeraire, which functions as a price benchmark, was also integrated in the equation as a unique price index conform Finkelstein et al. (Finkelstein, Karns, Nonnemaker, Todd, & Zhen, 2014). In a mathematic equation, the LA/AIDS system was defined as followed:

$$W_{hmit} = a_i + \sum_{j=1}^{j} \beta_{ij} \log p_{mjt} + \gamma \log\left(\frac{E}{P}\right) + \sum_{k=1}^{K} \delta_{ik} \eta_{hmtk} + u_{hmit}$$

where W_{hmit} is the food or beverage expenditure share for food or beverage group i for household h living in municipality m during wave t; p_{jt} is the price for food or beverage j at municipality level in wave t where the jth good is the composite numeraire, which acts as a benchmark; E is total household expenditures on beverages and food, h are variables at household and municipality level, and $\log p$ is the Laspeyres index price, which is a consumer index. h and m represent the number of households and municipalities, respectively; while k denotes the number of co-variables at household and municipality level. $\log P$ can be calculated through the following formula:

$$\log P_{jt} = \sum_{i=1}^{j-1} W_i * \log p_{mjt}$$

Both own and cross-price elasticities non-compensated for income of the demand for various plant-based milk and dairy milk were derived from the model and are subsequently used to predict the effect of a rise in price by 5.2%, which is the weighted sales tax rate of the Middle Atlantic division states, on public health (Colchero, Rivera Dommarco, Teruel, & Unar, 2008). Marshall proposed extending VAT to the main sources of dietary saturated fats. In this study, Marshall's proposal was replicated as best as possible within the categories provided by the data (Marshall, 2000). Individually, the effect on consumption of other milk beverage items was calculated using the appropriate cross-price elasticity value and nutritional values (Aydar, Ozcelik, & Tutuncu, 2020). An

in- or decrease in consumption (quantity purchased) was presumed to instantly and directly reflect what was actually eaten by consumers considering all other things being equal. As out of home (OOH) food consumption accounted for 43.6% of the total food and beverage consumption in the US Middle Atlantic division, the assumption was that food bought for home consumption was responsible for 43.6% of the total food consumption by energy, and that out of home food consumption was not affected by the sales tax changes examined (US Bureau of Labor Statistics, n.d.). In line with these assumptions, the effect on the nutritional intake, changes in salt intake and the intake of different types of fat (by their effect on cholesterol) on public health were estimated using empirical data derived from meta-analyses (He & MacGregor, 2003; Appleby, Clarke, Collins, Frost, & Peto, 1997; Gray, Mytton, Rayner, & Rutter, 2007).

In this study, seven retail milk categories were identified, namely dairy, almond, soy, coconut, rice, blends, and oat milk. In essence, point-of-sale data, including sales, volumes, and prices were derived from the Nielsen point-of-sale database. Beverage shares were calculated by summing expenditure on each category, measured through dollar sales derived from the Nielsen point-of-sale database, and dividing by total expenditure in the seven categories. In order to account for outliners, the INEGI method was applied in the collection of prices to estimate the consumer price index (CPI) and replace prices that exceed or undercut the average price by two standard deviations. In all, the calculations were performed using a spreadsheet model in Microsoft Excel.

3. Results

In the result section, both own and cross-price elasticities estimates are provided for the selected 7 milk categories in the Middle Atlantic division, which define the impact of a price increase or decrease on the quantity demanded of plant-based milk beverages. In accordance with these results, the relationship between consumer demand, the retail price of plant-based milk, and public health is presented.

3.1 Own and cross-price elasticities

In total, 17034 household units were sampled in the Middle Atlantic division as a part of the consumer expenditure surveys. In table 1, the proportion of households (*n*) with positive purchases among the included categories in the demand system is presented. In the Middle Atlantic division, oat milk shows the lowest percentage of households with positive expenditure among plant-based milk beverage categories. In addition, household unit penetration for blends and rice milk is relatively low at respectively 0.9% and 1.1%. In contrast, 93.0% of Middle Atlantic households report spending on dairy milk. Resultantly, dairy milk household unit penetration is the highest among household units in the Middle Atlantic, followed by almond milk with 30.7%.

Table 1: Proportion of household units in Middle Atlantic division with positive expenditures in refrigerated (plant-based) milk beverage categories.

Category	***n* with expenditure > 0**	**%**
Dairy milk	15842	93.0%
Almond milk	5230	30.7%
Soy milk	996	5.8%
Coconut milk	455	2.7%
Rice milk	182	1.1%
Blends	147	0.9%
Oat milk	26	0.2%

In table 2, the average unit values of the included categories in the demand system are reported by the household units with positive purchases, in USD. In addition, the minimum and maximum unit values are provided. As shown, dairy milk is cheaper per ounce than plant-based milk. Among plant-based milk, price variations are significant, especially between coconut milk and almond milk, which are respectively $0.051 and $0.090 per ounce.

Table 2: Unit values of (plant-based) milk beverages. Nielsen, Milk category, Unit Price, Middle Atlantic Division xAOC, Cal Yr 2018 W/E 12/29/18.

Category	**Mean unit value**	**Minimum**	**Maximum**
Dairy milk	1.82	1.33	2.37
Almond milk	5.78	3.99	7.05
Soy milk	4.49	3.37	5.88
Coconut milk	3.69	2.58	4.87
Rice milk	3.29	2.47	4.18
Blends	3.49	2.27	4.01
Oat milk	5.29	3.33	6.88

In table 3, the estimated own-price elasticity of the seven beverage categories and cross-price elasticities are shown with respect to increases in the price of milk beverages in 2018. In the left half of the table, the estimated own-price elasticity values are shown for the selected milk categories, which indicate the percentage change in quantity demanded for the item under consideration. In the right column, estimations of cross-price elasticities show the degree of substitution of various types of plant-based milk with dairy milk. As shown, a price increase in dairy milk is associated with greater consumption of almond, soy, coconut, rice, and oat milk, as well as blends. It must also be noted that own-price elasticities of the demand for plant-based milk beverages were estimated to be lower among household living in urban areas, as New York, Philadelphia, and Pittsburgh, relative to rural counterparts. In line with that, the price elasticity of demand for dairy milk is higher among rural dwellers compared to urban residents.

Table 3: Own and cross-price elasticity of the demand for (plant-based) milk beverages.

Category	**Own price elasticity**	**Cross price elasticity** (1% increase in the price of dairy milk)
Dairy milk	-1.73	-
Almond milk	-2.82	0.29
Soy milk	-2.01	0.19
Coconut milk	-1.89	0.09
Rice milk	-1.53	0.11
Blends	-2.12	0.21
Oat milk	-3.19	0.23

In summary, the results of this section of the results suggest that dairy milk penetration is the highest among Middle Atlantic household units followed by almond milk. In addition, plant-based milk is significantly more expensive relative to dairy milk. Also, both plant-based and dairy milk was estimated to have an elastic own-price elasticity of demand. At last, plant-based milk shows substitutive behaviour towards dairy, as the quantity demanded of these beverages would increase as dairy milk prices increase.

3.2 Effect of sales tax on public health

In table 4, the results of a sales taxation on saturated fat-rich retail dairy milk are examined, comparing expenditure, nutrient intake, and effects on public health. In this scenario, the results are purely based on consumers, who shift towards plant-based milk, as a result of the cross-price elasticities of demand, while assuming that other variables remain constant. In any case, overall calorie intake from milk consumption can reduce significantly by replacing dairy milk for plant-based milk, however, depending on what type of plant-based milk is being used to replace dairy milk, the overall calorie intake reduction may vary. By way of example, almond milk can reduce overall calorie intake by 80.0%, while calorie intake reduction remains limited to 18.9% when consuming rice milk. In addition, calorie intake derived from saturated fats could decrease significantly, especially when consuming almond or coconut milk, which reduces saturated fat intake by 96.0%. In the same way, reduced saturated fats intake decreases polyunsaturates and monounsaturates intake, which

subsequently negatively impacts serum cholesterol and counters the health benefits achieved from a reduction in saturated fat intake. Both saturated fats and serum cholesterol are, therefore, related in the analysis of the results. As a result, the change in mortality from Ischemic Heart Disease (IHD) and strokes is also minimal. In terms of salt intake, only oat and coconut milk provide superlative health benefits over dairy milk, while other plant-based milk beverages either have an equal or higher salt content. In specific, almond milk has a relatively high salt content, as almond milk can contain up to 40% more salt than dairy milk. It must, therefore, be noted that the change in salt intake, the change in mortiality from IHD and the change in mortality from stokes are interrelated factor. In addition, sugar intake can be reduced between 44.4% and 100% when consuming plant-based milk beverages instead of dairy milk. It is also important to note that an sales tax extension on retail dairy milk could increase expenditure on (plant-based) milk beverage by a mean of 148%, which is equivalent to an extra 62 cents per person per week.

Table 4: Beverage categories used within the model, together with consumption and nutritional data (Aydar, et al., 2020).

	Tax retail dairy milk high in saturated fats				
	Almond milk	**Soy milk**	**Coconut milk**	**Rice milk**	**Oat milk**
Change in household (plant-based) milk expenditure (%)	218	147	103	81	191
Change in calories consumed (%)	-80,0	-41,5	-78,9	-18,9	-37,4
Change in calories derived from saturated fat (%)	-96,0	-88,0	-56,0	-96,0	-92,0
Change in salt intake (%)	40,0	0,0	-30,0	0,0	-10,0
Change in sugar intake (%)	-100,0	-86,7	-100,0	-44,4	-100,0
Mean change in serum cholesterol	0,050	0,046	0,029	0,050	0,048
Change in mortality from IHD (%)	1,6 to 1,9	n/a	-1,2 to -1,4	n/a	-0,4 to -0,5
Change in mortality from stroke (%)	1,2 to 1,3	n/a	-0,9 to -1,0	n/a	-0,3 to -0,4

All in all, taxation of dairy milk to incentivize plant-based milk demand would reduce calorie, saturated fat, and sugar intake. At the same time, reduced saturated fat intake would reduce polyunsaturates and monounsaturates intake, which simultaneously increases serum cholesterol and increases the risk for IHD and strokes. In the majority of cases, salt intake will either reduce or remain constant when replacing dairy milk for plant-based milk, however, only for almond milk overall salt intake may increase through plant-based milk consumption.

4. Discussion

In the end, the results from the study could be used in the redesign and evaluation of current pricing policies related to milk beverage consumption, and the potential improvement of public health in the Middle Atlantic division, however some limitations as well as perspectives towards the interpretation of the results must be highlighted.

4.1 Reflection

In this thesis, a demand system for milk beverages was estimated, where after the own and cross-price elasticity of the demand for both dairy milk as well as plant-based milk beverages were derived. Both plant-based milk as well as dairy milk were estimated to have elastic price elasticities of demand between -1.53 and -3.19 respectively, which implies that a 10% increase in price would be followed by a decrease of 31.9% in the quantity demanded and that the percent quantity decrease is greater than the percent price increase. In respect of the price elasticity of demand for dairy milk, there are multiple studies available with varying results. Andreyeva's et. al (2010) systematic review, which was based on 29 dairy milk studies, concluded that the absolute value of mean price elasticity of dairy milk was inelastic at 0.59 between 1938 and 2007 (Andreyeva et al., 2010). In contrast, more recent estimates from Perloff (2010) and Davis (2009) show that dairy milk demand is elastic and show overlap with the results of this thesis (Blayney, Cooper, Davis, & Yen, 2009; Chouinard, Davis, Lafrance, & Perloff, 2010). A clarification for the discrepancy could be the timespan over which the results from Andreyeva et al. (2010) review were gathered. As of the 1970s, dairy milk has evolved from an endlessly growing commodity to a declining product. It is, therefore, reasonable to conclude that price elasticity and the associated willingness to pay has altered over time (USDA, 2019). In addition, various models were used in each study that was reviewed by Andreyeva et. Al (2010), while Perloff (2010) and Davis (2009) both applied Linear Approximation of the Almost Ideal Demand System, in which each beverage group was estimated independently (Chouinard et al., 2010; Blayney, et al., 2009). In regards to the price elasticity of plant-based milk beverages, only a handful of studies are available to cross-reference the findings in this thesis. In the available research, soy and almond milk price elasticities of demand were estimated at -3.37 and -2.72 (Copeland & Dharmasena, 2016; Copeland & Dharmasena, 2015). Ghazaryan's (2019) findings, however, indicate that non-dairy milk had a higher average elasticity -4.30, however, these findings are based on point-of-sales data from 2013 (Bonanno, Cho, & Ghazaryan, 2019).

In addition to the own-price elasticity of demand, the cross-price elasticity of demand for plant-based milk beverages was estimated in relation to a price increase or decrease of dairy milk beverages. In previous studies, substitutive behaviour has been found between milk, juice, coffee, and tea, however, none of these studies broke the milk category down into its subcategories (Andrews, Lin, Smallwood, & Yen, 2004; Capps & Dharmasena, 2009; Lee, Lin, & Smith, 2010; Heng, House, & Kim, 2017). Almond and soy milk represent the only two plant-based milk beverages of which cross-price elasticities have actually been estimated in previous studies. In these studies, higher dairy milk prices were associated with increases in almond and soy milk, namely through cross-price elasticities of respectively 1.01 and 0.98 (Copeland & Dharmasena, 2016; Copeland & Dharmasena, 2015). In this study, the cross-price elasticities were estimated to positive, which suggests that plant-based milk show substitute behaviour towards dairy milk beverages. In line with the expectations, these findings underlined that an increase in dairy milk drinks' prices could lead to increases in the demand for other goods, such as almond, soy, coconut, rice and oat milk, and blends. In addition, the

substitute rate of dairy milk for almond, soy and oat milk, and blends were amongst the highest in the milk category, however, it is unclear what the real effect will be if dairy milk retail prices decrease, as it also depends on the cross-price elasticity between the subcategory items. In addition, manufacturers may absorb a price increase to avoid loss of sales.

In accordance with the last research question, the effect on public health of introducing sales tax on (saturated-rich) dairy milk was estimated. In previous studies, evidence has been provided that sales tax could be effective to improve public health through a reduction of sugar-sweetened beverages demand (Genç, et al., 2019). In contrast, some studies suggest that food taxes, as a stand-alone initiative to improve public health, are ineffective, and will fail (Caraher & Cowburn, 2006). In this study, the findings suggest that beneficial reductions in saturated fat are partly offset by unintended effects caused by the estimated cross-price elasticities of demand and, therefore, align with the result from Caraher and Cowburn (2006). In short, these unintended effects can be categorized into three categories, namely salt intake, polyunsaturated and monounsaturated intake, and serum cholesterol. If saturated fat intake reduces, polyunsaturates and monounsaturates intake also reduce, which simultaneously results in a drop in serum cholesterol. A decrease in serum cholesterol represents a undesirable health effect, as this increases the likelihood of ischaemic heart disease (IHD) and strokes. In addition, a sales tax on retail dairy milk could also cause a rise in salt intake among consumers who switch to almond milk and might overall result in depletion of public health rather than an improvement. It is unclear what the magnitude of this effect will be, as it depends on the cross-price elasticity between the subcategory items. In addition, increased salt intake also impacts the change in mortality from IHD and strokes, uncovering another averse consequence of a sales tax extension on retail dairy milk. In the case of almond milk, a trade-off between the reduction in the proportion of energy derived from saturated fat and a reduction in salt intake could, therefore, be observed. At last, the impact of blends on public health could not be considered, as no data on nutritious value was available for this subcategory, since the (average) proportion of dairy milk and plant-based is distinctive per stock-keeping unit (SKU) and has therefore not been defined yet (Aydar, et al., 2020).

4.2 Limitations

As an important note, it must be stressed that several limitations exist in this study in relation to the estimated own and cross-price elasticities, which mostly relate to the data. Initially, categories of plant-based milk and dairy milk could not be split by fat content, which would have been valuable in order to isolate the possible effect of a sales tax on dairy milk with saturated fats from plant-based milk drinks without or with less saturated fats. Yet, only one-tenth of the dairy milk sold in the Middle Atlantic division is (saturated) fat-free or fat-arm dairy milk. It is also important to acknowledge that a household expenditure questionnaire is not an optimal instrument to estimate individual consumption, as purchases of beverages in this analysis could be underreported because expenditures for out of home or outside of the household consumption are excluded. In the Middle Atlantic division, 43.6% of food consumption were away from home food expenditures, which were not taken into account when reviewing the effects of sales tax on dairy milk. Individual expenditures, particularly of dairy milk, may also be underreported given that the head of the household is responsible for filling out the survey for the entire household unit, therefore, individual purchases may not be included if the head of the household ignores them. In addition, estimations could be

biased if underreporting is differential, which ultimately depends on the prices faced by individual purchasers.

As Finkelstein et al. (2014) states, two potential sources of endogeneity can be acknowledged in the Linear Approximation of the Almost Ideal Demand System model, namely measurement error in prices and omitted variables. In the estimations, measurement error could arise from both the numerator and denominator of the unit value calculation, as prices were derived from information on (plant-based) milk beverage expenditures reported by point-of-sale data. In line with that, the seasonality of purchases was not considered, which could bias the price-elasticity estimations if the pattern of (plant-based) milk beverages consumption varies according to weather changes. In addition, omitted variables could also have biased the results, as the unit values could be correlated with unobservable variables that influence demand. Ideally, unit values could have been aggregated at a geographic level, however, information on geographical locations was limited to five syndicated major markets, namely Albany, Buffalo Rochester, New York, Philadelphia and Pittsburgh, and the Middle Atlantic division, and eXtended All Outlet Combined, which includes food and grocery, drug, mass merchandisers, Walmart, club and dollar stores, and military DECA, in the data set (Finkelstein et al., 2014).

In addition, the results of effects on public health of introducing sales tax on (saturated-rich) dairy milk should be interpreted cautiously, as the results only provide a rough guide to the magnitude of the effect of a sales tax on saturated fat and salt intake. In accordance with that, the effect of other nutrients on health, which are not well characterized, were not considered in this thesis. In addition, the study is conducted under the assumption that out of home dairy milk consumption would be unaffected by the proposed sales tax. Alternatively, the milk categories used in the model contain a wide range of products, and it may not be reasonable to assume that all products within each category will behave in the same way. Better targeting of taxation to smaller, more precise beverage categories could, therefore, yield significantly better results. And lastly, the relationships between price changes and changes in health have been captured, primarily through point-of-sale data. It must, however, be stressed that a variety of factors other than price influence an individual's purchase behaviour, including the palatability and accessibility of foods, perception of and knowledge about beverages, and these factors are not captured in price elasticity of demand. In a like manner, a variety of factors other than diet, such as age, sex and lifestyle factors, were not considered in this study.

As food-related diseases are increasingly becoming a widely spread social issue in the Middle Atlantic division, policymakers must take action to improve public health. As previously indicated, a tax is a recommended tool to reduce the demand for a good, however, the results of this thesis suggest that a simple sales tax extension on dairy milk on its own may not yield the desired public health improvements. As a result, other interventions, that have proven to be effective to prevent and reduce health risks, should be considered. In addition, more research is required to identify unintended cross-elasticity effects and changes across a range of nutrients associated with a dairy milk tax. In this way, governmental institutions can map what factors influence public health and act accordingly. Instead of solely focusing on consumer demand, other criteria, such as growing and production, could be taken into consideration and shed a sophisticated view on a sales tax extension. In the future, the earnings of a sales tax on dairy milk could possibly be reinvested in public health to cover some of the costs associated with prevention and treatment of food-related diseases.

5. Conclusion

In this thesis, the objective was to estimate the price elasticity of demand to predict the impact of pricing policies on public health in the Middle Atlantic division. In line with that, the own and cross-price elasticity estimates in this thesis provide essential information for policy design and evaluation to improve public health. In contrast to other available literature, this thesis adds to existing literature by providing a full view on own and cross-price elasticities of various retail (plant-based) milk categories in the Middle Atlantic division. In addition, the results expose the relationship between consumer demand, the retail price of plant-based milk, and public health.

In the first place, the results of own-price elasticity of demand indicate that the demand for milk beverages was estimated between -1.53 and -3.19 in the Middle Atlantic region. Across the various milk categories, the own-price elasticities were estimated to be elastic, which implies that the percent quantity decrease is greater than the percent price increase. If an extension of sales tax would fully pass on to retail dairy milk prices, the expectation would be that retail dairy milk demand decreases by 9.0%.

In accordance with that, the appropriate cross-price elasticity values suggest that a 5.2% sales tax extension on dairy milk would cause a demand increase between 0.47% and 1.51% for plant-based milk beverages and were estimated between 0.09 and 0.29. In particular, almond, soy, blends, and oat milk show strong substitutive behaviour towards dairy milk, as demand would increase between 1.0% and 1.5% as a result of the proposed 5.2% sales tax extension on retail dairy milk in the Middle Atlantic division. In practice, the actual demand increase would however depend on the degree to which the manufacturers absorb the price increase. In addition, substitution to other caloric beverages poses a risk that the reduction in calories is offset by increased consumption of calories in other food or beverage products.

In line with that, the expected health benefits from plant-based milk substitution for dairy milk are variable per plant-based milk type, but modest overall. In all instances, plant-based milk substitution would reduce saturated fat intake between 56% and 96%. In the same way, reduced saturated fats intake would reduce polyunsaturates and monounsaturates intake, which negatively impacts serum cholesterol and counters the health benefits achieved from a reduction in saturated fat intake. In addition, substitution of dairy milk for almond milk would result in a small rise in salt intake, which has an adverse effect on public health. In spite of that, plant-based milk offers superlative health benefits compared to dairy milk in terms of calorie count and sugar intake.

In conclusion, the impact of price elasticity of demand for plant-based milk on public health in the United States Middle Atlantic division is inadequate to justify a sales extension on dairy milk. In spite of the strong links that cross-price elasticity values show between the various milk categories, the public health benefits achieved from dairy milk replacement for plant-based milk are countered due to either increased salt intake, increased serum cholesterol levels, or decreased polyunsaturated and monounsaturated intake. In other words, stakeholders may utilize the estimated own and cross-price elasticities to optimize, redesign and evaluate policies and strategies, however, no clear evidence could be provided that public health improves by incentivizing plant-based milk through sales tax extension.

6. Recommendations

As indicated in the conclusion, the impact of price elasticity of demand for plant-based milk on public health in the United States Middle Atlantic division is inadequate to justify a sales extension on dairy milk, primarily because the factors that affect public health are highly interdependent. In contrast, the own and cross-price elasticities estimates suggest that demand for various milk categories is intertwined and provide useful insights and essential information for policy design and evaluation.

In the short term, governmental institutions could, therefore, utilize the estimated own and cross-price elasticity values to evaluate and potentially redesign policies in order to conclude whether the focus and objective of current policies are misplaced. In addition, businesses could use own and cross-price elasticity values to optimize pricing strategies.

In the long-term, governments could study unintended cross-elasticity effects and changes across a range of nutrients associated with a dairy milk tax. In a like matter, governmental institutions should explore how other interventions, that have proven to be effective to prevent and reduce health risks, could complement a sales tax extension. In practice, this may imply that a sales tax introduction could be considered alongside other policy initiatives, which can interface with growing, production, and consumption of healthier beverages.

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