Factors affecting beef and plant-based protein consumption

by

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Abstract

Alternative protein options have been gaining popularity, motivated by increasing concerns over environmental sustainability and animal welfare. The growth in plant-based protein consumption has led to questions about how these new products might affect the beef industry. Using survey data from the Meat Demand Monitor, I evaluate factors that affect the consumption of beef and plant-based proteins and project how changing demographics might affect future protein consumption. The results show that consumption of plant-based protein and beef are not exclusive from one another. Additionally, growth in plant-based proteins need not come at the expense of the beef industry. As the U.S. population increases, expanding protein demand allows room for both beef and plant-based protein consumption to grow.

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Chapter 1 - Introduction

Alternative options to traditional farm-raised meat have been on the market for some time now, but recent growth in the popularity and availability of plant-based proteins has given rise to concerns over how these new products may impact the beef industry. What started as simply plants and cereals that provide additional protein options has developed into analogues that are similar in look or taste of meat and even to highly advanced, 3-D printed steaks using plant-protein extracts. As the technology has developed, alternatives to meat have been able to more closely mimic the taste, texture and even nutritional profile of traditional meat using plant proteins or cell-cultured tissues. The development of such products has been motivated by concerns over environmental sustainability, human health and animal welfare.

Global demand for meat is growing rapidly from both an increase in population and rising income levels in developing countries. This growing meat demand has led consumers in developed countries to advocate for a reduction in animal meat consumption. The Eat-Lancet report published in 2019 recommends a diet described as healthy for consumers as well as the environment consisting of mostly plant derived foods or only moderate amounts of animal meat. The report calls for more than a 100 percent increase in foods from plants and a greater than 50 percent reduction in foods such as sugar and red meat (Willet et al., 2019). Additionally, according to Santo et al. (2020), “growing scientific consensus has established that substantial shifts towards plant-forward diets … are essential for meeting climate change mitigation targets.” Numerous sources are increasingly advocating for a reduction or elimination of traditional meat consumption.

However, a vegetarian lifestyle is not suitable for everyone. In the U.S. there are five times more former vegetarians/vegans than there are current vegetarians/vegans; a trend that may be attributed to genetic differences that affect the ability of an individual to metabolize nutrients and thrive on a diet without meat (Van Vliet, Kronberg and Provenza, 2020). In addition, Lusk and Norwood (2009) found that meat is the most valuable food group to the typical U.S. consumer. Therefore, giving up meat or even reducing meat consumption is no small task. Enter plant-based protein alternatives.

Plant-based proteins increasingly resemble traditional meat products in taste and texture. Many studies have shown that consumer acceptance of an alternative protein is higher when the product imitates traditional meat in taste and texture (for example, see Onwezen et al., 2021; Slade, 2018). Taste, texture and mouth feel are cited as some of the largest challenges for creating a successful alternative protein (Kyriakopoulou, Dekkers and Van der Groot, 2018). This focus on recreating the taste and texture of traditional meat highlights the reality that some people believe they should reduce meat consumption yet are unwilling to give up meat entirely. This is where meat analogues come in to provide consumers with some similar elements of true meat but with a product derived from plants.

In fact, the target markets for plant-based proteins are not vegetarians and vegans – consumers who have already given up meat – but rather omnivores and flexitarians. These are consumers who eat some meat but may be looking for ways to reduce meat consumption. Vegetarians and vegans could be drawn to these modern meat alternatives, but they make up only a small percentage of the consumers of plant-based proteins (Identity of Primary Plant-Based…, 2021). These new products seem to be designed more for consumers who don't want to give up the satisfaction they receive from consuming traditional meat products.

Some proponents of plant-based protein believe that alternative proteins will eventually make traditional animal-based meat obsolete. Pat Brown, CEO and founder of Impossible Foods says that their mission is to “reduce humanity’s destructive impact on the global environment by completely replacing the use of animals as a food production technology.” His efforts to accomplish this involve aiming to create a protein source made from plants that is delicious, nutritious and affordable (Brown, 2018).

The beef industry is often a target for plant-based proteins. This may be due to the fact that beef is generally seen as having the greatest negative impact on the environment compared to other animal products (Santo et al., 2020). Furthermore, many of the most popular plant-based products currently on the market imitate ground beef products, for example the Impossible Burger or Beyond Burger. Therefore, the beef industry could face detrimental ramifications from alternative protein products. However, many of the claims that predict rapidly shrinking beef demand are not well founded or supported by industry experts (Santo et al., 2020).

In a report to the Cattleman’s Beef Board, Tonsor, Lusk and Schroeder (2021) found that the current threat to the beef industry from plant-based proteins is small. Evaluating results from choice experiments, they found that plant-based burgers are currently weak substitutes for beef. They report that beef exceeds plant-based proteins in consumer perceptions of taste, appearance, price and naturalness; plant-based proteins scored highest on animal welfare, health and environmental concerns. However, if the price of plant-based proteins decreases and consumer perceptions of the product’s taste and appearance improve, plant-based burgers could become a stronger substitute and a greater threat for the beef industry (Tonsor, Lusk and Schroeder, 2021).

The purpose of this thesis is to evaluate factors that affect plant-based protein and beef consumption as well as how changing demographic characteristics of the U.S. population might affect future consumption of these proteins. Using survey data from the nation-wide Meat Demand Monitor (MDM), I first assess if socio-demographic characteristics affect plant-based protein and beef consumption. Initial inspection of the MDM data reveals that consuming plant-based proteins in the prior day did not necessarily indicate a complete absence of animal-derived proteins in the diet. A multinomial logistic model is conducted to evaluate this further, using the four possible combinations of plant-based protein and beef consumption as a dependent variable and self-reported socio-demographic characteristics as explanatory variables.

The results reveal that the characteristics which indicate the highest likelihood of having consumed both beef and plant-based at least once in the prior day include being male, being between the ages of 18 and 44, and having kids under 12. Higher education and higher income are also found to increase the likelihood of having consumed both proteins in the same day. Age is found to be one of the strongest predictors of protein consumption. Consumers over 65 are more likely to have eaten something other than beef or plant-based in the prior day whereas consumers under 44 are more likely to have eaten beef and/or plant-based.

After finding that certain demographic characteristics could affect plant-based and beef consumption, I evaluate how changes in the distribution of these characteristics could predict future consumption. I conduct a separate model using the most influential demographic characteristics for which population projections can be found. This second multinomial logistic model includes age, gender, race, ethnicity, geographic region and education as explanatory variables, again using the same categories of possible combinations of beef and plant-based consumption as the dependent variable.

These results show very little change in the percentage of consumers eating beef and plant-based proteins. The largest impact is a slight increase in the percentage of consumers eating something other than beef or plant-based protein. Although the percentage of consumers eating beef is shown to decline slightly, the U.S. population is projected to increase by even more. Thus, when taking into account the increase in population, the number of consumers eating beef is projected to increase, as is the number of consumers eating plant-based proteins. Plant-based protein consumption shows the largest relative increase in number of daily selections; however, it remains a small proportion of consumers, especially when compared to beef. The growth for plant-based proteins is likely to come from growth in the overall demand for protein rather than directly from beef demand. Thus, there is room for both proteins in the grand scheme of things.

The rest of this report is organized as such: Chapter 2 provides an overview and background of alternative protein products, specifically focusing on plant-based proteins. Chapter 3 presents and discusses a multinomial logistic model to evaluate characteristics that affect beef and plant-based consumption. Chapter 4 develops a separate multinomial model used to project beef and plant-based consumption in the future and discusses implications for the beef industry. Chapter 5 provides conclusions as well as recommendations for future research.

Chapter 2 - Background and Literature Review

2.1 Types of Alternative Proteins

There are numerous methods used to produce alternative proteins. Some have been around for decades; tofu and tempeh for example are soy-based meat replacements that are designed to have somewhat similar flavors and characteristics of traditional meat. However, due to their lack of certain meaty qualities, these alternatives have not been able to fully satisfy Western diets (Kyriakopoulou, Dekkers and Van der Groot, 2018). This is what partially drove the development of meat analogues: products that strive to imitate all aspects of traditional animal-based meat from taste to texture and even nutritional profile. These products may be plant-based, cell-based or fermentation-based.

Many meat alternatives are developed using proteins extracted from plants; these will be referred to as plant-based proteins hereafter in this report. The Beyond Burger uses protein from pea plants to develop the shape and texture of ground beef, adding beet juice to give the appearance of “bleeding.” The Impossible Burger uses a protein called heme, derived from genetically engineered yeast, which gives its burgers the traditional “meaty” flavor (Van Loo, Caputo and Lusk, 2020). Cell-cultured protein involves taking stem cells from an animal and growing muscle tissue in a culture medium. This technique essentially involves growing animal tissues outside of the animal (Green and Angadjivand, 2018). There are also techniques involving fungal fermentation to produce mycoproteins which can take the form of long fibers that replicate traditional meat textures (Sha and Xiong, 2020). While all of these products are still being developed, plant-based proteins are by far the furthest along and the most common on store shelves. Therefore, this research focuses mainly on plant-based proteins.

2.2 Plant-Based Protein Timeline

Attempts to make meat analogues that truly replicate traditional meat date back to 1975 when MorningStar Farms began experimenting with spinning plant-based proteins into fibers to better imitate meat-like texture. Beyond Meat was founded in 2009 by Ethan Brown, who developed a love for animals while visiting a family farm. Impossible Foods was founded in 2011 after founder Pat Brown decided something needed to be done about the environmental impact from animal meat production. Other notable plant-based foods companies include Good Catch Foods – a plant-based fish company, Gardein and Quorn. More recently, established food brands have begun developing their own plant-based protein products (Byington, 2021).

Plant-based proteins took massive strides during the early 2010's. Beyond Meat launched its chicken strips in 2012 and partnered with Don Lee Farms for production. The UK based company Quorn released a product in the U.S. in 2011. By 2016, Impossible Foods was able to release its first Impossible Burger at restaurants and the Beyond Burger became available in retail stores. The success of these new products was recognized by many familiar U.S. food giants who began to seize the opportunity to expand into the plant-based protein sector. Kraft Foods bought Boca Burger and redeveloped the product and brand, Tyson invested in Beyond Meat in 2016 and Nestlé acquired a plant-based food company in 2017. Since then, Purdue, Cargill and JBS have all entered the plant-based space as well (Byington, 2021).

Numerous companies have begun developing their own brands of plant-based protein products. In addition to agreeing to sell Impossible Burgers in May of 2020, Kroger has released its own line of pea-protein based meatless products (Sha and Xiong, 2020; Byington, 2021). Kellogg's has Incogmeato, Trader Joe's has "Protein Patties", and Nestlé has meatless versions of DiGiorno Pizza and Stouffer's Lasagna. Numerous fast food and food service chains have also begun serving alternative meat options. You can find meatless menu items at Burger King, KFC, Qdoba, Red Robin, Pizza Hut and Taco Bell (Sha and Xiong, 2020: Byington, 2021; CB Insights, 2020).

Looking forward, many stakeholders of plant-based proteins believe that the product will see rapid growth over the coming years. The Impossible Foods CEO, Pat Brown has indicated that he believes plant-based protein will completely replace traditional meat within the next 15 years and that after 20 years, animal meat will be totally obsolete (O'Connor, 2019). Impossible Foods' mission is to disrupt the meat industry and completely replace animals in the food system within the next two decades (O'Connor, 2019). Some analysts have predicted that the plant-based protein sector will grow by seven percent annually to 2023. Plant-based protein supporters hope they can compete with traditional meat in terms of taste, price and convenience, allowing them to displace traditional meat production by the end of the 21st century (Broad, 2019).

2.3 Consumer Acceptance and Market Share

Much of the previous research on plant-based proteins focuses on consumer acceptance of these new products and estimating their potential market shares. Estimates of current market shares vary between studies. When compared only to beef, Van Loo, Caputo and Lusk (2020) report that (conditional on choosing an option) 72% of survey participants would choose beef, 23% would choose a plant-based protein and 5% would choose cell-cultured protein. Similarly, Slade (2018) estimates that 21% would choose plant-based protein, 65% would choose beef, 11% would choose cell-cultured protein and 4% would choose none. Including several protein options in the choice mix, Tonsor (2020a) estimates a current retail market share for plant-based proteins at 3% while ground beef accounts for 24% of retail market share. Plant-based proteins remain a relatively small share of the market compared to beef.

In order for the market share to approach the goals of alternative protein producers, the product must first overcome many obstacles, including consumer preferences and price. In a systematic review of literature related to consumer acceptance of alternative proteins, Onwezen et al. (2021) found that health and taste were consistently high drivers of acceptance of alternative proteins. Slade (2018) found that the two strongest predictors for alternative meat consumption were concern for the environment and a belief that livestock negatively impact the environment. Similarly, Tonsor, Lusk and Schroeder (2021) found that consumers who select plant-based proteins are more concerned about animal welfare and the environment than consumers who chose animal-based proteins. Food curiosity was also found to increase consumers' willingness to buy alternative proteins, however it is unclear if these consumers will become repeat buyers (Hwang et al., 2020).

Many studies have also looked at how demographic characteristics explain the likelihood of a consumer accepting plant-based protein. Age, education, and gender were consistently found to be significant predictors of plant-based protein acceptance across studies. Young, higher educated consumers are more likely to consume plant-based proteins (Slade, 2018; Van Loo, Caputo and Lusk, 2020; Onwezen et al., 2021; Tonsor, Lusk and Schroeder, 2021). More politically liberal consumers also have higher acceptance of plant-based proteins (Onwezen et al., 2021; Bryant et al., 2019). Furthermore, vegetarians and vegans were found to have higher acceptance of plant-based protein than regular meat eaters (Van Loo, Caputo and Lusk, 2020; Onwezen et al., 2021; Slade, 2018). However, when compared to demographic characteristics, social and psychological characteristics were found to be much more relevant in predicting the acceptance of alternative proteins. For example, environmental concerns increased willingness to purchase alternative proteins whereas the belief that farming is important to society decreased the willingness to purchase simulated meat (Slade, 2018).

Numerous previous studies have explored the effect of gender on alterative protein consumption. Many studies found that males are more likely to eat plant-based proteins. One factor in this is that males are more willing to try novel foods; for instance, one study found that males are more likely to try foods with visible insects present, whereas women were more receptive to soy-based alternative proteins (Slade, 2018). In addition, women are found to be more likely to reduce meat consumption in general (Slade, 2018; Malek, Umberger and Goddard, 2019). Michel, Hartmann and Siegrist (2020) found that females respond more positively towards vegetarian or vegan diets. Both males and females hold similar perceptions of meat alternatives, but females associate traditional meat with animals and suffering whereas males associate traditional meat with taste and positive evaluation (Michel, Hartmann and Siegrist, 2020). Furthermore, meat eating is linked to masculinity whereas vegetarianism is seen as feminine (Rothgerber, 2013). Thus it may be that females are more willing to cut meat out of their diet and replace it with protein rich plant foods (beans, nuts, lentils etc.) whereas males would rather replace meat with a substitute that is similar to traditional meat.

Relatedly, one major barrier to plant-based protein consumption is the importance of meat in consumers' diets. Onwezen et al. (2021) found that consumers with lower meat-attachment were more likely to favor plant-based proteins. Consumers with higher meat-attachment were actually more receptive to cell-cultured protein than plant-based protein since cell-cultured protein looks more like traditional meat. Schosler, De Boer and Boersema (2011) found evidence of a strong hierarchy within the food industry where animal derived products are viewed as superior to plant foods. Western culture tends to place the highest symbolic value on animal-based meats and the lowest value on plant-based foods (Cole and Morgan, 2013). Consumers in China and India are more likely accept plant-based protein that consumers in the U.S. (Bryant et al., 2019). Because of meat's high importance in U.S. diets, there may be significant barriers to achieving the goals set by proponents of plant-based proteins.

2.4 Opportunities and Challenges for Plant-Based Proteins

One of the strongest positions in support of plant-based protein is its environmental footprint compared to traditional meat. Slade (2018) found that the two strongest predictors for alternative protein acceptance were concern about the environment and a belief that livestock negatively affect the environment. Conversely, Lang (2019) found that environmental sustainability was ranked in the last two of eleven benefits of meat alternatives. Regardless, environmental sustainability appears to be one of the top positioning strategies for plant-based producers and supporters.

Alternative protein supporters tend to target the beef industry because they see it as having a significant negative environmental impact. Compared to beef, plant-based proteins can cause 87 to 93% less greenhouse gas emissions and use 89 to 98% less land (Santo et al., 2020). Impossible Foods claims to use 96% less land, 87% less water and 89% less greenhouse gas emissions compared to beef production (Impossible Foods Cuts…, 2021). A life cycle assessment of the Beyond Burger found that it generates 90% less greenhouse gas emissions, uses 93% less land and requires 46% less energy than beef (Heller and Keoleian, 2018).

However, when accounting for amino acid content and nutrient density differences between plant-based protein and beef, Van Vliet, Kronberg and Provenza (2020) suggest that the carbon footprint for animal products is similar to plant foods because traditional meat contains much more readily available nutrients. In fact, beef raised on well managed pastures can have a negative carbon footprint. Livestock can graze lands that are unsuitable for crop production and turn grasses and forages into edible products for humans (Santo et al., 2020; Lusk and Norwood, 2009). Nonetheless, if alternative proteins did reduce demand for traditional meat, it could also reduce demand for land clearing in regions such as South America where deforestation is a leading cause of climate change (Santo et al., 2020). Therefore, environmental health is one of the most commonly advocated benefits of plant-based proteins.

Another stance for plant-based protein producers is nutritional benefits. Red meat has been shown in some studies to increase the risk of certain diseases such as heart disease, diabetes, stroke and cancer (Santo et al., 2020). However, it also provides readily available key nutrients. Some nutrients are more easily obtained from plant derived foods while other nutrients are more readily available from animal products (Santo et al., 2020; Van Vliet, Kronberg and Provenza, 2020). One of the greatest challenges for plant-based proteins is to replicate not only taste and texture, but also the nutritional content of traditional meat (Kyriakopoulou, Dekkers and Van der Groot, 2018). Plant-based products typically have higher levels of sodium than traditional meat, which creates the additional challenge of reducing sodium in these products (Sha and Xiong, 2020).

Replacing meat with plant-based proteins does not necessarily reflect a healthy diet. Dr. Frank Hu from the Harvard T.H. Chan School of Public Health said, “replacing a hamburger with a plant burger is not an improvement in diet quality if you chase it with French fries and a sugar-laden soda” (O’Connor, 2019). Van Vliet, Kronberg and Provenza, (2020) suggest that replacing some meat with plant-based protein is unlikely to negatively affect overall nutrition, however, plant-based proteins should be treated as an alternative for sensory characteristics rather than a true nutritional supplement for meat. An omnivorous diet with whole foods and sustainably produced meat is most likely to benefit both human and ecological health (Van Vliet, Kronberg and Provenza, 2020).

One of the obstacles preventing plant-based protein from supplanting traditional meat is the current premium pricing. Retail prices are higher for plant-based proteins than for comparable traditional meats. From the supply side, costs will have to decrease in order for plant-based products to take over more market share from traditional meat. At the farm level, inputs to plant-based proteins are relatively inexpensive (Rubio, Xiang and Kaplan, 2020). However, because of the amount of post-processing required for plant-based proteins, the retail prices are much higher than for traditional meat. Processing costs account for almost 95% of the retail price for plant-based proteins whereas they represent only 50% of retail costs of beef (Rubio, Xiang and Kaplan, 2020).

If these products can be produced at competitive prices, plant-based proteins could offset market share from animal sourced meats (Ismail et al., 2020). The prices of these products are already coming down. In February of 2021, Impossible Foods announced its second price cut of the year, lowering suggested grocery store prices by 20%. Their goal is to eventually lower the price enough to undercut traditional meat products (Impossible Foods Cuts…, 2021). If these products are found by consumers to be close substitutes for traditional meat, this could lead to a major shift in market shares. Consumers who eat meat regularly were found to have a relatively elastic demand for plant-based burgers, meaning that as prices of plant-based burgers decline these consumers may be more willing to increase their consumption of these products (Tonsor, Lusk and Schroeder, 2021). Slade (2018) found however that individuals with a stronger preference for alternative protein options tend to be less sensitive to price. Therefore, it remains to be seen if the price cuts will truly be effective in accomplishing the desired rapid increase in market share for plant-based proteins.

2.5 Implications for Agriculture and the Beef Industry

If plant-based proteins do continue growing and take over a large portion of the market share, what will it mean for the agriculture industry? Newton and Blaustein-Rejto (2021) describe some possible social and economic opportunities and challenges arising from alternative proteins. Growth in the market for plant-based proteins may create additional demand for certain crops that could be sources of plant-proteins for these products. In fact, demand for pea crops in the U.S. has grown in response to Beyond Meat demand growth. These new markets may provide more choices for farmers and rural producers to sell their crops. There also may be some opportunities for expanding the diversity of plant proteins used if the alternative protein market does grow (Newton and Blaustein-Rejto, 2021).

Perhaps the more pressing question relates to the implications for the beef industry. By one estimate, beef demand could drop as much as 80 to 90% by 2035 if alternative protein options become five times cheaper than existing animal proteins (Santo et al, 2020). This would have very drastic effects. Half of the 1.2 million jobs in the beef and dairy industry could be lost and farmland values could collapse by 40 to 80% (Santo et al., 2020). This would have significant impact on industries that rely on by-products from animal production. There would also be significant change in the workforce involved in protein production as it shifts towards more factory settings and potentially moves to more urban areas, negatively impacting rural economies that currently rely on agriculture. These economic shifts could have major well-being implications for farmers, a group who already struggle with poor mental health (Santo et al., 2020).

A drastic shift away from animal agriculture would affect laborers in all levels of the livestock supply chain, including feedlot workers, veterinarians, animal feed manufactures and more. Meat production is a value-added enterprise; eliminating it entirely as some predict would cause major hardships on all people involved. However, the fear that farmers will inevitably suffer economic and livelihood loss due to increasing alternative protein demand is not necessarily valid (Newton and Blaustein-Rejto, 2021). In their interviews with experts from all involved stakeholder groups, Newton and Blaustein-Rejto (2021) found that no expert thought it likely that animal agriculture would be completely displaced in the foreseeable future. In addition, current consumer preferences do not support the projected major demand changes, especially since whole muscle products such as steaks and roasts are currently only available from animal sources (Tonsor, Lusk and Schroeder, 2021). While it will be important for the beef industry to remain informed about the plant-based protein industry, the claims that alternative proteins will completely erase animal meat production are unlikely to come true any time soon.

Santo et al. (2020) suggest that traditional meat may eventually become a premium good. Alternative meats have so far focused on producing replicas of lower quality goods such as burgers, sausages and crumbles. Even if plant-based proteins do grow as fast as supporters would like to see, there will likely remain a market for traditional meats, especially with premium cuts (Santo et al., 2020). Additionally, alternative proteins will likely compete more with large-scale animal agriculture, so some traditional meat producers could differentiate themselves in the market as small or organic. In this case, these small farms may benefit more from competing against plant-based protein rather than against large-scale farms (Newton and Blaustein-Rejto, 2021).

Another possibility is that a large movement towards vegetarian diets may make traditional meat consumption more affordable compared to vegetarianism. Lusk and Norwood (2009) found that a shift towards vegetarianism would lower corn prices and that in turn would reduce the price of meat, decreasing the cost of non-vegetarian diets as well. Finally, alternative protein might simply meet a growing demand for overall protein, as total demand for protein is increasing faster than the growth of alternative protein production. Therefore, alternative protein options may simply represent an additional form of protein that will capture some of the growing demand rather than displacing demand for beef (Newton and Blaustein-Rejto, 2021). For example, in one study, Tonsor, Lusk and Schroeder (2021) found that some of the consumers who chose plant-based proteins would not have likely consumed much beef, therefore growth in plant-based demand does not necessarily require a reduction in beef demand.

One factor that may largely influence how plant-based proteins impact beef demand is labeling regulation. There has been much debate over labeling of these products, specifically over whether they can be labeled as meat. At least 25 states have some sort of legislation to limit the labeling of plant-based proteins and/or cell-cultured proteins (O'Connor, 2019). In 2019, Representative Roger Marshal introduced a bill in the U.S. House of Representatives that would require plant-based proteins to be labeled with the word "imitation" immediately preceding or following the name to the product (U.S. House, 2019). Any labeling regulations stand to have a significant impact on consumer acceptance of these products in the US.

While there seems to be much contention between beef producers and plant-based protein producers, working cooperatively between the industries may represent an important opportunity. There are already products which blend plant foods with traditional meat. Consumers have a relatively high acceptance of blending ground beef with mushrooms as meat extenders. The most preferred format for blended meats tends to be burgers (Lang, 2019). If blending hybrid products of plant-based proteins and traditional meat brings the prices down, the total demand for both products could increase. Therefore, if the price of plant-based products does decrease rapidly and consumers are accepting of blended products, the beef industry may benefit from developing blended, hybrid products. This would appeal to consumers who want to reduce meat consumption but are not willing to entirely give up the benefits of traditional meat.

Another consideration in this scenario is whether alternative proteins could replace some imports in the production of ground beef. Ground beef is usually produced by combining 50/50 lean trimmings (trimmings that consist of 50% lean and 50% fat) with 90/10 trimmings to reach the desired final fat content. The U.S. beef industry is more efficient at producing high quality, grain fed, fat cattle that result in high grading steaks and roasts and 50/50 trimmings. Other countries have a comparative advantage in producing lean beef, thus a majority of the 90/10 trimmings needed to fill the U.S. ground beef demand are imported. This diversification and specialization is the reason that the U.S. is both a major importer and exporter of beef (Elam, 2003). Alternative proteins may present an opportunity to replace some imports and use domestically produced lean protein to mix with 50/50 trimmings and produce ground products. The technology to produce processed or ground products from alternative protein is further along in development than the production of whole muscle cuts like steaks, so there is certainly a potential to combine plant-based protein and traditional beef into a ground beef product (Saavoss, 2019). Since some countries do not have the same environmental regulations as the US, reducing imports of ground beef may have a higher impact on environmental sustainability than reducing demand for well managed U.S. cattle that can have a negative carbon footprint.

Chapter 3 - Modeling Characteristics of Beef and Plant-Based Protein Consumers

3.1 Motivation

Plant-based protein alternatives have seen growing popularity in recent years. The Meat Demand Monitor tracks U.S. consumer demand for several types of proteins through a monthly survey. After evaluating the survey data, it became apparent that some consumers indicated eating both beef and plant-based proteins in the prior day. In some ways this seems contrary to the tone expressed by the media as well as stakeholders in both industries. Some sources make it seem like consuming any plant-based protein would indicate a complete absence of traditional meat – including beef – from the diet. Therefore, in this section I present and discuss a model to evaluate factors that affect the probability of having consumed beef and/or plant-based protein in the prior day, using survey data from the Meat Demand Monitor.

3.2 Data and Methods

3.2.1 About the Meat Demand Monitor Survey

The Meat Demand Monitor is a project developed by Kansas State University in partnership with the beef and pork checkoffs. It includes a monthly, nation-wide, online survey which began in February 2020 and collects around 2,300 responses per month. The data is collected with the intention of representing the U.S. population in distribution of age, gender, educational attainment, geographic region, household income and race-ethnicity (Tonsor, 2020b). One part of the survey focuses on the participant’s prior day meals, asking about where the meals were consumed and what proteins were included. Another part of the survey is set up as a choice experiment to evaluate consumer willingness to pay for different types of proteins. In addition, the survey contains questions about participants' meat consumption habits, including values they consider when purchasing proteins, what type of diet they typically follow (i.e. vegan, vegetarian, etc.) and knowledge of issues within the meat industry (Tonsor, 2020c).

This research focuses on the prior day recall portion of the survey. Participants were asked to recall where they consumed each of the three main meals during the previous day: at home, away from home or neither. The survey then asks which proteins were included in each of the three meals. The options include beef, chicken, pork, fish/seafood, alternative proteins and other or no protein. Definitions are given for each of the protein type options. Alternative protein is defined in the survey as "foods, not derived from live animals that have been developed to be eaten in a meal for protein" (Tonsor, 2020b).

After a participant indicates which types of proteins were included in each meal, the survey follows up by asking about which specific products of that protein were included. For instance, a participant who indicated eating alternative proteins during the prior day is asked which type of alternative proteins they consumed; some of the options include plant-based patties, plant-based crumbs, beans, tofu, nuts, seeds, eggs, etc. A participant who indicated eating beef during the prior day would be asked to choose from options such as ribeye steak, ground beef/hamburger, roast, deli sliced beef, BBQ beef, etc. (Tonsor, 2020c).

3.2.2 Data Summary

One full year of survey data spanning from February 2020 to January 2021 was used in this study. The data is available on Kansas State University's AgManager website. Observations were dropped if participants were under 18 years of age or responded that they are not typically involved in grocery shopping. Additionally, observations were excluded if respondents failed a speed check question or admitted that some answers may be untruthful in a self-assessment question at the conclusion of the survey. Finally, observations were dropped if they indicated not residing in the United States. The final number of observations included in the analysis was 24,708. A table with a summary of demographic characteristics of survey respondents is included in the appendix.

To address the question of how plant-based proteins might impact the beef industry, the first step in analysis was to evaluate how many participants indicated eating beef and how many ate plant-based proteins in the prior day. I started at the broadest level, evaluating how many prior day meals included beef or alternative proteins. Figure 3-1 shows how many times beef and alternative proteins were included in each of the three meals. A main factor behind the large amount of breakfasts including alternative proteins is that eggs were listed as an alternative protein source. Because this research is primarily interested in evaluating non-animal derived proteins, I narrowed in more closely on participants specifically indicating having eaten plant-based patties or plant-based crumbs.

Figure 3-1: Prior Day Meals Containing Beef and Alternative Proteins

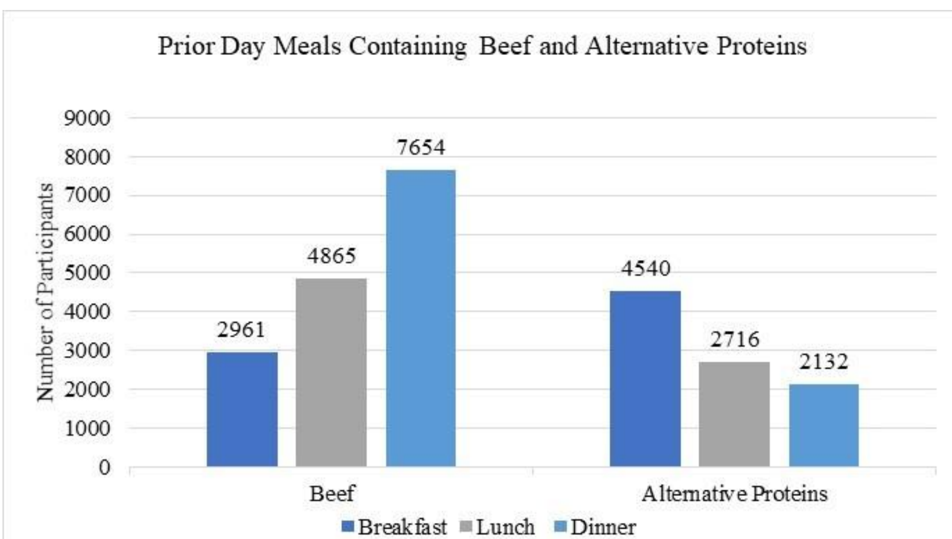
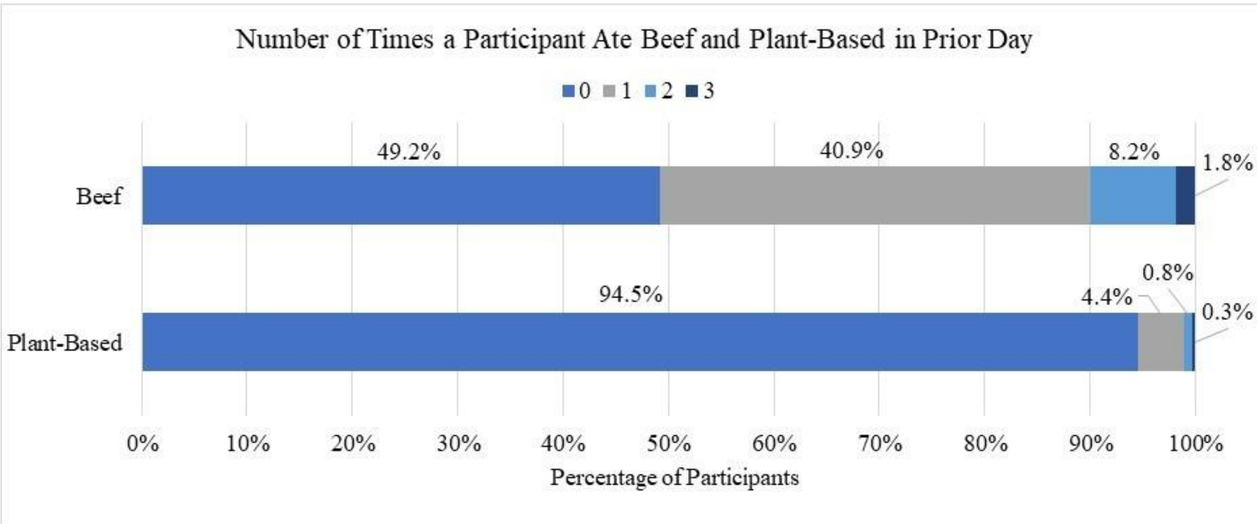


Figure 3-2 shows the number of times participants indicated eating beef and plant-based proteins in the prior day. Just over 5% of all respondents indicated consuming plant-based proteins at least once during the previous day. Over half of the participants indicated eating beef at least once during the prior day. This indicates that plant-based proteins still only account for a small share of protein consumption, especially when compared to beef.

Figure 3-2: Number of Times a Participant ate Beef or Plant-Based in Prior Day



Perhaps a more interesting insight comes from evaluating beef and plant-based consumption together. Of the 5% of respondents who indicated eating plant-based proteins, 53% indicated also eating beef during the prior day. In other words, 3% of all observations indicated eating both beef and plant-based proteins during the previous day. One major insight from this is that beef and plant-based consumption are not necessarily exclusive of each other. In fact, there were slightly more participants who ate *both* beef and plant-based than those who ate plant-based protein and not beef. In the following section, I develop a model to evaluate whether certain characteristics can affect the probability of someone eating beef and plant-based proteins.

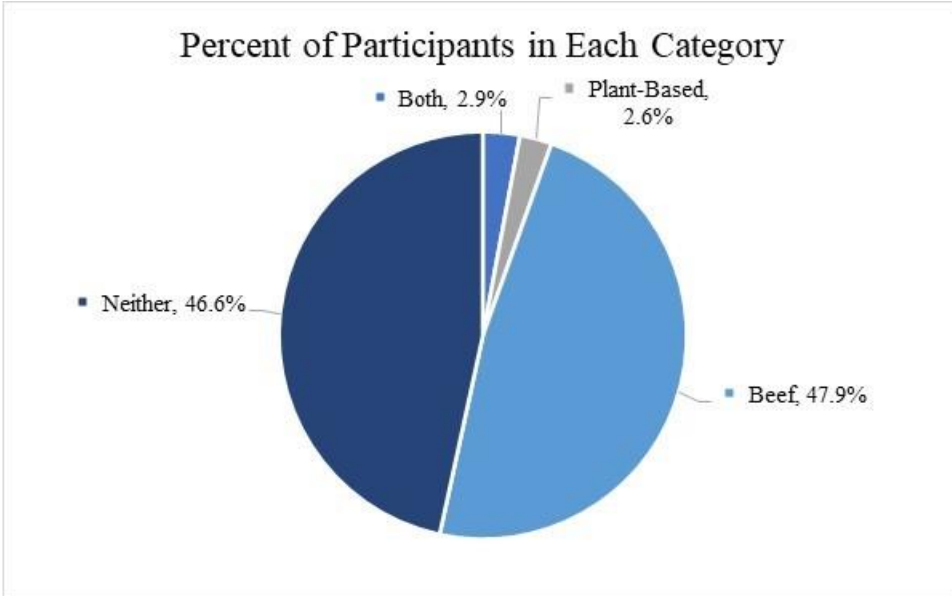
3.2.3 Prior Day Multinomial Logistic (MNL) Model Description

The first question of interest analyzed with this data is whether self-reported socio-demographic characteristics had an effect on the likelihood of having consumed plant-based proteins and/or beef in the prior day. To evaluate this, I adopt a multinomial logistic (MNL) model using the four possible combinations of beef and plant-based consumption as the dependent variable. Observations were split into four categories based on what they indicated in the prior day's meals:

1. Ate both plant-based protein and beef (referred to as both)
2. Ate plant-based protein and no beef (referred to as plant-based)
3. Ate beef and no plant-based protein (referred to as beef)
4. Ate neither beef nor plant-based protein (referred to as neither)

Figure 3-3 presents a summary of the four categories used as outcomes for the multinomial model. About 3% of respondents indicated eating both proteins at least once within the three meals during the previous day. Almost half of consumers indicated eating beef but not plant-based proteins at least once in the prior day. Less than 3% indicated eating plant-based proteins and not beef. Finally, 46% indicated eating something other than beef or plant-based proteins (neither). This "neither" category contains all other protein options, including chicken, pork, fish/seafood, alternative proteins other than plant-based patties or plant-based crumbs and other proteins.

Figure 3-3: Percent of Participants Indicating each Combination of Beef or Plant-Based



The assumption of a multinomial logistic model is that the outcome categories are not ordered; for instance, "both" has no ordinal meaning relative to "plant-based." A multinomial logistic regression models the probability of a respondent indicating each of the 4 categories. Given X_i as a vector of independent variables, the conditional probability of observing outcome j can be expressed as:

$$\Pr(Y = j \mid X_i) = \frac{e^{X_i \beta_j}}{\sum_{k=1}^{4} e^{X_i \beta_j}} \tag{1}$$

where β_j is the coefficient matrix specific to output j. The exponential of $X_i \beta_j$ is used to ensure non-negativity and dividing by $\sum_{k=1}^{4} e^{X_i \beta_j}$ ensures the probabilities sum to 1 (Fan, Kane and Haile, 2015). In order to estimate a unique set of parameters that generate these probabilities, one outcome must be set as a constant or base. In this case, I use the "neither" category as the constant, setting $\beta_4 = 0$. Therefore, the probabilities for each outcome can be expressed:

$$\Pr(Y = "neither" \mid X_i) = \frac{1}{1 + \sum_{k=1}^{3} e^{X_i \beta_j}} \tag{2}$$

and

$$\Pr(Y = j \mid X_i) = \frac{e^{X_i \beta_j}}{1 + \sum_{k=1}^{3} e^{X_i \beta_j}} \tag{3}$$

where *j* can now take on outcomes both, beef, or plant-based. A multinomial logistic model essentially estimates a series of binomial logistic models by comparing each of the other outcomes to the base outcome. Using the general form of a multinomial logistic model proposed by Hutcheson and Moutinho (2008), the final model estimates 3 equations:

$$\ln\left(\frac{\Pr(Y=both)}{\Pr(Y=neither)}\right) = \alpha^1 + b_1^1 x_1^1 + b_2^1 x_2^1 + b_3^1 x_3^1 + \cdots + b_{18}^1 x_{18}^1 \tag{4}$$

$$\ln\left(\frac{\Pr(Y=plant-based)}{\Pr(Y=neither)}\right) = \alpha^2 + b_1^2 x_1^2 + b_2^2 x_2^2 + b_3^2 x_3^2 + \cdots + b_{18}^2 x_{18}^2 \tag{5}$$

and

$$\ln\left(\frac{\Pr(Y=beef)}{\Pr(Y=neither)}\right) = \alpha^3 + b_1^3 x_1^3 + b_2^3 x_2^3 + b_3^3 x_3^3 + \cdots + b_{18}^3 x_{18}^3 \tag{6}$$

where b_i^j is the coefficient for variable *i* in model *j* and α^j is a constant for model *j*. Descriptions for x_i^j are listed in Table 3-1. Age, region, income, race and political party are categorical variables, therefore one level is omitted. For example, Midwest is omitted from region, so results are interpreted for each other region relative to the Midwest. All other variables are binomial variables and thus similarly interpreted relative to the omitted case.

Table 3-1: Variables Included in Prior Day Protein MNL Model

Variable	Description
x_1^j	1 if age = 45 to 64, 0 otherwise
x_2^j	1 if age = 65 or over, 0 otherwise
x_3^j	1 if male, 0 otherwise
x_4^j	1 if region = Northeast, 0 otherwise
x_5^j	1 if region = South, 0 otherwise
x_6^j	1 if region = West, 0 otherwise
x_7^j	1 if 4-year degree or higher, 0 otherwise
x_8^j	1 if income = $60,000 to $100,000, 0 otherwise
x_9^j	1 if income = over $100,000, 0 otherwise
x_{10}^j	1 if race = Black/African American, 0 otherwise
x_{11}^j	1 if race = any other race, 0 otherwise
x_{12}^j	1 if Hispanic, Spanish or Latino origin, 0 otherwise
x_{13}^j	1 if no kids, 0 otherwise
x_{14}^j	1 if married, 0 otherwise
x_{15}^j	1 if political party = Democratic, 0 otherwise
x_{16}^j	1 if political party = Other, 0 otherwise
x_{17}^j	1 if no farm experience, 0 otherwise
x_{18}^j	1 if indicated eating out, 0 otherwise

Notes: Age and Region are consistent with U.S. Census Bureau groupings; variable for Hispanic, Latino or Spanish origin is included separate from race following U.S. Census Bureau.

It is important to note that the four outcomes used in the MNL model simply indicate whether or not a participant ate beef and/or plant-based protein in the prior day. This does not allow for evaluation of different volumes of beef or plant-based protein consumption. For instance, the model does not differentiate between a participant that indicated eating beef in all three meals during the prior day versus one who only ate beef for one meal; nor does it differentiate between participants who may have eaten a higher quantity of each protein in a given meal. Furthermore, evaluating beef in general does not differentiate between consumers who ate whole-muscle cuts like steaks or roast and those who ate processed products like burgers or sausages. These factors do not detract from the overall implications of the model but are nonetheless important to consider when evaluating the results presented in the next section.

3.3 Results and Discussion

The coefficients from the model are presented in Appendix Table A-2. Each coefficient represents the change in the relative log odds for each combination of beef and/or plant-based as compared to the "neither" category. A positive (negative) coefficient indicates that the variable increases (decreases) the probability of observing that outcome relative to the base outcome. Since all variables in the model are either binomial or categorical, they are interpreted relative to the omitted case for that variable. Reporting the results with margins can aid in interpretation. Table 3-2 presents the marginal effects for each variable on each of the four outcomes. The marginal effects are interpreted relative to the omitted or base case for each variable.

Table 3-2: Marginal Effects of Prior Day Protein Model

Variable		**Both**	**Plant-Based**	**Beef**	**Neither**
Age *(Base = 18 to 44 Years)*					
	45 to 64 Years	-0.029***	-0.004	-0.067***	0.100***
		(0.003)	(0.003)	(0.009)	(0.009)
	65+ Years	-0.039***	-0.011***	-0.076***	0.126***
		(0.003)	(0.003)	(0.010)	(0.010)
Gender *(Base = Female)*					
	Male	0.017***	-0.006**	0.088***	-0.099***
		(0.002)	(0.002)	(0.006)	(0.006)
Region *(Base = Midwest)*					
	Northeast	0.007*	0.007*	-0.055***	0.041***
		(0.003)	(0.003)	(0.010)	(0.010)
	South	0.010***	0.002	-0.025**	0.013
		(0.003)	(0.003)	(0.009)	(0.008)
	West	0.008**	0.008*	-0.030**	0.015
		(0.003)	(0.003)	(0.010)	(0.010)

Variable	Both	Plant-Based	Beef	Neither
Education *(Base = Less than 4 Year Degree)*				
4 Year Degree or Higher	0.013***	0.010***	-0.068***	0.045***
	(0.003)	(0.002)	(0.007)	(0.007)
Household Income *(Base = Under 60,000)*				
60,000 to 100,000	0.008**	0.002	-0.026**	0.016*
	(0.003)	(0.003)	(0.008)	(0.008)
Over 100,000	0.012***	0.005	-0.014	-0.003
	(0.003)	(0.003)	(0.010)	(0.010)
Race *(Base = White)*				
Black/African American	0.009**	-0.006	-0.005	0.001
	(0.003)	(0.003)	(0.011)	(0.010)
Other	-0.001	0.009**	-0.018	0.009
	(0.003)	(0.004)	(0.010)	(0.010)
Ethnicity *(Base = Not Hispanic)*				
Hispanic, Latino or Spanish Origin	-0.003	0.006	0.019	-0.022*
	(0.003)	(0.003)	(0.010)	(0.010)
Political Party *(Base = Republican)*				
Democratic	-0.001	0.014***	-0.020*	0.007
	(0.003)	(0.002)	(0.008)	(0.008)
Other	-0.008**	0.006**	-0.046***	0.048***
	(0.003)	(0.002)	(0.008)	(0.008)
Marital Status *(Base = Not Married)*				
Married	0.001	-0.004	0.034***	-0.031***
	(0.003)	(0.002)	(0.007)	(0.007)
Kids *(Base = Kids Under 12)*				
No Kids Under 12	-0.021***	0.006*	-0.049***	0.064***
	(0.003)	(0.003)	(0.010)	(0.010)
Farm Experience *(Base = Farm Experience)*				
No Farm Experience	-0.003	0.002	-0.040***	0.042***
	(0.003)	(0.003)	(0.009)	(0.009)
Dining Out *(Base = Did not eat out)*				
Ate Out	0.025***	-0.000	0.122***	-0.147***
	(0.002)	(0.002)	(0.007)	(0.007)

Notes: Observations: 23,956
Standard errors in parentheses. Significance: * p<0.05, **p<0.01, ***p<0.001

The age variable had the greatest impact on prior day protein consumption. Comparted to those between 18 to 44-years old, participants over 44 years old were less likely to consume beef and/or plant-based proteins. Participants in the older age groups were much more likely to have eaten something other than beef or plant-based proteins. Other variables which showed significant impacts on the probabilities of prior day protein consumption were gender, education, household income, having kids under 12 in the household and having eaten away from home during the prior day.

Another helpful method of interpretation comes by using the model coefficients to calculate predictive probabilities. Table 3-2 presents the predictive probabilities for each variable and outcome category. These results are the average predicted probabilities calculated over the entire sample for each variable. For an example interpretation, assuming that the population were distributed exactly the same as the survey sample, except that instead everyone was 18 to 44 years old, 5% would have consumed both plant-based protein and beef in the prior day, 3% would have consumed plant-based protein and no beef, 53% would have consumed beef and no plant-based protein and 39% would have consumed neither. Alternatively, if everyone were over 65 years (but the distributions of all other variables remained identical to the survey), 52% would have eaten something other than beef or plant-based protein.

Table 3-3: Predictive Probabilities for Prior Day Protein MNL Model

Variable	Both	Plant-Based	Beef	Neither
Age				
18 to 44 Years	0.045	0.031	0.531	0.393
45 to 64 Years	0.016	0.026	0.465	0.493
65+ Years	0.006	0.020	0.455	0.519
Gender				
Male	0.037	0.023	0.527	0.413
Female	0.020	0.029	0.439	0.512
Region				
Northeast	0.028	0.029	0.451	0.492
Midwest	0.022	0.022	0.506	0.450
South	0.032	0.024	0.481	0.464
West	0.030	0.029	0.475	0.465
Education				
Less than 4 Year Degree	0.023	0.022	0.504	0.451
4 Year Degree or Higher	0.036	0.032	0.436	0.496
Household Income				
Under 60,000	0.024	0.024	0.489	0.463
60,000 to 100,000	0.032	0.026	0.463	0.478
Over 100,000	0.035	0.030	0.475	0.460
Race				
White	0.028	0.025	0.482	0.465
Black/African American	0.037	0.019	0.478	0.466
Other	0.027	0.035	0.464	0.474
Ethnicity				
Not Hispanic	0.030	0.025	0.477	0.468
Hispanic, Latino or Spanish Origin	0.027	0.030	0.496	0.446
Political Party				
Democratic	0.031	0.032	0.481	0.456
Republican	0.031	0.018	0.501	0.449
Other	0.023	0.025	0.455	0.497
Marital Status				
Not Married	0.028	0.028	0.463	0.481
Married	0.030	0.024	0.496	0.450

Variable	Both	Plant-Based	Beef	Neither
Kids				
Kids Under 12	0.042	0.021	0.524	0.413
No Kids Under 12	0.021	0.027	0.474	0.477
Farm Experience				
Farm Experience	0.032	0.024	0.514	0.430
No Farm Experience	0.028	0.026	0.474	0.472
Dining Out				
Only Home/Skipped	0.015	0.026	0.443	0.516
Ate Out	0.041	0.026	0.565	0.369
Overall Margin	0.029	0.026	0.479	0.466

Notes: Observations: 23,956
All values are significant at the 99.9% confidence level.
Average predictive probabilities for each variable across all observations. Overall margin is average predicted probabilities for each category over all observations.

Knowing from the coefficients that age is one of the strongest predictors of protein consumption, we can use the predictive probabilities to aid in pulling apart differences between protein categories. Consumers over 65 years are least likely to have eaten plant-based proteins and also least likely to have eaten beef. Younger consumers are much more likely to have eaten plant-based proteins and also more likely to have eaten beef. As discussed above, beef and plant-based protein are not exclusive of each other. Younger consumers seem especially willing to consume both proteins and therefore remain a very important market for both beef and plant-based proteins.

Males are much more likely to have consumed beef and females are much more likely to have consumed something other than beef or plant-based (neither). However, males are significantly more likely than females to have consumed both proteins. The predictive probabilities show a slightly higher likelihood of females consuming plant-based proteins. Many previous studies found that males were more willing to try plant-based proteins than females.

Here however, we see that females are more likely to have consumed plant-based protein alone (without beef) whereas males are more likely to have eaten both proteins. This supports the idea that males are less willing to give up meat consumption than females, however they may be willing to replace some traditional meat with meat analogues.

The characteristics that indicate the highest probabilities of someone eating both plant-based proteins and beef are being 18 to 44-years old, being male, having a 4-year degree or higher, having an income over $100,000, being black/African American and having kids under 12. Being young, male and having kids under 12 also represented the highest probabilities of having consumed beef as well as the lowest probabilities of having consumed neither protein. These three characteristics indicate the consumers who are most willing to throw both beef and plant-based proteins into their shopping carts. Therefore, this will remain a very important market segment for both industries.

For plant-based proteins, the characteristics indicating the highest probabilities of prior day consumption include having a four-year degree or higher, affiliating with the Democratic party, being any race other than white or black/African American and being 18 to 44-years old. The characteristics indicating the least likelihood of having consumed plant-based proteins are being over 65 years old, being black/African American and affiliating with the Republican party. This is also consistent with previous literature. Higher educated, liberal consumers of a minority race represent an important market for plant-based proteins.

During the survey, participants were asked if they ate their prior day meals at home or away from home. When included in the model, this factor shows a very strong, positive impact on the likelihood of eating plant-based protein, beef or both. This may suggest a social component of consuming beef and/or plant-based proteins. However, since the survey was conducted during the COVID-19 pandemic, there was a major shift in food service consumption habits. Therefore, more research would be needed to clearly evaluate the impact on plant-based protein consumption in at-home meals versus food service meals.

In summary, there are consumers who, between the three main meals in a given day, consume both beef and plant-based proteins. Being young, male and having kids under 12 at home represent the highest probabilities of this occurrence. In addition, higher education and higher income increase the probability of consuming both proteins in the same day. Age is the strongest predictor of the likelihood of having consumed each type of protein in the prior day; consumers under 44 years old are more likely to have consumed beef and/or plant-based and consumers over 65 years are more likely to have consumed something other than beef or plant-based.

The model reveals how socio-demographic characteristics affect beef and plant-based consumption. Other than the fact that the proteins are sometimes consumed together, this model does not say much about how plant-based proteins impact the beef industry. However, demographic characteristics of a population are not static, that is, these characteristics will change over time. In fact, it is not difficult to find predictions of how these characteristics will shift in future years. How might these predicted changes affect the probabilities of consuming beef and plant-based proteins in the future? The next section develops a separate model to estimate future predictive probabilities based on the projected changes in demographic characteristics within the U.S. population.

Chapter 4 - Projecting Future Beef and Plant-Based Consumption

4.1 Motivation

If socio-demographic characteristics can predict the probabilities of a person having consumed plant-based protein or beef in the prior day, how might projected changes in the distribution of these characteristics affect the predicted percentages of people consuming these proteins in the future? The U.S. population is aging. Certain states and regions are projected to see more population growth than others. Educational attainment has been increasing consistently over the last few decades and will likely continue to do so. As these factors change, one could also imagine that the likelihood of consuming beef and plant-based protein would also change. To analyze this, I estimate a new model and calculate predicted probabilities for beef and plant-based protein consumption, setting the distribution of demographic characteristics to projected future levels.

4.2 Data and Methods

4.2.1 Projection Estimates

The first step was to gather estimates for how demographic characteristics of the U.S. population will change in the future. The 2017 U.S. Census Bureau Population Projections provide future predictions for age, gender, race and ethnicity in the U.S. population from the year 2020 to 2060. The University of Virginia Weldon Cooper Center provides forecasts for individual state population growth that are used to develop population projections by region. Because education is a strong predictor of plant-based protein and beef demand, it is also included in the projection model. Assuming trends in education continue as they have over the past 20 years, an estimated 4.2 percentage point increase in the percentage of people with a four-year degree or higher by 2030 is used (McElrath and Martin, 2021). These projected distributions and changes are summarized in Table 4-1.

Table 4-1: Estimated Changes in U.S. Population Demographics

		2020	2030	Change
Age				
	18-44	46.1%	44.7%	-1.36
	45-64	32.2%	29.1%	-3.14
	65+	21.7%	26.2%	+4.51
Gender				
	Male	49.3%	49.3%	+0.06
	Female	50.7%	50.7%	-0.06
Region				
	Northeast	17.1%	16.3%	-0.81
	Midwest	20.7%	19.6%	-1.02
	South	38.3%	39.5%	+1.20
	West	23.9%	24.6%	+0.66
Education				
	Less than 4-year degree	66.7%	62.5%	-4.20
	4-year degree or higher	33.3%	37.5%	+4.20
Race				
	White	76.14%	74.2%	-1.95
	Black/African American	13.45%	13.8%	+0.35
	Other Race	10.41%	12.0%	+1.60
Ethnicity				
	Hispanic, Latino or Spanish	18.7%	21.0%	+2.27
	Not Hispanic	81.3%	79.0%	-2.27

Notes: Age, gender, race, ethnicity based on U.S. Census Bureau Population Projections available at: https://www.census.gov. Education projection based on past trends in education, see McElrath & Martin (2021). Region projections based on University of Virginia Weldon Cooper Center available at https://demographics.coopercenter.org/national-population-projections. Age is percentage of population 18 and over.

The goal was to evaluate how the percentage and number of daily selections in each of the four categories of beef and plant-based protein consumption would change with shifts in the distribution of demographic characteristics of the U.S. population. Each source used for population projections estimated levels for both 2020 and 2030, therefore I used both years to provide for comparisons. Using estimated 2020 distributions instead of current survey distributions for comparison more accurately reflected the predicted changes that were estimated in the population projections.

4.2.2 Protein Projection Multinomial Logistic (MNL) Model Description

Using the same four outcome categories for beef and plant-based protein consumption as in Chapter 3, a similar multinomial logistic model was developed using the variables for which projected changes in distributions could be obtained. The multinomial model can be expressed as:

$$\ln\left(\frac{Pr(Y=j)}{Pr(Y=neither)}\right) = \beta_j X \tag{7}$$

where j is one of the three outcomes: "both" "plant-based" or "beef"; β_j is a vector of coefficients specific to outcome j and X is the vector of explanatory variables. The list of variables is presented in Table 4-2. The model is estimated using the same set of MDM survey data discussed above.

Table 4-2: Variables Included in Protein Projection MNL Model

	List of Variables included in the MNL model:
x_1	1 if age = 45 to 64, 0 otherwise
x_2	1 if age = 65 or over, 0 otherwise
x_3	1 if male, 0 otherwise
x_4	1 if region = Northeast, 0 otherwise
x_5	1 if region = South, 0 otherwise
x_6	1 if region = West, 0 otherwise
x_7	1 if 4-year degree or higher, 0 otherwise
x_8	1 if race = Black/African American, 0 otherwise
x_9	1 if race = any other race, 0 otherwise
x_{10}	1 if Hispanic, Spanish or Latino origin, 0 otherwise

Notes: Age and Region are consistent with U.S. Census Bureau groupings; variable for Hispanic, Latino or Spanish origin is included separate from race following U.S. Census Bureau.

Once the multinomial logistic model was fit, it could be used to estimate predicted probabilities for each of the outcomes. I estimate adjusted predicted probabilities, setting the independent variables to specified values. The values used are the estimates of future distributions of demographic characteristics discussed above and presented in Table 4-1. Predicted probabilities for each outcome category are estimated for both 2020 and 2030. The resulting predicted probabilities can reflect a percentage of daily selections in each outcome category for each year. “Daily selections” refers to the number of consumers choosing to eat beef and/or plant-based at least once in a given day. Because the number of daily selections grows with the national population, I applied these percentages to estimated national population levels for 2020 and 2030. This provides an estimated number of consumers in each category.

Once again, it is important to note that the model is only able to predict changes to daily selections, or the number of consumers selecting beef and/or plant-based at least once in a day.

This does not account for changes in the number of times within a day that consumers choose each protein. It also does not account for differences in the quantity of each protein included in a meal. Although these factors certainly have implications for future protein demand, the general conclusions from this model remain relevant as an overall idea of how beef and plant-based protein consumption may change with the changing demographics.

4.3 Results and Discussion

Coefficients for this model are reported in the appendix. The marginal effects of each variable for all four categories are presented in Table 4-3. Marginal effects are the change in the probability of observing each outcome relative to the omitted or base case for each variable. For example, being 45 to 64 years old decreases the probability of having consumed both plant-based and beef by 4.4 percent compared to being 18 to 44 years old. Living in the Midwest increases the probability of having consumed beef relative to all other regions since there is a significant, negative marginal effect for all other regions.

Comparing the reported marginal effects in Table 4-3 and the demographic changes in Table 4-1, we can anticipate potential ways in which daily selections of plant-based protein and beef may change in the future. For example, there is an estimated 4.5% increase in the percentage of the population over 65. Compared to the youngest age group, being over 65 increases the likelihood of consuming something other than beef or plant-based protein (neither). Therefore, the aging population could drive an increase in the number of daily selections that do not include either plant-based protein or beef.

Table 4-3: Marginal Effects from Protein Projection MNL Model

Variable	Both	Plant-Based	Beef	Neither
Age *(Base = 18 to 44 Years)*				
45 to 64 Years	-0.052***	-0.003	-0.101***	0.156***
	(0.003)	(0.003)	(0.008)	(0.008)
65+ Years	-0.061***	-0.009***	-0.126***	0.196***
	(0.003)	(0.003)	(0.009)	(0.009)
Gender *(Base = Female)*				
Male	0.022***	-0.006**	0.097***	-0.112***
	(0.002)	(0.002)	(0.006)	(0.006)
Region *(Base = Midwest)*				
Northeast	0.007*	0.008*	-0.065***	0.050***
	(0.003)	(0.003)	(0.010)	(0.010)
South	0.012***	0.001	-0.027**	0.014
	(0.003)	(0.003)	(0.009)	(0.008)
West	0.010**	0.008**	-0.035***	0.017
	(0.003)	(0.003)	(0.010)	(0.010)
Education *(Base = Less than 4 Year Degree)*				
4 Year Degree or Higher	0.024***	0.011***	-0.068***	0.033***
	(0.002)	(0.002)	(0.007)	(0.007)
Race *(Base = White)*				
Black/African American	0.008*	-0.003	0.001	-0.006
	(0.003)	(0.003)	(0.010)	(0.010)
Other	-0.005*	0.010**	-0.024*	0.019
	(0.003)	(0.004)	(0.010)	(0.010)
Ethnicity *(Base = Not Hispanic)*				
Hispanic, Latino or Spanish Origin	0.001	0.006	0.038***	-0.045***
	(0.003)	(0.003)	(0.010)	(0.010)

Notes: Observations: 24,449
Standard errors in parentheses. Significance: * p<0.05, **p<0.01, ***p<0.001

The marginal effect on beef from the Hispanic variable is positive and significant. Therefore, the projected increase in the percentage of the population that is Hispanic could indicate an increase in the percentage of daily selections of beef. However, there is also a projected increase in the percentage of the population with a 4-year degree or higher. This signals a decrease in beef but an increase in plant-based protein consumption. To evaluate the effect of changing all variables simultaneously, I calculate adjusted predicted probabilities for each of the outcome categories setting variables to projected future values.

Table 4-4 displays the adjusted predicted probabilities resulting from setting independent variables to the specified levels. These represent projected changes in percentage of daily selections for each of the four categories that result from the changes in demographics. The changes for each category are very subtle. Plant-based protein consumption is projected to grow by 0.04 percentage points whereas the percentage of daily selections for beef is projected to decline by 0.47 percentage points. The selections in the "both" category also decline at 0.07 points but the "neither" category – those selecting something other than beef or plant-based protein – is projected to grow 0.5 percentage points.

Table 4-4: Projected Percentage of Daily Selections in Each Category

	Both	**Plant-Based**	**Beef**	**Neither**
2020 Percent per category	1.77%	2.53%	51.39%	44.31%
2030 Percent per category	1.70%	2.57%	50.92%	44.81%
Change in percentage points	-0.07%	0.04%	-0.47%	0.50%

Notes: Adjusted predictive probabilities holding variables at specified projection levels. Change is the difference in percentage points between projections.

The model does not predict very large changes in the percentages of people consuming plant-based protein, beef or both. Figure 4-1 shows the percentages of daily selections for each category projected to 2020 and 2030. There is no discernable difference between the two charts. Beef is still the largest category of daily selections and plant-based protein remains a small percentage. However, what these two pie charts do not reveal is the change in the "size of the pie" that is predicted over time as a result of population growth. In reality, the 2030 pie chart should be much larger than the 2020 chart, due to an increase in overall demand for protein.

Figure 4-1: Projected Change in Percentage of Daily Selections by Category

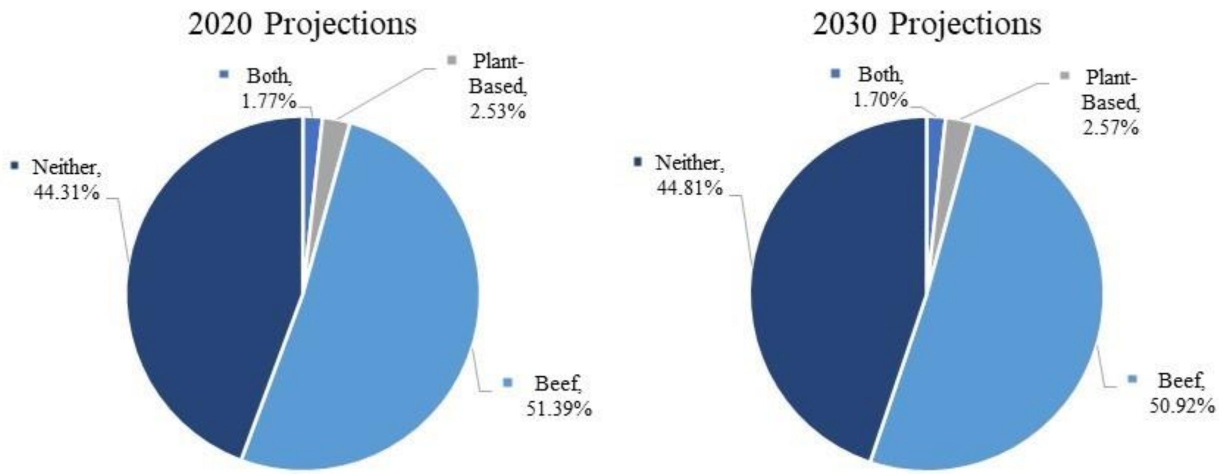


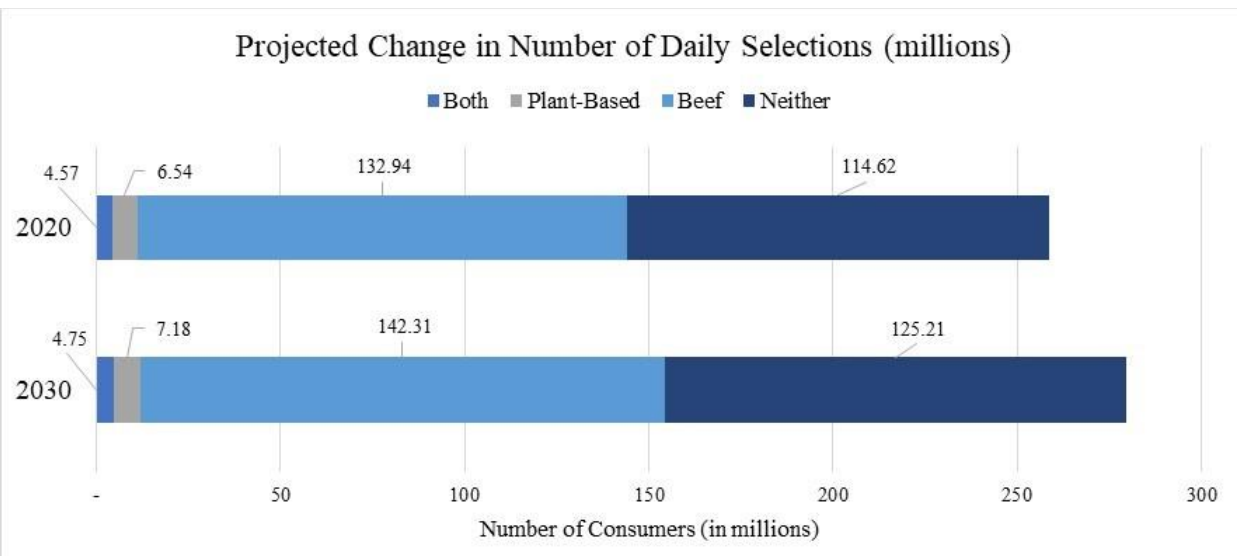
Table 4-5, as well as Figure 4-2 shows the change in the number of daily selections. The number of consumers eating neither beef nor plant-based is projected to grow the most over the 10 years used in this estimation; this category is comprised of proteins other than beef and plant-based, including chicken, pork, fish/seafood and other proteins. The beef and plant-based protein categories are predicted to grow a sizeable amount as well, at 7 and 10 percent respectively. While there is growth in the number of people selecting "both", this represents the smallest growth numerically (178,000) and relatively (4%) amongst all four categories. The number of daily selections of plant-based protein and not beef is projected to grow by the largest relative amount, increasing in number of selections by nearly 10 percent. However, it still remains a very small percentage of overall daily selections compared to the beef and neither options.

Table 4-5: Projected Number of Daily Selections in Each Category (1,000's)

	Both	Plant-Based	Beef	Neither	Population Estimate
2020 Number per category	4,574	6,542	132,936	114,620	258,672
2030 Number per category	4,752	7,179	142,307	125,212	279,449
Change in number per category	+178	+637	+9,371	+10,592	+20,777
Percent change in number per category	+3.89%	+9.73%	+7.05%	+9.24%	+8.03%
Percent of "New Consumers"	0.86%	3.06%	45.10%	50.98%	

Notes: U.S. population estimates for 18 and older from U.S. Census Bureau available at https://www.census.gov

Figure 4-2: Projected Change in Number of Daily Selections by Category



The population older than 18 in the U.S. is projected to increase by over 20 million from 2020 to 2030. This means 20 million more people making daily selections of proteins. Row 5 in

Table 4-5 shows a glimpse of how these new consumers may be distributed among the categories. Most will likely choose a protein other than beef or plant-based, followed by a large portion likely to choose beef and not plant-based. Three percent will likely choose plant-based proteins and not beef and less than 1 percent will choose to consume both beef and plant-based proteins.

Based on these estimates, it appears that the beef industry will see growth in number of daily selections of their product as demand for protein grows. Plant-based proteins will also see growth in daily selections of their product. However, based just on the changes in demographics, plant-based protein supporters may not see the rapid market share growth resulting from a decline in beef consumption that some have indicated wanting to see over the next decade. This means that there will have to be other factors that plant-based protein producers employ to reach their market share goals, such as pricing or advertising. The main point is that based on population growth and demographic change, there will be plenty of room for both beef and plant-based protein.

4.4 Implications

The model predicted very little change in the percentage of consumers selecting beef and plant-based protein. However, when applied to the population numbers, there was projected growth for daily selections of all proteins. While some proponents of plant-based proteins would like to see a major reduction in animal agriculture resulting from an increase in consumption of their product, it does not seem like that will be the case any time soon. Due to the growth in overall protein demand, plant-based proteins will likely continue to grow, but not necessarily at the expense of beef demand. Therefore, it is not inevitable for beef producers to suffer because of the increase in consumption of plant-based proteins.

Perhaps one illustration of this can be found in evaluating beef and chicken production and consumption over the years. Figure 4-3 shows per-capita consumption (or technically disappearance) over the last few decades. The graph clearly shows that per-capita beef consumption has fallen while chicken has seen major growth. Changing consumer preferences and increased affordability of chicken have driven much of the growth in chicken consumption. These factors also contributed partially to the decline in beef consumption. However, looking at production tells a slightly different story.

Figure 4-3: Annual U.S. Beef and Chicken Per Capita Consumption (Disappearance)

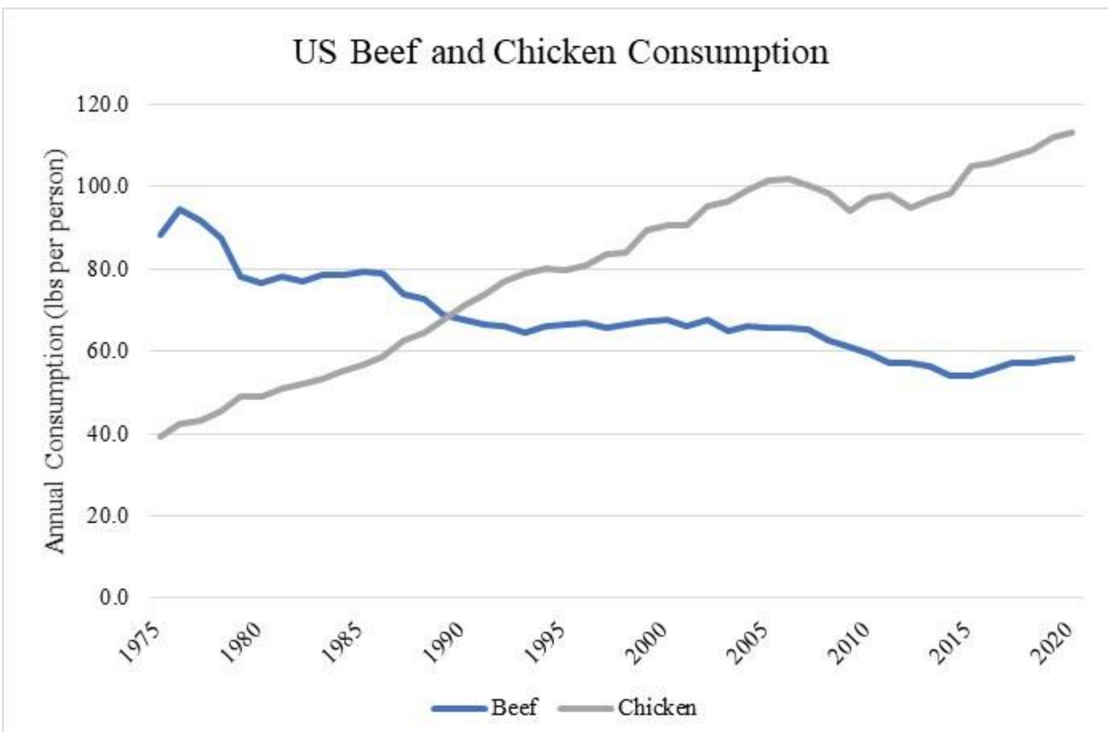
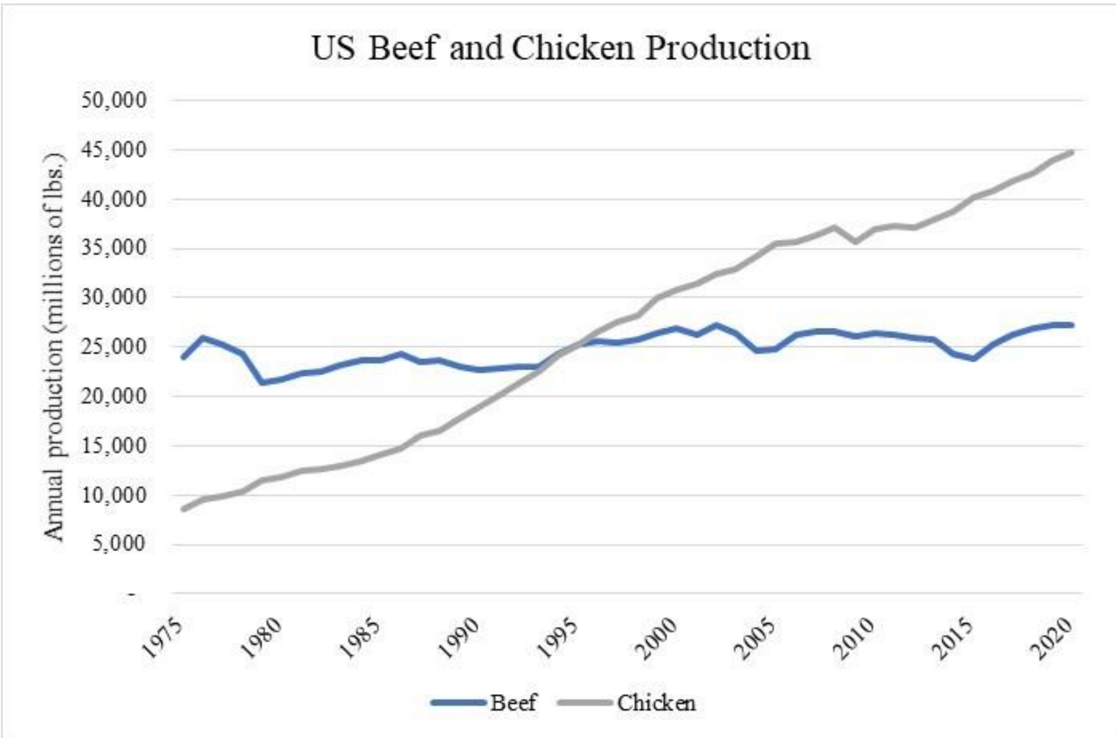


Figure 4-4 shows U.S. production of beef and chicken for the same time period. Chicken production has grown rapidly as the growth in consumption would imply. However, beef production has grown as well. Although there has been a significant decline in per-capita consumption of beef, production has not followed suit. This is driven by two main factors: population growth and exports. Estimating per-capita consumption using disappearance takes production, adds in beginning inventories and imports and subtracts out exports and ending inventories. The resulting disappearance is divided by population to arrive at a per-capita consumption approximation. Consequently, major growth in both exports and U.S. population has also contributed to the decrease in per-capita consumption. Growth in population and exports represents an overall growth in demand for protein.

Figure 4-4: Annual U.S. Beef and Chicken Production



Even though it may appear as if per-capita beef demand has suffered as a result of increased chicken consumption, the more accurate, full picture is one of total protein demand growth that has allowed room for growth of multiple protein types. Returning to the implications from this research, the growth that plant-based protein may capture is likely to be that of expanding protein demand. There are already many consumers who choose to consume both plant-based protein and beef in a given day. There is room in the protein space for both proteins to grow without necessarily having to steal market share.

One limitation to this discussion is that the projected daily selection estimates discussed above do not account for prices. Specifically, if the price of plant-based proteins eventually undercuts that of beef, there will likely be much larger effects on beef demand. While beef and chicken are mostly considered substitutes for one another, the goal of plant-based protein burger developers has been to perfectly replicate beef burgers. Therefore, if they were to succeed in creating a product that consumers perceive as a perfect substitute for beef and are able to lower the price below that of beef, the substitution effect would have a much greater negative impact on the beef industry that what chicken had.

One consideration for the beef industry in this case would be to create blended products that combine traditional meat with plant-based proteins. Plant-based proteins are able to more closely replicate ground products like burgers and sausages, therefore these products would be prime targets for blending. If plant-based protein becomes less expensive to produce and consumers perceive the products as close substitutes, blending would decrease the price of these hybrid products, increasing the quantity demanded for both traditional beef and plant-based proteins. In this way, plant-based proteins could compete with imports of lean beef destined for blending into ground products and thus fulfil a market segment for U.S.-produced products.

There will likely always remain a market for traditional beef, regardless of how much the price of plant-based proteins decrease. At this point, plant-based proteins are not able to replicate whole-muscle cuts, so traditional beef production will still be needed to fill the market for these products. Traditional beef may also eventually become more of a premium item. Additionally, there will always be loyal beef consumers who are insensitive to the price changes of other products. The predictions that animal agriculture, and more specifically beef production, will be obsolete within a few decades seem unlikely at this point.

Chapter 5 - Conclusion

While alternative protein options have been around for a while, their popularity seems to be growing with increasing concerns for environmental sustainability and animal welfare. Proponents of plant-based proteins have stated their desire and plan to completely eliminate animal agriculture within the next couple of decades. Previous research however does not seem to support this as a probability. But as plant-based proteins increase in popularity and availability, there is some concern about what this will mean for agriculture and especially for the beef industry.

The goal of this research was to evaluate factors that affect beef and plant-based protein consumption. Using data from the monthly, nationwide Meat Demand Monitor survey, I first found that consumption of beef and plant-based proteins is not entirely exclusive. There are some people who indicated eating both protein sources in the previous day. I then conducted a multinomial logistic model to evaluate this further. Observations were split into four categories based on the possible combinations of plant-based protein and beef consumption indicated in the prior day: ate both plant-based proteins and beef, ate plant-based proteins and not beef, ate beef and not plant-based proteins or ate neither.

A large proportion of respondents in the survey indicated eating beef, followed by those eating something other than beef or plant-based proteins (neither). Less than three percent indicated eating plant-based protein, and slightly more indicated eating both plant-based and beef. Being male, being between the ages of 18 and 44, having kids under 12, having a 4-year degree or higher and having a higher income are the factors which indicate a higher likelihood of having consumed both plant-based protein and beef in the prior day. Age was one of the top drivers of plant-based protein consumption with older consumers being much less likely to consume plant-based and younger consumers more likely to consume beef and/or plant-based. Higher education and higher income also increased the probability of consuming plant-based proteins and decreased the probability of consuming beef.

The second part of this research evaluated how changing demographic characteristics in the U.S. might predict future consumption of beef and plant-based proteins. There was very little predicted change in the percentages of consumers in each category. However, all four categories are predicted to grow in total number of daily selections. Beef and neither – consumers selecting something other than beef or plant-based – are both predicted to grow the most in number of daily selections. Plant-based protein is projected to have the most relative growth in number of daily selections, but it still remains a very small percentage of daily selections especially when compared to beef. Therefore, the growth of plant-based proteins is likely to come more from growth in overall protein demand rather than directly from beef demand.

Based on changes in U.S. demographics, there is very little projected change in the percentage of consumers selecting beef and plant-based proteins. However, if consumer preferences, attitudes or opinions shift, this could have a greater effect on consumption. For example, if plant-based protein producers succeed in positioning their product as superior to beef from a health or sustainability standpoint, they could steal more of the market share away from beef in the future. Additionally, if plant-based protein producers continue to lower prices as production costs decrease, they could also see more growth in market share resulting from consumers substituting these products for beef. However, it seems unlikely at this point that beef production will be entirely obsolete within the next few decades.

One limitation of this study is that the estimates presented in this model only take into account the changing demographics in the US. They do not account for changing values, attitudes or opinions. These characteristics may end up being much more important drivers of protein demand. If plant-based protein companies convince more of the U.S. population that a decrease in consumption of animal meat is necessary for environmental health, these alternative protein products could eventually erode more of the market share for beef than predicted here. Future research could be conducted to evaluate how changing attitudes or opinions could affect beef and plant-based protein consumption.

Additionally, future research could more closely evaluate how price changes of plant-based protein will affect demand for both beef and plant-based proteins. There has been some research on consumer acceptance of blended products that combine animal- and plant-derived proteins. Given the potential opportunities for blended products between plant-based and beef, future research could also evaluate both consumer acceptance of these products as well as how demand for these products might affect producers of both types of proteins.

Currently it seems as though beef producers and plant-based producers are completely at odds. There has been tension between the groups as they look ahead to the future of protein production and consumption. However, the results from this research indicate that there are consumers who currently eat both plant-based protein and beef. Certain demographic segments such as males and younger consumers represent a very important market for both proteins. Furthermore, there is very little predicted change in the percentage of daily selections for both products, and both protein sources are likely to see growth in the total number of daily selections due to a growing population. There is room for both products – in some consumer’s shopping carts and in the overall protein space.

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Appendix A - Additional Tables

Table A-1: Summary of Socio-Demographic Characteristics in Survey Sample

Variable		Percent of Sample	Variable		Percent of Sample
Age			Race		
	18-44	34.4%		*White*	76.1%
	45-64	38.7%		*Black/African American*	12.3%
	65+	26.9%		*Other Race*	11.6%
Gender			Ethnicity		
	Male	46.5%		*Hispanic, Latino or Spanish Origin*	87.3%
	Female	53.5%		*Not Hispanic*	12.7%
Region			Marital Status		
	Northeast	18.1%		*Married*	49.8%
	Midwest	21.7%		*Not Married*	50.2%
	South	38.1%	Kids		
	West	22.2%		*Kids under 12*	17.9%
Education				*No kids under 12*	82.1%
	Less than 4-year degree	64.7%	Political Party		
	4-year degree	35.3%		*Democratic*	38.4%
Income				*Republican*	31.8%
	Under 60,000	56.7%		*Other*	29.8%
	60,000-99,000	25.5%	Dining Out		
	Over 100,000	17.8%		*Ate out in prior day*	34.8%
				Did not eat out	65.2%

Notes: Age and Region are consistent with U.S. Census Bureau groupings; variable for Hispanic, Latino or Spanish origin is included separate from race following U.S. Census Bureau.

Table A-2: Coefficients from Prior Day MNL Model

Variable	Both	Plant-Based	Beef
Age *(Base = 18 to 44 Years)*			
45 to 64 Years	-1.335***	-0.387***	-0.386***
	(0.121)	(0.107)	(0.037)
65+ Years	-2.366***	-0.735***	-0.465***
	(0.221)	(0.131)	(0.043)
Gender *(Base = Female)*			
Male	0.933***	-0.007	0.428***
	(0.090)	(0.086)	(0.028)
Region *(Base = Midwest)*			
Northeast	0.166	0.189	-0.212***
	(0.149)	(0.136)	(0.044)
South	0.381**	0.048	-0.079*
	(0.127)	(0.123)	(0.037)
West	0.305*	0.266*	-0.094*
	(0.142)	(0.130)	(0.042)
Education *(Base = Less than 4 Year Degree)*			
4 Year Degree or Higher	0.332***	0.284**	-0.248***
	(0.097)	(0.092)	(0.032)
Household Income *(Base = Less than 60,000)*			
60,000 to 100,000	0.276*	0.052	-0.088*
	(0.108)	(0.105)	(0.035)
Over 100,000	0.442***	0.215	-0.018
Race *(Base = White)*	(0.120)	(0.123)	(0.043)
Black/African American	0.315**	-0.252	-0.007
	(0.113)	(0.147)	(0.046)
Other	-0.050	0.300**	-0.061
	(0.129)	(0.115)	(0.046)
Ethnicity *(Base = Not Hispanic)*			
Hispanic, Latino or Spanish Origin	-0.053	0.253*	0.092*
	(0.111)	(0.120)	(0.045)
Kids *(Base = Kids Under 12)*			
No Kids Under 12	-0.901***	0.085	-0.266***
	(0.104)	(0.128)	(0.043)
Marital Status *(Base = Not Married)*			
Married	0.142	-0.082	0.146***
	(0.102)	(0.094)	(0.031)

Variable	Both	Plant-Based	Beef
Political Party *(Base = Republican)*			
Democratic	-0.045	0.541***	-0.058
	(0.097)	(0.111)	(0.034)
Other	-0.465***	0.190	-0.215***
	(0.118)	(0.119)	(0.035)
Farm Experience			
No Farm Experience	-0.246*	-0.040	-0.188***
	(0.102)	(0.129)	(0.040)
Dining Out *(Base = Only Home/Skipped Meal)*			
Ate Out in Prior Day	1.422***	0.337***	0.606***
	(0.101)	(0.094)	(0.031)
Constant	-2.966***	-3.278***	0.514***
	(0.205)	(0.217)	(0.067)

Notes: Observations: 23,956
Base outcome is "Neither"
Standard errors in parentheses. Significance: * p<0.05, **p<0.01, ***p>0.001

Table A-3: Coefficients from Protein Projection MNL Model

Variable	Both	Plant-Based	Beef
Age *(Base = 18 to 44 Years)*			
45 to 64 Years	-2.033***	-0.462***	-0.579***
	(0.109)	(0.097)	(0.033)
65+ Years	-3.365***	-0.819***	-0.714***
	(0.209)	(0.119)	(0.037)
Gender *(Base = Female)*			
Male	1.113***	0.012	0.463***
	(0.085)	(0.085)	(0.027)
Region *(Base = Midwest)*			
Northeast	0.195	0.189	-0.249***
	(0.145)	(0.134)	(0.043)
South	0.459***	0.008	-0.083*
	(0.124)	(0.122)	(0.036)
West	0.370**	0.283*	-0.110**
	(0.140)	(0.129)	(0.041)
Education *(Base = Less than 4 Year Degree)*			
4 Year Degree or Higher	0.756***	0.338***	-0.214***
	(0.082)	(0.085)	(0.029)
Race *(Base = White)*			
Black/African American	0.275**	-0.098	0.018
	(0.105)	(0.142)	(0.043)
Other	-0.268*	0.304**	-0.097*
	(0.124)	(0.114)	(0.045)
Ethnicity *(Base = Not Hispanic)*			
Hispanic, Latino or Spanish Origin	0.144	0.335**	0.182***
	(0.106)	(0.117)	(0.044)
Constant	-2.970***	-2.840***	0.407***
	(0.136)	(0.130)	(0.041)

Notes: Observations: 24,449
Base outcome is “Neither”
Standard errors in parentheses. Significance: * p<0.05, **p<0.01, ***p>0.001