Assessing Economic Impacts of Plant-Based Meat Alternatives on U.S. Retail and Food Service Markets for Animal Protein

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ABSTRACT

Plant-based proteins have a long history in U.S. food markets and innovations in recent years have led to a new class of plant-based meat alternatives (PBMA) becoming commercially available in both retail and food service settings. Early market indicators for PBMA products, including company stock valuations, as well as qualitative excitement over novel offerings and widespread proliferation in food service outlets, pointed to high growth potential and strong consumer interest. However, the market has slowed and adjusted to the availability of PBMA, it has become less clear how PBMA affect overall protein markets, specifically animal proteins. The article addresses the relative value (as measured in willingness to pay estimates) consumers have for various animal and plant-based proteins in both the retail and food service cases. It then simulates market shares to examine prevalence of PBMA in consumer spending and subsequently estimates the consumer welfare impacts of PBMA availability in both types of markets. To further investigate the distribution of PBMA value and impacts across consumer types, these analyses are also broken down by self-reported consumer dietary patterns (Regular meat consumption, flexitarian, vegetarian, and vegan).

Keywords: *Consumer demand, Dietary patterns, Food choice, MDM, Plant-based meat alternatives.*

1. INTRODUCTION

Plant-based proteins have a long history in U.S. food markets and innovations in recent years have led to a new class of plant-based meat alternatives (PBMA) becoming commercially available in both retail and food service settings. Technologies like vegetarian heme proteins, which mimic the iron-based flavor and cooking properties of red meat, have given food manufacturers the opportunity to offer vegetarian meat analogues that more closely resemble real animal proteins than historical market offerings (Ahmad, Farooq, Alhamoud, Li, & Zhang, 2023). PBMA products, the most popular of which include Impossible and Beyond Meat beef analogues (Hu, Otis, & McCarthy, 2019) received increasing attention in the years immediately preceding the Covid-19 pandemic as they mainly debuted in food service settings while slowly becoming available in grocery meat cases (Andreani et al., 2023). The popularity of PBMA, especially in the retail setting, increased substantially early in the pandemic, particularly when red meat supply chains were struck by disruptions in the processing sector. From 2019 to 2020, retail sales of PBMA grew by 45 percent in the United States to $1.4 billion (Gaan, 2020). In 2022, an estimated 10 percent of U.S. consumers had purchased a PBMA meal at a food service location at least once (Pierce & Azoff, 2023).

PBMA products have experienced global popularity, with an estimated market value of $14 billion in 2019 (Baldi & Merener, 2021) and have proliferated rapidly. Between 2019 and 2021, nearly 5000 PBMA products were released on the global market, over a quarter of which were burger analogues (Andreani et al., 2023). As these products entered the market, question rose regarding how traditional animal-based proteins are affected. PBMA tend to mimic low grade cuts of meat, such as grinds, sausages, and processed products (Bonny, Gardner, Pethick, & Hocquette, 2017). Retail prices for PBMA products are typically higher than their animal-based counterparts (Petersen, Tatic, Hartmann, & Hirsch, 2023) limiting the ease with which PBMA might entice consumers to substitute away from meat. Even so, one goal often touted by manufacturers is for PBMA to displace animal protein demand (Beyond Meat Inc, 2023).

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Early market indicators for PBMA products, including company stock valuations, as well as qualitative excitement over novel offerings and widespread proliferation in food service outlets, pointed to high growth potential and strong consumer interest. However, the market has slowed and adjusted to the availability of PBMA (Baldi & Merener, 2021) it has become less clear how PBMA affect overall protein markets, specifically animal proteins. The role of consumer dietary patterns adds a further complication to evaluating these markets, as PBMA may not be valued evenly across consumer types. This article explores the extent PBMA may displace animal protein using 2020-2023 data from the Meat Demand Monitor, a project supported by the U.S. Beef and Pork Checkoff programs. The article addresses the relative value (as measured in willingness to pay estimates) consumers have for various animal and plant-based proteins in both the retail and food service cases. It then simulates market shares to examine prevalence of PBMA in consumer spending and subsequently estimates the consumer welfare impacts of PBMA availability in both types of markets. To further investigate the distribution of PBMA value and impacts across consumer types, these analyses are also broken down by self-reported consumer dietary patterns (regular meat consumption, flexitarian, vegetarian, and vegan).

2. THE MARKET FOR PLANT-BASED MEAT ALTERNATIVES: AN OVERVIEW

Plant-based proteins, the most common of which are based on legumes including beans, tofu, and lentils, have long been available to the U.S. consumer. When marketed as an alternative to or replacement for animal proteins, these products have often targeted consumers with diets restrictive of animal products, such as vegetarians and vegans1 (Andreani et al., 2023). As global public health and environmental authorities have increasingly advocated for reduced meat consumption, especially in developed countries, novel PBMA products emerged on the market. These products are designed to mimic the sensory qualities and nutritional profiles of their animal protein counterparts with the goal of appealing to consumers with no or few dietary restrictions on animal products (Hu et al., 2019). New food technologies have been developed to meet this goal, including vegetarian heme protein (produced, for example, by genetically engineered yeast organisms) and vegetable protein isolates and concentrates. These novel ingredients aim to reproduce the major sensory properties of meat, most notably the fibrous structure of muscle tissue and the iron-based flavors of red meat (Ahmad et al., 2023; Andreani et al., 2023). In 2022, meat analogs, PBMA products that attempt to mimic the eating characteristics of meat, accounted for 53 percent of U.S. plant-based protein product sales (by volume) in foodservice settings, a 14 percentage point increase from 2019 (Pierce & Azoff, 2023).

Despite the introduction of these products to the broad U.S. retail and food service markets, novel PBMA have not been immediately adopted by large segments of targeted consumers. Several studies have identified continued consumer reluctance to accept the sensory experience of PBMA as equivalent or superior to that of traditional animal proteins (Clark & Bogdan, 2019; Giacalone, Clausen, & Jaeger, 2022). Common PBMA products often technically qualify as ultra-processed foods (Bohrer, 2019; Metz, Neumann, & Fasshauer, 2023) a trait that further limits their appeal to many consumers (Hu et al., 2019). Moreover, although PBMA products are generally formulated to match the nutritional benefits of their meat counterparts, they have some nutritional downfalls, including high sodium content and reduced protein digestibility and bioavailability (Swing et al., 2021; Yang et al., 2023). Price also plays a major role in consumer acceptance, with most PBMA priced over meat limiting consumer adoption (Clark & Bogdan, 2019; Joseph, Searing, Watson, & McKeague, 2020; Pierce & Azoff, 2023).

In addition to the general barriers to adoption, consumer behavior towards PBMA demonstrates some unique characteristics that present further hurdles for the industry. Recent evidence indicates consumers have expressed interest in experimenting with PBMAs as a novelty but typically do not demonstrate sustained expenditures on PBMA products. Moreover, scanner data studies have revealed that household purchases of PBMA generally do not coincide with a decrease in spending on meat (Cuffey, Chenarides, Li, & Zhao, 2023; Neuhofer & Lusk, 2022). For example, Neuhofer and Lusk (2022) found that over 85 percent of the households that purchased a PBMA during their study period also purchased ground meat. The findings in the literature indicate that PBMA products are complementary to red meat or are purchased to meet the preferences of a subset of a household while other

1 Vegetarian and vegan diets can be defined in a variety of ways depending on the dietary practices of their adherents. For the purposes of this report, the vegetarian dietary pattern is defined as allowing the consumption of all plant-origin foods, dairy, and eggs, but excluding any product that contains meat, fish, shellfish, or poultry. The vegan dietary pattern is defined as exclusively allowing the consumption of plant-origin foods and disallows the consumption of any meat, poultry, fish, shellfish, dairy, eggs, or other food derived from animals.

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members prefer meat (Neuhofer & Lusk, 2022; Zhao, Wang, Hu, & Zheng, 2023). Cuffey et al. (2023) also suggested that some households might purchase PBMA as an experiential product (for example, to compare to a beef patty) rather than as a protein staple. A high occurrence (63 percent) of PBMA consumers in food service environments being one-time purchasers in 2022 supports this phenomenon (Pierce & Azoff, 2023).

The potential health benefits of PBMAs are often found to especially appeal to an emerging class of consumers known as flexitarians. Flexitarians are characterized as consumers willing to eat any type of food but who actively reduce their total animal product consumption (Mousel & Tang, 2016). It should be noted, however, that flexitarians are heterogeneous in their motivations, which can include any combination of ethical considerations, environmental concerns, and health goals (Boukid, 2021; Dagevos, 2021; Peschel & Grebitus, 2023). Consumer health perceptions of PBMA are supported by their substitute relationship with lean animal proteins, specifically poultry and fish, which are typically encouraged as healthier alternatives to red and processed meats (Zhao et al., 2023). Consumers with established values for the ethical, environmental, and health properties of their food, such as vegetarians, tend to have stronger preferences for PBMA products than consumers at large (Bryant & Sanctorum, 2021; Van Loo, Caputo, & Lusk, 2020). It has remained unclear, however, how the dietarily-differentiated segments of the consumer market might impact the overall demand for and growth potential of PBMAs and displace demand for animal proteins.

3. DATA AND METHODS

To examine the impacts PBMA might have on demand for animal proteins, this study employs data from the Meat Demand Monitor (MDM), a publicly available dataset collected and published by Kansas State University. The MDM conducts a monthly consumer survey to track and report U.S. consumer preferences, views and demand for common protein options, separated by retail and food service settings. The nationally representative sample consists of at least 2,000 respondents per month.2 MDM data is further described in published research by Bina and Tonsor (2024); Bina, Tonsor, and Briggeman (2023); Taylor, Tonsor, Lusk, and Schroeder (2023); Tonsor and Lusk (2022) and Tonsor, Lusk, and Tonsor (2021).

Data for this study cover the period of February 2020 to December 2023 and are aggregated on an annual basis for simple trend assessments. While some elements of the survey vary across time, such as pandemic-related questions in 2020-2021, among the core elements are dietary pattern self-identification and two standard, choose-one discrete choice experiments.

Respondents to the MDM are asked to categorize themselves based on a set of descriptions that most closely matches their personal diet. Five options are offered.

- Vegan vegetarian (Do not eat meat, fish, dairy, eggs, honey or any food derived from animals).
- Vegetarian (Do not eat meat or fish, but do eat dairy and eggs).
- Flexitarian/Semi-vegetarian (Mostly follow a vegetarian diet, but occasionally eat meat or fish).
- Regularly consume meat, fish/seafood, or products derived from animals.
- None of the above.

From these responses, consumers are identified in the data as vegan, vegetarian, flexitarian, or regular meat consumers. Consumers who did not self-identify a dietary pattern (i.e. chose 'None of the above') are included in the pooled analysis results but excluded from analyses which differentiate consumers by dietary pattern.3

Choice experiments are a common behavioral economic tool used to identify consumer value for a selection of options ("Alternatives") with varying attributes. High profile applications such as Lusk (2017) demonstrate the use of choice experiments in revealing household-level insights not available from more aggregated datasets. While every applied method as benefits and drawbacks, choice experiments have become a popular method for examining consumer preferences generating economic measures of interest including willingness-to-pay (WTP) and projected market shares for possible scenarios of interest as shown below.

2The Meat Demand Monitor (MDM) project was initiated prior to this study and was conducted independently of this report. Only publicly available data from the MDM are used and the elements used in this analysis are those which have been continuously collected and published since the project's inception. The MDM is partially funded by the Beef Checkoff and Pork Checkoff programs.

3The MDM contains questions which require participants to report their protein choices from the previous day. Responses to these questions were used to differentiate between self-declared vegans and vegetarians who were consistent (those who had not consumed meat, fish or poultry the previous day) and inconsistent (those who report being vegan or vegetarian but also report recently consuming meat, fish or poultry). When defining consumers as vegan or vegetarian in this report, only consistent vegans or vegetarians are included. Inconsistent vegans and vegetarians are included in the pooled analysis results.

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In the MDM, two choice experiments are conducted (Respondents are randomly allocated to one), one in each of two contexts: the retail context (i.e. if the choice were made in a grocery store) and the food service context (i.e. if the choice were being made at a restaurant). For the retail context, the respondents are first asked to imagine they are at the grocery store buying the ingredients to prepare a meal for themselves and their household for dinner.4 For the food service context, they are asked to imagine they are at their local restaurant for dinner. Respondents are presented with nine hypothetical scenarios in which the same menu of alternatives are available, as well as an option to choose none of the alternatives, but have differing prices. The respondent is then asked which alternative they would most likely buy if given the choice. By carefully designing the choice sets in and across each scenario, it is possible to identify average consumer values for each attribute or alternative.

The MDM employs simple choice experiments where alternatives are defined by just two attributes: protein type and price. The protein types offered differ slightly between the two contexts. In the retail context, consumers choose between ribeye steak, ground beef, pork chops, bacon, chicken breast, a PBMA patty, shrimp, or beans. In the food service context, consumers choose between a meal of ribeye steak, a beef hamburger (ground beef), pork chops, baby back ribs, chicken breast, a PBMA patty, shrimp, or salmon. Prices for each product are listed on a per pound basis for retail and a per meal basis for food service within each choice scenario and differ across scenarios to identify how price affects consumer choice. Variations in prices across choice scenarios also allow for the calculation of average maximum willingness to pay (WTP) for each protein type.

The data from the choice experiments are analyzed using logit models reflecting standard random utility theory application (Lusk, 2017). The resulting estimated coefficients are then used to calculate average willingness-to-pay. WTP estimates denote the maximum amount the average consumer would pay for the given protein in the given context. These values allow for direct comparison of average consumer value across proteins. WTP values are calculated for the pooled sample (i.e. all consumers together) and are also calculated for each group of consumers self-identified by dietary pattern (regular meat consumers, flexitarians, vegetarians, and vegans).

Once WTP has been calculated, different market scenarios can be simulated to examine how market shares would look under specified pricing structures. Market shares are simulated under the same pricing structure across all four years (2020-2023) to examine how the markets differ when the PBMA option is available and when it is absent**.** Specifically, we consider all eight available alternatives to be priced at their intermediate-levels and derive model implied choice probabilities that correspond with market share estimates. The changes in market shares between the two cases demonstrate how PBMA entering the market affects other proteins' capture of the market and allows the identification of which proteins are most affected by PBMA. Finally, parameter estimates reflecting consumer preferences can be used to estimate consumer welfare impacts from possible scenarios including the impact of PBMA entering the market. We follow the approach of Lusk, Norwood, and Pruitt (2006) as originally shown by Small (1978) by estimating the most residents would be willing to pay (per choice occasion then scaled up to annual, national estimates) to face a situation with PBMA being available compared to one with PBMA not being in their available choiceset.

4. RESULTS

4.1. Willingness to Pay

Willingness to pay (WTP) estimates are reported in Tables 1 and 2.5 These estimates reflect the maximum amount that a consumer would be willing to pay to purchase a pound of the given protein in a retail setting (Table 1) or to purchase a standard meal featuring the given protein in a dinner meal, food service environment (Table 2). The pooled willingness to pay estimates reflect the average value across the full sample. Estimates are also disaggregated by self-reported dietary pattern (Regular meat consumer, flexitarian, vegetarian, and vegan).

In a retail context, average consumer WTP is highest for ribeye steak, followed by shrimp, and lowest for beans in all years. Chicken breast, and ground beef also exhibit consistently high WTP values from 2020 to 2023, ranging from $5.72 to $7.39, comparable to the average WTP values for the plant-based meat alternative patty. Across the four years, consumer average WTP for any of the proteins trended upwards, which is in line with expectations since this time was characterized by much higher than typical food price inflation. The only proteins that did not

4The retail choice context also includes the condition that each offered product would be boneless and uncooked for the respondent to prepare at home as desired.
5All presented values are in nominal (not inflation-adjusted) terms. Accordingly, comments about the lack of increasing values over preceding years are conservative in nature given inflation that occurred during the 2020-2023 period.

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increase in average willingness to pay year over year were bacon, shrimp, and the two plant-based options (plant based alternative patty and beans). Though reaching a maximum average retail WTP of $7.11 in 2021, plant based alternative patty values saw the smallest increase of all proteins from 2020 to 2023, growing by 72 cents or 11.7 percent. Plant-based meat alternative market growth over the same time followed a similar trend, increasing rapidly from a small initial base during the early years of the Covid-19 pandemic, then slowly decreasing.

Table 1. Retail Willingness-to-Pay ($/lb).

Year	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	PBMA	Shrimp	Beans
Pooled (w/o Inconsistents)								
2020	13.64	5.72	4.44	3.41	5.87	6.13	7.43	1.52
2021	15.21	6.88	5.57	4.67	6.84	7.11	8.29	2.39
2022	15.17	7.20	5.83	4.88	7.17	7.10	8.11	2.74
2023	15.52	7.39	5.92	4.85	7.21	6.85	8.38	2.61
Regular meat consumers								
2020	15.63	6.61	5.63	4.62	6.62	6.61	8.73	1.53
2021	16.66	7.49	6.40	5.64	7.32	7.08	9.29	2.15
2022	16.76	7.88	6.72	5.79	7.68	7.13	9.31	2.45
2023	16.87	7.99	6.70	5.77	7.78	7.16	9.44	2.49
Flexitarians								
2020	14.77	7.00	4.75	2.86	8.71	9.47	8.61	4.08
2021	17.65	9.21	6.65	4.65	10.53	11.87	10.37	6.66
2022	17.83	9.17	7.13	5.29	10.93	11.16	10.01	6.51
2023	16.65	8.59	6.51	4.17	9.68	9.11	9.15	5.20
Vegetarians								
2020	-7.56	-10.99	-15.27	-17.88	-8.98	10.34	-0.29	5.27
2021	5.21	-5.07	-9.04	-9.01	-5.03	11.61	0.70	5.58
2022	4.90	-5.05	-6.95	-8.00	-4.37	12.01	-4.11	6.68
2023	1.73	-1.68	-7.91	-6.54	-3.58	11.76	0.72	6.32
Vegans								
2020	-26.68	-21.10	-22.88	-29.50	-20.36	16.34	-24.51	13.07
2021	0.50	-10.33	-13.90	-8.51	-15.05	22.11	-11.81	16.35
2022	-14.92	-13.02	-22.97	-17.50	-16.99	14.86	-20.69	9.55
2023	0.84	-9.42	-16.36	-15.24	-16.76	9.89	-16.54	9.52

At the pooled level, results are similar in the food service, dinner meal situation (Table 2). Average consumer WTP per meal is highest for ribeye steak and lowest for the plant based alternative patty in all years. In food service, ground beef and salmon were consistently the proteins with the second and third highest average WTP, ranging from $15.63 to $18.01 per meal. Chicken breast and pork chops tended towards relatively lower average WTP, though in both cases the value grew year over year from 2020 to 2023, with the WTP for pork chops growing the most of any evaluated protein at 18.0 percent. In contrast, and similar to the retail case, value for a plant based alternative patty meal grew by only $0.70 from 2020 to 2023, a relative growth of 7.2 percent, the smallest of any offered protein. Overall, the results indicate that consumers consistently are willing to pay more for animal protein options over the plant based alternative patty option in food service settings, with beef cuts being the most highly valued and the plant-based option receiving the lowest average WTP in all evaluated years.

When average WTP values are disaggregated by consumers' self-reported dietary patterns, it is clear that consumer value for different types of proteins vary depending on dietary preferences and variation is consistent with expectations. Representing the majority of residents, regular meat consumers drive many of the pooled results for the retail case, with willingness to pay rankings among regular meat consumers mirroring those of the pooled sample in each year despite higher magnitudes. Ribeye steak consistently receives the highest average WTP among regular meat consumers, followed by shrimp, while beans receive the lowest across all years. For

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consumers with diets that incorporate restricted consumption of animal products, however, the rankings shift. Flexitarians hold highest average WTP for ribeye steak, and in fact have higher values in some years than regular meat consumers for ribeye steak, while bacon ranks last in WTP in every year. This is consistent with the core motivations of flexitarians often including health consciousness, which could limit the value these consumers might have for a processed meat product like bacon. A preference ranking possibly influenced by health consciousness is further demonstrated in the third and fourth highest WTP values for flexitarians being for lean proteins, chicken breast or shrimp, in all years.

The ranking of WTP is very different when looking at consumers with dietary patterns that minimize or exclude animal products. For both vegetarians and vegans, the plant based alternative patty had the highest average WTP values in all years, ranging from $9.89 to $22.11, followed by beans. In general, in all years vegetarians and vegans had a negative WTP for nearly all animal proteins, with a few exceptions. Both vegetarians and vegans had positive WTP for ribeye steaks in some years, though these values were much lower than the pooled averages. Additionally, in 2021 and 2023, vegetarians had a positive, though slight ($0.70 to $0.72, less than 10 percent of the pooled average), average WTP for shrimp.

Differences across consumer subgroups are clearly reflected when noting that PBMA were available at alternative price levels of $9.49/lb, $11.99/lb, and $14.49/lb in the retail choice experiment. When presented at the intermediate offer level of $11.99/lb, in all four evaluated years neither Regular Meat Consumers nor Flexitarians would purchase as their WTP is below that level. Perhaps most striking is how by 2023 Vegans also valued PBMA less than this intermediate offer level, consistent with noted PBMA market challenges that grew within the evaluation period.

Trends in WTP in the food service case when broken out by dietary pattern indicate that consumers largely hold to their dietary restrictions but may make greater accommodations than they might for food at home consumption. Again, ribeye steak carries the highest average WTP value for both regular meat consumers and flexitarians, driving its lead in the pooled results as well. For regular meat consumers, the lowest WTP is observed for the plant based alternative patty, with values under $11 every year and consistently at least $4 less than the next lowest valued protein, pork chops. This contrasts with flexitarians, who had the lowest average WTP for pork chops in all years, followed by baby back ribs, indicating that flexitarians generally have reduced preferences for pork options. Flexitarian health consciousness is again evidenced by the second and third highest average WTP values being for salmon and chicken breast, two protein types often recommended by health professionals for healthy diets.

Again, vegetarians and vegans had the highest average WTP for the plant based alternative patty, with values comparable to the values regular meat consumers and flexitarians had for a ribeye steak meal. Nevertheless, for both vegans and vegetarians, positive WTP values were identified in all but one year (2020 for vegetarians) for ribeye steak, indicating that there may be some consumers who engage in circumstantial suspension of dietary restrictions in food service contexts if a protein option is available at an acceptable price. This is further evidenced by positive average WTP for many of the other animal proteins in various years across the sample. For example, a positive WTP was observed for vegans for salmon in 2021 ($2.87) and 2023 ($4.56), and a positive WTP for chicken breast was observed for vegetarians in 2020 ($3.16) and 2022 ($2.02). The magnitudes of these positive values, however, remains small and relatively unrealistic compared to average food away from home prices in the given year. Given the much higher value for a plant based alternative patty meal, consumers adhering to a vegetarian or vegan diet clearly demonstrate a strong preference for plant based alternative options over animal proteins in food service settings.

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Table 2. Food Service Willingness-to-Pay ($/dinner meal).

Year	Ribeye steak	Hamburger (Ground beef)	Pork chop	Baby back ribs	Chicken breast	PBMA	Shrimp	Salmon
Pooled (w/o Inconsistents)								
2020	21.79	15.81	11.91	15.32	14.95	9.75	15.01	15.63
2021	23.17	16.90	12.92	15.84	15.54	10.27	15.51	16.33
2022	23.87	17.48	13.68	16.35	16.21	10.47	16.18	17.17
2023	24.23	18.01	14.06	16.60	16.51	10.45	16.42	17.52
Regular meat consumers								
2020	24.34	17.13	13.59	17.58	16.24	9.56	16.77	17.39
2021	25.44	18.07	14.44	18.03	16.62	10.13	17.17	17.86
2022	26.66	19.23	15.60	18.87	17.80	10.36	18.18	18.92
2023	26.46	19.57	15.69	18.95	17.94	10.52	18.10	19.08
Flexitarians								
2020	24.42	19.98	15.53	16.88	21.05	20.58	19.13	22.50
2021	25.76	20.19	16.42	16.70	20.82	18.98	18.92	22.61
2022	23.71	18.31	14.73	15.30	19.51	17.38	17.97	21.23
2023	24.15	19.25	14.61	14.60	19.32	16.43	18.17	21.21
Vegetarians								
2020	-0.88	-5.87	-4.31	-3.59	3.16	16.43	0.85	-1.68
2021	0.83	-8.40	-9.13	-6.07	-0.17	20.89	-2.41	-5.30
2022	7.95	-0.51	-4.15	-3.70	2.02	18.09	2.27	8.95
2023	10.75	-2.89	-4.83	-10.31	-7.66	21.07	-1.78	-4.82
Vegans								
2020	3.85	5.33	-12.43	-1.14	-18.31	23.57	-9.23	-10.18
2021	7.97	1.69	-3.48	-2.88	-3.32	20.73	-5.82	2.87
2022	6.80	-8.03	-22.98	-12.18	-14.11	35.94	-17.97	-6.69
2023	12.71	0.78	1.30	-6.92	3.68	20.61	-1.29	4.56

4.2. Projected Market Shares – Among Examined Protein Options

Estimated models reflecting consumer preferences, by year and by dietary subset, are used in situations where all presented options are available for purchase at the intermediate levels employed in underlying choice experiments.6 Predicted market shares are presented for two cases: first when plant-based alternative patties are available in the market, and second when they are unavailable. The difference between these two situations represents the average extent to which plant-based alternatives would have displaced animal-based proteins across the 2020-2023 period. Note that shares are presented as the percent of consumers who choose an option, rather than opting out.

When looking at the retail market averaged across 2020-2023 for all consumers (Table 3), plant-based meat alternatives were predicted to capture 2.9 percent of retail sales. This is the smallest predicted share of any available protein and approximately two thirds that of the next smallest share protein, shrimp (4.9 percent). Both ground beef and chicken breast were expected to each capture over a quarter of the retail protein market on average, which is consistent with expectations and external estimates on relative retail market prevalence. While much of the small share of the plant-based alternative might be driven by the relatively high reference price ($11.99/lb.), this does not fully explain the small share, considering that ribeye steak captures 8.7 percent of the market despite an evaluated price of $16.99/lb that exceeds $11.99 for PBMA. In the event PBMA was absent from the retail market, the 2.9 percent share it would have otherwise captured is relatively evenly redistributed

6 In retail ($/lb) the intermediate offer prices were $16.99 for Ribeye Steak, $4.49 for Ground Beef, $4.99 for Pork Chops, $5.49 for Bacon, $3.99 for Chicken Breast, $11.99 for Plant-Based Patty, $10.99 for Shrimp and $2.99 for Beans and Rice. In food service ($/dinner meal) the intermediate offer prices were $21.49 for Ribeye Steak, $11.99 for Beef Hamburger, $16.99 for Pork Chop, $15.49 for Baby Back Ribs, $12.99 for Chicken Breast, $14.99 for Plant-Based Patty, $13.49 for Shrimp, and $16.99 for Salmon. Full choice experiment pricing details are described within Anderson (2023).

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amongst the remaining proteins. The absolute market share absorbed by PBMA in the retail market from each alternative protein ranges from 0.2 to 0.8 percentage points reflecting rather small adjustments for remaining proteins. The results indicate that the presence of PBMA reduces the percentage of consumers purchasing ground beef and ribeye steak by 0.8 and 0.3 percentage points, respectively. The shares for pork protein options are similarly reduced by 0.3 (bacon) and 0.4 (pork chops) percentage points on average while the share of consumers buying chicken breast would be 0.8 percentage points higher in the absence of PBMA. The least affected proteins are the seafood (shrimp) and other plant-based (beans) proteins, which both saw an average 0.2 percentage point reduction in share when PBMA was present in the market.

Table 3. Average retail market shares (2020-2023, intermediate offer prices).

Year	Ribeye steak	Ground beef	Pork chop	Bacon	Chicken breast	Plant based alternative patty	Shrimp	Beans
Pooled	8.7%	25.3%	14.3%	8.5%	27.6%	2.9%	4.9%	7.7%
Flexitarian	8.5%	18.6%	11.3%	7.1%	26.7%	6.7%	6.8%	14.4%
Regular meat consumer	6.9%	27.3%	14.5%	8.3%	31.5%	1.2%	4.2%	6.1%
Vegan	3.0%	5.4%	3.2%	3.6%	4.0%	30.2%	2.1%	48.4%
Vegetarian	1.5%	4.2%	1.5%	1.3%	4.4%	27.3%	3.1%	56.7%
Pooled	8.9%	26.0%	14.8%	8.7%	28.5%		5.1%	8.0%
Flexitarian	9.1%	19.9%	12.1%	7.6%	28.6%		7.3%	15.4%
Regular meat consumer	7.0%	27.7%	14.6%	8.4%	31.9%		4.2%	6.2%
Vegan	4.3%	7.7%	4.7%	5.2%	5.8%		3.1%	69.2%
Vegetarian	2.1%	5.7%	2.1%	1.8%	6.1%		4.3%	78.0%
	Difference							
Pooled	-0.3%	-0.8%	-0.4%	-0.3%	-0.8%		-0.2%	-0.2%
Flexitarian	-0.6%	-1.3%	-0.8%	-0.5%	-1.9%		-0.5%	-1.0%
Regular meat consumer	-0.1%	-0.3%	-0.2%	-0.1%	-0.4%		-0.1%	-0.1%
Vegan	-1.3%	-2.4%	-1.4%	-1.6%	-1.8%		-1.0%	-20.8%
Vegetarian	-0.6%	-1.5%	-0.6%	-0.5%	-1.7%		-1.2%	-21.3%

As expected, the impacts of retail PBMA availability are not evenly distributed across consumer groups when differentiated by dietary patterns. Following the trends identified in the WTP estimates, the pooled market shares are largely reflective of the regular meat consumers, who make up the bulk of the sample. Regular meat consumers are the least affected by the presence, and consequently by the absence, of PBMA, as only 1.2 percent of these consumers choose the PBMA option when available. By contrast, 6.7 percent of flexitarians, 30.2 percent of vegans, and 27.3 percent of vegetarians would elect the PBMA option if available in the retail setting. These consumers also generally exhibit a lower probability of purchasing beef and pork options and higher probability of choosing beans than the pooled sample or regular meat consumer group. Thus, the flexitarian, vegetarian, and vegan consumers are disproportionately affected by the removal of the PBMA option from the market. For flexitarians, the removal of PBMA results in a redistribution of market share predominantly driven by ground beef (1.3 percentage points) and chicken breast (1.9 percentage points), similar to the pooled case, though beans (1.0 percentage points) are third highest. For vegetarian and vegan consumers, however, beans capture the bulk of the redistributed market share from the absence of PBMA, with over 68 and 78 percent of vegetarians and vegans, respectively, who would have chosen PBMA choosing to buy beans instead.

Turning to the food service case Table 4 beef remains a leading option for market share in the pooled case, with over a quarter of consumers choosing ground beef meals (25.3 percent) and nearly 16 percent, the next highest share, choosing a ribeye steak meal. Chicken breast and shrimp follow closely while a plant based alternative patty meal takes the smallest share at 4.7 percent on average across the four years. Similar to the retail case, when the PBMA option is removed from the menu, it becomes clear that the bulk of the market share captured by the PBMA

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option comes from the beef and chicken meal options, as well as shrimp, with the PBMA share pulling approximately three quarters of its share from these items.

Table 4. Average food service (Dinner meal) Market shares (2020-2023, intermediate offer prices).

	Ribeye steak	Hamburger (Ground beef)	Pork chop	Baby back ribs	Chicken breast	Plant based alternative patty	Shrimp	Salmon
Pooled	15.7%	25.3%	5.0%	10.9%	15.5%	4.7%	14.1%	8.8%
Flexitarian	10.6%	19.1%	5.7%	7.5%	18.4%	11.1%	13.9%	13.6%
Regular meat consumer	16.0%	26.2%	4.0%	11.9%	15.7%	2.2%	15.4%	8.5%
Vegan	6.2%	8.3%	1.9%	3.2%	3.6%	70.4%	2.7%	3.7%
Vegetarian	3.4%	3.1%	1.2%	1.5%	5.8%	76.9%	4.8%	3.3%
Pooled	16.5%	26.6%	5.2%	11.5%	16.2%		14.8%	9.2%
Flexitarian	12.0%	21.5%	6.4%	8.4%	20.8%		15.7%	15.3%
Regular meat consumer	16.3%	26.8%	4.1%	12.2%	16.1%		15.8%	8.7%
Vegan	21.5%	26.6%	6.4%	10.1%	13.1%		9.1%	13.2%
Vegetarian	15.4%	13.7%	5.2%	6.4%	24.0%		20.3%	15.1%
	Difference							
Pooled	-0.8%	-1.3%	-0.2%	-0.5%	-0.8%		-0.7%	-0.4%
Flexitarian	-1.3%	-2.4%	-0.7%	-0.9%	-2.3%		-1.7%	-1.7%
Regular meat consumer	-0.4%	-0.6%	-0.1%	-0.3%	-0.4%		-0.4%	-0.2%
Vegan	-15.3%	-18.4%	-4.5%	-6.9%	-9.4%		-6.4%	-9.5%
Vegetarian	-12.0%	-10.6%	-4.0%	-4.9%	-18.1%		-15.5%	-11.8%

As with the retail case, when breaking food service market shares down by consumers' dietary patterns it is clear that the meat reducer or excluder groups are more heavily impacted by the presence and absence of a PBMA option. The share of regular meat consumers choosing the plant based alternative patty meal is 2.2 percent, of which 1.4 percent is captured from the beef or chicken options. In contrast, over 11 percent of flexitarians would choose the PBMA meal if offered, drawing heavily from consumers who would otherwise purchase a chicken breast, ground beef, or seafood meal (8.1 percentage points of 11.1). Interestingly, in the absence of an alternative plant protein option, the PBMA option would be chosen by between 70 and 77 percent of vegetarian and vegan consumers. Were the PBMA option to be unavailable for these consumers, of those who continue to make a purchase, most vegans elect a beef meal (21.5 percent of vegans choosing a meal choose a ribeye steak in the absence of a PBMA option, 26.6 percent choose a ground beef meal) while 44 percent of vegetarians choose chicken breast (24 percent) or shrimp (20.3 percent).

Overall, results indicate that PBMA options draw a relatively small share of the total market away from animal proteins and minimally processed plant proteins (beans). The majority of the market share PBMA does capture is primarily to the detriment of ground beef and chicken breast, though there is evidence that all available protein options suffer to some extent by the introduction of PBMA in the market. Nevertheless, PBMA represents a relatively small threat to the retail and food service markets for conventional animal proteins like beef, pork, and chicken. This is especially evident as the share of the market captured by PBMA on an annual basis across 2020 to 2023 has not changed substantially, remaining near or below 3 percent (retail) or 5 percent (food service) in each year. Although the introduction of PBMA options does not have a substantial impact on the retail or food service markets in general, for specific groups of consumers the availability of PBMA has a dramatic impact on food choices.

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4.3. Consumer Welfare Analysis

Table 5 presents estimates of the average value of retaining the retail availability of each protein option, aggregated by type. Estimated amounts are presented first per choice occasion and then in aggregate presuming 125 million households make one choice per week. On average, across the pooled sample, the availability of the plant based alternative patty in the retail setting was worth $0.09 per choice occasion with this value being lower in 2023 ($0.08) than in earlier years consistent with WTP and market share estimates presented earlier. Availability value varies substantially dependent on consumer subset as defined by dietary pattern, with regular meat consumers valuing the option to purchase PBMA at only $0.03 per choice occasion compared to a mean value of $3.65 per choice occasion for vegans (and as high as $5.04 in 2020).7 When calculating out the aggregate effects of these values, combined with the average consumer or household choices as reflected in the market shares analysis and assuming one choice occasion per week per household, the presence of the plant based alternative patty option in the retail market results in an average aggregate consumer welfare benefit of $743.3 million per annum across the four years of analysis. While estimated aggregate annual benefit increased from 2020 to 2021, it consistently declined from 2021 ($873.0 million) to 2023 ($550.1 million), largely driven by reductions in the per choice occasion value of the option for flexitarians, vegetarians and vegans. Consequently, the bulk of the total welfare impact of PBMA availability is borne by flexitarians (33 percent of total welfare impact), and vegans (27 percent) which is considerable given their disproportionately small prevalence within the population.

The welfare impacts of the availability of beef and chicken products offers a stark contrast to PBMA availability results. On average, across 2020-2023, the pooled value for beef (ribeye steak and ground beef) retail availability per choice occasion was $1.27, over 13 times that of the PBMA option, and for chicken breast it was $0.99. The average aggregate consumer welfare benefit of beef availability across the four years was $7.2 billion, with an average aggregate benefit of $6.3 billion for chicken breast. These findings contextualize the size of the estimated aggregate value of PBMA availability in the retail setting, which is just over a tenth the value of the ribeye and ground beef options' availability.

7 Note all consumer segments receive some benefit from increased options, beyond direct desirability of the product examined, given sheer utility presented by more alternatives. Stated differently, there is economic harm in restricted choice sets that goes beyond simple WTP values.

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Table 5. Consumer welfare impacts, loss of product options – retail.

Retail	2020	2021	2022	2023	Average 2020-2023
Loss of plant-based patty option					
Pooled	-0.09	-0.10	-0.10	-0.08	-0.09
Flexitarian	-0.34	-0.42	-0.36	-0.25	-0.34
Regular Meat Consumer	-0.03	-0.03	-0.03	-0.03	-0.03
Vegan	-5.04	-4.36	-3.57	-1.63	-3.65
Vegetarian	-1.29	-1.22	-1.07	-0.98	-1.14
Best, national aggregate retail consumer welfare estimate					
	(750,276,996.09)	(873,007,877.27)	(799,901,845.49)	(550,058,395.90)	(743,311,278.69)
Loss of beef options					
Pooled	-1.17	-1.28	-1.32	-1.31	-1.27
Flexitarian	-1.39	-1.63	-1.61	-1.57	-1.55
Regular Meat Consumer	-0.85	-0.99	-1.01	-1.03	-0.97
Vegan	-1.08	-1.00	-0.68	-0.70	-0.87
Vegetarian	-0.12	-0.28	-0.18	-0.26	-0.21
Best, national aggregate retail consumer welfare estimate					
	(6,419,708,896.01)	(7,458,240,130.95)	(7,526,301,650.45)	(7,534,622,182.09)	(7,234,718,214.87)
Loss of chicken option					
Pooled	-0.98	-0.98	-1.03	-1.00	-0.99
Flexitarian	-1.52	-1.50	-1.60	-1.48	-1.53
Regular Meat Consumer	-0.85	-0.86	-0.89	-0.90	-0.87
Vegan	-0.86	-0.37	-0.39	-0.17	-0.45
Vegetarian	-0.15	-0.19	-0.15	-0.17	-0.17
Best, national aggregate retail consumer welfare estimate					
	(6,144,054,855.62)	(6,243,515,920.65)	(6,454,244,706.09)	(6,354,125,892.47)	(6,298,985,343.71)

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The general trends observed for consumer welfare benefit of product availability hold when looking at the food service case Table 6 though the magnitude of the effects is increased. For the pooled sample, the mean value of the availability of the plant based alternative patty dinner meal is $0.26 per choice occasion across the four years, compared to $2.78 for ribeye steak and $0.90 for a chicken breast meal. Again, the values for vegans and vegetarians for the PBMA option are considerably higher than the pooled value, at $8.21 per choice occasion for vegans and $5.10 for vegetarians, between 19 and 31 times that of the pooled value. Similarly, when assessing the aggregate consumer benefit of the availability of PBMA options in a food service setting (or the loss conferred by their absence), PBMA is of substantial value to consumers ($4.0 billion per year, on average, from 2020-2023, based on 100 choice occasions per household per year), yet pales in comparison to ribeye steak ($31.2 billion per year). In all cases, the value of protein option availability is considerably higher in the food service context, as is expected, and demonstrates that PBMA is more valuable as a food service meal option than as a retail option when compared to ribeye steak or chicken breast.

Given the greater market share captured by PBMA in the food service case compared to the retail case, it appears that plant based alternatives have more potential to act to the detriment of animal proteins in the food away from home sector than the food at home sector. This is unsurprising since the findings in the literature show that retail PBMA choices are often complementary to animal protein purchases (Neuhofer & Lusk, 2022; Zhao et al., 2023). Even in the event of significant (10 percent) price reductions, Lusk, Blaustein-Rejto, Shah, and Tonsor (2022) estimated that any consequent increases in demand for PBMA would have relatively little impact on U.S. animal protein markets (0.15 percent reduction in U.S. beef cattle production). While this study's results show PBMA may have the potential to displace some meat consumption in the food service environment, it is less likely to do so in the grocery aisle. Moreover, the bulk of the welfare benefit derived from PBMA availability accrues to consumers with meat reducing or excluding diets (flexitarians, vegetarians, and vegans), further indicating that the displacement of meat consumption by PBMA is likely to be limited as regular meat consumers, the majority of the market, derive comparatively little value from those products.

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Table 6. Consumer welfare impacts, loss of product options – food service (Dinner meal).

Food service	2020	2021	2022	2023	Average 2020-2023
Loss of plant-based patty option					
Pooled	-0.27	-0.28	-0.26	-0.23	-0.26
Flexitarian	-1.09	-0.83	-0.75	-0.66	-0.83
Regular Meat Consumer	-0.09	-0.12	-0.10	-0.09	-0.10
Vegan	-7.29	-5.76	-14.71	-5.07	-8.21
Vegetarian	-3.66	-6.55	-3.85	-6.34	-5.10
Best, national aggregate retail consumer welfare estimate					
	(4,014,766,995.56)	(4,097,946,937.77)	(4,327,189,761.94)	(3,389,463,305.73)	(3,957,341,750.25)
Loss of beef options					
Pooled	-2.55	-2.79	-2.93	-2.84	-2.78
Flexitarian	-2.43	-2.56	-2.25	-2.54	-2.45
Regular Meat Consumer	-2.04	-2.36	-2.46	-2.47	-2.33
Vegan	-2.13	-0.62	-1.76	-0.58	-1.27
Vegetarian	-0.16	-0.32	-0.16	-0.64	-0.32
Best, national aggregate retail consumer welfare estimate					
	(27,873,102,891.16)	(32,495,690,938.96)	(32,347,720,124.78)	(31,894,751,417.96)	(31,152,816,343.22)
Loss of chicken option					
Pooled	-0.89	-0.89	-0.94	-0.86	-0.90
Flexitarian	-1.51	-1.42	-1.40	-1.35	-1.42
Regular Meat Consumer	-0.72	-0.73	-0.76	-0.75	-0.74
Vegan	-0.16	-0.15	-0.44	-0.31	-0.27
Vegetarian	-0.42	-0.41	-0.13	-0.10	-0.26
Best, national aggregate retail consumer welfare estimate					
	(10,715,788,022.10)	(10,939,041,033.78)	(10,867,593,921.28)	(10,407,612,469.12)	(10,732,508,861.57)

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5. CONCLUSION

From 2020 to 2023, plant-based meat alternatives were a moderately valued protein option across all U.S. consumer types in the retail context but received the lowest WTP in the food service setting. Consumer values for PBMA are much lower than those of beef and seafood options in both cases, though consumers are willing to pay more for PBMA than for chicken and pork options in the grocery store. While WTP for most proteins has grown from 2020 to 2023, likely accounted for by inflation and changing consumer expectations, WTP for PBMA has remained more fixed, especially in the food service context, averaging approximately $10 per meal.

On average considering a situation where PBMA and meat options are available at intermediate prices, PBMA has the potential to capture a relatively small share of the total retail and food service markets, averaging less than 5 percent across 2020-2023 in both contexts. This market share is most heavily captured at the expense of ground beef and chicken options, indicating those two industries face the most substantial potential impacts from PBMA's market presence. That said, the overall impact remains small consistent with PBMA averaging under 5 percent market share. This report's results demonstrate PBMA are unlikely to displace significant meat, seafood, or poultry consumption among U.S. consumers. This finding is consistent with previous studies identifying relatively small to moderate possible impacts of PBMA introduction on the beef industry (Cornelius, 2021; Lusk et al., 2022).

Although PBMA pose a minor threat to demand for traditional animal proteins for the broader U.S. consumer population, their effects are much more substantial for consumers with self-identified dietary patterns which reduce or exclude meat, fish, and poultry. Especially for vegans and vegetarians, PBMA options are more valuable and their absence results in a much higher welfare loss for those groups, both at the grocery store and in food service. Although PBMA are designed to appeal more to regular meat consumers (Hu et al., 2019) vegans and vegetarians continue to be the strongest consumer base for these products with the majority of the consumer welfare benefits of PBMA availability accruing to meat reducers and excluders. This finding is also consistent across food choice contexts.

The findings of this report are in line with market trends for PBMA. While PBMA products experienced substantial growth following their widespread introduction to retail and food service markets, sustaining their initial momentum has proven challenging. This study's results demonstrate that most consumers continue to value traditional animal protein options highly and tend to treat PBMA as a novel choice among many rather than a replacement for meat, poultry, and seafood. The current generation of PBMA products are likely to perform most strongly in food service settings and among consumers with dietary patterns that reflect a preference to limit or exclude meat, poultry, and seafood consumption.

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INSTITUTIONAL REVIEW BOARD STATEMENT

This study was approved by the Institutional Review Board of Kansas State University (Manhattan, KS USA), under protocol number 9970, dated February 2, 2022.

TRANSPARENCY

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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