Essays on physical exercise as a behavioral determinant of U.S. protein demand

by

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AN ABSTRACT OF A DISSERTATION

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Department of Agricultural Economics
College of Agriculture

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Abstract

Consumer preference and price sensitivity is a major driver of the U.S. food system. Consumers' food purchasing decisions have implications not only for individual health outcomes but also have upstream impacts on food retailing and manufacturing decisions, commodity production decisions, and prices experienced across all levels of the supply chain. In this dissertation, I seek to better understand the consumer side of the U.S. food system by evaluating a, thus far, unstudied determinant of food consumption and demand—physical exercise. Specifically, I focus on the relationship between physical exercise and animal protein purchasing and consumption. Nutritional studies and various media outlets have, for decades, discussed this relationship but no research has been conducted to quantify its economic impact. The remainder of this abstract outlines my four dissertation chapters.

In Chapter One, I determine the impacts of media information related to physical exercise on U.S. meat demand from 1993 through 2022. Including news media indices that capture publicly available information related to physical exercise and protein consumption in a food-separable Rotterdam demand model, I calculate news media elasticities. I find little to no evidence that news media attention to physical exercise has impacted aggregate demand for beef, pork, or chicken over time. Further, this media attention did not shift U.S. food demand into or out of the aggregate meat complex. This chapter has been accepted for publication in the *Journal of Agricultural and Resource Economics*.

Chapter Two examines the relationship between physical exercise and animal protein consumption (rather than demand). Using micro-level dietary recall and recreation data, I estimate the association of physical exercise with consumption of total protein, beef, pork, poultry, seafood, eggs, and dairy among U.S. adults. I find nonlinear associations, with those who exercise between

two and three hours per day having the highest level of total protein consumption. The direction and magnitude of association of physical exercise with disaggregate animal protein consumption differed by protein source. This confirmed what has been observed anecdotally in popular press and social media—not all protein sources are equal in the eyes of those who exercise. This chapter has been accepted for publication in *Nutrients*.

Having assessed physical exercise and its relationship with animal protein consumption, I then examine its relationship with animal protein demand. In Chapter Three, I utilize a novel source of consumer-level data in an AIDS framework to calculate price and expenditure elasticities separately for those who have exercise-related goals and those who do not. Specifically, an "open-ended" choice experiment is used to obtain survey respondents' purchasing information, which is then used to estimate the AIDS. I find that survey respondents who intentionally consume protein to meet their exercise goals have statistically lower own-price sensitivity for all evaluated protein goods. I further document the difficulties experienced in using open-ended choice experiment data and how future research could validate its use.

While analyzing the publicly available survey data used in Chapter Three, I discovered discrepancies in reported prior day food consumption between those who are exercise- and fitness-conscious and those who are not. For instance, eleven percent of survey participants who reported intentionally consuming protein to aid toward some fitness-related goal had also consumed eggs in the prior day. This is compared to eight percent of all other survey participants. I did not pursue this particular phenomenon but did note that eggs and other protein-dense food items (e.g., whey protein powder) were not included in either the survey's open-ended choice experiment or traditional, "choose one" choice experiment. With a sizable portion of a nationally representative sample indicating that they consume eggs, such omission of this product in the experimental design

seemed questionable. These observations, and prior research finding that choice experiment results are sensitive to construction of the choice set, motivated Chapter Four.

Chapter Four breaks from the theme of physical exercise but remains under the broader umbrella of consumer behavior and, further, delves more into the issue of experimental design that was broached in Chapter Three. In this chapter, which is intended to improve accuracy of consumer demand estimation, I consider the concept of separability (i.e., separability of goods) in choice experiment research. Specifically, I distribute several surveys that differ only in the food alternatives provided (such as eggs and whey protein powder mentioned above) in a discrete choice experiment and then estimate random parameters logit models of choice separately for each survey variant. Economic measures such as willingness-to-pay and market shares are calculated and compared across surveys. I find that slightly altering survey respondents' choice sets has substantial impact on mean willingness-to-pay estimates, the distribution of willingness-to-pay, and market shares—even for food alternatives that were available in every survey variant.

In sum, the findings from these chapters can be used to inform pricing and marketing strategies of U.S. food manufacturers and retailers, with these strategies having corresponding impacts on both livestock producers and consumers of animal protein. Further, future choice experiment design efforts may consider this work to improve economic conclusions.

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Chapter 1 - No Beef with Increased Media: The Impacts of Fitness Media on U.S. Meat Demand[1]

Introduction

The demand for meat is influenced by determinants such as income, own prices, and the relative prices of other food goods. Meat demand is also influenced by determinants that are more difficult to quantify such as health and nutritional perceptions, animal welfare concerns, religious or other dietary restrictions, and changes in consumer lifestyles. One factor in the latter category, which has yet to be formally considered in the meat demand literature, is the role of protein in aiding muscle building or in other pursuits related to physical exercise. Increasingly prevalent in the Unites States is participation in resistance training (U.S. Bureau of Labor Statistics, 2016; Meyersohn, 2023; Pandey, 2023; Thompson, 2023). Resistance training is a form of periodic exercise in which skeletal muscles work against external resistance to make them stronger and often results in muscle cell growth (Phillips and Winett, 2010).[2] These forms of exercise are intended for injury prevention and rehabilitation, general physical fitness, cosmetic alterations, or preparation for competitive sport (Stone, Stone, and Sands, 2007). Resistance training is often supplemented with the consumption of protein, whether it be from meat or other sources, to aid in the process of muscle repair and recovery. To the authors' knowledge, there have been no economic assessments of the relationship between resistance training (or other physical exercise pursuits) and the consumption of or demand for meat protein. As the first known economic

[1] Reprinted with permission from "No Beef with Increased Media: The Impacts of Fitness Media on U.S. Meat Demand" by Justin D. Bina, Glynn T. Tonsor, and Brian K. Coffey, 2024. Journal of Agricultural and Resource Economics, forthcoming. Copyright 2024 by Justin D. Bina, Glynn T. Tonsor, and Brian K. Coffey.

[2] The terms resistance training, strength training, and weightlifting are often used synonymously.

research in this area, our objective is to quantify how news media discussing that relationship has impacted U.S. demand for meat from 1993 to 2022. The remainder of this section further motivates that objective.

The National Academy of Medicine (formerly the Institute of Medicine) has provided for decades a series of dietary reference intakes to serve as a guide for nutrition (National Academies of Sciences, Engineering, and Medicine, 2006). These reference intakes have formed the basis of most federal and state nutrition programs (National Academies of Sciences, Engineering, and Medicine, 2006), including the U.S. Department of Agriculture (USDA) Dietary Guidelines for Americans (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020). The recommended dietary allowance (RDA) is one of such reference intakes and is defined as "the average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97-98 percent) healthy individuals in a particular life stage and gender group (National Academies of Sciences, Engineering, and Medicine, 2006)." For adults aged 19 years and older, the RDA for protein is 0.80 grams per kilogram of bodyweight per day [g/kg/day] (National Academies of Sciences, Engineering, and Medicine, 2006). To put this requirement into context, a 180-pound individual (roughly 81.6 kilograms) would be recommended to consume 65.3 grams of protein per day based on this RDA. As an example, this equates to 0.46 pounds (211 grams) of boneless, skinless, and roasted chicken breast (U.S. Department of Agriculture, 2019).

Importantly, various nutritional studies have recommended a different protein intake level for resistance-trained athletes and other exercising individuals. A meta-analysis on protein requirements for resistance-trained athletes by Wilson and Wilson (2006) suggests an intake of 1.2 to 2.2 g/kg/day. Jäger et al. (2017) further states the commonly cited reference intake of 0.80 g/kg/day is not appropriate for a training athlete to meet their daily protein needs and suggests a

minimum of 1.4 to 2.0 g/kg/day to optimize exercise training-induced adaptions. At time of publication, their recommended protein intake level for active individuals was the official stance of the International Society of Sports Nutrition (Jäger et al., 2017). Comparing these reference protein intake levels to the RDA prescribed by the National Academy of Medicine (2006), consumption of 1.2 to 2.2 g/kg would entail a 180-pound exercising individual eating between 98.0 and 179.6 grams of protein per day. This corresponds to between 0.70 and 1.28 pounds (316 to 579 grams) of boneless, skinless, and roasted chicken breast (U.S. Department of Agriculture, 2019)—substantially higher consumption than that recommended for an individual of similar weight who does not exercise.

To what extent health-focused U.S. consumers read refereed nutritional studies and, accordingly, adjust their protein consumption is unclear. However, the relationship between protein intake and physical activity (e.g., resistance training, aerobic training, and competitive sports) is commonly discussed in various media outlets. Headlines such as "5 things to know about protein," "Lift Weights, Eat More Protein, Especially if You're Over 40," and "Protein's Winning Ways" have appeared in major news media sources for decades and have highlighted the health benefits and importance of adequate protein intake for exercising individuals (Condor, 1995; Reynolds, 2018; Reynolds, 2023). Further, the introduction of social media platforms (e.g., Facebook, X [formerly Twitter], YouTube, Instagram, and TikTok) has made information regarding physical exercise and nutrition readily available to a mass audience. Reynolds (2023) notes videos including the "#protein" caption had been viewed over 9.1 billion times on the popular TikTok application as of May 2023, providing some indication of the topic's cultural prevalence.

Providing, to our knowledge, the first economic study that considers the intersection of physical exercise and protein, we focus on media's role as an informational tool and potential

driver of meat demand. Specifically, the objective is to quantify how news media information related to physical exercise impacts U.S. demand for beef, pork, and chicken at a national level. As no data collection effort has been conducted to track U.S. consumers' media intake and meat purchases at an individual level, a national and aggregated demand assessment is most appropriate for this work. Further, since social media information originates from a multitude of platforms—with varying degrees of feasibility in attaining said information—and is available for a relatively short period of time, we elect instead to use news media information (print and digital) from major news outlets.[3] This reflects our assumption that news content related to physical exercise and meat consumption aligns with consumers' awareness of the role protein may play in their personal health and fitness goals.

Prior Research

A host of research has assessed the influence of various media sources on demand for meat proteins. Burton and Young (1996), in estimating the impact of bovine spongiform encephalopathy (BSE) on British demand for beef and other meat products, extended the dynamic version of Deaton and Muellbauer's (1980) almost ideal demand system (AIDS) by incorporating consumers' awareness of the disease as a demand shift variable. Their measure of consumer awareness was a linear aggregation of the quarterly number of newspaper articles published that mentioned BSE. Such a media index, when incorporated into a dynamic AIDS model, allowed them to quantify the short- and long-run impacts on meat demand of media coverage related to BSE. Verbeke and Ward

[3] It is important to note that news information originating from print and digital articles is commonly "reposted" or "shared" on social media, with links often provided to the original source. Mobile news applications further distribute these articles to potentially younger, or more technologically savvy consumers of news information. Overall, the news media information discussed in this study spills over to other outlets, with the method of news consumption likely being fungible.

(2001) likewise incorporated a media index in an AIDS framework to evaluate the impacts of negative television (TV) press on the demand for fresh meat in Belgium. In contrast to Burton and Young (1996), their media index was a sum of negative TV news reports less positive news reports and was compared to actual TV advertising expenses. Simulating the impact of negative TV press and advertising, Verbeke and Ward (2001) then explored the potential of commercial advertising to counter negative press information. Later research by Piggott and Marsh (2004) generalized the AIDS model by accounting for pre-committed levels of consumption and, additionally, incorporated food safety indices to account for newspaper coverage of product recalls, salmonella, E. coli, and other contamination-related terms. Importantly, their indices—calculated in a similar fashion as Burton and Young (1996)—were constructed separately for beef, pork, and poultry. This procedure allowed them to evaluate own- and cross-commodity effects of food safety variables on U.S. meat demand.

Marsh, Schroeder, and Mintert (2004) again used the linear aggregation approach of Burton and Young (1996) to construct news media indices with a focus on the impact of product recall information on U.S. demand for beef, pork, and poultry. Own- and cross-commodity impacts of media coverage were assessed with Piggot and Marsh's (2004) proposed method of constructing indices separately by meat product. Marsh, Schroeder, and Mintert (2004) provided an important extension of prior related work by incorporating the media variables in Barten (1964) and Theil's (1965) Rotterdam demand model. This approach was later adopted by Tonsor, Mintert, and Schroeder (2010) and Tonsor and Olynk (2011) in their work, which assessed the impacts of human health and animal welfare concerns, respectively, on U.S. meat demand. Other approaches have since been developed to estimate meat demand response to media information, which have varied in functional forms and commodities analyzed (Yadavalli and Jones, 2014; Wang and de

Beville, 2017). In general, these studies found economically small impacts of media volume on meat demand with relatively larger price and expenditure marginal effects.

Methods

A consumer's utility maximation problem is given by:

$$\max_{x}\{u(x,H)\ s.t.\ x \geq 0,\ p'x = m\} \quad (1)$$

where *u* denotes utility, *x* is an *n*-vector of goods consumed at an *n*-vector of prices *p*, m is total expenditure that is fixed for the consumer, and *H* is an *M*-vector of demand shift variables that reflect news media information on meat consumption and physical exercise. The consumer optimally allocates fixed expenditure *m* across the *n*-vector of goods *x* subject to an exogenous level of *H*. Using first-order conditions, the Marshallian demand of a well-behaved consumer for good *i* is $x_i(p, m, H)$.

Model Specification

We assume that news media information on the relationship between meat consumption and physical exercise may not only affect substitution patterns between meat proteins, but could also influence substitution into or out of the meat complex entirely.[4] A food separable model of beef, pork, chicken, and all other food allows for examination of within-meat impacts of media information as well as shifts into or out of aggregate meat consumption (Marsh, Schroeder, and Mintert, 2004). That is, the food separable model, as estimated in this study, allows for total meat demand to change with news media coverage. This is not possible if applying a meat separable assumption, which restricts the weighted sum of media elasticities across all meat equations to

[4] "Meat complex" here is defined as beef, pork, and chicken. We discuss the omission of turkey in the Data section.

zero, and requires at least one to be negative and one to be positive (Marsh, Schroeder, and Mintert, 2004).

Similar to Marsh, Schroeder, and Mintert (2004), Tonsor, Mintert, and Schroeder (2010), and Tonsor and Olynk (2011), an absolute price version of Barten (1964) and Theil's (1965) Rotterdam model is estimated with the model's share equations:

$$\bar{w}_{it}\Delta \ln(x_{it}) = \alpha_i + \beta_i \Delta \ln(\bar{q}_t) + \sum_{j=1}^{n} c_{ij}\, \Delta \ln(p_{jt}) + \sum_{k=1}^{3} d_{ik}\, D_k + \sum_{l=1}^{2} \gamma_{il}\, T_l + \sum_{m=1}^{M} \delta_{im} \Delta \ln(H_m) + \sum_{m=1}^{M}\sum_{l=1}^{2} \theta_{iml}\, \Delta \ln(H_m)\, T_l + v_i \quad (2)$$

where $\bar{w}_{it} = 0.5(w_{i,t} - w_{i,t-1})$ is the average budget share of the *i*th good (i = 1,…,n); Δ is the first difference operator; x_{it} is the per capita consumption of good *i* in time *t*; $\Delta \ln(\bar{q}_t)$ is the Divisia volume index where $\Delta \ln(\bar{q}_t) = \sum_{j=1}^{n} \bar{w}_{it} \Delta \ln(x_{it})$; p_{jt} is the price of good j in time *t*; D_k is a quarterly dummy variable capturing seasonality in demand; T_l is a dummy variable for decade; H_m is the *m*th exogenous demand shifter (i.e., a news media index); v_i is a random error term; and α_i, β_i, c_{ij}, d_{ik}, γ_{il}, δ_{im}, and θ_{iml} are parameters to be estimated.

News media indices related to the relationship between the respective meat proteins and physical exercise are interacted with categorical decade variables. This allows for the influence of media information on meat demand, and the associated media elasticities, to vary over time. This is desirable because the prevalence of news media—used in our index construction—has changed as over the course of the study period (Grundy, 2022; Naseer and St. Aubin, 2023), perhaps leading to important temporal differences in the impact on meat demand.

Prior to estimation, the *j*th equation was dropped to avoid singularity of the variance-covariance matrix of error terms. Coefficients for the *j*th equation are derived using adding-up

restrictions. Further, homogeneity and symmetry restrictions are imposed to guarantee consistency with consumer theory. Adding-up conditions in the Rotterdam model are:

(3) $$\sum_{i=1}^{n}\beta_i = 1, \sum_{i=1}^{n} c_{ij} = 0, \sum_{i=1}^{n} d_{ik} = 0, \sum_{i=1}^{n}\gamma_{il} = 0, \sum_{i=1}^{n}\delta_{im} = 0, \text{ and } \sum_{i=1}^{n}\theta_{iml} = 0$$

and ensure that the sum of budget shares across all included goods always equal one. Homogeneity and symmetry restrictions are imposed by:

(4) $$\sum_{j=1}^{n} c_{ij} = 0 \text{ and } c_{ij} = c_{ji}.$$

Homogeneity of degree zero in all prices and total expenditure implies that scaling all prices and total expenditure by the same constant will not affect quantities of goods demanded. Further, budget shares remain fixed in the absence of changes in relative prices or total expenditure.

Rotterdam expenditure and compensated price elasticities are, respectively (Marsh, Schroeder, and Mintert, 2004; Goodwin, Ramsey, and Chvosta, 2018):

(5) $$\eta_i = \frac{\beta_i}{w_i} \text{ and } \varepsilon_{ij} = \frac{c_{ij}}{w_i}$$

while shift, or media, elasticities are:

(6) $$\mathrm{K}_{iml} = \frac{\delta_{im} + \theta_{iml}}{w_i}$$

which, through incorporating interactions of media index terms with categorical decade terms, allows demand sensitivity to media information to vary over time periods. Using equation (6), $\mathrm{K}_{im0} = \frac{\delta_{im}}{w_i}$ is the elasticity estimate for the mth media index on the ith good and for the default decade (i.e., all media-decade interaction terms are equal to zero). Marsh, Schroeder, and Mintert (2004) used a similar approach to calculate current period and long-run media elasticities.

Estimation

Potential endogeneity in meat prices and expenditures was assessed via Wu-Hausman specification tests. Specifically, the model was estimated in four separate ways. First, prices and expenditures were assumed to be exogenous and the model was estimated using ordinary least squares (OLS) and iterative seemingly unrelated regression (ITSUR). Next, price and expenditures were assumed to be endogenous and the model was estimated using the instrumental variable methods iterative two-stage least squares (IT2SLS) and iterative three-stage least squares (IT3SLS) regression. The instruments used were the same period total food expenditure, price index for energy, nearby corn futures, 13-week treasury bill, federally inspected red meat and chicken production, and up to their four-quarter lagged values (with the exception of total food expenditure). Additional instruments included were up to four-quarter lagged meat prices, per capita quantities, and media indices (H_m).

We also evaluated several autocorrelation corrections as described by Berndt and Savin (1975). These included: i) a null correction matrix which restricts all elements to be zero (i.e., there is no autocorrelation correction; $\rho_{ij} = 0 \; \forall_{ij}$), ii) a diagonal correction matrix which restricts off-diagonal elements to be zero and allows diagonal elements to be unique ($\rho_{ij} = 0 \; \forall_{i \neq j} \; and \; \rho_{ij} \neq 0 \; \forall_{i=j}$), and iii) a complete autocorrelation matrix where all elements are allowed to differ individually from zero ($\rho_{ij} \neq 0 \; \forall_{ij}$). Adjusted likelihood ratio tests were used to compare alternative model specifications.

The adjusted likelihood ratio test statistics for systems estimations were calculated as $LR[MT - 0.5(N_u + N_r) - 0.5M(M+1)]/(MT)$ where LR is the unadjusted log-likelihood value, M is the number of equations, T is the number of observations, N_u is the number of parameters in the unrestricted model, and N_r is the number of parameters in the restricted model (Moschini, Moro, and Green, 1994; Marsh, Schroeder, and Mintert, 2004).

The preferred estimation procedure and model specification depends on the sequence of testing. That is, results of Hausman specification tests for endogeneity and adjusted likelihood ratio tests for autocorrelation correction depend on which test is conducted first. As such, we first conducted Hausman tests on three models characterized by a null, diagonal, and complete autocorrelation correction matrix. OLS was preferred for the model using a null correction matrix, as well as for both models accounting for autocorrelation. Second, for each estimation method (i.e., OLS, ITSUR, IT2SLS, and IT3SLS) we conducted adjusted likelihood ratio tests to determine the appropriate autocorrelation correction matrix. A diagonal matrix was the preferred specification using OLS and ITSUR estimation methods while a null matrix was preferred using IT2SLS and IT3SLS estimation. Further, the log-likelihood value was greatest for a model characterized by an ITSUR estimation with diagonal autocorrelation correction matrix, which we use to provide our results. Based on the sequence of tests discussed above we treat prices and expenditure as predetermined (i.e., exogenous) over the study period and do not include off-diagonal autocorrelation correction elements in our modeling.

Wald tests on media-related parameters are conducted to evaluate their joint significance by meat protein and period. This is necessary because in the proposed model, news media's influence on meat demand varies across both goods and time and is a function of several parameters. Simply reporting statistical significance of individual parameters is not overly useful in this assessment. We further use the variance of Wald-type test statistics to obtain standard errors for all elasticity estimates. Gregory and Veall (1985) and Phillips and Park (1988) note that the Wald test is not invariant to nonlinear transformations of the null hypothesis. That is, in small samples, changing the form of a nonlinear restriction to a form that is algebraically equivalent can yield different numerical values of the Wald test statistic. Noting the use of mean budget shares

(w_i) in equations (5) and (6), this important limitation does not impact Rotterdam elasticity estimates.

Data

The demand model is estimated using quarterly data for beef, pork, chicken, and all other food goods from 1993 through 2022. Beef, pork, and chicken retail prices supporting this study are from the USDA Economic Research Service (ERS) and are based on U.S. Bureau of Labor Statistics (BLS) retail price data (U.S. Department of Agriculture Economic Research Service, 2023c). Monthly retail prices were aggregated to quarterly prices by taking a simple average and were then deflated by the BLS (2023c) consumer price index (CPI) for food. Beef, pork, and chicken quantities are quarterly retail weight per capita disappearance (in pounds) obtained from ERS (2023d). Prior meat demand studies constructed an aggregate poultry price and quantity, consisting of chicken and turkey. We elected not to include turkey data in this study because turkey represents a substantially smaller share of aggregate meat disappearance than other meat proteins, creating potential scaling issues when included as a unique share equation. Further, a combined poultry share equation may mask important information on media's influence over chicken—a protein source of key interest when considering health- and fitness-conscious consumers.

All other food is included in the demand assessment, resulting in a conditional food demand model that improves insights on media's influence over meat proteins relative to a meat-separable model. Quarterly total food expenditure data was obtained from the U.S. Bureau of Economic Analysis (2023). Total food expenditures were deflated by the CPI for food and converted to per capita expenditures. Other food expenditures were then calculated as total food expenditures (on a real and per capita basis) less real, per capita expenditures on beef, pork, and chicken. Per Eales and Unnevehr (1993), other food quantity was calculated by deflating total food expenditures,

converting to a per capita basis, and then subtracting per capita disappearance of beef, pork, and chicken. The "other" food price is then the ratio of real, per capita other food expenditure to quantity (Eales and Unnevehr, 1993).

Data used for instrumental variable approaches, and associated Hausman specification tests, is from the BLS (2023b) CPI for energy series, a Yahoo! Finance (2023) archive of closing values for the 13-week treasury bill, a Livestock Marketing Information Center (2023) archive of nearby corn futures closing prices, and the USDA Agricultural Marketing Service AMS_3658 and Poultry Slaughter reports for federally inspected red meat and chicken production (U.S. Department of Agriculture National Agricultural Statistics Service, 2023).[5]

Media Indices

ProQuest Central (2024) was used to construct indices capturing public news information on the relationship between meat consumption and physical exercise. Three indices were created and included in equation (2) as H_m. We limited data collection to articles appearing in the ProQuest Central U.S. Major Dailies database. This database archives print and digital articles published in five of the country's largest national and regional newspapers: the Chicago Tribune, the Los Angeles Times, the New York Times, the Wall Street Journal, and the Washington Post. By using the U.S. Major Dailies database, we capture news media information that is accessible to most U.S. residents while omitting information from smaller local news outlets that is of little relevance on a national scale, burdensome—if not infeasible—to collect, and that may present issues of double counting (reflecting the recirculation of common articles across news media outlets). While the news outlets used in our index construction oftentimes require paid subscriptions, we

[5] The AMS_3658 report was formerly the SJ_LS711 report. Meat production data was obtained from a USDA National Agricultural Statistics Service online database.

emphasize that the information contained in these articles is commonly cross-referenced in other outlets or posted on social media platforms (with article titles, images, and general "tone" available to all viewers).[6] All indices were calculated as the quarterly, linear aggregation of articles written in English, appearing in the aforementioned sources, and including the keywords defined in the succeeding paragraph. Our method of index construction follows closely the work of Burton and Young (1996) and Marsh, Schroeder, and Mintert (2004).

The keywords used in our searches of the ProQuest Central U.S. Major Dailies database were i) "beef AND (exercise OR fitness OR physical health)", ii) "pork AND (exercise OR fitness OR physical health)", and iii) chicken AND (exercise OR fitness OR physical health)". These are referred to as *Media_Beef*, *Media_Pork*, and *Media_Chicken* throughout the remainder of the article. Additionally, we included the modifier "NOT government" in each of the searches to eliminate articles regarding politics and governmental activity that were present in our initial search efforts.[7]

Marsh, Schroeder, and Mintert (2004) state that meat recall information may have spillover effects on consumer demand for other meat products. We make a similar assumption in that news media related to one sector may have spillover impacts on other meat sectors. As such, our demand model allows for own-species and cross-species effects in each of the share equations. Further, our

[6] "Clickbait" websites—or websites that are designed to attract attention and generate web traffic—may reflect sources of information that do not require subscriptions and, accordingly, have broad viewership. We elected not to incorporate clickbait-type outlets in our index construction as these outlets are known to produce sensationalized or misleading content that may not reach a representative sample of the population. That is, we are unsure if this type of content is consumed disproportionately by certain demographic groups or groups with particular interests (i.e., physical exercise). If so, incorporating such information in our index construction yields media attention variables that do not reflect information that is consumed by the average citizen.

[7] For example, the search terms "pork" and "exercise" initially returned articles related to pork barrel spending, legislative activity, etc.

approach does not make directional distinctions. That is, articles suggesting either a positive or negative impact of physical exercise on protein consumption are equally weighted. Though health- and fitness-related media articles may be "demand improving" or "demand reducing," we elect not to distinguish between the two because those distinctions can be highly subjective (Mazzocchi, 2006). For instance, an article related to *lean* beef consumption and exercise may be viewed in a positive light by a consumer who is concerned over potential health risks of fat consumption. Conversely, the same article may be viewed in a negative light by a consumer who subscribes to the keto diet, which is characterized by high fat and minimal carbohydrate intake. Additionally, it is possible from our method of index construction that an article related to multiple meat proteins is included in multiple indices, creating an issue of double counting and an overstating of the number of exercise-related articles. The constructed indices are moderately, but not strongly, correlated over the period of study (0.41 to 0.48), easing concern that news articles are being captured in multiple indices to a substantial degree.[8] Ultimately, the main interest is in net effects on aggregate beef, pork, and chicken demand, making the narrower distinctions of directionality and multi-protein information beyond the scope of this study.

Descriptive Statistics

Descriptive statistics for real retail meat prices, per capita meat disappearance, and news media indices are in Table 1.1. In real terms, beef, pork, and chicken prices averaged $2.12, $1.50, and $0.86 per pound, respectively, from 1993 through 2022. Per capita disappearance averaged 15.5, 12.5, and 20.6 pounds per quarter for beef, pork, and chicken, respectively, over the same period.

[8] An aggregate media index constructed from articles with the terms "(protein OR beef OR pork OR chicken) AND (exercise OR fitness OR physical health) NOT government" eliminated the issue of double counting and provided similar economic conclusions.

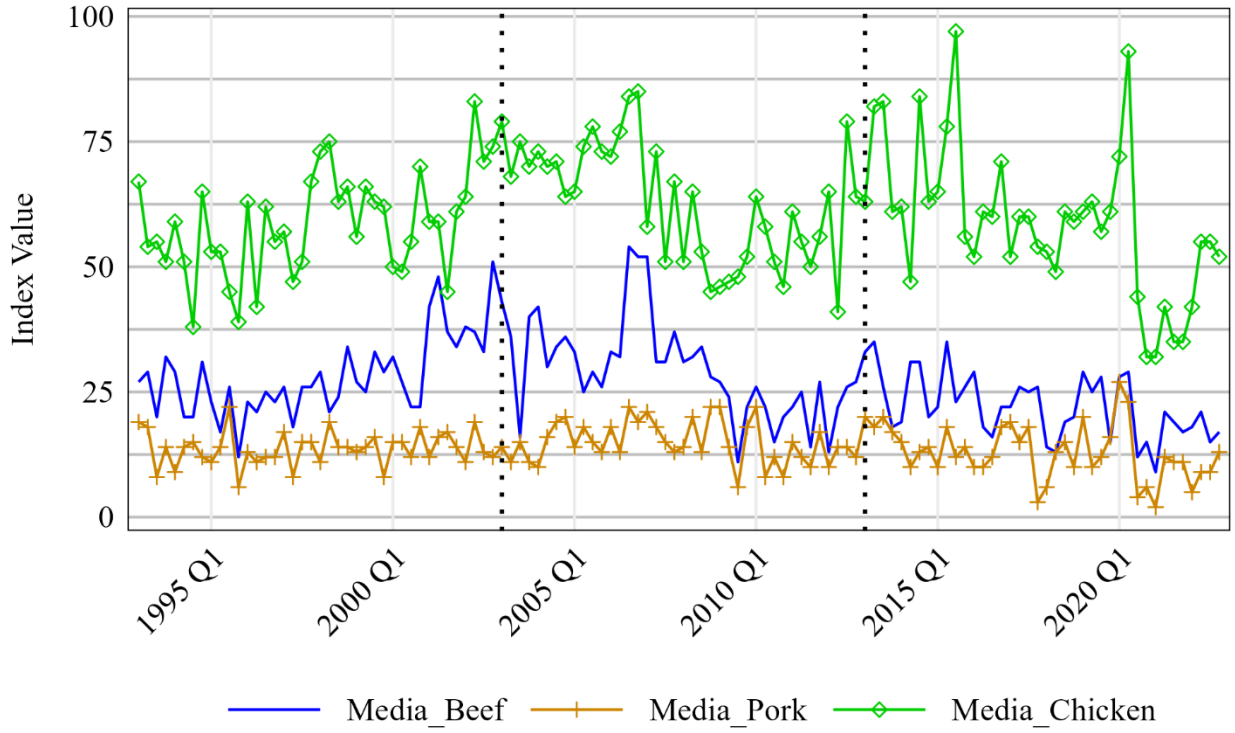
Table 1.1. Descriptive Statistics of Quarterly Data (1993–2022)

Variable	Mean	SD	Minimum	Maximum
Beef disappearance (lb/capita)	15.51	1.23	13.11	17.55
Pork disappearance (lb/capita)	12.52	0.77	10.82	14.30
Chicken disappearance (lb/capita)	20.62	2.23	16.36	25.74
Retail beef price ($/lb)	2.12	0.25	1.70	2.75
Retail pork price ($/lb)	1.50	0.08	1.31	1.71
Retail chicken price ($/lb)	0.86	0.09	0.72	1.03
Beef news media index	26.55	8.86	9.00	54.00
Pork news media index	13.88	4.50	2.00	27.00
Chicken news media index	60.22	12.69	32.00	97.00

Note: Prices are inflation adjusted (i.e., deflated by the BLS CPI for food, 1982-1984 = 100). Indices are a simple sum of articles.

Beef, pork, and chicken news media indices averaged 26.6, 13.9, and 60.2 print and digital articles per quarter, respectively. Average quarterly index values indicate that chicken receives relatively more news media coverage related to physical exercise. This is not surprising given the typically lower fat contents in chicken cuts relative to beef and pork cuts, and the appeal that may yield among health-conscious consumers. Worth noting is that none of the news media indices experienced a value of zero during the period of study. This is ideal because a critical input in the Rotterdam demand model is the natural logarithm of the index values. Figure 1.1 depicts values of the beef, pork, and chicken news media indices over time.

Figure 1.1. Species-Specific Quarterly News Media Indices (1993–2022)



Index values vary over time for each species, prompting the inclusion of decade and decade-media interaction regressors in equation (2)[9]. *Media_Beef* averaged 28.0, 29.5, and 22.2 articles per quarter in the 1993–2002, 2003–2012, and 2013–2022 periods, respectively. Similar trends are apparent for *Media_Pork*, with an average article count of 13.7, 15.0, and 13.0 per quarter in the same decades. *Media_Chicken*, though still declining in number of articles from the second decade to the third, did not decline to the same extent as the beef and pork media indices. The average article count for *Media_Chicken* was 58.4, 63.1, and 59.1 for the 1993–2002, 2003–

[9] We elected to use broad decade and decade-media interactions rather than shorter time intervals i) to reduce model complexity and retain degrees of freedom when conducting Hausman specification tests and ii) to bypass potential endogeneity of interval selection and media impacts (e.g., the five-year period from 2002 through 2006 was characterized by relatively higher *Media_Chicken* values). Further, results indicate that news media influences are neither statistically nor economically significant across the entire period of study.

2012, and 2013–2022 periods, respectively. There did not appear to be sizable seasonal trends in beef-, pork-, or chicken-related news media attention to physical exercise. Monthly average index values capturing these seasonal trends are in Appendix Table A.1.

Results

The preferred Rotterdam model was selected after a sequence of Hausman specification tests and adjusted likelihood ratio tests and is characterized by an ITSUR estimation with a diagonal autocorrelation adjustment. Table 1.2 depicts coefficient estimates from the preferred model. Values in square brackets are news media-related parameter names. We are most interested in these parameters as they are used to calculate news media elasticities. Adjusted R^2 values indicate the model captures 72 percent, 88 percent, and 55 percent of the in-sample variation in beef, pork, and chicken, respectively. The estimated price coefficient matrix is negative definite, implying that curvature restrictions are satisfied. Seasonal trends for beef and pork align with prior studies (Marsh, Schroeder, and Mintert, 2004; Tonsor, Mintert, and Schroeder, 2010; Tonsor and Olynk, 2011), while those for chicken differ—perhaps due to our omission of highly seasonal turkey consumption.

Table 1.2. Coefficient Estimates of Rotterdam Model, Quarterly Data (1993–2022)

	Share Equation		
Dependent Variable	Beef	Pork	Chicken
Intercept	-3.70E-04***	4.60E-04***	-1.80E-04***
	(5.00E-05)	(3.10E-05)	(2.80E-05)
Expenditure	4.21E-03*	-4.60E-04	9.69E-04
	(2.17E-03)	(1.42E-03)	(1.37E-03)
Beef Price	-3.94E-03***		
	(5.74E-04)		
Pork Price	4.16E-04	-1.66E-03***	
	(3.61E-04)	(5.22E-04)	
Chicken Price	-4.30E-04	1.84E-04	-1.80E-04

	Share Equation		
Dependent Variable	Beef	Pork	Chicken
	(3.61E-04)	(4.14E-04)	(6.36E-04)
Other Food Price	3.95E-03***	1.06E-03	4.26E-04
	(8.21E-04)	(6.90E-04)	(7.66E-04)
Quarter 1 Dummy	2.95E-04***	-8.90E-04***	2.74E-04***
	(7.70E-05)	(4.50E-05)	(3.40E-05)
Quarter 2 Dummy	8.23E-04***	-6.40E-04***	3.22E-04***
	(5.70E-05)	(3.80E-05)	(3.60E-05)
Quarter 3 Dummy	3.79E-04***	-2.90E-04***	2.10E-04***
	(7.90E-05)	(4.80E-05)	(3.70E-05)
Decade Dummy (2003-2012)	-3.00E-05	-2.00E-05	-3.00E-05
	(3.10E-05)	(2.10E-05)	(2.40E-05)
Decade Dummy (2013-2022)	-3.06E-06	8.37E-06	-1.21E-06
	(3.20E-05)	(2.20E-05)	(2.40E-05)
Media_Beef	-2.00E-05 [δ_{11}]	-1.20E-04 [δ_{21}]	-1.20E-04 [δ_{31}]
	(1.30E-04)	(8.40E-05)	(7.70E-05)
Media_Pork	5.60E-05 [δ_{12}]	6.70E-05 [δ_{22}]	5.60E-05 [δ_{32}]
	(9.80E-05)	(6.20E-05)	(5.20E-05)
Media_Chicken	-9.00E-05 [δ_{13}]	1.58E-04 [δ_{23}]	-4.00E-05 [δ_{33}]
	(1.85E-04)	(1.17E-04)	(1.03E-04)
Media_Beef x *Decade* (2003-2012)	-1.20E-04 [θ_{11_1}]	1.09E-04 [θ_{21_1}]	3.20E-05 [θ_{31_1}]
	(1.62E-04)	(1.05E-04)	(9.50E-05)
Media_Pork x *Decade* (2003-2012)	5.00E-05 [θ_{12_1}]	-1.80E-04** [θ_{22_1}]	-7.00E-05 [θ_{32_1}]
	(1.36E-04)	(8.60E-05)	(7.30E-05)
Media_Chicken x *Decade* (2003-2012)	1.81E-04 [θ_{13_1}]	-2.10E-04 [θ_{23_1}]	1.34E-04 [θ_{33_1}]
	(2.77E-04)	(1.73E-04)	(1.42E-04)
Media_Beef x *Decade* (2013-2022)	-1.00E-05 [θ_{11_2}]	7.80E-05 [θ_{21_2}]	3.00E-05 [θ_{31_2}]
	(1.70E-04)	(1.10E-04)	(1.01E-04)
Media_Pork x *Decade* (2013-2022)	-1.10E-04 [θ_{12_2}]	-1.20E-04 [θ_{22_2}]	-4.00E-05 [θ_{32_2}]
	(1.16E-04)	(7.40E-05)	(6.30E-05)

	Share Equation		
Dependent Variable	Beef	Pork	Chicken
Media_Chicken x *Decade* (2013-2022)	-2.00E-04 [θ_{13_2}]	-3.50E-04** [θ_{23_2}]	4.00E-05 [θ_{33_2}]
	(2.47E-04)	(1.60E-04)	(1.41E-04)
Autocorrelation Adjustment (ρ_{11})	-4.63E-01***		
	(9.17E-02)		
Autocorrelation Adjustment (ρ_{22})		-3.65E-01***	
		(9.38E-02)	
Autocorrelation Adjustment (ρ_{33})			-1.10E-01
			(1.03E-01)
Observations	120		
Adjusted R^2	0.71	0.88	0.55
Log-Likelihood Value	2,664.34		

Note: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the ten, five, and one percent levels, respectively. Values in parenthesis are standard errors. Values in square brackets are media-related parameter names. The default (i.e., dropped) quarter dummy is Quarter 4, while the default decade dummy is the 1993–2002 period.

To evaluate the joint significance of news media indices, by meat protein and period, a series of Wald tests were conducted on various combinations of the estimated coefficients. The results of the Wald tests are in Table 1.3. From the estimates for *Media_Beef*, *Media_Pork*, and *Media_Chicken* shown in Table 1.2, news media indices did not have statistically significant impacts on the demand for any meat protein in the default decade of 1993 to 2002. Further, Table 1.3 results indicate these influences were likewise not statistically different from zero in the succeeding two decades (five percent confidence level).

Table 1.3. Wald Tests on Coefficient Estimates of Rotterdam Model

Impact of:	On Quantity of:	In Period:	Test	*p*-value
Media_Beef	Beef	2003–2012	$\delta_{11}+\theta_{11_1}=0$	0.1796
Media_Pork	Beef	2003–2012	$\delta_{12}+\theta_{12_1}=0$	0.2636
Media_Chicken	Beef	2003–2012	$\delta_{13}+\theta_{13_1}=0$	0.6472
Media_Beef	Pork	2003–2012	$\delta_{21}+\theta_{21_1}=0$	0.9108

Impact of:	On Quantity of:	In Period:	Test	*p*-value
Media_Pork	Pork	2003–2012	$\delta_{22}+\theta_{22_1}=0$	0.0684
Media_Chicken	Pork	2003–2012	$\delta_{23}+\theta_{23_1}=0$	0.6804
Media_Beef	Chicken	2003–2012	$\delta_{31}+\theta_{31_1}=0$	0.1237
Media_Pork	Chicken	2003–2012	$\delta_{32}+\theta_{32_1}=0$	0.8472
Media_Chicken	Chicken	2003–2012	$\delta_{33}+\theta_{33_1}=0$	0.3720
Media_Beef	Beef	2013–2022	$\delta_{11}+\theta_{11_2}=0$	0.7500
Media_Pork	Beef	2013–2022	$\delta_{12}+\theta_{12_2}=0$	0.3839
Media_Chicken	Beef	2013–2022	$\delta_{13}+\theta_{13_2}=0$	0.0621
Media_Beef	Pork	2013–2022	$\delta_{21}+\theta_{21_2}=0$	0.5876
Media_Pork	Pork	2013–2022	$\delta_{22}+\theta_{22_2}=0$	0.2157
Media_Chicken	Pork	2013–2022	$\delta_{23}+\theta_{23_2}=0$	0.0600
Media_Beef	Chicken	2013–2022	$\delta_{31}+\theta_{31_2}=0$	0.1510
Media_Pork	Chicken	2013–2022	$\delta_{32}+\theta_{32_2}=0$	0.6020
Media_Chicken	Chicken	2013–2022	$\delta_{33}+\theta_{33_2}=0$	0.9587

Tests on coefficient estimates can be extended to evaluate the joint significance of all news media indices on a specific meat protein and in a specific decade. For example, a Wald test on the hypothesis that $\delta_{11}+ \theta_{11_2}+ \delta_{12}+ \theta_{12_2}+ \delta_{13}+ \theta_{13_2}$ equals zero is, equivalently, a test on the hypothesis that all news media indices (i.e., *Media_Beef*, *Media_Pork*, and *Media_Chicken*) had no effect on demand for beef in the 2013–2022 period. From these tests, all news media indices had (jointly) statistically significant effects on beef demand in 2013–2022 (point estimate of -0.0004; *p*-value of 0.0106), pork demand in 2013–2022 (point estimate of -0.0003; *p*-value of 0.0042), and—utilizing the adding-up restrictions described in equation (3)—other food demand in 2013–2022 (point estimate of 0.0007; *p*-value of 0.0019). This finding indicates that news media information related to *all* meat consumption and physical exercise had demand-reducing effects on beef and pork in the most recent decade, with this demand flowing into other food goods. However, the economic implications of this phenomenon are better assessed through elasticities, discussed in the next section.

Elasticities

Equations (5) and (6) and mean budget shares were used to calculate expenditure, compensated price, and news media elasticities, with statistical significance being assessed through Wald tests on the model parameters. Mean budget shares over the 1993–2022 period for beef, pork, chicken, and other food were 0.92, 0.53, 0.49, and 98.06 percent, respectively. The remainder of this study focuses on the elasticity estimates, which are depicted in Table 1.4.

Table 1.4. Estimated Expenditure, Compensated Price, and News Media Elasticities (1993–2022)

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Expenditure	0.4586*[a]	-0.0862[a]	0.1965[a]	1.0150***[a]
Beef Price	-0.4288***[b]	0.0788	-0.0863	0.0040***
Pork Price	0.0453	-0.3153***[b]	0.0374	0.0011
Chicken Price	-0.0463	0.0349	-0.0375[b]	0.0004
Other Food Price	0.4298***	0.2015	0.0864	-0.0056***[b]
News Media Elasticities (1993–2002)				
Media_Beef	-0.0023	-0.0221	-0.0246	0.0003
Media_Pork	0.0061	0.0126	0.0114	-0.0002
Media_Chicken	-0.0095	0.0299	-0.0090	0.0000
News Media Elasticities (2003–2012)				
Media_Beef	-0.0157	-0.0014	-0.0181	0.0002
Media_Pork	0.0116	-0.0208*	-0.0020	0.0000
Media_Chicken	0.0102	-0.0098	0.0182	-0.0001
News Media Elasticities (2013–2022)				
Media_Beef	-0.0038	-0.0073	-0.0185	0.0002
Media_Pork	-0.0058	-0.0093	0.0037	0.0001
Media_Chicken	-0.0315*	-0.0362*	-0.0010	0.0005*

Note: Single, double, and triple asterisks (*, **, ***) indicate elasticity estimates that are statistically different than zero at the ten, five, and one percent levels, respectively; [a] indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; [b] indicates compensated own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities are calculated at the mean values of the budget shares. Standard errors and associated *p*-values were obtained from Wald tests on the model parameters.

It should be noted that point estimates in this study cannot be directly compared to those of prior work due to differences in separability assumptions (i.e., meat versus food separable

models), the inclusion or omission of turkey data, and differing periods of study. However, some broad findings are worth mentioning. Expenditure elasticities for beef, pork, chicken, and other food were 0.46, -0.09, 0.20, and 1.02, respectively, with beef and other food estimates statistically different from zero at a confidence level of at least ten percent. These results are consistent with prior work that found beef to be a normal good and other food to have the highest expenditure elasticity when included in a demand system with aggregate meat proteins (Marsh, Schroeder, and Mintert, 2004; Tonsor, Mintert, and Schroeder, 2010).

Compensated own-price elasticities were -0.43, -0.32, -0.04, and -0.01 for beef, pork, chicken, and other food, respectively. All own-price elasticity estimates were statistically different than -1.0 at the five percent level of confidence, with beef, pork, and other food being statistically different than zero. Several demand studies found pork to be the most sensitive to changes in own price and aggregate poultry to be the least, relative to other meat proteins (Brester and Schroeder, 1995; Tonsor, Mintert, and Schroeder, 2010; Tonsor and Olynk, 2011). Marsh, Schroeder, and Mintert (2004) findings of relatively elastic beef demand is more aligned with our results, though inelastic chicken demand found in this study is broadly supported by prior work. There is no evidence of cross-price impacts between meats in the 1993–2022 period. This is similar to findings of Marsh, Schroeder, and Mintert (2004) and Tonsor, Mintert, and Schroeder (2010) in the 1982–1998 and 1982–2007 periods, respectively.

News media elasticities were sporadically statistically different than zero, and only at the ten percent level of confidence. In the 2003–2012 period, a 1 percent increase in news media articles related to pork and physical exercise was associated with a 0.02 percent decrease in national pork disappearance. This result indicates a multi-directional component to news media influences on meat demand. That is, meat demand may increase or decrease if the volume of

exercise- and health-related news media content increases. In the 2013–2022 period, news media related to chicken and physical exercise yielded diminished demand for both beef (-0.03 elasticity) and pork (-0.04 elasticity), suggesting protein-specific news media information may pull demand away from other meat proteins. Interestingly, chicken-related news media in the same period did not have demand-increasing impacts on chicken but, rather, was associated with increased demand for other food goods (0.0005 elasticity). This suggests the presence of a directional impact of news media on other food demand—such that increased information on the relationship between meat consumption and physical exercise or fitness shifts aggregate food demand out of meat and into other food sources. That said, the joint impact of all news media indices on demand for other food in 2013–2022 (recalling a point estimate of 0.0007; *p*-value of 0.0019), when divided by the mean budget share for other food (0.9806), yields a news media elasticity that is, pragmatically, zero.

While news media elasticity estimates were only periodically statistically significant (ten percent confidence) and were of small magnitude across all meat proteins and decades, it is important to place results in the context of observed quarter-over-quarter changes in news media information. In the 2003–2012 period, the largest percentage change in *Media_Pork* occurred between the third and fourth quarters of 2009 (200 percent), which, when multiplied by the corresponding news media elasticity for pork, yielded a 4.16 percent reduction in national pork disappearance. Of note, however, is the small number of articles included in *Media_Pork* in Quarter 3 and 4 of 2009 (6 and 18, respectively). As such, pork news media influences on meat demand should be interpreted with care. Perhaps more meaningful are changes in disappearance stemming from *Media_Chicken* in the 2013–2022 period. The largest quarter-over-quarter change in *Media_Chicken* in the period was 79 percent (47 to 84 news articles), occurring between the second and third quarters of 2014. When multiplied by the relevant news media elasticities, the

quarterly change in news articles related to chicken and physical exercise resulted in reductions in national beef and pork disappearance of 2.49 and 2.86 percent, respectively. The corresponding increase in other food disappearance over the same quarters was relatively smaller in magnitude, at just 0.04 percent. As noted by Tonsor and Olynk (2011), although point estimates of media elasticities are small in magnitude, over long periods of time (or in this study, over large quarter-to-quarter changes in news articles) increased media attention may have notable impacts on the U.S. meat industry. We emphasize, however, that the results of this study indicate only sporadic news media influence on meat demand (at the ten percent confidence level), with these influences having economic significance only with extremes changes in the level of fitness-related news media information available to consumers.

Robustness Checks

To increase confidence in the robustness of findings shown above, alternative model specifications were estimated i) incorporating more refined search terms in news media index construction and ii) utilizing the thirty years of price and disappearance data prior to the coronavirus disease 2019 (i.e., COVID-19) pandemic.[10] Elasticity estimates derived from these alternative Rotterdam specifications are in Appendix Tables A.2 and A.3. The first alternative included the additional search term "AND fat" in *Media_Beef*, *Media_Pork*, and *Media_Chicken*. This further eliminated news articles that were not related to the relationship between each meat protein and physical exercise by specifying that the term "fat"—relevant in both meat-related news media information and fitness- or health-related news media information—need be present in the article. Appendix

[10] Additional sensitivity assessments included 1) constructing news media indices as an annual rolling sum of articles, 2) constructing news media indices as a cumulative sum of articles, 3) omitting decade and news media interaction terms, and 4) using an "aggregate" media index that included all articles related to protein, beef, pork, or chicken and exercise. These results are in Appendix Tables A.4 through A.7.

Figure A.1 depicts values of the adjusted beef, pork, and chicken news media indices over time. These adjusted indices averaged 6.2, 3.9, and 13.8 search results per quarter for beef, pork, and chicken, respectively.[11] The second alternative maintained the original news media indices but differed in the period of analysis. Specifically, data was used from 1990 through 2019 to eliminate potential substantial changes in demand stemming from COVID-19's impact on meat prices and consumer spending habits, which have been discussed thoroughly by Weersink et al. (2021), Zeballos and Dong (2022), and other researchers.

Expenditure and compensated price elasticities were robust to changes in news media index construction and period of analysis. News media elasticities across all specifications were intermittently statistically significant and always small in magnitude. Further, the negative impact of chicken and fitness-related news media on pork demand in the most recent decade was the only relationship that was persistent when assessing sensitivity of results (ten percent confidence). Pairing results of our primary specification and sensitivity assessments, we conclude that there is little to no evidence of news media related to physical exercise and fitness having influences on the demand for beef or pork at a national level, and only slight evidence that chicken- and fitness-related news media had spillover effects on the demand for pork in the last decade. Further, there is no evidence that fitness-related news media information moves demand for food into or out of the meat complex. It is important to consider, however, that these results reflect the relationship between physical exercise and meat consumption as discussed in major news outlets. Conclusions may vary with the source of information (i.e., medical journals and social media).

[11] The adjusted beef and pork news media indices experienced values of zero in five quarters in the 1993–2022 period. For these quarters, zero values were replaced with values of one. This was necessary as the Rotterdam model requires inclusion of the natural logarithm of the news media indices.

Conclusions

This article extends previous research assessing the impact of media information on the demand for meat proteins. Specifically, we investigate whether news media related to physical exercise and fitness has influenced the demand for beef, pork, and chicken in the U.S. from 1993 through 2022. We account for own- and cross-commodity impacts of news media and, since the prevalence of news media has changed over the period of study, allow news media elasticities to vary across each decade. Further, we maintain the assumption that the demand for meat products cannot be estimated separately from other food goods (i.e., we estimate a food-separable demand system). This assumption allows for insights on substitution patterns into or out of total meat consumption, rather than just substitution between meat products. From the results of the primary model specification and a collection of sensitivity assessments, the main findings of this study are i) the cross-commodity impact of physical exercise- and chicken-related news media on the demand for pork was statistically significant (ten percent confidence) in the 2013–2022 period but was not economically meaningful, ii) other own- and cross-commodity impacts of exercise-related news media were absent, and iii) news media information on physical exercise and meat consumption did not shift U.S. food demand between meat proteins and other food.

Several considerations need to be made when assessing these results. First, and most important, our measure of media information on physical exercise and fitness reflects articles appearing in major newspapers. We deemed this the most appropriate and feasible method to gauge the influence of media on meat demand over multiple decades, as social media data has been available for a relatively short period, originates from a wide array of platforms, and is not conceivably attainable across all sources due to privacy restrictions and steep costs. However, an extension of this study could explicitly control for all forms of media information available to U.S.

consumers, provided that social media data collection becomes substantially more feasible moving forward. Such an extension could additionally include clickbait-type digital information that we omitted from our news media index construction. Second, news media information on physical exercise and fitness can have sentiment that either improves or reduces the demand for meat, which we do not account for in our construction of media indices. Though creating news media indices separately based on each article's sentiment toward meat consumption would provide a more complete assessment, this requires what we believe to be an undue amount of subjectivity on behalf of the researcher in sorting news articles and, further, violates data use restrictions regarding the text mining of news articles. That said, it is possible that "positive" news articles increase meat demand, "negative" news articles decrease meat demand, and our generally null results reflect a netting out to zero effects.

Leveraging available data on national U.S. meat purchases and media information, this study provides the first known economic assessment of physical exercise-related news media and its impact on U.S. consumers' aggregate demand for meat proteins. Natural extensions of this research include i) an assessment of actual protein consumption among individuals who partake in physical exercise, perhaps leveraging richer household level data, ii) individual-level demand assessments to estimate elasticities or willingness-to-pay for disaggregate protein goods as a function of exercise habits, and iii) a monetary valuation of physical exercise to the U.S. food industry and, specifically, to protein-rich foods such as meat or eggs. This novel work and its findings provide a base that will hopefully spur further research into the thus far understudied economic impacts of a societal interest in exercise and fitness on food consumption habits.

Chapter 2 - Non-Linear Association of Exercise with Animal Protein Consumption Among U.S. Adults[12]

Introduction

U.S. animal protein consumption has garnered renewed attention in recent years. Coronavirus disease 2019 (COVID-19) impacted the economic markets for meat and eggs, with simultaneous supply disruptions and consumer "panic buying" pushing prices for those goods over historical highs (Balagtas and Cooper, 2021; Kassas and Nayga Jr., 2021; Ramsey et al., 2021). News media covered the phenomenon for months (Bunge, Nassauer, and Kang, 2020; Kang, 2021), while economic literature devoted to supply chain performance in domestic meat markets quickly appeared in refereed journals. Similarly, and soon thereafter, the avian influenza outbreak of 2022 resulted in sizable reductions in the U.S. commercial chicken and turkey flock, again impacting the availability and prices of poultry and egg products in U.S. grocery stores (Thomas, 2022; U.S. Department of Agriculture Economic Research Service, 2023a; U.S. Department of Agriculture Economic Research Service, 2023b).

Human and animal health factors have not been the only drivers of renewed interest in animal protein consumption. Sustainability in agriculture and concerns over the environment have also contributed to recent discussion surrounding livestock production and the consumption of food products derived from animals. Willits-Smith et al. (2023) is a noteworthy example of these discussions, noting the environmental impacts of U.S. beef production and evaluating the demographic and behavioral determinants of disproportionate beef consumption. Additionally,

[12] Reprinted with permission from "Non-Linear Association of Exercise with Animal Protein Consumption Among U.S. Adults" by Justin D. Bina and Glynn T. Tonsor, 2024. Nutrients, 16, 1438. Copyright 2024 by Justin D. Bina and Glynn T. Tonsor.

plant-based meat alternatives have become a “hot topic” in the U.S. food industry, serving as a source of protein for consumers who are worried about the environmental impact of livestock production, the handling of livestock raised for human consumption, or the human health impacts of animal-derived food products. Emergence of these meat alternatives has prompted economic research on consumer demand for alternative and traditional meat products, how U.S. food consumers substitute between the two, and how demand for alternative meat impacts environmental and climate outcomes (Van Loo, Caputo, and Lusk, 2020; Lusk et al., 2022; Tonsor and Bina, 2023).

Recent attention to domestic meat markets and, more generally, animal protein consumption warrants updated empirical assessments. A host of prior work has assessed trends and correlates of animal protein consumption (Wang et al., 2010; Daniel et al., 2011; Pasiakos et al., 2015; Zeng et al., 2019; Beasley et al., 2020; Love et al., 2020; O’Connor et al., 2022; Willits-Smith et al., 2023) or has quantified the impact of animal protein consumption on human health outcomes (Wang and Beydoun, 2009; Kappeler, Eichholzer, and Rohrmann, 2013; Morris and Jacques, 2013; Agarwal, Fulgoni, and Berg, 2015). This work has varied in period of study, aggregation of animal protein intake (i.e., all animal protein consumption, processed meat consumption, beef consumption, etc.), and demographic characteristics and health outcomes of key interest. As an example, recent research has found that 12 percent of Americans were responsible for half of all beef consumed in the U.S. from 2015 to 2018, with males being more likely than females to consume a disproportionate amount of beef (Willits-Smith et al., 2023). Similar efforts explored seafood consumption, finding that 56 percent and 31 percent of seafood purchases (by weight) occurred in retail and restaurants, respectively, from 2007 to 2016 (Love et al., 2020). Related to human health outcomes, high protein intakes were found to be associated

with modest increases in appendicular skeletal muscle mass in non-obese and physically inactive Americans aged 50 years or older (Morris and Jacques, 2013). Further, meat consumption, specifically, was found to be positively associated with obesity among U.S. adults (Wang and Beydoun, 2009) but not with mortality (Kappeler, Eichholzer, and Rohrmann, 2013). Though the quantity of research dedicated to understanding animal protein consumption is sizable, there exists an important knowledge gap. Physical exercise has not been assessed as a potential determinant of total protein and disaggregated animal protein consumption.[13] It is our objective to quantify the association of physical exercise with consumption of total protein, beef, pork, poultry, seafood, eggs, and dairy among U.S. adults. The remainder of this introductory section further motivates that objective.

The National Academy of Medicine (formerly the Institute of Medicine) has provided for decades a series of dietary reference intakes that are intended to serve as a guide for good nutrition and have informed most food and nutrition policies and programs (National Academies of Sciences, Engineering, and Medicine, 2006). The recommended dietary allowance (RDA) is one of such reference intakes, defined as "the average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97-98 percent) healthy individuals in a particular life stage and gender group (National Academies of Sciences, Engineering, and Medicine, 2006)." For total protein, the RDA for all adults aged 19 years and over is 0.80 grams per kilogram of bodyweight per day (g/kg/d) (National Academies of Sciences, Engineering, and

[13] Kappeler et al. (2013) controlled for the numbers of days spent in moderate or vigorous physical activity per week when estimating the association of meat intake with mortality, but did not quantify the association of physical exercise with meat or protein intake. Wang and Beydoun (2009) controlled for physical activity when examining the association of meat consumption with obesity but, again, did not assess the association of physical exercise with meat or protein intake.

Medicine, 2006). To put the National Academy of Medicine (National Academies of Sciences, Engineering, and Medicine, 2006) recommendation into context, an 80 kilo-gram individual would need to consume 64 grams of pure protein per day to meet the RDA, which equates to around 206 grams of boneless, skinless, and roasted chicken breast (U.S. Department of Agriculture, 2019).

Important to this study, and in part inspiring our objective, some prior work in the field of nutrition has noted that higher intakes of protein are needed for individuals who are physically active (Wilson and Wilson, 2006; Jäger et al., 2017). In particular, the International Society of Sports Nutrition, in their official stance on protein requirements for exercising individuals, recommend that training athletes consume in the range of 1.4 to 2.0 g/kg/d (Jäger et al., 2017). This range of intake corresponds to up to 160 grams of pure protein per day for an 80 kilogram individual, or up to 516 grams of boneless, skinless, and roasted chicken breast (U.S. Department of Agriculture, 2019)—substantially higher intake levels than those recommended by the National Academy of Medicine (2006) for the average individual.

The purpose of our research is not to determine the adequate level of protein intake for those who are engaged in physical exercise pursuits. However, we highlight that discussion surrounding the relationship between physical exercise and protein consumption has migrated from nutritional studies to popular press and social media. Examples of this discussion are abundant in print and digital news media (Reynolds, 2023; Murphy, 2024), and can be easily found across social media platforms (e.g., TikTok, YouTube, etc.) from a simple search of the terms “protein”, “fitness”, “exercise”, etc. Additionally, and from U.S. Bureau of Labor Statistics (2023a) estimates, 20.1 percent of Americans aged 15 years and over engaged in some form of sport, exercise, or recreation on an average day in 2022. This prevalence of exercise, paired with documented societal interest in its relationship to protein, suggests important implications on

nationwide health outcomes (e.g., skeletal muscle mass among older Americans, obesity prevalence, etc.) and the economic markets for protein-dense food products.

This research contributes to the general understanding of the determinants of animal protein consumption by (1) evaluating determinants across a variety of animal protein sources previously unstudied (i.e., pork, eggs, and dairy) and (2) considering a potentially important behavioral component of consumption (i.e., physical exercise). Results from this study can be used to inform food and nutrition programs focused on protein intake, educate U.S. food producers on consumer behavior in domestic protein markets, and guide future academic research on other food groups.

Materials and Methods

Sample

This study utilized survey data from the 2007-2008 through 2017-2018 cycles of the National Health and Nutrition Examination Survey (NHANES), which includes 75,402 participants in total. Conducted by the National Center for Health Statistics (NCHS) branch of the Centers for Disease Control and Prevention, NHANES is a nationally representative survey designed to assess the health and nutritional status of civilian, non-institutionalized adults and children in the U.S. (Chen et al., 2020). Important to this study, demographic and socioeconomic characteristics of NHANES participants are obtained during in-home interviews (Zipf et al., 2013). Physical activity data and a 24-hour dietary recall are obtained during visits to a mobile examination center (MEC) with a second, follow-up 24-hour dietary recall being obtained for most participants (approximately 87 percent) via telephone between three and ten days following the MEC exam (Zipf et al., 2013). The analytical sample was restricted to participants aged 18 years and older with complete data for physical activity (n = 36,525). Assessments of protein consumption were further restricted to

participants who provided at least one reliable 24-hour dietary recall (n = 32,375). Further detail on survey design and data collection is provided elsewhere, along with NCHS Ethics Review Board approval of the NHANES program (National Center for Health Statistics, 2024b; National Center for Health Statistics, 2024a). As this study analyzes publicly available data, it did not require approval from our institutional review board.

Dietary Intake

Dietary intake is reported in the NHANES databases as it was consumed. That is, food items and estimated quantities are reported without specifying quantities of the individual components (i.e., the quantity of beef or cheese contained within a "burrito" is not reported). While NHANES data does provide caloric, macronutrient, and micronutrient content of each reported food item, as-consumed food item amounts need to be translated to equivalents of their respective animal protein components. To address this issue, we utilized the USDA Agricultural Research Service's Food Patterns Equivalents Database (FPED), which was developed to convert NHANES-reported food items into their corresponding ounce, cup, or gram equivalents of broad nutritional food components (Food Surveys Research Group, 2023). These food components include, among others: (1) total meat, poultry, seafood, organ meats, and cured meat; (2) eggs (chicken, duck, goose, quail) and egg substitutes; and (3) total milk, yogurt, cheese, and whey.

Combining FPED equivalents data with text from the food description for each NHANES-reported food item, we allocated equivalents to beef, pork, poultry, seafood, combination (i.e., multi-meat), egg, and dairy categories.[14] For instance, if the description of a reported food item contained beef (e.g., "Beef, steak, flank") and mentioned no other meat, the full amount of the "total meat, poultry, seafood, organ meats, and cured meat" ounce equivalents were allocated to

[14] Dairy is measured in cup equivalents. Meat and eggs are measured in ounce equivalents.

beef. If the food description included beef and another meat (e.g., “Bacon cheeseburger, 1 medium patty, plain, on white bun”) or did not mention a specific meat (e.g., “Frankfurter or hot dog, plain, on bun”), the ounce equivalents were allocated to the combination meat category. It is important to note that this combination meat category primarily includes frankfurters and hot dogs, bologna, pepperoni, and other cured or luncheon meat derived from multiple animal protein sources. In the instance of multi-meat food items, some prior work has allocated a fixed proportion of ounce equivalents to each meat category (O’Connor et al., 2022; Willits-Smith et al., 2023). For example, half of the total meat ounce equivalents of a bacon cheeseburger would be allocated to beef and half to pork. We elected instead to utilize a combination category as the share of multi-meat food product quantity belonging to each animal protein source is highly product specific and cannot be determined without substantial subjectivity on behalf of the researcher. However, our utilization of a combination meat category understates the true consumption of beef, pork, poultry, and seafood.

For the 87 percent of participants who provided two reliable 24-hour dietary recalls, daily intakes were calculated as an average across the two days (Wang and Beydoun, 2009; Wang et al., 2010; Zeng et al., 2019). Otherwise, daily intakes reflect only the first dietary recall obtained from the MEC exam. It should be noted that the measures of dietary intake for protein and disaggregate animal proteins utilized in this study do not reflect participants’ usual intakes. For episodically consumed foods such as beef or seafood, our dietary intake construction does not correct for measurement error inherent in one- or two-day food consumption recalls and overestimates the true number of non-consumers. Some NHANES-based consumption studies have implemented the National Cancer Institute (NCI) method of calculating usual intakes that are more representative of individuals’ typical food consumption patterns (Morris and Jacques, 2013; Pasiakos et al., 2015;

O'Connor et al., 2022). However, we elected to analyze raw, rather than usual, intakes for two primary reasons: (1) the NCI method does not allow for predicted usual intake values of zero and (2) measurement error in the outcome variable does not bias estimates of the association of predictor with outcome if the measurement error is random and independent of the predictors (Wooldridge, 2010a).

Regarding the former, we do not expect all participants to be consumers of disaggregated animal proteins such as seafood and, as such, elected against a method that does not allow for nonconsumption. Further, statistical methods have been developed to account for censored data (i.e., nonconsumption) and provide important insight into marginal effects of predictors on uncensored and censored outcomes. We discuss one of such methods in ensuing sections. Regarding the latter, as our primary objective is to quantify the association of physical exercise with animal protein consumption, measurement error in the outcome variable (i.e., animal protein intake) is not overly important because it does not bias estimates of that association. We do, however, report the number of non-consumers in the descriptive statistics for each animal protein source, as statistics on raw intake are influenced by measurement error.

Physical Exercise

NHANES participants are asked a sequence of questions regarding their physical activity. First, participants are asked, "In a typical week {do you/does SP} do any moderate-intensity [vigorous-intensity] sports, fitness, or recreational activities that cause a small [large] increase in breathing or heart rate such as brisk walking, bicycling, swimming, or volleyball for at least 10 minutes continuously?" If answering "yes" to this question, participants are then asked, "In a typical week, on how many days {do you/does SP} do moderate-intensity [vigorous-intensity] sports, fitness or

recreational activities?" and "How much time {do you/does SP} spend doing moderate-intensity [vigorous-intensity] sports, fitness or recreational activities on a typical day?"

Moderate and vigorous physical activity was coded as zero minutes per day (min/d) if a participant answered "no" to the first question. Conditional on having answered "yes" to the first question, participants' daily moderate and vigorous physical activity was then calculated by multiplying the number of days per week they partake in moderate and vigorous activity and the minutes per day spent in that activity on those days, all divided by seven days per week to obtain a daily average. We combined daily moderate and vigorous activity into one aggregate physical exercise variable that is of key interest in the remainder of this study.

Statistical Analysis

Weighted means of daily physical exercise were computed by survey cycle, demographic characteristic, and body weight. Further, the concentration of exercise by demographic cohort across the entire period of study was computed by dividing each cohort's total minutes of daily physical exercise by the grand total of daily physical exercise reported by all NHANES participants. These analyses incorporated the MEC exam sample weights, which were adjusted to account for the combination of six NHANES survey cycles (2007-2008 to 2017-2018), following NCHS (2024c) suggested methods. Weighted means of aggregate protein consumption and disaggregated animal protein consumption were also computed by survey cycle, demographic characteristic, body weight, and physical exercise level and using the dietary day one sample weight suggested by NCHS (2024c), again adjusted for the combination of survey cycles. Dietary day one sample weights are likewise utilized in the regression analyses discussed below.

The association of daily physical exercise with total protein consumption was assessed through univariate ordinary least squares (OLS) regression. Since protein consumption is never

zero, methods accounting for censored (i.e., zero) observations are not necessary. Further, total protein consumption was not estimated jointly with disaggregated animal protein consumption because increases or decreases in animal protein consumption necessarily increase or decrease total protein consumption. All regression analyses utilized categorical physical exercise variables as there were a substantial number of non-active (i.e., zero minutes of daily physical exercise) NHANES participants that may have substantially different protein consumption. Additionally, categorical (versus continuous) physical exercise variables allow for nonlinearity in the association of exercise with protein consumption. Finally, we included controls for survey cycle (capturing temporal differences in consumption), age, gender, race, educational attainment, and annual household income, which may confound the association between protein consumption and physical exercise if omitted.

We did not, however, control for body weight as it is determined with protein consumption simultaneously, which can yield biased parameter estimates unless appropriate instrumental variables can be identified and utilized in estimation. Wooldridge (2010b) provides further motivation for instrumental variables estimation of single-equation linear models. We do note, however, that omitted variable bias exists by not having controlled for body weight. Since body weight is positively correlated with both the outcome (i.e., intake, consumption) and predictor (i.e., physical exercise), estimates of the association of exercise with consumption may be biased upward. Justifying the omission of body weight as a covariate, and providing confidence in our final results, a model specification that did control for body weight yielded OLS estimates that were not appreciably different than the primary specification we present.

To account for the censored nature of episodically consumed animal proteins, the association of physical exercise with these intakes was assessed through censored, or Tobit,

regression (Tobin, 1958; McDonald and Moffitt, 1980). Further, animal proteins were estimated jointly in a multivariate Tobit model to account for interdependencies in the economic markets for each of these protein sources and the corresponding correlation between errors in each equation. The multivariate Tobit model was estimated via maximum likelihood estimation, again incorporating physical exercise as a series of categorical variables and controlling for survey cycle, age, gender, race, educational attainment, and annual household income.

Given the substantial number of non-consumers for the respective animal proteins, latent marginal effects from the multivariate Tobit are not overly meaningful. As such, we computed marginal effects on the expected value for intake for all observations (censored and uncensored) and for uncensored observations, which are referred to as unconditional and conditional marginal effects, respectively. Calculation of Tobit marginal effects can be found elsewhere (McDonald and Moffitt, 1980; Wooldridge, 2010c). Standard errors obtained from the original multivariate Tobit estimation do not apply to unconditional and conditional marginal effects. To obtain appropriate standard errors, we employed a Krinsky-Robb simulation procedure. Briefly, the Krinsky-Robb method involves taking *n* draws from a multivariate normal distribution parameterized by mean being the parameter estimate vector and variance being the variance-covariance matrix obtained from the original model estimation (Krinsky and Robb, 1986). Thus, *n* simulated parameter estimate vectors are constructed with marginal effects calculated from each, generating an empirical distribution (Krinsky and Robb, 1986). The Krinsky-Robb procedure of calculating standard errors was utilized, rather than a bootstrap method, as it vastly reduces the computational burden of estimating *n* seven-equation multivariate Tobit models.

Data preparation and computation of weighted means were conducted using R software version 4.2.2 and the R "survey" package. OLS and multivariate Tobit estimation were conducted using SAS 9.4's REG and QLIM procedures, respectively.

Results

Descriptive statistics, regression estimates, and marginal effects for aggregate protein, meat, and egg consumption are presented in grams per day (g/d), while dairy is presented in cups per day (c/d).

Means of Physical Exercise

Tables 2.1 and 2.2 displays average daily physical exercise by NHANES survey cycle and participant characteristics. Averages depicted in Tables 2.1 and 2.2 are unconditional, meaning that they were computed incorporating both those individuals who reported physical exercise and those who did not. The share of non-exercising individuals (i.e., those who reported zero minutes per day in moderate or vigorous recreational activity) ranged from 0.52 in the 2013-2014 NHANES cycle to 0.58 in the 2007-2008 cycle.

Table 2.1. Daily Physical Exercise by NHANES Survey Cycle and Participant Characteristics

	Daily Physical Exercise (min/d)					
	2007-2008 (*n* = 6,216)		2009-2010 (*n* = 6,521)		2011-2012 (*n* = 5,858)	
	Mean (SE)	*n*	Mean (SE)	*n*	Mean (SE)	*n*
Survey Cycle						
2007-2008	21.03 (0.59)	6,216				
2009-2010			21.40 (0.57)	6,521		
2011-2012					24.70 (0.73)	5,858
2013-2014						
2015-2016						
2017-2018						
Gender						
Male	25.42 (0.98)	3,058	26.36 (0.90)	3,170	29.34 (1.17)	2,893
Female	16.93 (0.69)	3,158	16.78 (0.71)	3,351	20.37 (0.88)	2,965
Age						

	Daily Physical Exercise (min/d)					
	2007-2008 (*n* = 6,216)		2009-2010 (*n* = 6,521)		2011-2012 (*n* = 5,858)	
	Mean (SE)	*n*	Mean (SE)	*n*	Mean (SE)	*n*
18-24	34.06 (1.97)	749	32.99 (1.94)	846	46.03 (2.83)	846
25-34	26.02 (1.62)	923	24.53 (1.50)	1,012	27.43 (1.56)	947
35-44	22.06 (1.38)	994	22.19 (1.32)	1,090	24.42 (1.71)	926
45-54	16.54 (1.17)	1,000	19.09 (1.27)	1,072	21.54 (1.62)	939
55-64	17.30 (1.62)	995	17.73 (1.42)	978	17.94 (1.51)	951
65+	13.23 (0.93)	1,555	14.88 (0.95)	1,523	16.03 (1.39)	1,249
Race/Ethnicity						
Non-Hispanic White	22.00 (0.78)	2,849	22.68 (0.76)	3,077	25.28 (1.01)	2,105
Non-Hispanic Black	19.07 (1.19)	1,299	19.88 (1.30)	1,193	24.88 (1.29)	1,553
Mexican American	17.63 (1.27)	1,097	16.25 (1.14)	1,224	20.46 (2.01)	589
Other	19.58 (1.57)	971	19.47 (1.34)	1,027	24.25 (1.43)	1,611
Education*						
College Graduate	27.75 (1.37)	1,100	28.30 (1.16)	1,259	30.05 (1.37)	1,397
High School/Some College	21.26 (0.82)	3,125	20.72 (0.77)	3,356	24.40 (1.02)	3,016
<High School	12.67 (0.91)	1,976	13.82 (1.18)	1,889	16.13 (1.45)	1,431
Annual Household Income*						
<$20,000	14.05 (1.07)	1,416	16.78 (1.21)	1,387	24.23 (1.78)	1,429
$20,000-$74,999	20.19 (0.80)	3,263	19.11 (0.82)	3,362	21.98 (1.01)	2,728
$75,000+	25.97 (1.25)	1,284	26.88 (1.02)	1,426	28.28 (1.32)	1,379
Body Weight*						
50 kg or less	19.50 (3.61)	175	16.92 (3.34)	186	12.64 (1.78)	195
50.01-65 kg	20.59 (1.20)	1,172	21.25 (1.36)	1,203	27.30 (1.75)	1,159
65.01-80 kg	22.57 (1.13)	1,870	21.59 (0.94)	1,990	27.21 (1.34)	1,728
80.01-95 kg	23.54 (1.31)	1,432	23.12 (1.24)	1,526	24.83 (1.45)	1,325
>95 kg	17.53 (1.17)	1,233	20.06 (1.17)	1,384	20.62 (1.53)	1,126

Note: *Across the entire period of study, 82, 2,282, and 1,880 NHANES participants did not provide educational attainment, annual household income, and body weight, respectively. Observations for these traits will not match the total number of observations.

Table 2.2. Daily Physical Exercise by NHANES Survey Cycle and Participant Characteristics Cont.

	Daily Physical Exercise (min/d)					
	2013-2014 (*n* = 6,111)		2015-2016 (*n* = 5,973)		2017-2018 (*n* = 5,846)	
	Mean (SE)	*n*	Mean (SE)	*n*	Mean (SE)	*n*
Survey Cycle						
2007-2008						
2009-2010						
2011-2012						
2013-2014	22.33 (0.61)	6,111				
2015-2016			23.73 (0.69)	5,973		

	Daily Physical Exercise (min/d)					
	2013-2014 (*n* = 6,111)		2015-2016 (*n* = 5,973)		2017-2018 (*n* = 5,846)	
	Mean (SE)	*n*	Mean (SE)	*n*	Mean (SE)	*n*
2017-2018					23.62 (0.78)	5,846
Gender						
Male	26.53 (1.02)	2,915	27.05 (1.08)	2,876	28.13 (1.23)	2,834
Female	18.43 (0.68)	3,196	20.65 (0.88)	3,097	19.43 (0.97)	3,012
Age						
18-24	34.21 (2.00)	855	36.9 (2.63)	713	40.78 (2.80)	690
25-34	28.28 (1.66)	971	28.81 (1.45)	1,034	30.83 (2.02)	864
35-44	20.67 (1.32)	1,021	24.31 (1.70)	946	22.68 (1.72)	823
45-54	20.58 (1.39)	963	22.32 (1.70)	953	18.48 (1.62)	834
55-64	18.10 (1.47)	996	18.19 (1.85)	956	18.06 (2.02)	1,137
65+	15.23 (1.10)	1,305	17.13 (1.18)	1,371	16.56 (1.23)	1,498
Race/Ethnicity						
Non-Hispanic White	21.82 (0.81)	2,570	24.16 (1.01)	1,906	23.30 (1.12)	2,031
Non-Hispanic Black	23.43 (1.39)	1,254	26.74 (1.45)	1,260	24.32 (1.53)	1,339
Mexican American	22.74 (2.00)	848	21.40 (1.39)	1,061	25.69 (2.09)	789
Other	23.55 (1.20)	1,439	21.22 (0.99)	1,746	23.28 (1.39)	1,687
Education*						
College Graduate	27.21 (1.08)	1,443	29.96 (1.32)	1,421	28.82 (1.64)	1,336
High School/Some College	21.45 (0.87)	3,284	22.99 (0.96)	3,098	22.72 (0.98)	3,312
<High School	16.57 (1.22)	1,372	13.23 (1.16)	1,446	15.06 (1.57)	1,182
Annual Household Income*						
<$20,000	18.08 (1.35)	1,231	20.46 (2.02)	1,176	21.08 (1.87)	1,008
$20,000-$74,999	21.37 (0.91)	2,985	20.16 (0.86)	2,846	21.74 (1.20)	2,728
$75,000+	25.47 (1.06)	1,602	28.78 (1.30)	1,497	26.76 (1.33)	1,496
Body Weight*						
50 kg or less	21.69 (3.88)	227	26.61 (4.19)	193	24.83 (9.21)	184
50.01-65 kg	25.14 (1.31)	1,179	26.49 (1.82)	1,121	25.96 (1.94)	1,036
65.01-80 kg	23.33 (1.10)	1,828	26.46 (1.27)	1,732	24.59 (1.25)	1,651
80.01-95 kg	22.79 (1.30)	1,371	23.83 (1.57)	1,347	23.78 (1.49)	1,236
>95 kg	19.10 (1.25)	1,253	18.45 (1.03)	1,256	21.21 (1.55)	1,327

Note: *Across the entire period of study, 82, 2,282, and 1,880 NHANES participants did not provide educational attainment, annual household income, and body weight, respectively. Observations for these traits will not match the total number of observations.

The grand mean of daily physical exercise across all survey cycles and individual characteristics was 22.83 min/d. Temporal differences exist in daily physical exercise, being lowest in the 2007-2008 survey cycle at 21.03 min/day and highest in the 2011-2012 cycle at 24.70

min/day. Though declining about one min/day following the 2011-2012 period, average daily physical exercise was still 12.33 percent higher in 2017-2018 than ten years prior, highlighting a U.S. population that has become generally more physically active over time. Important to note is that substantial changes in physical exercise may have occurred following the COVID-19 pandemic; however, 2021-2023 NHANES survey data had not yet been released for analysis at time of writing. Though not a perfect comparison to NHANES-based exercise measures, estimates from the American Time Use Survey indicate that U.S. citizens aged 15 years and over participated in 17.40 min/d of sports, exercise, and recreation in 2022, which was the same activity level reported pre-pandemic in 2018 (U.S. Bureau of Labor Statistics, 2019; U.S. Bureau of Labor Statistics, 2023a).

U.S. males spent more time in physical exercise per day than females, on average, across the period of study. As of 2017-2018, males spend 28.13 min/day exercising compared to females' 19.43 min/d—44.77 percent higher. Differences also exist by age with daily physical exercise skewed toward younger individuals. In 2017-2018, individuals aged 18-24, 25-34, 35-44, 45-54, 55-64, and over 65 years reported daily physical exercise of 40.78, 30.83, 22.68, 18.48, 18.06, and 16.56 min/day, respectively, on average. Across all age cohorts, more time was spent in daily physical exercise in 2017-2018 than in 2007-2008. Percentage increases in daily exercise over those ten years ranged from 2.77 for those aged 45-54 years to 25.10 for those aged 65 and older. Of note is that individuals aged 34 years and younger reported daily physical exercise nearly 20 percent higher in 2017-2018 than in 2007-2008. With younger people exercising increasingly more over time, exercise pursuits may have progressively larger impacts on U.S. food consumption and in other industries (i.e., apparel and textiles, sports equipment, etc.) that cater to the exercising sub-population. This is especially true if young, exercising individuals maintain their exercise habits

into later years of life, though long-running panel data is required for assessments of that phenomenon.

Time spent in exercise was not appreciably different by race, with non-Hispanic whites, non-Hispanic blacks, Mexican Americans, and all other races reporting 2017-2018 physical exercise of 23.30, 24.32, 25.69, and 23.28 min/d, respectively, on average. Larger differences in daily physical exercise exist by individuals' educational attainment and annual household income. Those without high school degrees, with high school degrees or some college, and having graduated college reported physical exercise of 15.06, 22.72, and 28.82 min/day on average in 2017-2018, respectively. These exercise levels reflect percentage increases of 18.91, 6.88, and 3.83 over 2007-2008 averages. Similar trends are present in time spent exercising by income. Individuals with annual household incomes under $20,000, between $20,000 and $74,999, and $75,000 or greater reported physical exercise of 21.08, 21.74, and 26.76 min/day on average in 2017-2018, respectively. These reflect percentage increases over 2007-2008 averages of 50.08, 7.67, and 3.06. We are unsure why individuals with less formal schooling and lower incomes reported greater relative increases in physical exercise over time. These results suggest that exercise pursuits have become less costly and more accessible over time; however, NHANES data does not allow us to further distinguish between participants' type of exercise or its financial burden.

Concentration of Exercise

Table 2.3 depicts the concentration of daily physical exercise by demographic cohort over the entire period of study, providing insight on which groups have disproportionate exercise activity and potentially elevated perceived protein needs. With 432 distinct cohorts (across two gender, six age, four race, three education, and three household income groupings), we display only the 28

cohorts that accounted for at least one percent of total reported physical exercise. In total, the 36,525 NHANES participants providing exercise data accounted for 833,991 minutes of daily physical exercise.

Table 2.3. Concentration of Daily Physical Exercise by Cohort

Gender	Age	Race/Ethnicity	Education	Annual Household Income	*n*	Physical Exercise (min/d)	% of Total
Male	45-54	Non-Hispanic White	College Graduate	$75,000+	206	19,061.72	2.29
Female	45-54	Non-Hispanic White	College Graduate	$75,000+	215	19,010.09	2.28
Male	25-34	Non-Hispanic White	High School/Some College	$20,000-$74,999	370	18,896.45	2.27
Male	18-24	Non-Hispanic White	High School/Some College	$20,000-$74,999	228	17,399.66	2.09
Male	35-44	Non-Hispanic White	College Graduate	$75,000+	192	17,048.27	2.04
Female	35-44	Non-Hispanic White	College Graduate	$75,000+	243	16,498.80	1.98
Male	18-24	Non-Hispanic White	High School/Some College	$75,000+	174	14,824.28	1.78
Male	65+	Non-Hispanic White	College Graduate	$75,000+	258	14,545.52	1.74
Female	65+	Non-Hispanic White	High School/Some College	$20,000-$74,999	794	14,423.30	1.73
Female	25-34	Non-Hispanic White	College Graduate	$75,000+	209	14,402.72	1.73
Male	55-64	Non-Hispanic White	College Graduate	$75,000+	199	14,278.10	1.71
Female	18-24	Non-Hispanic White	High School/Some College	$20,000-$74,999	265	13,229.70	1.59
Male	25-34	Non-Hispanic White	College Graduate	$75,000+	160	13,202.82	1.58
Male	45-54	Non-Hispanic White	High School/Some College	$75,000+	193	12,340.75	1.48
Male	65+	Non-Hispanic White	High School/Some College	$20,000-$74,999	715	12,290.15	1.47
Female	55-64	Non-Hispanic White	College Graduate	$75,000+	142	12,084.43	1.45
Male	35-44	Non-Hispanic White	High School/Some College	$20,000-$74,999	310	11,359.87	1.36
Male	65+	Non-Hispanic White	College Graduate	$20,000-$74,999	300	11,241.49	1.35
Male	55-64	Non-Hispanic White	High School/Some College	$75,000+	171	11,067.85	1.33
Male	25-34	Non-Hispanic White	High School/Some College	$75,000+	127	10,730.18	1.29
Female	25-34	Non-Hispanic White	High School/Some College	$20,000-$74,999	321	9,780.40	1.17
Male	35-44	Non-Hispanic White	High School/Some College	$75,000+	174	9,597.69	1.15

Gender	Age	Race/Ethnicity	Education	Annual Household Income	*n*	Physical Exercise (min/d)	% of Total
Female	45-54	Non-Hispanic White	High School/Some College	$75,000+	175	9,507.13	1.14
Male	55-64	Non-Hispanic White	High School/Some College	$20,000-$74,999	267	9,301.67	1.12
Female	18-24	Non-Hispanic White	High School/Some College	$75,000+	129	9,114.88	1.09
Male	25-34	Non-Hispanic White	College Graduate	$20,000-$74,999	126	8,810.29	1.06
Female	25-34	Non-Hispanic White	College Graduate	$20,000-$74,999	139	8,724.57	1.05
Male	45-54	Non-Hispanic White	High School/Some College	$20,000-$74,999	284	8,467.18	1.02
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Total					36,525	833,990.70	100.00

White males and females aged 45-54 years having graduated from college and with at least $75,000 in annual household income accounted for the largest share of total time spent in physical exercise. These cohorts, accounting for 0.56 (male) and 0.59 (female) percent of NHANES respondents, were responsible for 2.29 (male) and 2.28 (female) percent of all reported daily physical exercise. Across the 28 cohorts accounting for at least a one percent share of total exercise, 18 were male cohorts, all were non-Hispanic white, all had at least a high school degree, and all had at least $20,000 in annual household income. These 28 demographic cohorts comprised 19.40 percent of NHANES participants used in this assessment (7,086 of 36,525) but accounted for 43.31 percent of time exercising.

Means of Consumption

Moving into dietary intake, the grand mean of total protein consumption across all survey cycles and individuals was 81.97 g/d, comparable to prior work using NHANES dietary recall data (Pasiakos et al., 2015; Beasley et al., 2020). Further, average protein consumption per kilogram of body weight was 1.03 g/d. Among all NHANES participants, 63.24 percent met the National

Academy of Medicine (2006) RDA of 0.80 g/kg/d. Additionally, among just participants who reported spending some time each day in physical exercise, only 21.70 percent consumed at least the 1.40 g/kg/d of protein recommended for exercising individuals by the International Society of Sports Nutrition (Jäger et al., 2017). Grand means of beef, pork, poultry, seafood, combination meat, egg, and dairy consumption were, respectively, 32.89 g/d, 19.46 g/d, 49.08 g/d, 17.64 g/d, 14.53 g/d, 12.37 g/d, and 1.22 c/d. Though differences in period of study and disaggregation of animal proteins make comparisons to prior work difficult, mean intakes for seafood and poultry are broadly consistent with previous findings (Daniel et al., 2011; Zeng et al., 2019; Love et al., 2020), as is the relative ordering of red meat (i.e., beef and pork), poultry, and seafood (Daniel et al., 2011; Zeng et al., 2019).

The total number of non-consumers by NHANES survey cycle are depicted in Table 2.4, along with the share of participants being non-consumers. Detailed reporting of protein consumption and disaggregated animal protein consumption by survey cycle and individual characteristics is then available in Tables 2.5 and 2.6.

Table 2.4. Number of Non-Consumers by Animal Protein and Survey Cycle

		Protein	Beef	Pork	Poultry	Seafood	Combo	Egg	Dairy
Survey Cycle	Total *n*	*n* (share)	*n* (share)	*n* (share)	*n* (share)	*n* (share)	*n* (share)	*n* (share)	*n* (share)
2007-2008	5,678	-	2,513 (0.44)	3,016 (0.53)	1,964 (0.35)	4,143 (0.73)	3,500 (0.62)	3,422 (0.60)	493 (0.09)
2009-2010	6,046	-	2,730 (0.45)	3,322 (0.55)	2,192 (0.36)	4,278 (0.71)	3,905 (0.65)	3,622 (0.60)	503 (0.08)
2011-2012	5,071	-	2,616 (0.52)	2,886 (0.57)	1,678 (0.33)	3,507 (0.69)	2,740 (0.54)	3,007 (0.59)	534 (0.11)
2013-2014	5,354	-	2,876 (0.54)	3,042 (0.57)	1,817 (0.34)	3,742 (0.70)	2,911 (0.54)	3,077 (0.57)	572 (0.11)
2015-2016	5,250	-	3,047 (0.58)	3,050 (0.58)	1,883 (0.36)	3,813 (0.73)	2,851 (0.54)	2,935 (0.56)	689 (0.13)
2017-2018	4,976	-	2,824 (0.57)	2,956 (0.59)	1,806 (0.36)	3,575 (0.72)	2,808 (0.56)	2,792 (0.56)	649 (0.13)
Total	32,375	-	16,606 (0.51)	18,272 (0.56)	11,340 (0.35)	23,058 (0.71)	18,715 (0.58)	18,855 (0.58)	3,440 (0.11)

Over the period of study, 51, 56, 35, 71, 58, 58, and 11 percent of individuals were non-consumers of beef, pork, poultry, seafood, combination meat, eggs, and dairy, respectively. Again, these descriptive statistics are influenced by our use of raw intakes for episodically consumed foods, rather than usual intakes. However, there are noticeable temporal differences, which should not be influenced by the measure of intake. Notably, the share of individuals who did not consume beef increased from 44 percent in 2007-2008 to 57 percent in 2017-2018. The share of non-consumers of pork and dairy also increased over time, though to a lesser magnitude. Conversely, the share of individuals who did not consume combination meats or eggs slightly decreased from 2007-2008 to 2017-2018.

Table 2.5. Daily Protein Consumption by NHANES Survey Cycle and Participant Characteristics

		Daily Consumption			
		Protein (g/d)	Beef (g/d)	Pork (g/d)	Poultry (g/d)
	n	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Total	32,375	81.97 (0.29)	32.89 (0.42)	19.46 (0.30)	49.08 (0.49)
Survey Cycle					
2007-2008	5,678	81.42 (0.69)	37.11 (0.99)	20.02 (0.73)	47.70 (1.09)
2009-2010	6,046	83.13 (0.65)	37.75 (0.96)	21.29 (0.70)	49.94 (1.16)
2011-2012	5,071	82.29 (0.73)	33.65 (1.11)	17.91 (0.68)	47.36 (1.11)
2013-2014	5,354	83.28 (0.70)	31.09 (0.90)	19.32 (0.72)	49.99 (1.10)
2015-2016	5,250	81.51 (0.76)	28.04 (1.13)	19.83 (0.80)	49.64 (1.36)
2017-2018	4,976	80.29 (0.77)	30.39 (1.08)	18.48 (0.81)	49.72 (1.33)
Gender					
Male	15,785	96.26 (0.47)	43.12 (0.74)	25.16 (0.53)	56.61 (0.83)
Female	16,590	68.63 (0.28)	23.34 (0.41)	14.13 (0.31)	42.04 (0.54)
Age					
18-24	4,225	84.23 (0.92)	33.71 (1.18)	17.09 (0.81)	58.11 (1.55)
25-34	5,092	87.37 (0.76)	33.17 (0.98)	18.19 (0.69)	57.81 (1.29)
35-44	5,130	86.20 (0.73)	35.06 (1.06)	19.52 (0.72)	53.40 (1.27)
45-54	5,191	83.14 (0.69)	34.98 (1.10)	20.97 (0.78)	48.52 (1.12)
55-64	5,400	80.55 (0.74)	32.46 (1.12)	20.60 (0.87)	44.06 (1.20)
65+	7,337	71.39 (0.48)	28.34 (0.77)	19.73 (0.58)	35.39 (0.78)
Race/Ethnicity					
Non-Hispanic White	13,258	81.99 (0.4)	33.77 (0.58)	20.07 (0.42)	45.41 (0.66)
Non-Hispanic Black	7,023	78.10 (0.55)	30.32 (0.78)	18.20 (0.52)	64.54 (1.04)

		Daily Consumption			
		Protein (g/d)	Beef (g/d)	Pork (g/d)	Poultry (g/d)
	n	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Mexican American	4,988	86.86 (0.78)	36.35 (1.17)	16.13 (0.72)	50.44 (1.26)
Other	7,106	81.93 (0.64)	28.66 (0.88)	19.72 (0.61)	52.78 (1.19)
Education*					
College Graduate	7,115	85.80 (0.56)	28.62 (0.82)	16.82 (0.57)	51.57 (1.00)
High School/Some College	17,181	81.36 (0.41)	34.70 (0.58)	20.66 (0.42)	49.11 (0.67)
<High School	8,019	77.36 (0.59)	34.10 (0.89)	19.94 (0.66)	44.54 (0.94)
Annual Household Income*					
<$20,000	6,678	76.79 (0.67)	31.91 (0.91)	19.44 (0.73)	45.83 (1.05)
$20,000-$74,999	16,112	80.59 (0.41)	33.69 (0.58)	20.02 (0.43)	47.22 (0.64)
$75,000+	7,880	86.27 (0.56)	32.47 (0.81)	19.01 (0.57)	52.64 (1.00)
Body Weight*					
50 kg or less	1,009	71.53 (1.56)	24.81 (1.76)	16.90 (1.58)	41.05 (2.24)
50.01-65 kg	6,228	73.19 (0.58)	25.13 (0.74)	15.31 (0.51)	42.86 (1.01)
65.01-80 kg	9,959	79.96 (0.53)	30.86 (0.75)	18.46 (0.57)	47.18 (0.87)
80.01-95 kg	7,720	85.64 (0.61)	35.40 (0.90)	20.39 (0.61)	52.32 (1.06)
>95 kg	7,144	88.98 (0.64)	39.89 (0.99)	23.45 (0.73)	54.02 (1.09)
Physical Exercise					
0 min/d	16,851	77.68 (0.39)	33.77 (0.60)	20.55 (0.44)	44.98 (0.65)
1-30 min/d	8,155	82.27 (0.53)	32.15 (0.82)	18.52 (0.59)	49.33 (0.92)
31-60 min/d	4,261	85.88 (0.79)	30.60 (1.04)	18.45 (0.77)	53.86 (1.37)
61-120 min/d	2,199	92.20 (1.32)	32.70 (1.66)	19.12 (1.11)	56.27 (1.98)
121-180 min/d	571	98.55 (3.40)	39.21 (3.00)	18.60 (1.95)	67.38 (6.21)
181-240 min/d	206	95.91 (4.01)	35.88 (6.17)	14.11 (2.32)	63.94 (6.58)
241-300 min/d	62	93.88 (4.85)	40.03 (10.05)	19.79 (6.38)	53.48 (7.85)
>300 min/d	70	91.67 (6.57)	46.21 (15.13)	19.08 (5.38)	60.3 (13.03)

Note: *Across the entire period of study, 60, 1,705, and 315 NHANES participants did not provide educational attainment, annual household income, and body weight, respectively. Observations for these traits will not match the total number of observations.

Table 2.6. Daily Protein Consumption by NHANES Survey Cycle and Participant Characteristics Cont.

		Daily Consumption			
		Seafood (g/d)	Combo (g/d)	Egg (g/d)	Dairy (c/d)
	n	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Total	32,375	17.64 (0.37)	14.53 (0.22)	12.37 (0.17)	1.22 (0.01)
Survey Cycle					
2007-2008	5,678	16.01 (0.74)	12.62 (0.44)	10.91 (0.35)	1.29 (0.02)
2009-2010	6,046	18.36 (0.94)	11.22 (0.41)	11.02 (0.33)	1.41 (0.02)
2011-2012	5,071	18.01 (0.87)	16.19 (0.56)	11.67 (0.39)	1.25 (0.03)
2013-2014	5,354	19.33 (0.83)	15.46 (0.49)	12.56 (0.38)	1.25 (0.03)

		Daily Consumption			
		Seafood (g/d)	Combo (g/d)	Egg (g/d)	Dairy (c/d)
	n	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
2015-2016	5,250	17.18 (1.06)	16.22 (0.57)	13.58 (0.47)	1.12 (0.02)
2017-2018	4,976	16.92 (0.87)	15.16 (0.66)	14.22 (0.50)	1.04 (0.03)
Gender					
Male	15,785	19.42 (0.60)	18.63 (0.36)	14.27 (0.27)	1.38 (0.02)
Female	16,590	15.98 (0.43)	10.70 (0.25)	10.60 (0.21)	1.08 (0.01)
Age					
18-24	4,225	13.46 (0.88)	16.32 (0.58)	10.90 (0.46)	1.33 (0.03)
25-34	5,092	15.79 (0.73)	16.43 (0.54)	13.44 (0.46)	1.26 (0.02)
35-44	5,130	17.96 (0.99)	16.31 (0.55)	12.63 (0.42)	1.23 (0.03)
45-54	5,191	18.57 (0.84)	14.99 (0.60)	12.28 (0.41)	1.22 (0.03)
55-64	5,400	20.94 (1.18)	13.26 (0.56)	12.69 (0.43)	1.20 (0.03)
65+	7,337	18.13 (0.67)	10.47 (0.37)	11.94 (0.30)	1.12 (0.02)
Race/Ethnicity					
Non-Hispanic White	13,258	15.63 (0.50)	14.49 (0.30)	11.62 (0.23)	1.35 (0.01)
Non-Hispanic Black	7,023	22.54 (0.74)	15.09 (0.41)	12.34 (0.29)	0.85 (0.01)
Mexican American	4,988	17.08 (0.98)	19.15 (0.65)	17.44 (0.49)	1.08 (0.02)
Other	7,106	23.45 (0.78)	11.26 (0.39)	12.70 (0.36)	1.00 (0.02)
Education*					
College Graduate	7,115	20.67 (0.68)	11.75 (0.40)	12.29 (0.34)	1.29 (0.02)
High School/Some College	17,181	16.48 (0.53)	15.65 (0.31)	12.14 (0.23)	1.22 (0.01)
<High School	8,019	16.37 (0.66)	15.53 (0.45)	13.30 (0.34)	1.10 (0.02)
Annual Household Income*					
<$20,000	6,678	14.56 (0.63)	15.06 (0.46)	12.30 (0.35)	1.19 (0.02)
$20,000-$74,999	16,112	16.90 (0.52)	15.10 (0.30)	12.51 (0.23)	1.20 (0.01)
$75,000+	7,880	20.03 (0.73)	13.62 (0.43)	11.96 (0.32)	1.29 (0.02)
Body Weight*					
50 kg or less	1,009	14.63 (1.40)	7.75 (0.67)	10.01 (0.75)	1.15 (0.06)
50.01-65 kg	6,228	17.38 (0.70)	10.98 (0.40)	10.32 (0.32)	1.11 (0.02)
65.01-80 kg	9,959	17.67 (0.68)	12.85 (0.37)	11.95 (0.30)	1.22 (0.02)
80.01-95 kg	7,720	17.36 (0.67)	15.40 (0.41)	13.22 (0.37)	1.28 (0.02)
>95 kg	7,144	18.63 (0.91)	19.26 (0.57)	13.85 (0.38)	1.26 (0.02)
Physical Exercise					
0 min/d	16,851	16.30 (0.56)	15.26 (0.30)	12.10 (0.23)	1.14 (0.01)
1-30 min/d	8,155	17.26 (0.59)	14.11 (0.46)	11.41 (0.30)	1.25 (0.02)
31-60 min/d	4,261	20.10 (0.90)	12.85 (0.53)	12.91 (0.47)	1.26 (0.03)
61-120 min/d	2,199	20.44 (1.43)	14.16 (0.76)	15.06 (0.75)	1.46 (0.05)
121-180 min/d	571	23.43 (3.89)	15.21 (1.54)	15.24 (1.34)	1.51 (0.09)
181-240 min/d	206	20.04 (4.73)	19.56 (3.37)	17.30 (2.96)	1.45 (0.10)
241-300 min/d	62	10.16 (4.33)	25.15 (4.46)	14.74 (4.35)	1.38 (0.23)
>300 min/d	70	17.51 (12.32)	15.34 (3.85)	9.99 (2.66)	1.10 (0.19)

Note: *Across the entire period of study, 60, 1,705, and 315 NHANES participants did not provide educational attainment, annual household income, and body weight, respectively. Observations for these traits will not match the total number of observations.

Noting again the increasing share of individuals who did not consume beef, pork, or dairy, the average consumption level of these animal proteins decreased from 2007-2008 to 2017-2018. Pork consumption decreased by 7.69 percent over the period, while beef and dairy each decreased by over 18 percent. By contrast, combination meat and egg consumption increased by 20.11 and 30.32 percent over the same time. Beef consumption declines and egg consumption growth from 2007 through 2018 is consistent with USDA Economic Research Service estimates of nationwide disappearance (U.S. Department of Agriculture Economic Research Service, 2023d). Beyond these simple temporal differences, substantial heterogeneity exists in consumption between demographic groups. Across all survey cycles, U.S. males reported total protein, beef, pork, poultry, seafood, combination meat, egg, and dairy consumption of 96.26 g/d, 43.12 g/d, 25.16 g/d, 56.61 g/d, 19.42 g/d, 18.63 g/d, 14.27 g/d, and 1.38 c/d, respectively, on average. These values reflect consumption that is 40.25, 84.76, 78.01, 34.66, 21.51, 74.21, 34.64, and 28.26 percent higher than that of females. Gender differences in total protein and animal protein consumption found here have been consistently documented in prior assessments using NHANES dietary recall data (Wang et al., 2010; Daniel et al., 2011; Pasiakos et al., 2015; Zeng et al., 2019; Love et al., 2020).

Individuals aged 65 years and over consumed lower amounts of total protein, beef, poultry, combination meat, and dairy than younger individuals. This age cohort reported total protein consumption of 71.39 g/d, beef of 28.34 g/d, poultry of 35.39 g/d, combination meat 10.47 g/d, and dairy of 1.12 c/d on average. By comparison, those aged 18 to 24 years consumed 82.23 g/d of total protein, 33.71 g/d of beef, 58.11 g/d of poultry, 16.32 g/d of combination meat, and 1.33

c/d of dairy on average. Prior studies have also noted relatively lower total protein, red meat, and poultry consumption for the elderly sub-population (Wang et al., 2010; Daniel et al., 2011; Zeng et al., 2019; Beasley et al., 2020). Mexican Americans averaged the highest levels of total protein, beef, combination meat, and egg consumption at 86.86 g/d, 36.35 g/d, 19.15 g/d, and 17.44 g/d, respectively. Beasley et al. (2020) likewise examined higher total protein consumption among Hispanics, while Daniel et al. (2011) and Zeng et al. (2019) similarly found higher consumption of unprocessed red meat. Conversely, non-Hispanic blacks reported the highest average consumption of poultry and seafood at 64.54 g/d and 22.54 g/d, respectively, which is broadly consistent with findings of Daniel et al. (2011) and Zeng et al. (2019). Non-Hispanic whites accounted for relatively higher rates of pork and dairy consumption at 20.07 g/d and 1.35 c/d, respectively.

Differences also exist in consumption by individuals' educational attainment and annual household income for most protein sources. Those having graduated from college reported relatively higher consumption of poultry (51.57 g/d), seafood (20.67 g/d), and dairy (1.29 c/d) and relatively lower consumption of beef (28.62 g/d), pork (16.82 g/d), and combination meat (11.75 g/d). Similarly, individuals in the highest income bracket consumed poultry (52.64 g/d), seafood (20.03 g/d), and dairy (1.29 c/d) at higher rates than lower earners. Regarding total protein consumption, college graduates and those with annual household incomes of at least $75,000 consumed 85.80 and 86.27 g/d, respectively, while those without a high school degree or earning less than $20,000 annually consumed around 77 g/d in total protein, on average.

Interestingly, individuals who do not partake in physical exercise had substantially lower daily total protein consumption at 77.68 g/d but did not always have lower average consumption of specific animal proteins. This indicates that those who exercise—generally consuming more

total protein each day than those who do not—may be disproportionately seeking protein from sources that are not derived from animals or do not find some animal sources of protein to be sufficient for their health- and fitness-related needs. Excluding daily physical exercise categories with fewer than 500 respondents (i.e., 181-240 min/d, 241-300 min/d, and greater than 300 min/d), non-exercisers had the lowest average consumption of total protein (77.68 g/d), poultry (44.98 g/d), seafood (16.30 g/d), and dairy (1.14 c/d). Conversely, the 571 NHANES participants that reported daily physical exercise of 121 to 180 minutes had the highest average consumption of total protein (98.55 g/d), beef (39.21 g/d), poultry (67.38 g/d), seafood (23.43 g/d), eggs (15.24 g/d), and dairy (1.51 g/d). Important to note is that powders or liquid concentrates that are meant to be added to liquids (i.e., protein powders) are included in NHANES prior day intake reporting, classified as "beverages" (National Center for Health Statistics, 2020). Thus, dietary supplements such as whey protein powders are included in our assessment and are reflected in estimates of dairy consumption. This explains in part the higher reported dairy consumption among heavy exercisers and lower dairy consumption among those who do not exercise.

Association Between Physical Exercise and Protein Consumption

Results of the total protein OLS regression are presented in Table 2.7. Estimates with *p*-values of 0.05 or lower are considered to be statistically significant. Default values for the categorical variables are: 0 min/d of physical exercise, the 2007-2008 NHANES survey cycle, females, age 18 to 24, non-Hispanic white, no high school degree, and annual household income less than $20,000. An additional categorical variable was included for NHANES participants who did not provide data on annual household income (n = 1,705) to determine if these individuals were statistically different in their protein consumption and to avoid the omission of a sizable portion of the study sample.

Table 2.7. OLS Regression Predicting Total Protein Consumption

Predictor	ME (g/d)	95% CI	*p*
Intercept	62.66	60.84, 64.48	<.0001
Physical Exercise			
0 min/d	-	-	-
1-30 min/d	2.08	1.18, 2.98	<.0001
31-60 min/d	3.24	2.14, 4.34	<.0001
61-120 min/d	6.77	5.35, 8.20	<.0001
121-180 min/d	12.41	9.72, 15.11	<.0001
181-240 min/d	9.11	4.89, 13.32	<.0001
241-300 min/d	7.57	-1.12, 16.26	0.088
>300 min/d	4.07	-4.43, 12.57	0.348
Survey Cycle			
2007-2008	-	-	-
2009-2010	1.28	0.01, 2.56	0.049
2011-2012	0.05	-1.22, 1.32	0.936
2013-2014	1.23	-0.03, 2.49	0.056
2015-2016	-0.50	-1.77, 0.76	0.435
2017-2018	-1.76	-3.02, -0.50	0.006
Gender			
Male	26.55	25.83, 27.28	<.0001
Female	-	-	-
Age			
18-24	-	-	-
25-34	3.33	1.99, 4.67	<.0001
35-44	2.67	1.31, 4.03	0.0001
45-54	0.19	-1.15, 1.54	0.777
55-64	-1.95	-3.32, -0.58	0.005
65+	-9.45	-10.81, -8.09	<.0001
Race/Ethnicity			
Non-Hispanic White	-	-	-
Non-Hispanic Black	-2.61	-3.79, -1.43	<.0001
Mexican American	4.97	3.61, 6.33	<.0001
Other	-0.34	-1.43, 0.74	0.537
Education			
College Graduate	6.45	5.17, 7.72	<.0001
High School/Some College	3.71	2.64, 4.78	<.0001
<High School	-	-	-
Annual Household Income			
<$20,000	-	-	-

Predictor	ME (g/d)	95% CI	*p*
$20,000-$74,999	0.85	-0.25, 1.95	0.129
$75,000+	3.17	1.94, 4.39	<.0001
Did Not Report	0.63	-1.39, 2.65	0.541
n	32,375		
Adj. R^2	0.18		
Model F value	266.83		
Model *p* value	<.0001		

Physical exercise was positively associated with total protein consumption up to levels of 240 min/d (four hours). Exercising one half hour or less per day was associated with an additional 2.08 g/d of protein consumption relative to not exercising. This reflects total protein consumption that is 3.32 percent higher than that of non-exercisers, holding all other predictors at their default values. The magnitude of association was greater for higher levels of daily exercise, peaking at an additional 12.41 g/d of protein consumption when exercising between two and three hours per day (relative to not exercising), or 19.81 percent higher protein consumption holding all other predictors at their default values. Physical exercise exceeding 240 min/d was not associated with elevated total protein consumption at the 95 percent confidence level. As only 132 NHANES participants reported physical activity exceeding 240 min/d, this result could be driven by outliers within the small sub-sample. Alternatively, individuals participating in this level of physical exercise may be engaged in recreational pursuits that are not intended to build muscle (e.g., distance running) and do not have a perceived elevated need for protein. Again, we cannot distinguish the type of physical exercise using NHANES data.

Derived from a multivariate Tobit regression, conditional marginal effects on disaggregated animal protein consumption are depicted in Tables 2.8 and 2.9. These reflect effects of the predictors on uncensored observations (i.e., the marginal effects on animal protein

consumption conditional on consumption being non-zero). We forego detailed discussion on unconditional marginal effects but include those estimates in Appendix Tables B.1 and B.2.

Table 2.8. Multivariate Tobit Conditional Marginal Effects on Animal Protein Consumption

	Conditional Marginal Effect			
Predictor	Beef (g/d)	Pork (g/d)	Poultry (g/d)	Seafood (g/d)
Physical Exercise				
0 min/d	-	-	-	-
	-	-	-	-
1-30 min/d	-3.83	-4.31*	9.21*	9.41*
	[-8.09, 0.43]	[-7.59, -1.03]	[5.11, 13.31]	[3.76, 15.06]
31-60 min/d	-13.30*	-8.31*	13.87*	26.46*
	[-18.49, -8.11]	[-12.38, -4.23]	[8.88, 18.86]	[19.57, 33.34]
61-120 min/d	-16.13*	-7.53*	10.60*	23.25*
	[-22.89, -9.37]	[-12.74, -2.32]	[4.12, 17.09]	[14.20, 32.30]
121-180 min/d	7.56	-8.52	21.93*	18.76*
	[-4.98, 20.10]	[-18.40, 1.37]	[9.69, 34.17]	[1.33, 36.20]
181-240 min/d	-7.74	-19.30*	27.88*	10.17
	[-27.55, 12.07]	[-34.62, -3.99]	[8.87, 46.89]	[-17.2, 37.55]
241-300 min/d	2.31	-11.10	-4.88	-16.59
	[-37.95, 42.58]	[-42.90, 20.70]	[-44.46, 34.70]	[-75.82, 42.64]
>300 min/d	9.46	-10.50	7.12	2.02
	[-30.12, 49.05]	[-41.84, 20.85]	[-30.72, 44.96]	[-54.29, 58.34]
Survey Cycle				
2007-2008	-	-	-	-
	-	-	-	-
2009-2010	-0.23	1.44	1.98	8.97*
	[-6.14, 5.69]	[-3.18, 6.05]	[-3.74, 7.71]	[0.97, 16.97]
2011-2012	-11.17*	-9.37*	-1.86	2.90
	[-17.06, -5.27]	[-13.98, -4.75]	[-7.55, 3.83]	[-5.09, 10.88]
2013-2014	-20.04*	-3.97	3.14	6.40
	[-25.84, -14.24]	[-8.59, 0.65]	[-2.54, 8.82]	[-1.51, 14.32]
2015-2016	-34.24*	-4.16	-1.50	-16.61*
	[-40.13, -28.35]	[-8.77, 0.45]	[-7.21, 4.21]	[-24.63, -8.60]
2017-2018	-22.98*	-7.48*	0.82	-10.02*
	[-28.83, -17.13]	[-12.02, -2.94]	[-4.91, 6.55]	[-17.95, -2.09]
Gender				
Male	52.58*	32.34*	23.81*	-3.40
	[49.13, 56.04]	[29.65, 35.02]	[20.51, 27.10]	[-7.92, 1.12]
Female	-	-	-	-
	-	-	-	-

	Conditional Marginal Effect			
Predictor	Beef (g/d)	Pork (g/d)	Poultry (g/d)	Seafood (g/d)
Age				
18-24	-	-	-	-
	-	-	-	-
25-34	4.44	10.62*	1.30	12.26*
	[-1.97, 10.84]	[5.44, 15.81]	[-4.79, 7.39]	[3.32, 21.20]
35-44	12.72*	17.20*	-6.03	25.62*
	[6.30, 19.15]	[11.98, 22.42]	[-12.13, 0.08]	[16.55, 34.69]
45-54	10.67*	21.73*	-17.81*	36.01*
	[4.29, 17.04]	[16.62, 26.83]	[-23.94, -11.69]	[26.95, 45.08]
55-64	6.26	23.55*	-26.04*	53.71*
	[-0.26, 12.77]	[18.25, 28.84]	[-32.27, -19.81]	[44.41, 63.01]
65+	-4.29	25.31*	-40.79*	57.49*
	[-10.76, 2.18]	[20.14, 30.48]	[-46.87, -34.70]	[48.27, 66.70]
Race/Ethnicity				
Non-Hispanic White	-	-	-	-
	-	-	-	-
Non-Hispanic Black	-12.43*	-1.82	49.06*	52.75*
	[-18.07, -6.79]	[-6.08, 2.45]	[43.71, 54.41]	[45.25, 60.25]
Mexican American	-0.01	-17.87*	12.97*	31.57*
	[-6.39, 6.37]	[-22.84, -12.90]	[6.77, 19.17]	[22.69, 40.45]
Other	-18.33*	-3.00	14.80*	54.82*
	[-23.52, -13.14]	[-6.99, 1.00]	[9.85, 19.75]	[47.98, 61.67]
Education				
College Graduate	-13.49*	-12.97*	20.30*	31.90*
	[-19.51, -7.47]	[-17.62, -8.32]	[14.43, 26.17]	[23.86, 39.95]
High School/Some College	6.16*	3.96*	13.21*	7.20*
	[1.13, 11.20]	[0.03, 7.88]	[8.23, 18.18]	[0.43, 13.97]
<High School	-	-	-	-
	-	-	-	-
Annual Household Income				
<$20,000	-	-	-	-
	-	-	-	-
$20,000-$74,999	3.71	3.09	5.86*	17.48*
	[-1.43, 8.84]	[-0.93, 7.11]	[0.86, 10.87]	[10.28, 24.67]
$75,000+	0.55	0.98	16.37*	35.32*
	[-5.20, 6.29]	[-3.52, 5.48]	[10.78, 21.96]	[27.26, 43.38]
Did Not Report	-5.34	-8.88*	11.97*	21.08*
	[-14.85, 4.17]	[-16.26, -1.49]	[2.87, 21.07]	[8.19, 33.97]
n	32,375			
Log-Likelihood	-605,669			
AIC	1,211,772			

Note: Asterisks (*) indicate a marginal effect that is statistically significant at the 95 percent confidence level. Values in brackets [ ] are 95 percent confidence intervals around the marginal effect, calculated using Krinsky-Robb standard errors. Log-likelihood and AIC values are from the original multivariate Tobit estimation (parameter estimates are not shown).

Table 2.9. Multivariate Tobit Conditional Marginal Effects on Animal Protein Consumption Cont.

	Conditional Marginal Effect		
Predictor	Combo (g/d)	Egg (g/d)	Dairy (c/d)
Physical Exercise			
0 min/d	-	-	-
	-	-	-
1-30 min/d	-3.10*	-0.28	0.15*
	[-5.39, -0.81]	[-2.32, 1.76]	[0.10, 0.21]
31-60 min/d	-10.05*	3.88*	0.09*
	[-12.81, -7.29]	[1.36, 6.39]	[0.02, 0.16]
61-120 min/d	-11.32*	8.71*	0.40*
	[-14.90, -7.74]	[5.47, 11.96]	[0.31, 0.49]
121-180 min/d	-9.67*	9.41*	0.60*
	[-16.29, -3.04]	[3.19, 15.63]	[0.43, 0.78]
181-240 min/d	0.95	13.01*	0.45*
	[-9.39, 11.29]	[3.37, 22.64]	[0.18, 0.72]
241-300 min/d	18.15	7.07	0.42
	[-2.70, 39.00]	[-12.56, 26.70]	[-0.14, 0.97]
>300 min/d	-15.91	-9.81	-0.25
	[-36.94, 5.13]	[-29.57, 9.94]	[-0.79, 0.30]
Survey Cycle			
2007-2008	-	-	-
	-	-	-
2009-2010	-5.48*	0.33	0.24*
	[-8.75, -2.21]	[-2.57, 3.24]	[0.15, 0.32]
2011-2012	15.64*	2.51	-0.06
	[12.33, 18.95]	[-0.41, 5.43]	[-0.14, 0.02]
2013-2014	11.17*	6.13*	-0.09*
	[7.90, 14.44]	[3.23, 9.04]	[-0.17, -0.01]
2015-2016	16.19*	7.44*	-0.30*
	[12.90, 19.48]	[4.53, 10.34]	[-0.38, -0.22]
2017-2018	13.18*	9.07*	-0.41*
	[9.92, 16.44]	[6.15, 12.00]	[-0.49, -0.33]
Gender			
Male	23.28*	7.72*	0.44*
	[21.41, 25.14]	[6.05, 9.39]	[0.40, 0.49]
Female	-	-	-

	Conditional Marginal Effect		
Predictor	Combo (g/d)	Egg (g/d)	Dairy (c/d)
	-	-	-
Age			
18-24	-	-	-
	-	-	-
25-34	1.00	11.95*	-0.12*
	[-2.36, 4.35]	[8.75, 15.15]	[-0.21, -0.04]
35-44	-0.18	12.68*	-0.16*
	[-3.56, 3.21]	[9.45, 15.92]	[-0.25, -0.08]
45-54	-5.10*	13.91*	-0.20*
	[-8.46, -1.74]	[10.69, 17.14]	[-0.28, -0.11]
55-64	-13.01*	17.07*	-0.26*
	[-16.36, -9.66]	[13.78, 20.36]	[-0.35, -0.18]
65+	-22.54*	16.91*	-0.36*
	[-25.92, -19.16]	[13.67, 20.15]	[-0.45, -0.28]
Race/Ethnicity			
Non-Hispanic White	-	-	-
	-	-	-
Non-Hispanic Black	-4.19*	5.58*	-0.94*
	[-7.12, -1.25]	[2.90, 8.25]	[-1.02, -0.87]
Mexican American	3.81*	19.84*	-0.51*
	[0.45, 7.17]	[16.75, 22.93]	[-0.59, -0.42]
Other	-17.50*	4.46*	-0.67*
	[-20.29, -14.72]	[1.95, 6.97]	[-0.74, -0.60]
Education			
College Graduate	-8.27*	0.81	0.21*
	[-11.51, -5.02]	[-2.05, 3.66]	[0.13, 0.29]
High School/Some College	2.71	-0.86	0.10*
	[-0.01, 5.44]	[-3.27, 1.56]	[0.03, 0.17]
<High School	-	-	-
	-	-	-
Annual Household Income			
<$20,000	-	-	-
	-	-	-
$20,000-$74,999	1.08	1.41	-0.08*
	[-1.73, 3.89]	[-1.11, 3.93]	[-0.15, 0.00]
$75,000+	-2.40	-1.05	-0.05
	[-5.51, 0.72]	[-3.84, 1.74]	[-0.13, 0.03]
Did Not Report	-3.89	2.98	-0.15*
	[-9.04, 1.26]	[-1.52, 7.48]	[-0.28, -0.02]
n	32,375		
Log-Likelihood	-605,669		

	Conditional Marginal Effect		
Predictor	Combo (g/d)	Egg (g/d)	Dairy (c/d)
AIC	1,211,772		

Note: Asterisks (*) indicate a marginal effect that is statistically significant at the 95 percent confidence level. Values in brackets [ ] are 95 percent confidence intervals around the marginal effect, calculated using Krinsky-Robb standard errors. Log-likelihood and AIC values are from the original multivariate Tobit estimation (parameter estimates are not shown).

The association of physical exercise with animal protein consumption differed by sign and by protein source. Exercise levels of 31 to 60 min/d and 61 to 120 min/d were associated with reductions in daily beef consumption of 13.30 g and 16.13 g, respectively, relative to not exercising. Pork and combination meat also displayed a negative association with physical exercise, with magnitudes of association being highest at 181 to 240 min/d of physical exercise for pork (marginal effect of -19.30) and 61 to 120 min/d of physical exercise for combination meats (marginal effect of -11.32). Consider that, among those who reported non-zero consumption, mean consumption was 66.87 g/d, 44.37 g/d, and 32.77 g/d for beef, pork, and combination meat, respectively. The negative marginal effects of physical exercise between 31 and 120 min/d witnessed for each of these protein sources represent 20-24, 17-19, and 31-35 percent reductions from the conditional means, respectively. These results indicate that, although individuals who partake in physical exercise consume more total protein than those who do not, some protein sources are less desired. This may be due to nutritional content of beef, pork, and combination meat products (e.g., luncheon meat) that does not align with exercisers' perceived nutrition needs.

Conversely, physical exercise generally had a positive association with poultry, seafood, egg, and dairy consumption. The magnitude of association was largest for poultry at 181 to 240 min/d of exercise (marginal effect of 27.88), for seafood at 31 to 60 min/d (marginal effect of 26.46), for eggs at 181 to 240 min/d (marginal effect of 13.01), and for dairy at 121 to 180 min/d (marginal effect of 0.60). Conditional mean consumption for poultry, seafood, eggs, and dairy was

75.62 g/d, 65.14 g/d, 30.52 g/d, and 1.34 c/d, respectively. Looking again at exercise levels between 31 and 120 min/d, the marginal effects represent 14-18, 36-41, 13-29, and 7-30 percent increases from the conditional means for poultry, seafood, eggs, and dairy, respectively. These effects suggest substantially higher consumption of these protein sources for individuals who exercise between one half hour and two hours per day. As these individuals make up 19.95 percent of the study sample (6,460 of 32,375 participants with a reliable dietary recall) in a nationally representative survey, consumption differences among this behavioral group can have notable influence on nationwide health outcomes and the economic markets for various protein sources.

Discussion

Prior research efforts have been conducted to determine trends and correlates of total protein and animal protein consumption in the U.S. Though differing in outcome measure and individual characteristics of key interest, our results are consistent with previous literature's conclusions regarding consumption by gender, age, and race/ethnicity. To complement that literature, this study uses NHANES data from 2007 to 2018 to assess determinants of consumption across a broader range of animal protein sources (i.e., pork, eggs, and dairy) and, importantly, considers physical exercise habits, which have thus far been an understudied behavioral component of U.S. food consumption.

A host of conclusions are drawn from our results. First, from descriptive statistics for physical exercise, over half of the U.S. population was not engaged in physical exercise over the period of study. However, the average time spent in physical exercise per day generally increased over the ten-year period, being roughly 24 min/d in 2017-2018. Roughly 20 percent increases in physical exercise from 2007-2008 to 2017-2018 were reported among citizens aged 34 years and younger, suggesting that—to the extent this trend continues and younger people maintain their

exercise habits into later years of life—exercise pursuits will have progressively larger impacts on U.S. food consumption and the broader economy. Further, those with the least education and annual household income reported the greatest relative increases in daily physical exercise from 2007-2008 to 2017-2018. Physical exercise may have become less costly, or otherwise more accessible, for these demographic groups over time. However, the nature of NHANES physical activity reporting precludes us from determining the type or cost of participants' exercise pursuits. Finally, non-Hispanic white participants with at least a high school degree and having at least $20,000 in annual household income accounted for a disproportionate share of total minutes spent in exercise per day.

Physical exercise was positively associated with total protein consumption up to the level of 240 min/d. The magnitude of association ranged from an additional 2.08 g/d (1 to 30 min/d of exercise) to 12.41 g/d (121 to 180 min/d of exercise), relative to the levels of non-exercisers. Physical exercise generally exhibited a negative association with consumption of beef, pork, and combination meats. Conversely, a positive association was observed with consumption of poultry, seafood, eggs, and dairy. Further, marginal effects of physical exercise on disaggregated animal protein consumption were sizable in magnitude (see Tables 2.8 and 2.9) and suggest substantial differences in protein consumption patterns between those who exercise and those who do not. Though prior research has not evaluated the association of physical exercise with animal protein consumption in a national or observational setting, these results confirm what has been observed at least anecdotally in popular press and social media: not all protein sources are equal in the eyes of those who exercise. Differences in nutritional content, relative costs, and convenience likely influence which animal protein sources are most consumed by the exercising behavioral group. Red meat or further processed (i.e., smoked, cured) products may be less appealing to the exercise-

and fitness-conscious population due to potential concerns over dietary cholesterol, sodium, other nutritional considerations, or price. On the other hand, animal protein sources with lower fat content (e.g., chicken, fish), being less costly (e.g., eggs), or being more convenient (e.g., dairy-based powders) may be more desired by this behavioral group. It is important to remember, however, that nutritional content, price, and convenience of consumption varies within an animal protein source. This means that, as an example, avid exercisers may desire to consume *less* 73 percent lean ground beef and *more* 93 percent lean ground beef relative to those who do not exercise. We encourage those finer, product-specific consumption patterns to be assessed in future work.

A limitation of this work is that it was based on only the first day of dietary recall conducted in the NHANES. However, average daily protein consumption depicted in Tables 2.5 and 2.6 is largely consistent with prior refereed work that has utilized the raw dietary intake in various ways. Further, our primary objective of quantifying the association of physical exercise with consumption of total protein, beef, pork, poultry, seafood, eggs, and dairy among U.S. adults is not impacted by a potentially mismeasured outcome variable (Wooldridge, 2010a). Additional limitations are that (1) we use NHANES data up to only the 2017-2018 survey cycle and (2) we cannot distinguish between types of physical exercise. Regarding the former, NHANES data collection efforts were disrupted during COVID-19. Data collection and analysis for a 2021-2022 sample was expected to occur through 2023, with the data being released to the public in mid-to-late 2023 (Paulose-Ram et al., 2021). However, at the time of writing this study in 2024, that data had not yet been made available. Regarding the latter, it is likely that differences in protein consumption exist among those who engage in different exercise pursuits. For example, an avid weightlifter may desire more protein for the purpose of aiding muscle growth. Unfortunately,

NHANES reporting only captures aggregate time spent in physical activity and, as such, we cannot speak to the more intricate details of its association with protein consumption.

Marginal effects found in this study, NHANES and Bureau of Labor Statistics (2023a) estimates of exercise prevalence, and recent findings that over 30 percent of the U.S. adult population intentionally consumes protein to aid in their fitness-related goals (Bina and Tonsor, 2023), suggest large and meaningful influences of physical exercise on the U.S. food system. This has several implications. First, any form of intervention to address animal protein consumption needs to consider consumers' behavioral characteristics—importantly, their physical exercise habits. This mirrors comments made by Willits-Smith et al. (2023) in their discussion of methods to reduce consumption of environmentally-impactful foods. As an ancillary point and related to Willits-Smith et al. (2023), our results show that physical exercise has a negative association with consumption of beef—a source of animal protein that has a relatively higher impact on aggregate greenhouse gas emissions. Higher levels of physical exercise among the U.S. population may reduce demand for beef, eventually resulting in cattle inventory reductions and reduced emissions in that sector. Second, U.S. livestock producers and food manufacturers need to consider more seriously the exercising behavioral group. Representing a sizable share of the market for protein and demonstrating substantial differences in protein consumption, this group may substantially drive profit potential for producers in the U.S. food sector. To take advantage of these differences in consumption and capture additional revenue, food pricing and marketing strategies should be tailored to the exercising population. Additionally, changes in the prevalence of physical exercise may substantially alter demand for animal-derived protein goods, which, in turn, should inform livestock production decisions. Finally, and on a related note, the economic markets for animal proteins are susceptible to the preferences and purchase behavior of those engaged in physical

exercise. This has economic welfare implications for all U.S. consumers of animal protein, which future research efforts can empirically assess. It is our hope that this study motivates those future assessments.

Conclusion

In conclusion, we used a nationally representative U.S. sample to quantify the association of physical exercise with consumption of total protein, beef, pork, poultry, seafood, eggs, and dairy. Roughly half of U.S. adults were engaged in some type of physical exercise from 2007 to 2018, with the average time spent in physical exercise increasing from 21 min/d in 2007-2008 to 24 min/d in 2017-2018. 19 percent of the study sample accounted for 43 percent of time spent in physical exercise, with this subsample comprised of non-Hispanic white individuals with at least a high school degree and at least $20,000 in annual household income. Non-linear associations of physical exercise with total protein consumption and disaggregated animal protein consumption were present. Physical exercise displayed a positive association with total protein, poultry, seafood, eggs, and dairy consumption. Conversely, physical exercise displayed a negative association with consumption of beef, pork, and combination meats. This research can be used to inform healthy eating campaigns, improve marketing efforts and profit potential among U.S. livestock and food producers, and better understand the social welfare impacts that the exercising behavioral group has in the U.S. food industry.

Chapter 3 - Impacts of Exercise Pursuits on U.S. Retail Protein Demand

Introduction

Physical exercise is a common leisure-time activity among U.S. residents. From the U.S. Bureau of Labor Statistics' (2023a) American Time Use Survey, 20.1 percent of Americans aged 15 years and over regularly participated in sports, exercise, and recreation in 2022. Further, of those who engaged in sports, exercise, and recreation, an average of 1.44 hours per day were dedicated to those activities (U.S. Bureau of Labor Statistics, 2023a). Important to this research, physical exercise, whether utilized for general physical well-being or as part of a dedicated training protocol, is commonly supplemented with protein consumption to aid in muscle repair and growth. Headlines in major news outlets (Condor, 1995; Reynolds, 2023) over several decades and easily verified evidence from social media platforms (e.g., YouTube, TikTok, etc.) suggests a societal interest in the relationship between physical exercise and protein consumption. That relationship has yet to be evaluated in an *economic* assessment of food demand and consumption behavior.

To motivate our work further, there exists a discrepancy between commonly cited reference intakes for protein for the average individual and recommended intake levels for an exercising individual. The National Academy of Medicine (2006) provides a series of dietary reference intakes that are intended to serve as a guide for nutrition and have informed most food and nutrition programs and policies. One of these reference intakes is the recommended dietary allowance (RDA) and is defined as "the average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97-98 percent) of healthy individuals in a particular life stage and gender group" (National Academies of Sciences, Engineering, and Medicine, 2006). The

RDA for protein for all adults aged 19 years and over is 0.8 grams per kilogram of bodyweight per day (National Academies of Sciences, Engineering, and Medicine, 2006).

Importantly, evidence has been put forth in the field of nutrition that suggests higher protein intakes are needed for individuals who partake in resistance training (i.e., weightlifting) or are otherwise physically active. Consolidating results from numerous nutritional studies and book chapters, Wilson and Wilson (2006) note that recommended protein intakes for athletes far exceed the National Academy of Medicine's RDA, ranging from 1.2 to 2.2 g/kg/d. Additionally, the International Society of Sports Nutrition, in their official stance on protein requirements for exercising individuals, note that total protein and calorie intake are the most important factors in promoting positive adaptions to resistance training (Jäger et al., 2017). Further, the RDA of 0.8 g/kg/d is not adequate for a training athlete to meet their daily needs and protein intakes of 1.4 to 2.0 g/kg/d should serve as a minimum recommendation (Jäger et al., 2017). This range represents protein intake 1.75 to 2.5 times greater than the RDA commonly prescribed for the average individual.

While the relationship between physical exercise and protein consumption has been discussed thoroughly across media outlets and in peer-reviewed nutritional studies, the economic implications of that relationship have yet to be empirically assessed. This is an important gap in existing research as physical exercise pursuits represent a non-traditional determinant of protein demand that may have significant influences on consumers' purchasing behavior in U.S. food markets. Any influence of exercise habits on food purchases, correspondingly, has upstream implications for grain and livestock producers and food manufacturers. That is, gains or losses in revenue in the U.S. food industry may depend on consumers' exercise habits and perceived need for protein. Additionally, the effectiveness of food marketing or pricing schemes may vary by

exercise habits and by food product. We provide a seminal economic assessment of the understudied health- and fitness-conscious behavioral group with the following objectives: i) estimate price elasticities for retail protein products among consumers who are engaged in physical exercise pursuits and ii) determine if differences in price elasticities exist between the exercising and non-exercising subpopulations.

Data

Meat Demand Monitor

We utilize micro-level consumer data from the Meat Demand Monitor (MDM). Briefly, the MDM is an online, national survey funded by the U.S. beef and pork checkoff programs that is intended to capture consumer behavior in U.S. domestic retail and foodservice meat markets (Tonsor, 2020). Designed to be representative of the U.S. population with respect to gender, age, race, educational attainment, region of residence, and income (Tonsor, 2020), the MDM survey is distributed monthly and has a pooled cross-sectional structure (i.e., the same respondents are not surveyed each month). The first-party data company Dynata is used to distribute the online survey and targets upwards of 3,000 usable responses each month. The survey consists of roughly 35 questions and is intended to take 10 to 15 minutes to complete (Tonsor, 2024), with participants who successfully complete the survey then randomly selected to receive a free Apple iPad.

The MDM survey includes two components of vital importance to this work. First, respondents are asked "*Do you intentionally eat protein to aid in meeting strength-training or other fitness-related goals?*" For the purposes of this study, respondents who answer yes to this question are defined as "trainees," while those who answer no are defined as "non-trainees." Second, an open-ended choice experiment (OECE) is included to capture respondents' preferences for a variety of retail protein goods. The details of this choice experiment are discussed in an

ensuing section. Importantly, the MDM serves as the only known source of information on both consumers' exercise habits and protein purchasing behavior.

The data set includes MDM responses for the entirety of 2023, totaling 48,191 observations. We implement the data filtering procedure overviewed in the MDM project methodology statement (Tonsor, 2020). Importantly, the MDM survey asks respondents about their status as the household's primary grocery shopper. The data filtering procedure outlined by Tonsor (2020) omits respondents who do not do any grocery shopping but does not omit respondents who do some, but less than one-half of grocery shopping for their household. We elected to follow this procedure as i) only four percent of the study sample indicated that they do some, but less than one-half of shopping and ii) elasticity estimates discussed later were robust to inclusion of these respondents. We did, however, further omit respondents who did not provide a usable OECE or key demographic information, leaving 31,594 responses for subsequent analyses.

Demographic Information

Table 3.1 provides descriptive statistics of the sample, and by respondents' status as a trainee or non-trainee. Of note is that 32.7 percent of the sample meets our definition of a trainee (i.e., they intentionally consume protein to aid in their fitness pursuits), suggesting that health- and fitness-conscious individuals may have a sizable influence on aggregate protein demand.

Table 3.1. Descriptive Statistics of Consumer Demographic Information

	Trainees (n = 10,323)	Non-trainees (n = 21,271)	Full Sample (n = 31,594)
Continuous Variable		Mean (SD)	
Age (years)	44.29 (15.76)	54.53 (15.79)	51.19 (16.49)
Height (inches)	67.21 (4.13)	66.68 (3.97)	66.86 (4.03)
Weight (pounds)	167.17 (38.82)	174.33 (41.37)	171.99 (40.69)
Categorical Variable		Proportion (SE)	
Gender			
Male	0.56 (0.005)	0.43 (0.003)	0.47 (0.003)
Female	0.44 (0.005)	0.57 (0.003)	0.53 (0.003)

	Trainees (n = 10,323)	Non-trainees (n = 21,271)	Full Sample (n = 31,594)
Annual Household Income (dollars)			
Less than $20,000	0.14 (0.003)	0.16 (0.002)	0.15 (0.002)
$20,000 to $99,999	0.65 (0.005)	0.71 (0.003)	0.69 (0.003)
$100,000 or greater	0.21 (0.004)	0.14 (0.002)	0.16 (0.002)
Race			
White	0.65 (0.005)	0.76 (0.003)	0.72 (0.003)
Black	0.20 (0.004)	0.13 (0.002)	0.15 (0.002)
Other	0.15 (0.004)	0.12 (0.002)	0.13 (0.002)
Census Region			
Northeast	0.17 (0.004)	0.18 (0.003)	0.18 (0.002)
South	0.39 (0.005)	0.38 (0.003)	0.39 (0.003)
Midwest	0.19 (0.004)	0.23 (0.003)	0.21 (0.002)
West	0.24 (0.004)	0.21 (0.003)	0.22 (0.002)
Education			
High school degree or lower	0.27 (0.004)	0.29 (0.003)	0.28 (0.003)
Some college	0.39 (0.005)	0.43 (0.003)	0.42 (0.003)
Bachelor's degree or higher	0.34 (0.005)	0.28 (0.003)	0.30 (0.003)
Household Size			
1	0.22 (0.004)	0.26 (0.003)	0.25 (0.002)
2	0.30 (0.005)	0.43 (0.003)	0.38 (0.003)
3	0.21 (0.004)	0.15 (0.002)	0.17 (0.002)
4	0.18 (0.004)	0.10 (0.002)	0.12 (0.002)
5 or more	0.09 (0.003)	0.07 (0.002)	0.08 (0.001)

Welch's *t*-tests and two-proportions *z*-tests were conducted to compare sample means and proportions, respectively, between trainees and non-trainees. We omit reporting of test statistics as the only demographic or body measurement indicator that was not statistically different (five percent level) between the two behavioral groups was the proportion of survey respondents from the Northeast Census region. Though a large sample size likely drives statistical differences between trainees and non-trainees, several respondent traits are sizably different in magnitude. Trainees were around ten years younger than non-trainees, on average, and reported bodyweights around seven pounds lower. Additionally, among the trainee group, 56 percent were male and 44 percent were female. Conversely, 43 percent of the non-trainee group were male and 57 percent

were female. Annual household incomes of $20,000 to $99,999 were reported more frequently among the non-trainee group, while incomes exceeding $100,000 were reported more frequently among the trainee group. The proportion of black and other non-white respondents was relatively higher in the trainee group than in the non-trainee group. Differences were also present between the two behavioral groups with respect to household size. Lower (higher) household sizes were reported relatively more frequently in the non-trainee (trainee) sub-sample.

Prices and Expenditures

The prices presented to MDM respondents in their OECE are randomly generated. Specifically, each survey respondent is presented with a price for each choice experiment good that is randomly drawn from a uniform distribution with minimum and maximum values that are product specific. Table 3.2 depicts descriptive statistics for these randomized prices and respondents' stated choice experiment expenditures. Trainees' mean expenditures ranged from 32 percent (ground beef) to 200 percent (plant-based patty) higher than non-trainees'.

Table 3.2. Descriptive Statistics of OECE Prices and Expenditures

	Randomized Prices ($/lb.)		Expenditures ($)	
			Trainees	Non-trainees
OECE Good	Mean	Range	Mean (SD)	
Ribeye Steak	17.00	14.49 - 19.49	22.50 (21.85)	10.99 (15.88)
Ground Beef	4.48	1.99 - 6.99	7.80 (6.01)	5.89 (5.01)
Pork Chop	4.97	2.49 - 7.49	7.36 (6.59)	4.80 (5.07)
Bacon	5.48	2.99 - 7.99	7.72 (7.08)	4.74 (5.28)
Chicken Breast	3.98	1.49 - 6.49	7.60 (5.70)	5.53 (4.78)
Plant-Based Patty	12.00	9.49 - 14.49	12.40 (15.64)	4.12 (9.82)
Shrimp	11.00	8.49 - 13.49	14.51 (14.01)	7.58 (9.99)
Beans & Rice	2.98	0.49 - 5.49	4.28 (4.59)	2.33 (3.31)

Methodology

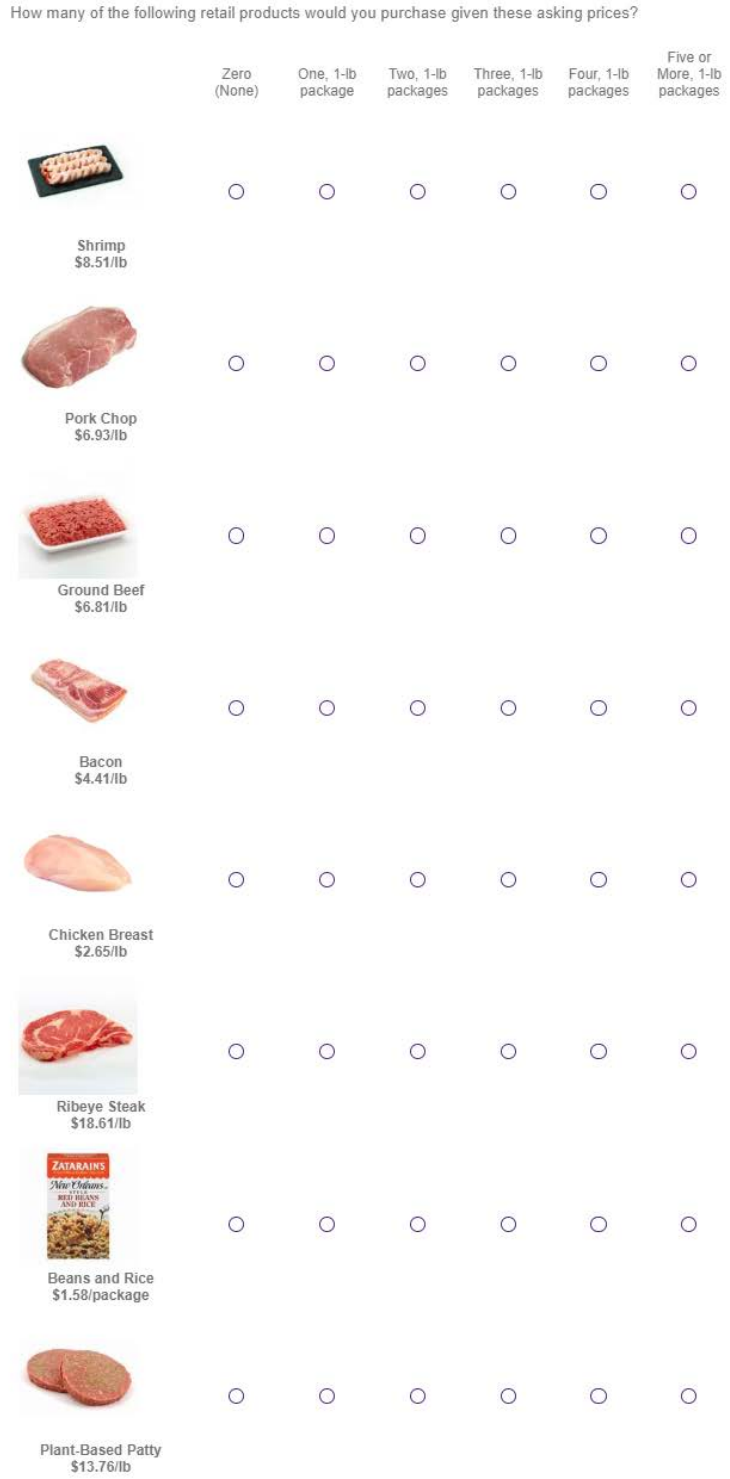
Open-Ended Choice Experiment

As opposed to "choose one" discrete choice experiments that have traditionally been used to estimate consumer willingness-to-pay and demand schedules, OECEs permit researchers to collect richer consumer data by allowing participants to choose as many units of as many goods as they wish (Corrigan et al., 2009). The name-your-quantity exercise better mimics consumers' experiences purchasing food at grocery stores and supermarkets and has been used in a variety of work eliciting willingness-to-pay for golden rice (Corrigan et al., 2009), dairy products (Elbakidze et al., 2014), and high heat-treated wheat products (Wongprawmas et al., 2016). Dennis, Tonsor, and Lusk (2021) note that the OECE allows for interior solutions, permitting for improved tracing out of the indifference curve and better understanding of substitution patterns between two products. Further, since quantities are allowed to vary, the OECE framework can be used to inform additional demand specification, such as an Almost Ideal Demand System (AIDS) or Rotterdam model (Dennis, Tonsor, and Lusk, 2021).

The OECE utilized for this study is depicted in Figure 3.1. Shown a list of eight retail protein goods, respondents are asked to choose which goods they would purchase, and their quantities (from zero pounds to five or more pounds), given randomly generated prices. This is completed one time by each respondent (i.e., there is only one choice task). The protein goods listed are ribeye steak, ground beef, pork chop, bacon, chicken breast, plant-based patty, shrimp, and beans and rice. These represent typically higher- and lower-valued beef and pork items, commonly consumed white meat and seafood items, as well as non-meat protein sources. Descriptions of the products are not provided other than the randomly generated prices. A benefit

of utilizing this OECE-derived data for demand specification is that prices can be treated as truly exogenous, eliminating the need for instrumental variable approaches.

Figure 3.1. Open-Ended Choice Experiment (OECE) Framework



Several issues arise when using micro-level consumer data obtained from this OECE. First, as the experiment was designed, quantities purchased are bounded between zero and five or more pounds. It is important to implement econometric techniques designed to provide consistent parameter estimates when using censored data, which we discuss accordingly. Second, this OECE is akin to Dennis, Tonsor, and Lusk (2021) in that it is hypothetical and does not directly include incentive-compatibility controls or "cheap talk" scripts. We conduct a series of robustness assessments to verify our main conclusions in the presence of potentially overstated expenditures but leave further evaluations of stated versus revealed preferences in the context of demand specification (i.e., AIDS, Rotterdam) to future research. Finally, MDM respondents do not report income, total expenditures, or total food expenditures in a format usable for estimation of an unconditional or food-separable demand model. As such, we maintain the assumption that the eight OECE products are weakly separable and can be described independently of other goods. Further, we have no reason to believe that separability assumptions impact the main conclusions drawn regarding differences between the trainee and non-trainee consumer groups.

Almost Ideal Demand System

The structural model used in this study is the popular AIDS proposed by Deaton and Muellbauer (1980), which is an attractive choice for empirical estimation given its flexibility and straightforward imposition of the restrictions of consumer theory. The AIDS, in budget share form, is described by:

$$w_i = \bar{\alpha}_i + \sum_j \gamma_{ij} log p_j + \beta_i log(\frac{x}{P}) \quad (1)$$

where w_i is the budget share for the *i*th good, p_j is the price for the *j*th good, x is the total expenditure across the OECE products, P is a price index defined by:

(2) $$logP = \alpha_0 + \sum_i \bar{\alpha}_i logp_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij}\, logp_i logp_j$$

and γ_{ij} and β_i are parameters to be estimated.

Non-price factors such as demographic characteristics and body measurements are incorporated into the intercept term $\bar{\alpha}_i$ as demand shifters à la Coffey, Schroeder, and Marsh (2011) and Dong, Gould, and Kaiser (2004). These non-price factors are, specifically, respondents' month of survey response (accounting for seasonality in demand), age, gender, annual household income, race, region of residence, educational attainment, household size, height, and weight. While not of key interest, it is important to control for these consumer characteristics to prevent potential distortion in the association between trainee-status and protein demand. The intercept is then formally defined as:

(3) $$\bar{\alpha}_i = \alpha_i + \sum \rho_{ik} D_k$$

where D_k represents *k* consumer characteristics and α_i and ρ_{ik} are parameters to be estimated. For the sake of clarity, we have followed the notation of Coffey, Schroeder, and Marsh (2011) in their modeling of household level meat demand. However, we emphasize that the unit of observation here is at the survey respondent level and that budget shares, prices, expenditures, and demographic information are indexed by respondent.

The demand model described by equation (1) is estimated with SAS 9.4's MODEL procedure and using iterative seemingly unrelated regression. Prior to estimation, the *j*th share equation is dropped to avoid singularity of the variance-covariance matrix. Coefficients and associated elasticities for the *j*th good can then be obtained using adding-up restrictions. Adding-up, homogeneity of degree zero in prices and expenditures, and Slutsky symmetry restrictions are imposed on the model parameters. These ensure that the sum of budget shares across all goods

always equals one, that scaling all prices and total expenditure by the same constant does not affect quantities of goods demanded, and that budget shares remain fixed in the absence of changes in relative prices or total expenditure. The necessary restrictions are:

(4) $$\sum_{i=1}^{n} \alpha_i = 1;\ \sum_{i=1}^{n} \rho_{ik} = 0;\ \sum_{i=1}^{n} \beta_i = 0;\ \sum_{i=1}^{n} \gamma_{ij} = 0;\ \gamma_{ij} = \gamma_{ji}$$

Expenditure (η_i), Marshallian (ε_{ij}^{m}), and Hicksian (ε_{ij}^{h}) elasticities are derived for the *i*th good following Green and Alston (1990):

(5) $$\eta_i = 1 + \frac{\beta_i}{w_i};\ \varepsilon_{ij}^{m} = -\delta_{ij} + \frac{\gamma_{ij} - \beta_i\left(\bar{\alpha}_j + \sum_k \gamma_{kj} log p_k\right)}{w_i};\ \varepsilon_{ij}^{h} = \varepsilon_{ij}^{m} + w_j \eta_i$$

where δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j;\ \delta_{ij} = 0$ for $i \neq j$) and w_i are means of budget shares taken across the entire sample.

To achieve our stated objectives, it is necessary to obtain elasticities separately for trainees and non-trainees. We use adjusted likelihood ratio tests to compare a pooled model (i.e., full sample; trainees and non-trainees) to separate models. Adjusted likelihood ratio test statistics for systems estimations were calculated as $LR[MT - 0.5(N_u + N_r) - 0.5M(M+1)]/(MT)$ where *LR* is the unadjusted log-likelihood value, *M* is the number of equations, *T* is the number of observations, N_u is the number of parameters in the unrestricted model, and N_r is the number of parameters in the restricted model (Moschini, Moro, and Green, 1994; Marsh, Schroeder, and Mintert, 2004). Test results indicate that trainee and non-trainee protein demand should be estimated separately.

Expectation Maximization Algorithm

As MDM respondents are allowed to choose zero quantities in the OECE, censored expenditures need to be addressed in the empirical strategy. Greene (2018) illustrates the moments of a censored normal variable. Importantly, the expected mean and variance of, say, budget shares depend not

only on the weighted average of explanatory variables, but also on the probability of the share being censored at a given value. Simply regressing censored budget shares against a set of prices and demographic information using ordinary least squares (OLS) will yield biased estimates. This bias does not become smaller as the sample size increases, meaning that OLS estimates are also not consistent. Table 3.3 depicts the share of survey participants who elected not to purchase each OECE good. Zero quantities are more prevalent for higher-valued goods such as ribeye steak and plant-based patty, and less prevalent for goods like ground beef and chicken breast. Across all OECE goods, trainees chose the zero-quantity option less frequently than non-trainees, suggesting greater willingness for this behavioral group to purchase protein-dense food products.

Table 3.3. Share of OECE Non-Purchasers

Product	Trainees (n = 10,323)	Non-trainees (n = 21,271)	Full Sample (n = 31,594)
Ribeye Steak	0.31	0.57	0.49
Ground Beef	0.13	0.22	0.19
Pork Chop	0.23	0.36	0.31
Bacon	0.24	0.38	0.34
Chicken Breast	0.11	0.21	0.17
Plant-Based Patty	0.49	0.79	0.69
Shrimp	0.30	0.51	0.44
Beans & Rice	0.26	0.47	0.40

A host of literature discusses demand estimation with censored expenditures and offers various corrections. Briefly, Wales and Woodland (1983) overview two general approaches. The first is a Kuhn-Tucker approach, which derives share equations from the maximation of an explicitly specified random utility function (Wales and Woodland, 1983; Dong, Gould, and Kaiser, 2004). Limitations of this approach include i) difficulty in identifying a utility function that allows for system estimation and ii) probabilities of purchase not summing to one (Dong, Gould, and Kaiser, 2004). The second is an Amemiya-Tobin approach that derives share equations from a

nonstochastic utility function and, to account for differences between latent and observed expenditure shares, adds random error terms to the deterministic shares (Wales and Woodland, 1983; Dong, Gould, and Kaiser, 2004). Shonkwiler and Yen (1999), most notably, and other researchers have developed two-step methods based on the Amemiya-Tobin approach to reduce complexity of estimation (Dong, Gould, and Kaiser, 2004). These methods, however, impose adding-up restrictions only to latent expenditure shares and have ignored the budget constraint in observed shares (Dong, Gould, and Kaiser, 2004; Nava and Dong, 2022).

To account for censored expenditures, we elect instead to utilize the Expectation Maximization (EM) algorithm developed by Dempster, Laird, and Rubin (1977). This algorithm allows for computation of maximum likelihood estimates from incomplete data and can be applied in situations where data is missing, censored, or truncated (Dempster, Laird, and Rubin, 1977). Further, the EM algorithm allows us to bypass the forementioned issues that have plagued prior censored demand estimation efforts and can be easily extended to other demand specifications.[15] Huang, Sloan, and Adamache (1987) applied the EM algorithm to seemingly unrelated Tobit regression estimation, highlighting efficiency gains obtained from EM estimation while Breiman, Tsur, and Zemel (1993) extended the EM framework to regression analysis and provided evidence that, when errors are normally distributed, the algorithm yields maximum likelihood estimates that are consistent and asymptotically normal. Tsur (1983) additionally investigated the use of the EM

[15] We estimate a standard nonlinear AIDS. However, our use of the EM algorithm to account for censored expenditures was partially driven by its ease of extension to other demand specifications. We considered the Generalized AIDS to assess if trainees had pre-committed expenditures for protein goods but found no evidence of pre-commitment (except for beans and rice) and experienced poor model fit. We also considered the Quadratic AIDS to assess nonlinearity in Engel curves. However, this highly nonlinear and complex specification proved too computationally burdensome. The large number of iterations required by the EM algorithm and a need to construct bootstrap standard errors made estimation of the Quadratic AIDS in this application infeasible.

algorithm in estimating limited dependent variable models, concluding that maximum likelihood estimates can be derived using ordinary and generalized least squares if the EM algorithm is employed. In the context of food demand systems, the EM algorithm has been used to estimate product substitution effects when consumers experience stock-outs in beverage vending machines (Anupindi, Dada, and Gupta, 1998) as well as in estimating household meat demand in the presence of zero expenditures (Coffey, Schroeder, and Marsh, 2011). Further details and mathematical proofs of the EM algorithm can be found in the aforementioned studies. We provide instead a practitioner's guide to implementing the EM process in a micro-level demand system, guided by the work of Breiman, Tsur, and Zemel (1993) and Coffey, Schroeder, and Marsh (2011).

The EM algorithm is an iterative procedure that begins with estimation of the demand system as if it were "complete" (i.e., no zero quantities). In what is known as the *Expectation* step, parameter estimates from the initial estimation are used to predict expenditure shares for each included good. Latent zero shares (w_i) for each respondent and good *i* are replaced with predicted shares ($\overline{w}_i$) if and only if the predicted share is non-negative.[16] Note that since predicted shares can be negative, not all latent zero shares will be replaced. Wales and Woodland (1983) and Dong, Gould, and Kaiser (2004) provide the formal rule for mapping predicted shares to latent shares:

(6)
$$w_i^p = \begin{cases} w_i & \text{if } w_i \geq 0 \\ \overline{w}_i & \text{if } w_i = 0 \text{ and } \overline{w}_i \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

[16] Quantities in the OECE are also bounded at five or more pounds. However, only 1.03 percent (plant-based patty) to 3.95 percent (chicken breast) of MDM respondents chose this quantity option. Consequently, we treat this quantity option as "five pounds" and, further, elect not to replace budget shares for respondents that purchase five pounds of any given good. Additionally, since prices are randomly generated for each respondent and good, seldom-reported quantities of five pounds do not yield truly censored expenditures and have negligible impact on elasticity estimates. Of course, future applications of OECEs in traditional demand estimation should be cognizant of the impacts of upper-bound censoring in experimental design.

where w_i^p is an intermediate share that needs to be normalized to ensure that budget shares sum to one:

(7) $$w_i^* = \frac{w_i^p}{\sum_i w_i^p}$$

The new vector of shares w_i^* is then used as the dependent variables in a second estimation of the demand system, known as the *Maximation* step. The *Expectation* and *Maximation* steps are repeated, replacing zero budget shares and re-estimating the demand system until the parameter estimates change by some predetermined convergence criteria. To reduce computational burden, starting values of the parameter estimates at each iteration of the EM estimation are set as the values of the estimates obtained from the prior iteration. For this study, the EM process is repeated until the largest absolute change between iterations in any of the 238 parameters is less than 0.001.

Standard Errors and Hypothesis Testing

Efron (1994) discusses bootstrap methods for situations of missing data, including those using the EM algorithm. The simple nonparametric bootstrap was found to provide computationally convenient and efficient confidence intervals. Accordingly, we implement a nonparametric bootstrap approach to calculate standard errors for all parameter estimates and elasticities. Specifically, a random sample of observations (of the same size as the original sample) is drawn from the entire data set, with replacement, and the AIDS model described by equation (1) is solved using the EM algorithm. Following Coffey, Schroeder, and Marsh (2011), this process was repeated 100 times (and separately for trainees and non-trainees). The resulting 100 vectors of parameters and elasticities form an empirical distribution for each estimate. The bootstrap standard error for estimate θ is then:

(8)
$$SE(\hat{\theta}) = \sqrt{\frac{1}{B-1}\sum_{b=1}^{B}\left(\widehat{\theta_b} - \bar{\theta}\right)^2}$$

where B is the number of bootstrap samples (100 in this case) and $\bar{\theta}$ is the mean of the estimates across the B bootstrap samples.

To assess differences in elasticities between trainees and non-trainees, it is necessary to compare results from two demand estimations. Having simulated 100 elasticity vectors (via bootstrap) for each consumer group, it is then straightforward to implement a Poe, Giraud, and Loomis (2005) comparison of the two empirical distributions. For each elasticity, every possible difference between the distributions is computed, creating a complete combinatorial of 10,000 elements ($100 * 100$). If the differences are specified as, say, trainees' own price elasticity for ribeye steak *less* non-trainees' own price elasticity for ribeye steak, the proportion of non-negative differences is the *p*-value associated with the one-sided hypothesis test that trainees' own price elasticity for ribeye steak is greater than or equal to non-trainees'.[17]

Results

The AIDS, estimated separately for trainees and non-trainees using the EM algorithm, was specified with OECE-derived expenditure data from the MDM survey. Intercept terms were modified to include respondents' month of survey response, demographic characteristics, and body measurements. Estimates of the two primary AIDS models are depicted in Appendix Tables C.1 and C.2. The nonparametric bootstrap procedure employed in estimation generated 100 simulated estimates for each parameter and elasticity, which were used to construct standard errors and in subsequent hypothesis testing.

[17] The proportion of negative differences is, conversely, the *p*-value associated with the one-sided hypothesis test that non-trainees' own price elasticity for ribeye steak is greater than trainees'.

Overview of Seasonal and Demographic Demand Shifters

Month demand shifters are only sporadically statistically significant (five percent level) and with no clear pattern across product, time of year, or respondents' trainee status. The use of a single year of consumer data and highly disaggregated food products may be the cause for the absence of seasonal associations. However, a collection of consumer characteristics have associations with protein demand that are consistent across trainee status. Increasing age is associated with increasing demand for pork chops and shrimp and decreasing demand for plant-based patties and beans and rice. Males have lower demand for bacon, chicken breast, and shrimp relative to females, and higher demand for beans and rice. Consumers in the lowest income bracket have the lowest demand for shrimp and, unsurprisingly, the highest demand for beans and rice. Geographic differences in demand also exist with consumers in the Midwest Census region having the highest demand for ground beef and consumers from the Northeast and West regions having the lowest demand for pork chops. Additionally, Northeast consumers have lower demand for bacon and higher demand for shrimp and plant-based patties than consumers from other regions. Those with at least a four-year college degree have lower demand for ground beef, pork chop, and bacon than those without, and higher demand for plant-based patties, shrimp, and beans and rice. Household sizes of three people or more have lower demand for shrimp than single-person households. Finally, regarding consumers' body measurements, increasing weight was associated with increasing demand for ground beef, pork chop, and bacon and decreasing demand for plant-based patties.

Elasticities

The remainder of this study focuses on elasticities derived from AIDS parameter estimates, as these are of more direct interest than the parameters themselves and can inform conclusions

regarding differences in price and expenditure sensitivity between trainees and non-trainees. Expenditure and Hicksian (compensated) price elasticities for trainees and non-trainees are depicted in Table 3.4. These were constructed using trainees' and non-trainees' mean budget shares obtained from equation (7) and for the final iteration of the respective EM estimations.

Table 3.4. Trainee and Non-trainee Expenditure and Hicksian Price Elasticity Estimates

	Trainee quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	1.38^{*+}	0.71^{*+}	0.85^{*+}	0.90^{*+}	0.56^{*+}	1.30^{*+}	1.16^{*+}	0.35^{*+}
Prices of:								
Ribeye Steak	-0.87^{*-}	0.48*	0.35*	0.37*	0.48*	-0.24*	-0.04	0.72*
Ground Beef	0.24*	-0.75^{*-}	0.02	0.02	-0.05*	0.15*	0.10*	-0.12*
Pork Chop	0.16*	0.02	-0.65^{*-}	0.03	0.00	0.07*	0.09*	-0.03
Bacon	0.17*	0.02	0.03	-0.69^{*-}	0.01	0.12*	0.06*	-0.02
Chicken Breast	0.26*	-0.06*	0.00	0.01	-0.75^{*-}	0.18*	0.14*	-0.22*
Plant-Based Patty	-0.16*	0.20*	0.10*	0.17*	0.22*	-0.46^{*-}	-0.01	0.37*
Shrimp	-0.03	0.17*	0.17*	0.11*	0.22*	-0.01	-0.49^{*-}	0.33*
Beans & Rice	0.23*	-0.08*	-0.02	-0.02	-0.13*	0.18*	0.13*	-1.03*
	Non-trainee quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	1.57^{*+}	0.72^{*+}	0.88^{*+}	0.88^{*+}	0.62^{*+}	1.47^{*+}	1.26^{*+}	0.36^{*+}
Prices of:								
Ribeye Steak	-1.70^{*-}	0.48*	0.48*	0.49*	0.40*	-0.44*	0.03	0.77*
Ground Beef	0.43*	-1.14^{*-}	0.06*	0.10*	0.01	0.30*	0.30*	-0.02
Pork Chop	0.35*	0.05*	-1.14^{*-}	0.09*	0.03*	0.23*	0.20*	0.05*
Bacon	0.36*	0.08*	0.09*	-1.32^{*-}	0.08*	0.31*	0.19*	0.07*
Chicken Breast	0.39*	0.01	0.05*	0.11*	-1.03^{*-}	0.46*	0.30*	-0.11*
Plant-Based Patty	-0.22*	0.17*	0.16*	0.22*	0.24*	-0.97*	-0.08*	0.29*
Shrimp	0.03	0.35*	0.28*	0.28*	0.32*	-0.16*	-1.12^{*-}	0.40*
Beans & Rice	0.35*	-0.01	0.03*	0.04*	-0.05*	0.26*	0.17*	-1.45^{*-}

Note: Asterisks (*) indicate elasticity estimates that are statistically different than zero at the five percent level; superscript "+" indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; superscript "-" indicates Hicksian own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities were calculated at the mean values of the budget shares. Standard errors and associated *p*-values were constructed via bootstrap.

Expenditure elasticities across each product and trainee status are statistically different than zero and 1.0 at the five percent level. Ribeye steak, plant-based patty, and shrimp are luxury items, with a 1.0 percent increase in expenditure yielding 1.38, 1.30, and 1.16 percent increases in quantities demanded, respectively, for trainees (i.e., those intentionally consuming protein to aid in their fitness-related goals). Non-trainees are more sensitive to expenditure for those products, having expenditure elasticities of 1.57, 1.47, and 1.26 for ribeye steak, plant-based patty, and shrimp, respectively. Non-trainees' chicken demand is also relatively more sensitive to expenditure. Elasticity estimates found here should not be directly compared to most prior studies on U.S. meat demand due to differences in aggregation and separability assumptions. However Coffey, Schroeder, and Marsh (2011) and Dong, Davis, and Stewart (2015) provide censored demand estimation of disaggregate protein goods that are more comparable to our results. Coffey, Schroeder, and Marsh (2011) likewise found beef steak and seafood expenditure elasticities exceeding 1.0; however, expenditure elasticities for pork chop and chicken breast were substantially higher than our estimates. Expenditure elasticities for ribeye steak that are greater than other products is consistent with findings of Dong, Davis, and Stewart (2015).

Trainees are substantially less own-price sensitive than non-trainees across all protein goods. Our results indicate that, if prices increase, food retailers would gain revenue from trainees (own-price elasticities between zero and -1.0) and lose revenue from non-trainees (own-price elasticities less than -1.0) on the included products. This likely reflects a perceived need of health- and fitness-conscious individuals to consume protein, such that their purchase decisions are not influenced by prices to the same extent as those not pursuing some fitness goal. Hicksian own-price elasticities are generally statistically different than -1.0 at the five percent level, with the exception of beans and rice for trainees and plant-based patty for non-trainees.

Each consumer group is most responsive to changes in the price of beans and rice and ribeye steak, and least responsive to changes in price of plant-based patty. Relatively higher own-price sensitivity for beans and rice may result from consumers' ease of finding alternative carbohydrate sources (i.e., potatoes, pastas, etc.). Prior scanner data- and survey-based demand assessments have reported own-price elasticities of plant-based burgers and other meat alternatives being among the highest of all evaluated food products (Zhao et al., 2022; Tonsor, Lusk, and Schroeder, 2023; Kilders, Caputo, and Lusk, 2024). We are unsure why relatively lower own-price elasticities were observed for plant-based patty in this assessment (beyond differences in time period examined) but emphasize that this occurs for both behavioral groups with trainees being less own-price sensitive (aligning with results for other OECE goods). In comparison to related work, Coffey, Schroeder, and Marsh (2011) found higher Hicksian own-price elasticities for beef steak and pork chop, and lower elasticities for seafood. Importantly, comparisons of price sensitivity for ground beef and chicken breast to Coffey, Schroeder, and Marsh (2011) depend on trainee status. For example, our trainee (non-trainee) sample was less (more) responsive to ground beef price than a pooled sample of the population that was likely varying in their exercise habits (Coffey, Schroeder, and Marsh, 2011). Again, differing separability assumptions can yield differing results, but comparison to the most adjacent demand estimation suggests that aggregation of consumers' exercise behavior can mask important differences in food purchasing patterns. Related work of Lusk and Tonsor (2016) similarly indicates that heterogenous demand analysis (by income in their case) informed by micro-level data reveals important differences in consumers' demand schedules for various meat products.

Substitution patterns among trainees and non-trainees vary slightly in magnitude and in statistical significance. However, they do not differ in direction. That is, any combination of two

products are either net substitutes or net complements for both trainees and non-trainees or, at the least, conclusions cannot be drawn based on the absence of statistical significance. Ribeye steak is a net substitute for ground beef, pork chop, bacon, chicken breast, and beans and rice, and is a net complement for plant-based patty. Ground beef, pork chop, bacon, and chicken breast are all net substitutes for plant-based patty and shrimp. Additionally, chicken breast is a net complement for beans and rice while plant-based patty and shrimp are net substitutes. Though results indicate that traditional protein items of ground beef, pork chop, bacon, and chicken breast compete with non-traditional items of plant-based patty and shrimp, the magnitudes of substitution are not substantial (cross-price elasticities all less than 0.5). Dong, Davis, and Stewart (2015) similarly found Hicksian cross-price elasticities that, while statistically significant, were not large in magnitude across any combination of protein goods. This signals that demand determinants have impacts primarily within category and that less impact stems from market developments in other protein categories.

Trainee versus Non-trainee Elasticities

Formal hypothesis testing is required to establish if trainee and non-trainee elasticities for the eight OECE protein goods are statistically different. A Poe, Giraud, and Loomis (2005) complete combinatorial was constructed for each expenditure and price elasticity and was defined as trainees' elasticity *less* non-trainees' elasticity. As such, each *p*-value is associated with the one-sided hypothesis test that trainees' elasticity is greater than or equal to non-trainees' (the null hypothesis). These *p*-values are depicted in Table 3.5.

Table 3.5. *P*-values of One-Sided Hypothesis Tests

	Quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	0.000	0.119	0.044	0.851	0.000	0.000	0.000	0.459
Prices of:								

	Quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Ribeye Steak	1.000	0.000	0.000	0.000	0.000	0.902	0.076	0.000
Ground Beef	0.518	1.000	0.021	0.000	0.000	0.809	0.000	0.000
Pork Chop	0.002	0.010	1.000	0.021	0.007	0.067	0.001	0.000
Bacon	0.003	0.000	0.020	1.000	0.000	0.109	0.000	0.000
Chicken Breast	0.999	0.000	0.011	0.000	1.000	0.358	0.000	0.000
Plant-Based Patty	0.985	0.000	0.000	0.000	0.000	1.000	0.970	0.002
Shrimp	0.073	0.000	0.000	0.000	0.000	0.929	1.000	0.001
Beans & Rice	0.072	0.000	0.000	0.000	0.000	0.987	0.016	1.000

Note: Each complete combinatorial of elasticity differences contains 10,000 elements (100*100). The proportion of non-negative differences is the *p*-value associated with a one-sided hypothesis test. The null hypothesis is that the difference between trainees' elasticities and non-trainees' is greater than or equal to zero (i.e., trainees' elasticities are more positive). We reject the null hypothesis if the *p*-value is less than or equal to 0.05.

We reject the null hypothesis that trainees' expenditure elasticities are greater than or equal to non-trainees' for ribeye steak, pork chop, chicken breast, plant-based patty, and shrimp. This provides empirical evidence of our observation in Table 3.4 that non-trainees are more sensitive to expenditure in their demand for those products. We do not have a definitive explanation as to why trainees are less sensitive to expenditure for these five goods, but not for ground beef, bacon, or beans and rice. We hypothesize that, since i) beans and rice have a relatively higher carbohydrate content and ii) ground beef and bacon have historically been the victims of healthy eating campaigns (e.g., media attention to heart disease, obesity, etc.), trainees are more inclined to allocate additional expenditure to the products that are either relatively denser in protein content or do not have an associated stigma with respect to human health.

Regarding compensated own-price elasticities, we fail to reject the null hypothesis that trainees' own-price elasticities are greater (i.e., more positive) than or equal to non-trainees,' and for each protein good. Every bootstrap simulated own-price elasticity for trainees was greater than every simulated value for non-trainees, yielding *p*-values of 1.00 for each hypothesis test. Using OECE-derived consumer data and an AIDS with EM algorithm (accounting for censored micro-

level data), we can conclude that trainees are less responsive in quantity demanded for various disaggregate protein goods from changes in own price.

Further, Table 3.5 Poe, Giraud, and Loomis (2005) *p*-values reveal slight substitution differences between trainees and non-trainees that were not initially apparent from Table 3.4 elasticity reporting. That is, trainees' cross-price elasticities were generally lower than (i.e., less positive than) non-trainees'. Though not universally true, trainees have a lower willingness to substitute toward ground beef, pork chop, bacon, chicken breast, shrimp, and beans and rice as the prices of other products increase. A recent assessment by Bina and Tonsor (2024b) found associations of physical exercise with animal protein consumption that differed in sign across animal protein sources. They noted that not all protein sources are created equal in the eyes of the exercising population and that differences in nutritional content, relative costs, and convenience may drive which animal proteins are most consumed by those who exercise (Bina and Tonsor, 2024b). In that light, cross-price elasticities found in this study may be influenced by perceived nutritional differences between protein goods—making trainees relatively less willing to substitute between products if that substitution does not align with their perceived dietary requirements. Future research can assess that phenomenon. In this study, we reiterate that, while substitution patterns may be statistically different between behavioral groups, they are generally not *economically* different. The largest magnitude difference we observed in cross-price elasticities was for plant-based patty and chicken breast at 0.28 (0.18 for trainees and 0.46 for non-trainees).

Additionally, we note that Lusk and Tonsor (2016) found i) demand and own-price sensitivity that differed by consumer income levels and by meat product and ii) own-price sensitivity that was smaller in the upper end of the price distribution than in the lower end. Given recent contraction of the U.S. beef cow inventory (U.S. Department of Agriculture National

Agricultural Statistics Service, 2024), supply reductions (all else equal) will yield an increase in retail beef prices. In such a situation, our findings suggest that non-trainees are the first to be "priced out" of the market. Trainees may then represent a progressively larger share of the market for beef with aggregate own-price elasticities shrinking toward zero when beef prices increase, mirroring the results of Lusk and Tonsor (2016). Own-price sensitivity that was lower for trainees across each OECE product suggests that these market impacts extend to pork, chicken, and other protein sources. Finally, academic efforts that have historically included demographic controls or heterogeneity assessments in the context of food demand may be missing important determinants of consumers' purchasing behavior. We have shown that exercise behavior is associated with significantly different demand schedules for protein items. Perhaps other behavioral groups have meaningfully different demand and consumption for protein or other foods, which future research efforts can reveal.

Sensitivity to Hypothetical Bias

While subject inattention bias is mitigated via multiple "trap" questions (Tonsor, 2020), incentive-compatibility controls or "cheap talk" scripts are not directly included in the MDM survey's OECE. Thus, there is concern that respondents overstate expenditures in the hypothetical experiment. Additionally, the OECE does not include a temporal component (e.g., weekly versus biweekly food purchases) and the experiment, thus, is treated as a single shopping "trip" without regard to shopping frequency.

Describing expenditure shares, rather than total expenditures, the AIDS framework is well-suited to help address the issues of potential hypothetical bias in purchases and the lack of information on shopping frequency. That is, if one assumes purchases of *all* products are overstated to the same degree, the issue of hypothetical bias in total expenditures is not overly

meaningful as shares are unaffected. However, purchases may be overstated relatively more or less *between* products. This situation can impact expenditure and price elasticities. As such, we test the sensitivity of our main conclusions regarding elasticity differences between behavioral groups. Specifically, respondents were omitted from analysis i) whose total OECE expenditure (across all eight goods) was greater than their self-reported weekly food-at-home expenditure and ii) whose total OECE expenditure plus $100 was greater than their self-reported weekly food-at-home expenditure. This reduced the trainee (non-trainee) sample size to 7,131 (18,742) and 1,808 (5,332) observations, respectively. The AIDS described by equation (1) was then re-estimated using the EM algorithm for the new sub-samples.

Elasticity estimates and Poe, Giraud, and Loomis (2005) hypothesis test results are depicted in Appendix Tables C.3 through C.6. Expenditure elasticities are robust to (potential) overstating of OECE expenditures—in magnitude and necessity versus luxury conclusions—for both trainees and non-trainees. Conclusions regarding differences in trainee and non-trainee expenditure elasticities are generally stable. In the most extreme data filtering scenario, there is no longer statistical evidence that non-trainees are more sensitive to expenditure in their demand for pork chop or chicken breast; however, elasticity estimates between groups for those two goods were quite close in magnitude in the original estimation (Table 3.4). Also in the extreme scenario, non-trainee sensitivity to expenditure for beans and rice was statistically greater than that of trainees, which may stem simply from the vast change in data utilized and that those expenditure elasticity estimates were quite close in magnitude between behavioral groups in the original data (Table 3.4).

Own-price elasticities for trainees and non-trainees become progressively more negative as respondents are filtered according to their OECE spending relative to food-at-home spending.

However, this phenomenon may best be explained by our removal of respondents with lower incomes and single-person households (who have lower food-at-home expenditures). Regardless of the mechanism by which own-price elasticities change (e.g., filtering of lower incomes, mitigating hypothetical bias in expenditures, etc.), each sensitivity assessment indicates that trainees' demand for every good is less own-price sensitive than non-trainees'. This is verified from Poe, Giraud, and Loomis (2005) hypothesis tests (Appendix Tables C.5 and C.6) and provides confidence in our main conclusions.

Substitution patterns are also robust to the potential overstating of OECE expenditures. Signs of cross-price elasticities are identical across alternative specifications or, at the least, conclusions cannot be drawn based on the absence of statistical significance (five percent level). Additionally, and consistent with primary results, trainees generally have slightly lower willingness to substitute toward ground beef, pork chop, bacon, chicken breast, shrimp, and beans and rice as the prices of other products increase—at least in the less extreme sensitivity assessment (Table C.5). In the more extreme sensitivity assessment, these relationships begin to break down; however, magnitudes of cross-price elasticities between behavioral groups were quite similar using the full data and, as such, our drastic trimming of observations is the likely cause of changes in hypothesis test results depicted in Table C.6.

Though mitigating the impact of hypothetical bias *ex ante* is ideal, our utilization of the only long-running data set containing both consumers' exercise habits and meat purchases required an *ex-post* mitigation strategy. Our omission of respondents with overstated choice experiment expenditures relative to self-reported weekly food-at-home expenditures yielded expenditure and cross-price elasticity estimates comparable to those derived from the original sample. The magnitudes of own-price elasticity estimates were sensitive to potential hypothetical bias in

expenditures, which can impact conclusions on the association between price and revenue changes. However, and most important to our objectives, our findings that i) non-trainees are more sensitive to expenditure in their demand for ribeye steak, pork chop, chicken breast, plant-based patty, and shrimp and ii) trainees are less own-price sensitive across all goods are robust.

Discussion

Non-traditional demand determinants may have sizable, yet understudied, impacts on the U.S. food industry. Food expenditure data is often aggregated to the national level, providing no insight into these non-traditional determinants of demand. Further, popular home- or retail-based scanner data sources, while including valuable information on consumers' demographic and socioeconomic characteristics, do not capture other consumer characteristics or behavioral patterns that can drive food purchases. As such, demand assessments that aim to quantify the impacts of those characteristics or behavioral patterns require novel data collection efforts.

One method of assessing non-traditional demand determinants is through OECEs. By allowing multi-product and multi-unit purchases in a discrete choice framework, researchers can estimate price sensitivity for consumers that vary across a wide array of attributes and using traditional demand estimation methods (Dennis, Tonsor, and Lusk, 2021). In addition to providing relatively inexpensive consumer-level demand information, OECEs allow for calculation of demand elasticities for hypothetical goods (Dennis, Tonsor, and Lusk, 2021) and for heterogeneity assessments across any desired demographic or behavioral group. With the benefits of OECE-derived consumer data, however, come a host of challenges.

This study utilized the OECE contained within the existing MDM survey. For this particular economic analysis, the MDM was an attractive source of data given its focus on consumer behavior in the U.S. domestic meat market, widespread use in related economic

assessments (Taylor et al., 2022; Tonsor et al., 2021), and long-running nature.[18] In using an existing OECE, we identify and discuss several considerations that need be made in future experimental designs.

First, and most important, is the inclusion of cheap talk scripts, incentive compatibility mechanisms, and budget constraints in the OECE. As the MDM-based OECE did not contain any of these controls for hypothetical bias in stated expenditures, we attempted *ex post* to assess validity of our main conclusions through a series of robustness checks. Future research can evaluate the use of these controls—common in the "choose one" discrete choice literature—in an open-ended choice framework.

Additionally, given the products included in the MDM's OECE, we maintained the assumption that demand for ribeye steak, ground beef, pork chop, bacon, chicken breast, plant-based patty, shrimp, and beans and rice was weakly separable from other goods and could be estimated as part of a conditional demand model. While these represent some of the most widely consumed meat and non-meat protein sources, a more complete assessment would include a measure of spending on all other food or all other goods. While the MDM does capture respondents' food expenditures and household income, it is not reported in a manner that is cleanly compatible with OECE-derived expenditure data. Future survey designs using this type of choice experiment should consider i) the included food goods or ii) how to incorporate other consumer spending for a food-separable or unconditional demand assessment.

[18] The MDM survey has included its OECE since January 2023. This allows for control of seasonality in demand for protein goods, which is otherwise not possible using one-off survey efforts.

Conclusions

This study utilized OECE-derived consumer data to estimate demand elasticities for retail protein goods separately for trainees and non-trainees. Differences in elasticities between the two behavioral groups were empirically tested. To our knowledge, this is the first economic assessment that has considered the relationship between physical exercise and the demand for protein. From our primary results and sensitivity assessments, we find that trainees (defined as those who intentionally consume protein to aid in meeting their fitness-related goals) are less sensitive to expenditure in their demand for ribeye steak, pork chop, chicken breast, plant-based patty, and shrimp relative to non-trainees. This suggests a perceived protein requirement, such that their expenditures on certain protein goods are "sticky" and do not adjust to expenditure or income changes to the same degree as non-trainees. Additionally, there was no statistical evidence that trainees had different sensitivity to expenditure than non-trainees in their demand for ground beef, bacon, and beans and rice; a result for which we do not have a definitive explanation.

Further, trainees are substantially less sensitive to own-price changes across all evaluated goods. The magnitudes of own-price elasticities indicate that food retailers can gain revenue from price increases among trainees, while simultaneously losing revenue from non-trainees, though that specific inelastic/elastic demand distinction is sensitive to potential overstating of choice experiment expenditures. However, consistent across the primary results and follow-up sensitivity assessments is that trainees are relatively own-price insensitive, which may result in this behavioral group representing a progressively larger share of the market for protein in the instance of rising prices and, correspondingly, national aggregate own-price elasticities moving toward zero.

Finally, trainees are slightly less willing to shift consumption toward ground beef, pork chop, bacon, chicken breast, shrimp, and beans and rice (relative to non-trainees) as the prices of

other products increase. This suggests that not all food substitutions are aligned with the health- and fitness-conscious population's perceived dietary requirements. However, we emphasize that cross-price elasticities observed in this study were not sizably different in magnitude between behavioral groups and, thus, these differences may not be economically meaningful.

MDM responses show that roughly a third of the U.S. population is actively consuming protein to aid in their fitness pursuits. Our work shows, additionally, that the exercising behavioral group has substantially different demand schedules for retail protein goods. Collectively, these findings have meaningful implications for academic research and the U.S. protein industry. Prior consumer-level demand assessments, though considering certain demographic characteristics, represent an aggregation of consumers' exercise patterns. Our results suggest that future assessments need to consider these exercise pursuits, in addition to the traditional controls for household income, age, gender, etc. Further, the effectiveness of marketing and pricing strategies among food manufacturers depends on consumers' exercise habits. The relative sizes of exercising and non-exercising consumer groups, and differences in their purchasing patterns, have ramifications for the profit potential of food retailers, food manufacturers, and upstream producers.

Future research can further identify best practices when using OECE-derived consumer data or empirically assess the impacts of the challenges we discussed in this study. Additionally, survey-based consumer analyses should more seriously consider respondents' behavioral patterns (e.g., exercise habits) or other characteristics that may sizably influence economic conclusions. Finally, and of most importance to food producers and retailers, a monetary valuation to the U.S. food industry of the societal interest in health and physical fitness can be conducted. We hope the efforts and results reflected in this study motivate that future research.

Chapter 4 - Do Separability Assumptions Matter in Choice Experiment Research?

Introduction

"Separability assumptions have been used over and over again, but their usefulness depends on the ability to classify goods into groups for which the separability assumption may be considered empirically valid (Barten, 1977)."

The concept of separability in demand analysis, introduced by Leontief (1947) and Sono (1961), predates widespread use of choice experiment methods by decades. Put simply, any group of goods are "separable" from another good (or group) *X* if the order of the values of preference corresponding to their respective quantities is independent of good *X* (Sono, 1961). Restated, when the ratios of marginal values of preference for any given quantities of, say, *A*, *B*, and *C* are independent of the quantity of *X*, then *A*, *B*, and *C* are separable from *X* (Sono, 1961). This concept has been expanded to two-stage optimization (i.e., two-stage budgeting) and *strong* versus *weak* separability distinctions, which make possible the estimation of consumer demand in the presence of an immense number of commodities and services in consumers' budget sets. By assuming consumers allocate expenditure between groups (where within-group expenditure allocations are then performed independently) and changes in prices in one group do not impact preference ordering in another group (i.e., weak separability), researchers can drastically reduce the number of demand equations and quantify substitution patterns within only the commodity group of interest.

While the concept of separability and assumptions regarding separability of goods have been commonplace in traditional demand estimation (e.g., AIDS, Rotterdam, etc.), they largely have not been discussed in relatively newer choice experiment (CE) research. Other than the

requirement that presented CE alternatives be mutually exclusive, exhaustive, and finite (Train, 2009), the selection of alternatives has typically been driven by the specific research objective and not by the validity or appropriateness of selection with respect to separability between alternatives. The fact that experimental design efforts have yet to seriously consider separability assumptions motivates this research.

While some CEs are used to quantify willingness-to-pay (WTP) for specific product characteristics (rather than being focused on the product itself)—and, as such, may not need be particularly mindful of product selection—this is not always the case. A host of examples exist in academic research where WTP, demand curves, and price elasticities are derived from labeled CEs and are presented for industry use and policy analyses. Notable examples of such research efforts in the context of U.S. food demand include Lusk and Tonsor (2016), which revealed nonlinear and income-dependent demand for meat products, and Van Loo et al. (2020), who assessed the impact of product branding and information on demand for various traditional and alternative meat products. In the same way that substitution patterns and income effects are dependent on separability assumptions in a traditional demand framework, the WTP estimates, market shares, and price elasticities derived from these, and similar, efforts may be influenced by the alternatives presented to CE participants.

Related work has noted that CE-based food demand assessments often assume that food attributes shown to participants are independent of attributes not shown (Gao and Schroeder, 2009). This is likely a strong assumption, as WTP estimates have repeatedly been found to be sensitive to the number and type of attributes included in the experimental design (Gao and Schroeder, 2009; Tonsor, 2011; Pozo, Tonsor, and Schroeder, 2012). These studies, implementing unlabeled CEs that varied in attributes included, indicate that slight changes in CE participants'

choice sets can notably impact economic conclusions derived from the resulting choice data. It stands to reason that the separability assumptions—in this study, assessed as the replacement of alternatives in a CE—that drive researchers' selection of alternatives may also influence economic conclusions. That is, the goods included in a CE may not be independent of those not included and economic measures derived from the CE may be conditional on which goods were available to participants.

Noting the gap in research related to CE design and relevant findings of Gao and Schroeder (2009), Pozo et al. (2012), and Tonsor (2011), the objective of this study is to determine how separability assumptions (i.e., assumptions on appropriate inclusion of CE alternatives) impact CE results. Specifically, we determine how changing the CE choice set (in terms of the labeled alternatives made available) impacts the associated estimates for WTP, market shares, and price elasticities. Results of this study can be used to inform future CE design efforts, improve the validity of economic conclusions drawn from survey and experiment-based research, and guide food marketers' use of CEs in demand forecasts and marketing strategies.

Experimental Design

Control

Data used in this study comes from the Meat Demand Monitor (MDM) project that began in February 2020 with funding support from the U.S. beef and pork checkoff programs (Tonsor, 2020). The MDM is a national, online survey that is distributed monthly to a sample that is designed to be representative of the U.S. population in terms of gender, age, race, educational attainment, annual household income, and region of residence (Tonsor, 2020). Importantly, data from the MDM has a pooled, cross-sectional structure (i.e., a different sample of respondents is surveyed each month) with roughly 3,000 useable survey responses recorded each month. The

MDM focuses on domestic meat demand—in both retail and foodservice settings—and includes questions framed to improve understanding of meat demand and purchase decisions (Tonsor, 2020).

Key to this study, the MDM presents one-half of respondents with a retail-framed CE (and one-half a foodservice-framed CE), from which WTP and market share estimates for various protein goods are calculated and reported each month. For respondents receiving the retail-framed CE, the following script is provided: "Imagine you are at the grocery store buying ingredients to prepare a meal for you or your household. Each product would be boneless and uncooked for you to prepare at home as desired. For each of the following 9 questions, please indicate which you would most likely buy. The only difference across these 9 questions is the price ($/lb) of each option". The full experimental design is composed of 27 unique choice tasks, with these being blocked into three groups and respondents randomly assigned to one of the three blocks. Figure 4.1 depicts an example choice task while Table 4.1 reports the eight retail protein goods and their price levels.

Figure 4.1. Example Choice Experiment Choice Task

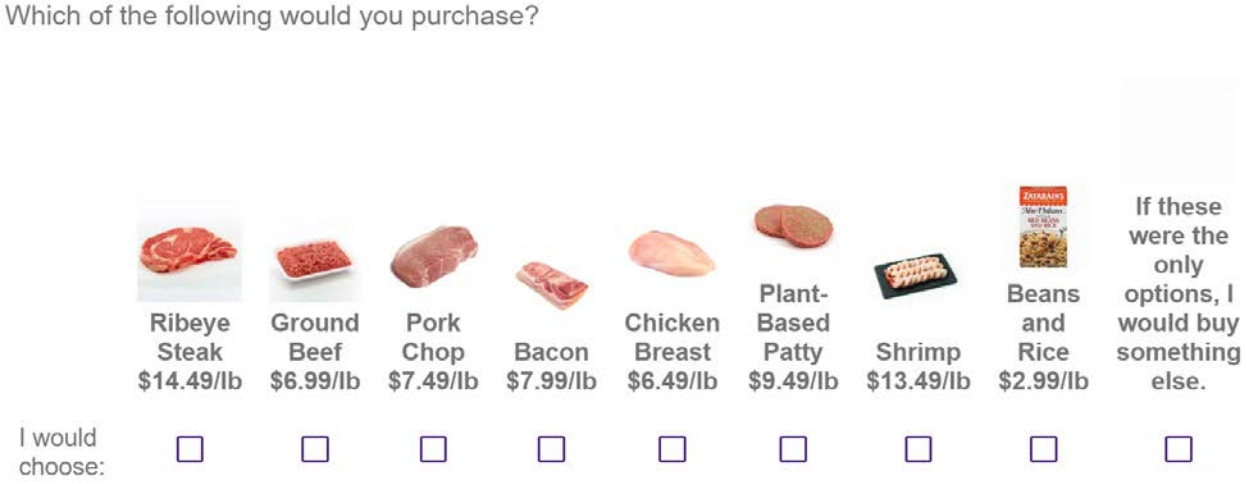


Table 4.1. MDM Retail-Framed Choice Experiment Alternatives and Price Levels

	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans and Rice
Price Level 1 ($/lb)	14.49	1.99	2.49	2.99	1.49	9.49	8.49	0.49
Price Level 2 ($/lb)	16.99	4.49	4.99	5.49	3.99	11.99	10.99	2.99
Price Level 3 ($/lb)	19.49	6.99	7.49	7.99	6.49	14.49	13.49	5.49

In this study, the MDM is treated as the "control." That is, economic results obtained from the MDM's retail-framed CE are treated as a baseline to which we compare a series of treatments. The MDM is an attractive choice as a control as it focuses on an economically important component of U.S. consumers' diets. Jointly, cattle and calves, hogs, and broiler chickens accounted for over $167 billion in cash receipts in 2022 (U.S. Department of Agriculture Economic Research Service, 2024). By comparison, food grains (i.e., rice, rye, and wheat), vegetables and melons, and fruits and nuts accounted for cash receipts of $17 billion, $25 billion, and $27 billion, respectively (U.S. Department of Agriculture Economic Research Service, 2024). In addition to the economic relevance of the MDM's meat focus, the project has also been cited in various government testimonies, industry-focused educational outputs, and academic research articles (Tonsor, Lusk, and Tonsor, 2021; Taylor et al., 2022; Bina, Tonsor, and Briggeman, 2023; Bina and Tonsor, 2023; Bina and Tonsor, 2024a). Thus, the stability of economic conclusions derived from the MDM's CE has implications for policymakers, producer groups and food manufacturers, and scholarly research.

Treatments

To achieve our stated objective, two standalone surveys were constructed and distributed in a manner nearly identical to the MDM. These surveys were again distributed in an online format and to a sample that was designed to be representative of the U.S. population. The survey instruments were similar to that of the base MDM, except that all respondents received a retail-

framed CE (as opposed to one-half of respondents) and that the protein goods in the CE varied slightly across the treatment arms. Specifically, the CE in "MDM Variant 1" included one dozen eggs as an alternative rather than plant-based patty and the CE in "MDM Variant 2" included a one-pound package of whey protein powder rather than shrimp. Eggs represent a protein source that is commonly consumed whole or as an ingredient in other food items while whey protein represents a dairy-based product that is notable for its convenience of consumption.[19] Plant-based patty and shrimp were chosen as the alternatives to be replaced as they are the least frequently chosen products in the base MDM CE. Recalling the economic relevance of meat protein, as observed in USDA Economic Research Service reporting of cash receipts, the sensitivity of demand for ribeye steak, ground beef, pork chop, bacon, and chicken breast to changes in respondents' choice sets are of key interest and, thus, these alternatives were left unchanged (in addition to beans and rice).

In both MDM variants, the only change to the CE was the replacement of one alternative. Thus, there remained 27 unique choice tasks comprised of eight protein goods with three price levels and a ninth, opt-out option. These choice tasks were again blocked into three groups, with MDM variant respondents randomly assigned one of the three blocks. Importantly, the price levels of eggs in MDM Variant 1 were set at \$0.99, \$1.99, and \$2.99 per dozen, reflecting a range of prices that were observed across major food retailers' online listings at time of survey construction. Price levels of whey protein powder in MDM Variant 2 were set at \$14.99, \$19.99, and \$24.99 per

[19] As the base MDM survey does not include a dairy-based protein source in its retail-framed CE, we considered the inclusion of dairy in a variant CE as an appropriate method of assessing separability assumptions. Additionally, including a commonly consumed protein item (i.e., eggs) in Variant 1 and a less commonly consumed protein item (i.e., whey protein powder) in Variant 2 provides insight into appropriate experimental design with respect to economic relevance of choice alternatives.

pound. These levels were determined by searching Amazon listings of popular whey protein brands (i.e., Dymatize, Ghost, Legion, Myprotein, Naked, and Optimum Nutrition), converting listed prices to dollars per pound, and establishing a representative range.

Our decision to *replace* CE alternatives rather than to omit or add an alternative was driven by a desire to keep the variant CE designs similar to that of the base MDM in terms of the number of alternatives presented and the number of choice tasks. This permitted CE complexity and overall survey length to be similar for the control group and each treatment arm. However, a tradeoff of this decision exists in that differences in economic measures derived from each set of choice data are driven by two effects: i) the omission of an alternative and ii) the inclusion of a new alternative. Future research can assess pure alternative-omission or alternative-inclusion effects, provided that that research takes caution to keep survey length and complexity consistent across samples.

The MDM variants were distributed from November 2023 through February 2024, with over 2,000 useable responses recorded for each. The November 2023 through February 2024 base MDM survey results were pooled for direct temporal comparison with the MDM variants.

Descriptive Statistics

Base MDM and variant responses were omitted if 1) the respondent did not receive a retail-framed choice experiment (base MDM only), 2) the respondent indicated being under the age of 18, 3) the respondent was not their household's primary grocery shopper, 4) an embedded attentiveness check was failed, or 5) the respondent indicated not being truthful in their answers. The final data set used for this analysis included 6,036 responses from the base MDM (54,324 choices made), 2,178 responses from MDM Variant 1 (19,602 choices made), and 2,159 responses from MDM Variant 2 (19,431 choices made). Descriptive statistics of the sample are reported in Table 4.2.

Table 4.2. Descriptive Statistics of Sample

	Proportion (SE)		
	Base MDM	MDM Variant 1	MDM Variant 2
Variable	n = 6,036	n = 2,178	n = 2,159
Gender			
Male	0.481 (0.006)	0.489 (0.006)	0.491 (0.006)
Female	0.519 (0.006)	0.511 (0.006)	0.509 (0.006)
Age (years)			
18-24	0.034 (0.002)	0.034 (0.002)	0.033 (0.002)
25-34	0.111 (0.004)	0.103 (0.004)	0.114 (0.004)
35-44	0.188 (0.005)	0.184 (0.005)	0.201 (0.005)
45-54	0.182 (0.005)	0.176 (0.005)	0.176 (0.005)
55-64	0.255 (0.006)	0.275 (0.006)	0.258 (0.006)
65+	0.231 (0.005)	0.228 (0.005)	0.217 (0.005)
Race/Ethnicity			
White	0.724 (0.006)	0.725 (0.006)	0.720 (0.006)
Black	0.148 (0.005)	0.153 (0.005)	0.152 (0.005)
Other	0.128 (0.004)	0.123 (0.004)	0.128 (0.004)
Annual Household Income			
$20,000 and under	0.148 (0.005)	0.147 (0.005)	0.152 (0.005)
$20,001-$100,000	0.679 (0.006)	0.674 (0.006)	0.682 (0.006)
$100,000 and over	0.174 (0.005)	0.179 (0.005)	0.166 (0.005)
Education			
High school or lower	0.262 (0.006)	0.260 (0.006)	0.246 (0.006)
Some college	0.413 (0.006)	0.410 (0.006)	0.418 (0.006)
Bachelor's degree or higher	0.325 (0.006)	0.330 (0.006)	0.336 (0.006)
Census Region			
Midwest	0.213 (0.005)	0.206 (0.005)	0.207 (0.005)
Northeast	0.179 (0.005)	0.181 (0.005)	0.184 (0.005)
South	0.378 (0.006)	0.377 (0.006)	0.376 (0.006)
West	0.230 (0.005)	0.236 (0.005)	0.233 (0.005)
Diet			
Regularly consumes meat	0.786 (0.005)	0.781 (0.005)	0.794 (0.005)
Flexitarian	0.111 (0.004)	0.111 (0.004)	0.093 (0.004)*
Vegetarian	0.022 (0.002)	0.023 (0.002)	0.022 (0.002)
Vegan	0.026 (0.002)	0.018 (0.002)*	0.021 (0.002)
Other	0.055 (0.003)	0.066 (0.003)	0.069 (0.003)*

Note: Asterisks (*) indicate proportions that are statistically different (95 percent confidence) than those from the base MDM.

Two proportions *z*-tests were conducted to compare sample proportions between the MDM variants and the base MDM. The proportion of respondents who indicated that they were vegan

vegetarians in MDM Variant 1 was statistically different (95 percent confidence) than the proportion of base MDM respondents but was not sizably different in magnitude. The proportion of MDM Variant 2 respondents who reported being a flexitarian (i.e., primarily vegetarian but occasionally consumes meat or fish) or subscribing to some other diet was significantly different than the base MDM but, again, were not substantially different in magnitude. From descriptive statistics depicted in Table 4.2, respondents from the two survey variants can be validly compared to those from the control survey.

Econometric Methods

Model Specification

Choice data obtained from the base MDM and variants is analyzed in a random utility framework. Following McFadden (1973) and utilizing the notation of Train (2009), decision maker *n*, when faced with *J* alternatives, obtains from alternative *j* utility U_{nj}. The decision maker maximizes utility such that they choose alternative *i* if and only if $U_{ni} > U_{nj} \forall j \neq i$. There are aspects of utility that the research cannot observe and, thus, utility is decomposed as $U_{nj} = V_{nj} + \varepsilon_{nj}$, where V_{nj} represents the observable portion of utility and ε_{nj} represents the unobservable portion that is treated as random. The multinomial logit model (MNL) of choice is obtained by assuming that ε_{nj} is independently, identically distributed extreme value with logit choice probabilities simplifying to:

(1) $$P_{nj} = \frac{e^{V_{nj}}}{\sum_j e^{V_{nj}}}.$$

Several important limitations of the standard MNL make its use undesirable in this application. First, substitution patterns (i.e., cross-price elasticities) are restricted to being identical across all alternatives—a result of the independence of irrelevant alternatives property (Train,

2009). Second, parameter estimates that describe the observable portion of utility, V_{nj}, are identical for each decision maker *n*. Regarding the former, it is not appropriate to assume that, when faced with a price change for one good, consumers proportionately change their consumption of all other goods. Regarding the latter, in comparing the stability of economic conclusions derived from varying choice sets, not only are we interested in differences in point estimates but are also interested in differences in distributions. For example, does replacing plant-based patty with eggs in consumers' choice sets shift the distribution of WTP for chicken breast? Allowing parameter estimates (and associated economic measures) to vary across individuals is required for such assessment.

To relax the restrictive assumptions of the MNL, we consider a random parameters logit (RPL) model, which is also known as the mixed logit model. Importantly, the RPL is an attractive specification as is allows for random taste variation and unrestricted substitution patterns (Train, 2009). RPL choice probabilities are given by the integral of standard MNL probabilities over a distribution of parameters:

$$P_{nj} = \int L_{nj}(\beta) f(\beta) d\beta \,, \tag{2}$$

where $L_{nj}(\beta)$ is the logit probability evaluated at parameters β:

$$L_{nj}(\beta) = \frac{e^{V_{nj}(\beta)}}{\sum_j e^{V_{nj}(\beta)}} \,, \tag{3}$$

and $f(\beta)$ is a density function. Further detail on the RPL is more elegantly provided by Train (2009).

We consider four model specifications: 1) a MNL, 2) a MNL with controls for respondents' demographic characteristics, 3) a RPL, and 4) a RPL with controls for respondents' demographic characteristics. All model specifications consist of alternative-specific constants for the eight CE

products and a single, linear price effect. The utility specifications for the models we evaluate are provided in Table 4.3.

Table 4.3. Alternative Model Specifications

Model	Description	Utility Specification
1	MNL	$U_{nj} = \beta_j + \alpha p_j + \varepsilon_{nj}$
2	MNL with controls	$U_{nj} = \beta_j + \alpha p_j + \sum_k \delta_k X_{nk} + \varepsilon_{nj}$
3	RPL	$U_{nj} = (\beta_j + \sigma_j d_n) + \alpha p_j + \varepsilon_{nj}, d_n \sim N(0,1)$
4	RPL with controls	$U_{nj} = (\beta_j + \sigma_j d_n) + \alpha p_j + \sum_k \delta_k X_{nk} + \varepsilon_{nj}, d_n \sim N(0,1)$

Note: All models included alternative-specific constants and a single, linear price effect.

The MNL models are estimated using conventional maximum likelihood estimation. For RPL models, the terms β_j and σ_j represent, respectively, the mean and standard deviation of alternative-specific constant *j*. These models are estimated using simulated maximum likelihood techniques and 500 individual-specific Modified Latin Hypercube Sampling draws (Hess, Train, and Polak, 2006). Likelihood ratio tests are conducted to determine a preferred specification (i.e., with versus without controls, MNL versus RPL) for each sample (i.e., base MDM and variants). Model fit measures are depicted in Table 4.4, while the results of the likelihood ratio tests are depicted in Table 4.5. For each sample, the preferred specification is an RPL model controlling for demographic characteristics.

Table 4.4. Model Fit Measures

Survey	Model	Description	# Parameters	Log-Likelihood	AIC	BIC
Base MDM	1	MNL	9	-95,967	191,951	192,031
	2	MNL with controls	28	-95,622	191,299	191,548
	3	RPL	17	-85,612	171,258	171,409
	4	RPL with controls	36	-85,275	170,622	170,942
MDM Variant 1	1	MNL	9	-35,882	71,783	71,854
	2	MNL with controls	28	-35,756	71,567	71,788
	3	RPL	17	-33,213	66,460	66,594
	4	RPL with controls	36	-33,086	66,244	66,528
MDM Variant 2	1	MNL	9	-33,271	66,560	66,631
	2	MNL with controls	28	-33,099	66,254	66,474
	3	RPL	17	-29,808	59,651	59,785

Survey	Model	Description	# Parameters	Log-Likelihood	AIC	BIC
	4	RPL with controls	36	-29,640	59,352	59,635

Table 4.5. Likelihood Ratio Tests

Survey	Test	χ^2	df	*p*-value	Conclusion
Base MDM	Model 2 vs. 1	690	19	<0.001	reject MNL without controls in favor of MNL with controls
	Model 3 vs. 1	20,710	8	<0.001	reject MNL without controls in favor of RPL without controls
	Model 4 vs. 3	674	19	<0.001	reject RPL without controls in favor of RPL with controls
MDM Variant 1	Model 2 vs. 1	254	19	<0.001	reject MNL without controls in favor of MNL with controls
	Model 3 vs. 1	5,339	8	<0.001	reject MNL without controls in favor of RPL without controls
	Model 4 vs. 3	254	19	<0.001	reject RPL without controls in favor of RPL with controls
MDM Variant 2	Model 2 vs. 1	344	19	<0.001	reject MNL without controls in favor of MNL with controls
	Model 3 vs. 1	6,925	8	<0.001	reject MNL without controls in favor of RPL without controls
	Model 4 vs. 3	337	19	<0.001	reject RPL without controls in favor of RPL with controls

Economic Measures

Mean WTP is estimated, separately for each survey and alternative *j*, as the ratio of the utility associated with alternative *j* and the utility of price:

(4) $$WTP_j = -\frac{\beta_j}{\alpha}.$$

For the RPL models, the numerator is supplemented with the standard deviation term σ_j to obtain a distribution of WTP estimates. Additionally, marginal WTP estimates are calculated for each survey as:

(5) $$WTP_j - WTP_i = \left(-\frac{\beta_j}{\alpha}\right) - \left(-\frac{\beta_i}{\alpha}\right) \forall j \neq i\ .$$

These reflect the difference in mean WTP for two alternatives and captures the premium or discount consumers will pay for good *j* over good *i*.

Standard errors for WTP and marginal WTP estimates are constructed via a Krinsky and Robb (1986) resampling procedure. Given the initial parameter vector θ and variance-covariance matrix V obtained from estimating the MNL and RPL models, and a set of WTP and marginal WTP formulas:

(6) $$\psi_n = f_n(\theta)$$

where ψ_n is the *n*th WTP or marginal WTP and f_n is a function of parameters, 10,000 random draws are taken for θ from a multivariate normal distribution parameterized by mean θ and variance-covariance matrix V. For each draw, the WTP and marginal WTP, ψ_n, are calculated. Thus, an empirical distribution is generated for each economic measure of interest (Krinsky and Robb, 1986).

A standard error for each WTP and marginal WTP is then computed from the simulated values using the formula:

(7) $$\widehat{SE}(\widehat{\psi_n}) = \sqrt{\widehat{Var}(\widehat{\psi_n})} = \sqrt{\frac{1}{B-1}\sum_{b=1}^{B}(\widehat{\psi_{n_b}}^{*} - \overline{\psi_n}^{*})^2}$$

where $\widehat{\psi_{n_b}}^{*}$ is the estimate of ψ_n from the *b*th Krinsky-Robb sample, $\overline{\psi_n}^{*} = \frac{1}{B}\sum_{b=1}^{B}\widehat{\psi_{n_b}}^{*}$ is the sample mean of the distribution, and *B* is equal to the number of simulated draws of the parameters (i.e., 10,000).

Market shares, or choice probabilities, of the eight CE goods are also calculated. For MNL models, this is easily done using parameter estimates and means of the data (i.e., prices and demographic information) in equation (1). However, market shares derived from RPL models need to be calculated via simulation as the indirect utility, $V_{nj}(\beta)$, in equation (3) is a function of the random term d_n that is distributed according to a standard normal distribution. Following Train

(2009) and Lusk and Tonsor (2016), we 1) draw a value of d_n from a standard normal distribution, 2) calculate the logit formula (equation [3]) with this draw, and 3) repeat the process numerous times. The average is the simulated market share:

(8) $$\check{P}_j = S_j = \frac{1}{R}\sum_{r=1}^{R} L_j(\beta^r)$$

where *R* is the number of draws and prices and demographic information are held at their mean values. We use *R* = 10,000 in our calculations.

Lastly, arc elasticities are calculated following Lusk and Tonsor (2016). First, market shares are calculated for the *j* = 8 CE alternatives at the midpoints of the data (using equation [1] for MNL models and equation [8] for RPL models). These values are denoted $\bar{S}_j$. The arc elasticity associated with a change in the price of alternative *i* is then:

(9) $$\gamma_{ji} = \frac{\partial S}{\partial P} * \frac{P}{S} = \frac{S_j' - \bar{S}_j}{P_i' - \bar{P}_i} * \frac{\bar{P}_i}{\bar{S}_j} = \frac{S_j' - \bar{S}_j}{\bar{S}_j} * \frac{\bar{P}_i}{P_i' - \bar{P}_i} = \frac{S_j' - \bar{S}_j}{\bar{S}_j} * \frac{\bar{P}_i}{x\bar{P}_i - \bar{P}_i}$$

$$= \frac{S_j' - \bar{S}_j}{\bar{S}_j} * \frac{\bar{P}_i}{(x-1)\bar{P}_i} = \frac{S_j' - \bar{S}_j}{\bar{S}_j} * \frac{1}{x-1}$$

where S_j' is the new market share calculated from changing mean price $\bar{P}_i$ to P_i'. Here, *x* is a multiplier on mean price. To assess nonlinearity in arc elasticities, we increase (decrease) the mean price of alternative *i* by 10 percent intervals (up to +/- 50 percent) while holding the price of all other alternatives constant. Thus, *x* ranges from 0.5 to 1.5.

Results

Frequencies of choice across the three survey variants are depicted in Table 4.6. Two proportions *z*-tests were again used to compare sample proportions between the MDM variants and the base MDM. Replacing plant-based patty with eggs in Variant 1 yielded relativity lower choice frequencies for all other alternatives, with differences in frequencies relative to the base MDM

being statistically significant (95 percent confidence). Of note is that the proportion of times that the opt-out option, ground beef, and chicken breast were selected decreased by 2.6, 3.0, and 5.6 percent, respectively. These shifts facilitated 19.1 percent selecting eggs in Variant 1 versus 2.2 percent selecting plant-based patty in the control group.

Table 4.6. Frequencies of Choices Across Survey Variants

	Proportion		
	Base MDM choices = 54,324	MDM Variant 1 choices = 19,602	MDM Variant 2 choices = 19,431
Frequency of choice			
Opt-Out	0.068	0.042*	0.073*
Ribeye Steak	0.067	0.056*	0.067
Ground Beef	0.240	0.210*	0.242
Pork Chop	0.133	0.111*	0.136
Bacon	0.076	0.068*	0.080
Chicken Breast	0.266	0.210*	0.278*
Beans and Rice	0.085	0.073*	0.094*
Plant-Based Patty	0.022	-	0.020
Shrimp	0.044	0.039*	-
Eggs	-	0.191	-
Whey Protein	-	-	0.011

Note: Asterisks (*) indicate proportions that are statistically different (95 percent confidence) than those from the base MDM.

Conversely, replacing shrimp with whey protein powder in Variant 2 did not always yield statistically significant differences in choice frequencies, which is consistent with only 1.1 percent selecting whey protein in Variant 2. Variant 2 respondents' frequency of choosing the opt-out option, chicken breast, and beans and rice were slightly higher than base MDM respondents'. While Variant 1 replaced a relatively less frequently chosen alternative (plant-based patty) with a very commonly consumed food item (eggs), Variant 2 replaced a relatively less frequently chosen alternative (shrimp) with a food item (whey protein) that is more tailored to a specific, fitness-focused demographic and less consumed by the general population. This may explain differential results between variants as seen through choice frequencies.

From Table 4.5 likelihood ratio tests, model (4) was the preferred specification across all survey variants and is characterized by heterogeneous alternative-specific constants (i.e., an RPL model), a single and linear price effect, and controls for respondent characteristics. The remainder of this study presents and discusses results associated with this specification. Parameter estimates from the preferred specification, and for each survey variant, are depicted in Appendix Table D.1.

Willingness-to-Pay

The distribution of WTP for each CE alternative and across each survey variant is depicted in Table 4.7. The relative ordering of ribeye steak, ground beef, pork chop, bacon, chicken breast, and beans and rice (i.e., the alternatives available in each survey variant), in terms of mean WTP, remained the same across the base MDM and MDM variants. Respondents always had the highest mean WTP for ribeye steak, followed by ground beef, chicken breast, pork chop, bacon, and beans and rice. However, differences in mean WTP and distribution were observed.

Table 4.7. Willingness-to-Pay Distributions

Product	-2 SD	-1 SD	Mean WTP	+1 SD	+2 SD
			Base MDM		
Ribeye Steak ($/lb)	3.18*	8.62*	14.06*	19.50*	24.94*
	[2.20, 4.15]	[7.80, 9.43]	[13.34, 14.77]	[18.81, 20.18]	[24.20, 25.68]
Ground Beef ($/lb)	3.83*	5.96*	8.09*	10.21*	12.34*
	[3.14, 4.52]	[5.29, 6.63]	[7.42, 8.75]	[9.55, 10.88]	[11.66, 13.03]
Pork Chop ($/lb)	2.14*	4.41*	6.68*	8.95*	11.22*
	[1.42, 2.85]	[3.73, 5.09]	[6.01, 7.35]	[8.28, 9.62]	[10.53, 11.92]
Bacon ($/lb)	3.38*	4.78*	6.17*	7.57*	8.96*
	[2.63, 4.14]	[4.09, 5.47]	[5.51, 6.84]	[6.90, 8.24]	[8.25, 9.68]
Chicken Breast ($/lb)	2.47*	5.10*	7.73*	10.36*	12.99*
	[1.77, 3.16]	[4.42, 5.77]	[7.06, 8.39]	[9.69, 11.03]	[12.30, 13.68]
Beans and Rice ($/lb)	-4.80*	-1.11*	2.58*	6.27*	9.96*
	[-5.60, -4.01]	[-1.83, -0.39]	[1.90, 3.25]	[5.59, 6.94]	[9.24, 10.67]
Plant-Based Patty ($/lb)	-9.84*	-3.01*	3.82*	10.66*	17.49*
	[-11.37, -8.31]	[-4.19, -1.83]	[2.93, 4.71]	[9.93, 11.38]	[16.72, 18.26]
Shrimp ($/lb)	-0.81	3.63*	8.08*	12.52*	16.96*
	[-1.75, 0.13]	[2.84, 4.43]	[7.37, 8.78]	[11.84, 13.20]	[16.23, 17.69]
Eggs ($/dozen)	-	-	-	-	-

Product	-2 SD	-1 SD	Mean WTP	+1 SD	+2 SD
	-	-	-	-	-
Whey Protein ($/lb)	-	-	-	-	-
	-	-	-	-	-
			MDM Variant 1		
Ribeye Steak ($/lb)	6.93*	11.36*	15.79*	20.22*	24.65*
	[5.22, 8.64]	[9.82, 12.90]	[14.36, 17.23]	[18.82, 21.63]	[23.20, 26.11]
Ground Beef ($/lb)	5.22*	7.14*	9.05*	10.97*	12.88*
	[3.80, 6.65]	[5.74, 8.54]	[7.67, 10.44]	[9.58, 12.36]	[11.47, 14.29]
Pork Chop ($/lb)	3.17*	5.35*	7.54*	9.73*	11.92*
	[1.70, 4.63]	[3.94, 6.77]	[6.16, 8.93]	[8.34, 11.12]	[10.50, 13.34]
Bacon ($/lb)	4.46*	5.86*	7.25*	8.65*	10.04*
	[2.94, 5.98]	[4.43, 7.29]	[5.87, 8.64]	[7.26, 10.04]	[8.60, 11.49]
Chicken Breast ($/lb)	4.30*	6.42*	8.54*	10.66*	12.79*
	[2.88, 5.72]	[5.03, 7.81]	[7.16, 9.93]	[9.27, 12.06]	[11.37, 14.21]
Beans and Rice ($/lb)	-3.23*	0.20	3.62*	7.05*	10.48*
	[-4.75, -1.70]	[-1.24, 1.64]	[2.23, 5.02]	[5.65, 8.45]	[9.03, 11.92]
Plant-Based Patty ($/lb)	-	-	-	-	-
	-	-	-	-	-
Shrimp ($/lb)	1.43	5.41*	9.39*	13.36*	17.34*
	[-0.31, 3.18]	[3.86, 6.96]	[7.95, 10.82]	[11.96, 14.76]	[15.87, 18.80]
Eggs ($/dozen)	1.48*	3.85*	6.22*	8.59*	10.96*
	[0.06, 2.90]	[2.46, 5.25]	[4.84, 7.61]	[7.20, 9.98]	[9.54, 12.38]
Whey Protein ($/lb)	-	-	-	-	-
	-	-	-	-	-
			MDM Variant 2		
Ribeye Steak ($/lb)	4.08*	9.65*	15.21*	20.78*	26.35*
	[2.32, 5.84]	[8.14, 11.16]	[13.86, 16.57]	[19.46, 22.10]	[24.94, 27.76]
Ground Beef ($/lb)	5.30*	7.36*	9.42*	11.48*	13.54*
	[3.98, 6.63]	[6.07, 8.66]	[8.14, 10.70]	[10.19, 12.77]	[12.22, 14.85]
Pork Chop ($/lb)	3.46*	5.74*	8.02*	10.30*	12.58*
	[2.09, 4.82]	[4.43, 7.05]	[6.74, 9.30]	[9.01, 11.59]	[11.25, 13.91]
Bacon ($/lb)	4.18*	5.83*	7.48*	9.12*	10.77*
	[2.78, 5.58]	[4.51, 7.15]	[6.19, 8.76]	[7.83, 10.42]	[9.43, 12.12]
Chicken Breast ($/lb)	4.06*	6.65*	9.24*	11.83*	14.43*
	[2.74, 5.38]	[5.36, 7.95]	[7.96, 10.53]	[10.54, 13.13]	[13.10, 15.75]
Beans and Rice ($/lb)	-4.37*	-0.23	3.90*	8.04*	12.18*
	[-5.84, -2.90]	[-1.59, 1.12]	[2.61, 5.20]	[6.74, 9.34]	[10.81, 13.55]
Plant-Based Patty ($/lb)	-8.60*	-1.79	5.03*	11.84*	18.65*
	[-11.22, -5.98]	[-3.85, 0.28]	[3.41, 6.64]	[10.47, 13.21]	[17.20, 20.10]
Shrimp ($/lb)	-	-	-	-	-

Product	-2 SD	-1 SD	Mean WTP	+1 SD	+2 SD
	-	-	-	-	-
Eggs ($/dozen)	-	-	-	-	-
	-	-	-	-	-
Whey Protein ($/lb)	-1.82	4.29*	10.40*	16.51*	22.63*
	[-4.98, 1.33]	[1.87, 6.71]	[8.61, 12.19]	[15.12, 17.91]	[21.17, 24.08]

Note: Asterisks (*) indicate statistical significance at the five percent level or lower. Values in brackets [ ] represent 95 percent confidence intervals. Standard errors were constructed from a Krinsky-Robb resampling of parameter estimates.

Mean WTP observed when eggs were provided in respondents' choice sets rather than plant-based patty (i.e., MDM Variant 1) were higher across all other alternatives. Further, the distribution of WTP shifted to the right for ground beef, pork chop, bacon, beans and rice, and shrimp, meaning that, for any given price of those alternatives, a larger share of respondents were willing to purchase. Distributions of WTP for ribeye steak and chicken breast did not appear to shift entirely rightward in MDM Variant 1, relative to base MDM estimates, as those distributions also "tightened up." That is, though the mean WTP estimates for ribeye steak and chicken breast were higher in MDM Variant 1, the standard deviations around the mean WTP were smaller.

Again, mean WTP observed when whey protein powder was provided in respondents' choice sets rather than shrimp (i.e., MDM Variant 2) were higher across all other alternatives. Additionally, the distribution of WTP shifted to the right for all alternatives in MDM Variant 2 relative to the base MDM. Recalling from Table 4.6 that shrimp was only chosen in 4.4 percent of choice tasks in the base MDM and whey protein was only chosen in 1.1 percent of choice tasks in MDM Variant 2, omitting or including alternatives in a CE can have substantial influence on economic measures of interest even if those alternatives are seldomly chosen by CE participants. Further, the smallest difference in mean WTP estimates was $0.82 per pound (chicken breast in the base MDM versus Variant 1). This has important implications for experimental design as

researchers make decisions on CE alternatives using a basket of similar goods (e.g., protein-dense foods).

Marginal Willingness-to-Pay

Marginal WTP calculated using equation (5) and for each survey variant are depicted in Table 4.8. For clarity, we report only marginal WTP for the six CE alternatives that were present in each survey variant. Marginal WTP does not change in sign as survey respondents' available CE alternatives are changed. That is, respondents were always willing to pay a premium or discount for alternative *j* over alternative *i* regardless of slight changes in the availability of other alternatives. For example, respondents across the base MDM and both MDM variants were always willing to pay a premium for ribeye steak over ground beef, pork chop, bacon, chicken breast, and beans and rice.

Table 4.8. Marginal Willingness-to-Pay Estimates

WTP for:	Minus WTP for:	Base MDM	MDM Variant 1	MDM Variant 2
Ribeye Steak	Ground Beef	5.972* (0.150)	6.739* (0.219)	5.791* (0.255)
	Pork Chop	7.378* (0.152)	8.249* (0.224)	7.194* (0.258)
	Bacon	7.884* (0.150)	8.540* (0.223)	7.737* (0.257)
	Chicken Breast	6.332* (0.152)	7.250* (0.221)	5.970* (0.259)
	Beans and Rice	11.481* (0.164)	12.169* (0.248)	11.309* (0.278)
Ground Beef	Pork Chop	1.406* (0.062)	1.510* (0.107)	1.403* (0.105)
	Bacon	1.912* (0.064)	1.801* (0.112)	1.946* (0.109)
	Chicken Breast	0.360* (0.056)	0.511* (0.088)	0.178 (0.093)
	Beans and Rice	5.509* (0.094)	5.430* (0.157)	5.517* (0.161)
Pork Chop	Bacon	0.506* (0.070)	0.291* (0.126)	0.543* (0.122)
	Chicken Breast	-1.046* (0.065)	-0.999* (0.108)	-1.224* (0.110)
	Beans and Rice	4.103* (0.097)	3.919* (0.167)	4.115* (0.169)
Bacon	Chicken Breast	-1.552* (0.067)	-1.290* (0.114)	-1.767* (0.116)
	Beans and Rice	3.597* (0.097)	3.629* (0.168)	3.571* (0.169)
Chicken Breast	Beans and Rice	5.498* (0.158)	5.761* (0.261)	6.497* (0.676)

Note: Marginal WTP is calculated as the mean WTP for alternative *j* less the mean WTP for alternative *i*. Asterisks (*) indicate statistical significance at the five percent level or lower. Values in parentheses are standard errors constructed from a Krinsky-Robb resampling of parameter estimates.

Though marginal WTP (i.e., the premium/discount relationship between alternatives) was robust to altering the choice set, the magnitude differed substantially at times depending on the pair of alternatives and survey variant. For example, respondents from MDM Variant 1 indicated a mean WTP for ribeye steak that was $6.74 per pound higher than ground beef. This is compared to base MDM results, where the marginal WTP for the same product combination was only $5.97 per pound. Conversely, the same marginal WTP derived from MDM Variant 2 responses was much closer to base MDM results at $5.79 per pound. Differences in marginal WTP derived from experiments with varying choice alternatives can impact pricing and marketing schemes of food manufacturers and retailers. For instance, a food retailer, having viewed WTP estimates derived from the base MDM, may believe consumers will pay a nearly $6 per pound premium for ribeye steak over ground beef and adjust prices of both products simultaneously to maximize revenue. In actuality, consumers may be willing to pay a premium that is closer to $7 per pound (as seen in Variant 1 results) but, since the researcher did not consider preferences for eggs in the experimental design, the potential additional premium was never observed by the industry stakeholder.

Market Shares

Market shares across the three survey variants are presented in Table 4.9. Shares calculated from MDM Variant 1 results were sizably different in magnitude than those derived from the base MDM. Including eggs (rather than plant-based patty) in respondents' choice sets—representing over 21 percent of the market—had share-reducing impacts on all other alternatives. Notably, the market share of chicken breast fell by 6 percentage points, from 27.3 percent in the base MDM to 21.3 percent in Variant 1. Additionally, the market share of ground beef fell by roughly 3.5 percent in Variant 1 (relative to the base MDM) which suggests some degree of substitutability between aggregate animal protein sources. Although the market shares of ribeye steak, bacon, and the opt-

out option were quite similar in both surveys, it should be noted that the relative ordering changed from the base MDM to Variant 1. In sum, discrepancies between base MDM and Variant 1 market shares highlight the importance of careful choice alternative selection, as changing choice sets by one alternative yielded market share estimates and relative ordering that were notably different.

Table 4.9. Estimated Market Shares (%)

Product	Base MDM	MDM Variant 1	MDM Variant 2
Opt-Out	7.01	4.34	7.40
Ribeye Steak	6.67	5.23	6.75
Ground Beef	24.22	20.78	24.05
Pork Chop	12.19	10.08	12.45
Bacon	6.34	5.78	6.88
Chicken Breast	27.30	21.32	28.95
Beans and Rice	8.67	7.36	10.12
Plant-Based Patty	2.74	-	2.59
Shrimp	4.86	4.00	-
Eggs	-	21.10	-
Whey Protein	-	-	0.81

The inclusion of whey protein powder (having an estimated market share of just 0.8 percent) and omission of shrimp did not have the same magnitude impact on market shares. However, chicken breast and beans and rice estimated shares did increase by 1.7 and 1.4 percent (compared to base MDM estimates), respectively, when shrimp was no longer available in the choice set. Additionally, the relative ordering of ribeye steak and bacon again changed from the base MDM to Variant 2, but these share estimates were quite close in both surveys.

Arc Elasticities

For brevity, we discuss arc elasticities resulting from a 10 percent increase and a 10 percent decrease in the price of the respective alternatives, and across each survey variant. To highlight impacts of choice alternative selection on economic measures, we further focus only on arc elasticities of alternatives that were available in each survey variant (i.e., ribeye steak, ground beef,

pork chop, bacon, chicken breast, and beans and rice). These are reported in Table 4.10. The full set of arc elasticities is available in Appendix Tables D.2 through D.4.

Table 4.10. Arc Elasticity Estimates

		Quantity of:					
Change of:	Price of:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Beans and Rice
				Base MDM			
+10%	Ribeye Steak	-3.95	0.29	0.30	0.32	0.26	0.26
	Ground Beef	0.33	-1.29	0.45	0.51	0.39	0.40
	Pork Chop	0.18	0.24	-1.67	0.30	0.22	0.22
	Bacon	0.11	0.15	0.16	-2.11	0.13	0.13
	Chicken Breast	0.30	0.39	0.42	0.46	-1.05	0.36
	Beans and Rice	0.07	0.09	0.09	0.10	0.08	-0.93
-10%	Ribeye Steak	-5.82	0.42	0.43	0.47	0.38	0.39
	Ground Beef	0.36	-1.40	0.48	0.54	0.42	0.43
	Pork Chop	0.21	0.27	-1.91	0.34	0.25	0.25
	Bacon	0.13	0.18	0.20	-2.59	0.16	0.16
	Chicken Breast	0.32	0.42	0.44	0.48	-1.11	0.39
	Beans and Rice	0.08	0.10	0.10	0.11	0.09	-1.01
				MDM Variant 1			
+10%	Ribeye Steak	-4.46	0.25	0.26	0.27	0.24	0.23
	Ground Beef	0.32	-1.40	0.39	0.42	0.37	0.34
	Pork Chop	0.17	0.20	-1.75	0.23	0.19	0.19
	Bacon	0.11	0.13	0.14	-2.12	0.13	0.12
	Chicken Breast	0.28	0.34	0.35	0.38	-1.23	0.31
	Beans and Rice	0.07	0.08	0.08	0.09	0.08	-0.99
-10%	Ribeye Steak	-7.14	0.39	0.42	0.43	0.38	0.37
	Ground Beef	0.35	-1.54	0.43	0.46	0.40	0.38
	Pork Chop	0.20	0.23	-2.04	0.27	0.23	0.22
	Bacon	0.14	0.16	0.17	-2.62	0.16	0.15
	Chicken Breast	0.31	0.37	0.38	0.41	-1.33	0.34
	Beans and Rice	0.08	0.09	0.09	0.10	0.08	-1.08
				MDM Variant 2			
+10%	Ribeye Steak	-3.85	0.28	0.29	0.32	0.26	0.25
	Ground Beef	0.32	-1.28	0.44	0.49	0.38	0.37
	Pork Chop	0.18	0.24	-1.62	0.29	0.22	0.21
	Bacon	0.12	0.16	0.17	-2.03	0.14	0.13

		Quantity of:					
Change of:	Price of:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Beans and Rice
	Chicken Breast	0.31	0.42	0.44	0.47	-1.01	0.36
	Beans and Rice	0.08	0.10	0.10	0.11	0.09	-0.86
-10%	Ribeye Steak	-5.60	0.41	0.42	0.46	0.38	0.37
	Ground Beef	0.35	-1.39	0.48	0.53	0.42	0.40
	Pork Chop	0.20	0.28	-1.86	0.32	0.25	0.24
	Bacon	0.14	0.19	0.20	-2.46	0.17	0.16
	Chicken Breast	0.34	0.44	0.46	0.49	-1.07	0.39
	Beans and Rice	0.08	0.11	0.11	0.12	0.10	-0.93

From base MDM results, own-price arc elasticities are more inelastic at higher prices than at lower prices. That is, consumers are less price sensitive at higher prices. For example, at prices 10 percent higher than the mean price for ribeye steak, the own-price arc elasticity for ribeye steak was -3.95. This means that as ribeye steak price increases by 1 percent from this price level, quantity demanded of ribeye steak decreases by 3.95 percent. Conversely, at prices 10 percent lower than the mean price for ribeye steak, the own-price arc elasticity for ribeye steak was -5.82. This means that as ribeye steak price increases by 1 percent from this price level, quantity demand of ribeye steak decreases by 5.82 percent. This mirrors findings of Lusk and Tonsor (2016) and demonstrates nonlinearity in price sensitivities. Further, and also consistent with Lusk and Tonsor (2016), cross-price arc elasticities are slightly larger in magnitude for price decreases across all product combinations, suggesting less substitutability at higher prices. These findings are largely consistent across each survey variant.

With the exception of own-price arc elasticities of ribeye steak in MDM Variant 1, elasticities appear to be robust to choice set construction. Of course, this conclusion in based on observable differences in magnitudes of elasticities across the base MDM survey and survey

variants. Formal testing between the surveys is needed to determine if statistical differences exist in arc elasticities.

Discussion

Little attention has been paid to separability in CE research. Here, separability refers to the appropriate inclusion of goods in a CE participant's choice set. While this issue has been covered extensively in traditional demand estimation (e.g., AIDS, Rotterdam, etc.), the stability of economic measures derived from CE results to changes in participants' available choice alternatives has not been considered. This study sought to better understand how measures such as WTP, market shares, and substitution patterns are impacted by researchers' selection of labeled alternatives.

To fulfill our objectives, two surveys were distributed alongside the long-running MDM, varying only in the alternatives included in a retail protein-focused CE. Specifically, we replaced one MDM CE alternative with another protein-dense food product. In Variant 1, the new alternative, eggs, was selected as a protein source that is widely consumed whole or as an ingredient in other foods. In Variant 2, the new alternative, whey protein powder, was selected as a protein source that is less commonly consumed and exhibited relatively low frequency of selection in CE results. The sensitivity of MDM-derived economic measures (i.e., WTP, market shares, and substitution patterns) were then assessed by comparing base results to those derived from the variant surveys. As the variant surveys were designed and distributed in an identical

fashion to that of the MDM (other than slightly altering the CE choice sets), differences between survey variants can be attributed to CE alternative selection.[20]

Since the CEs included in the base MDM survey and variants reveal stated preferences (i.e., no actual transfers of money were made), hypothetical bias is a concern. However, our objective was not to determine "true" estimates of WTP or other economic measures. Rather, the objective of this study was to determine differences in economic measures arising from decisions made on labeled alternatives in a CE. Further, CEs distributed through each of the survey variants were identical except for one choice alternative and, thus, any potential hypothetical bias would be present in each set of results. We have no reason to believe that hypothetical bias stemming from stated, rather than revealed, preference methods would drive the discrepancies across survey variants that were found in this study.

We find that the relative ordering of the unchanged choice alternatives, in terms of mean WTP, did not differ across the varying choice sets. However, mean WTP estimates calculated from MDM variant survey results were consistently higher than those calculated from base results. Further, depending on survey variant and choice alternative, the distribution of WTP shifted to the right or, at the least, changed in spread (i.e., the standard deviation around the mean WTP became larger or smaller) relative to base MDM results. Considering that, in MDM Variant 2, the replaced good (i.e., shrimp) experienced a selection frequency of only 4.4 percent (in the base MDM) and the new good (i.e., whey protein) experienced a selection frequency of only 1.1 percent, even slight and seemingly irrelevant changes in the choice set appear to have meaningful impacts on WTP

[20] It should be noted that ratios of parameter estimates, such as WTP and market shares, can be appropriately compared across samples because they are not impacted by the scale parameter associated with the respective logit models. However, parameter estimates themselves cannot be directly compared without adjusting for differing scale parameters.

estimates. These impacts, correspondingly, extend to marginal WTP estimates, or the premium (discount) consumers are willing to pay for one product over another.

We also find that estimated market shares are sensitive to changes in CE choice alternatives. However, and unlike WTP estimates, they are much more sensitive to the inclusion or omission of more commonly consumed foods (i.e., eggs) than they are to less commonly consumed, or niche, foods (i.e., whey protein). Further, arc elasticities derived from market shares were generally robust to changes in available choice alternatives, suggesting that relative preferences are not impacted by context effects, or the composition of the choice set (at least in terms of alternatives).

A host of implications result from our findings. Mirroring comments made by both Gao and Schroeder (2009) and Tonsor (2011), researchers must be careful in drawing conclusions from CE studies. While those studies focused on attributes of unlabeled CE alternatives, we focused on the selection of labeled alternatives and likewise experienced sensitivity in WTP estimates. Gao and Schroeder (2009) further noted that results derived from WTP studies may be inaccurate reflections of consumers' actual food purchasing decisions if WTP estimates are conditional on the number of food attributes shown to the respondent. We arrive at a similar conclusion, finding that WTP estimates are conditional on the type of labeled alternatives shown to the respondent. Any assumptions that included alternatives are independent of alternatives not included are likely misguided and may lead to erroneous economic conclusions. This point is clear from our inclusion of eggs in MDM Variant 1 and the corresponding changes in mean WTP for and market share of chicken breast.

Split-sample designs, as implemented in this study and Tonsor (2011), have revealed notable differences in economic measures as respondents' choice sets are changed—either in terms

of available alternatives or presented attributes. Tonsor (2011) advocated for wider use of split-sample designs as a form of sensitivity assessment, noting that this strategy has become more feasible with the increased use of internet-based surveys. Adapting the suggestion of Tonsor (2011) that researchers could use multiple CE designs that vary in "control attributes," we further propose that designs should vary in "control alternatives." That is, variant CEs could be designed (such as in this study) that differ slightly in available labeled alternatives. WTP, market shares, and substitution patterns associated with the "main alternatives" could then be evaluated across designs to confirm or refute the primary findings. Further, this approach better mimics real-world situations where some products are unavailable for a period of time (e.g., supply chain disruptions, retail stockouts, etc.) and can map out how consumers' purchasing behavior changes for other products during that period.

Regardless of whether researchers recognize the impact of separability assumptions and explicitly account for them in CE design (either through split-samples or other methods), food marketers should use this study as evidence that demand forecasts based on CE methods are conditional on the types of products presented. This applies to MDM WTP estimates reported monthly and any other public or private effort to map out consumers' demand schedules. Our work shows that perceptions of food purchasing behavior may be misguided if CE choice tasks are not designed with separability assumptions in mind or if conclusions are not validated through (in this case) split-sample sensitivity assessments. These perceptions, if used to craft marketing and pricing schemes, may yield suboptimal profit outcomes for food retailers. Further, consumer demand conclusions informed by CE research influence derived demand for food inputs (i.e., grain, livestock) and have ramifications for prices and welfare experienced across each leg of the food supply chain.

Future Work

Results from this study were derived from RPL models characterized by random, normally distributed alternative-specific constants and a single, linear price effect. Future checks of robustness can implement alternative-specific and quadratic price effects. Further, allowing for correlation in alternative-specific constants or cross-equation error terms may also serve as valuable extensions. Additional model fit measures may be needed (e.g., out-of-sample fit measures, BIC, AIC) to determine the preferred specification. Finally, though this study tested if demographic proportions and frequencies of choice were statistically different across samples, it did not formally test for statistical differences in economic measures (i.e., mean WTP and WTP distributions, marginal WTP, market shares, and arc elasticities), instead discussing only the observable magnitude differences. Determining an appropriate method to test differences in these measures across samples is a necessary next step in this research, which will provide improved insight on the impacts of separability in CE research.

References

Agarwal, S., V.L. Fulgoni, and E.P. Berg. 2015. “Association of Lunch Meat Consumption with Nutrient Intake, Diet Quality and Health Risk Factors in U.S. Children and Adults: NHANES 2007–2010.” Nutrition Journal 14: 128. doi: 10.1186/s12937-015-0118-9.

Anupindi, R., M. Dada, and S. Gupta. 1998. “Estimation of Consumer Demand with Stock-Out Based Substitution: An Application to Vending Machine Products.” Marketing Science 17(4): 406–423. doi: 10.1287/mksc.17.4.406.

Balagtas, J.V., and J. Cooper. 2021. “The Impact of COVID-19 on United States Meat and Livestock Markets.” Choices 36(3): 1–10.

Barten, A.P. 1964. “Consumer Demand Functions Under Conditions of Almost Additive Preferences.” Econometrica 32(1/2): 1–38. doi: 10.2307/1913731.

Barten, A.P. 1977. “The Systems of Consumer Demand Functions Approach: A Review.” Econometrica 45(1): 23–51. doi: 10.2307/1913286.

Beasley, J.M., M.J. Firestone, C.J. Popp, R. Russo, and S.S. Yi. 2020. “Age and Racial/Ethnic Differences in Dietary Sources of Protein, NHANES, 2011–2016.” Frontiers in Nutrition 7(76). doi: 10.3389/fnut.2020.00076.

Berndt, E.R., and N.E. Savin. 1975. “Estimation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances.” Econometrica 43(5/6): 937–958. doi: 10.2307/1911336.

Bina, J.D., and G.T. Tonsor. 2023. Meat Demand Monitor: Protein Consumption and Physical Fitness. Extension Paper. Kansas State University. Available online at https://www.agmanager.info/livestock-meat/meat-demand/monthly-meat-demand-monitor-survey-data/meat-demand-monitor-protein. [Accessed Aug. 1, 2023].

Bina, J.D., and G.T. Tonsor. 2024a. Meat Demand Monitor: Fitness-Driven Consumers Purchase Labeled Meat More Frequently. Extension Paper. Kansas State University. Available online at https://www.agmanager.info/livestock-meat/meat-demand/monthly-meat-demand-monitor-survey-data/meat-demand-monitor-fitness. [Accessed Apr. 17, 2024].

Bina, J.D., and G.T. Tonsor. 2024b. “Non-Linear Association of Exercise with Animal Protein Consumption among U.S. Adults.” Nutrients 16(10): 1438. doi: 10.3390/nu16101438.

Bina, J.D., G.T. Tonsor, and B.C. Briggeman. 2023. “COVID-19 Federal Aid and Household Food Expenditures.” Journal of Agricultural and Applied Economics 55(4): 567–608. doi: 10.1017/aae.2023.31.

Breiman, L., Y. Tsur, and A. Zemel. 1993. “On a Simple Estimation Procedure for Censored Regression Models with Known Error Distributions.” The Annals of Statistics 21(4): 1711–1720.

Brester, G.W., and T.C. Schroeder. 1995. “The Impacts of Brand and Generic Advertising on Meat Demand.” American Journal of Agricultural Economics 77(4): 969–979. doi: 10.2307/1243820.

Bunge, J., S. Nassauer, and J. Kang. 2020. “Grocers Hunt for Meat as Coronavirus Hobbles Beef and Pork Plants.” Wall Street Journal, April 23, sec. Business. Available online at https://www.wsj.com/articles/grocers-hunt-meat-as-coronavirus-hobbles-beef-and-pork-plants-11587679833. [Accessed Apr. 4, 2024].

Burton, M., and T. Young. 1996. “The Impact of BSE on the Demand for Beef and Other Meats in Great Britain.” Applied Economics 28(6): 687–693. doi: 10.1080/000368496328434.

Chen, T.C., J. Clark, M.K. Riddles, L.K. Mohadjer, and T.H.I. Fakhouri. 2020. National Health and Nutrition Examination Survey, 2015−2018 : Sample Design and Estimation Procedures. 2(184). Vital and Health Statistics. National Center for Health Statistics. Available online at https://stacks.cdc.gov/view/cdc/88305.

Coffey, B.K., T.C. Schroeder, and T.L. Marsh. 2011. “Disaggregated Household Meat Demand with Censored Data.” Applied Economics 43(18): 2343–2363. doi: 10.1080/00036840903194238.

Condor, B. 1995. “Protein’s Winning Ways.” Chicago Tribune, April 19. Available online at https://www.chicagotribune.com/news/ct-xpm-1995-04-19-9504190194-story.html. [Accessed Nov. 27, 2023].

Corrigan, J.R., D.P.T. Depositario, R.M. Nayga Jr, X. Wu, and T.P. Laude. 2009. “Comparing Open-Ended Choice Experiments and Experimental Auctions: An Application to Golden Rice.” American Journal of Agricultural Economics 91(3): 837–853. doi: 10.1111/j.1467-8276.2009.01267.x.

Daniel, C.R., A.J. Cross, C. Koebnick, and R. Sinha. 2011. “Trends in Meat Consumption in the USA.” Public Health Nutrition 14(4): 575–583. doi: 10.1017/S1368980010002077.

Deaton, A., and J. Muellbauer. 1980. “An Almost Ideal Demand System.” The American Economic Review 70(3): 312–326.

Dempster, A.P., N.M. Laird, and D.B. Rubin. 1977. “Maximum Likelihood from Incomplete Data via the EM Algorithm.” Journal of the Royal Statistical Society. Series B (Methodological) 39(1): 1–38.

Dennis, E.J., G.T. Tonsor, and J.L. Lusk. 2021. “Choosing Quantities Impacts Individuals Choice, Rationality, and Willingness to Pay Estimates.” Agricultural Economics 52(6): 945–962. doi: 10.1111/agec.12678.

Dong, D., B.W. Gould, and H.M. Kaiser. 2004. “Food Demand in Mexico: An Application of the Amemiya-Tobin Approach to the Estimation of a Censored Food System.” American Journal of Agricultural Economics 86(4): 1094–1107. doi: 10.1111/j.0002-9092.2004.00655.x.

Dong, D., C.G. Davis, and H. Stewart. 2015. “The Quantity and Variety of Households’ Meat Purchases: A Censored Demand System Approach.” Agricultural Economics 46(1): 99–112. doi: 10.1111/agec.12143.

Eales, J.S., and L.J. Unnevehr. 1993. “Simultaneity and Structural Change in U.S. Meat Demand.” American Journal of Agricultural Economics 75(2): 259–268. doi: 10.2307/1242910.

Efron, B. 1994. “Missing Data, Imputation, and the Bootstrap.” Journal of the American Statistical Association 89(426): 463–475. doi: 10.2307/2290846.

Elbakidze, L., R.M. Nayga Jr., H. Li, and C. McIntosh. 2014. “Value Elicitation for Multiple Quantities of a Quasi-Public Good Using Open Ended Choice Experiments and Uniform Price Auctions.” Agricultural Economics 45(2): 253–265. doi: 10.1111/agec.12044.

Food Surveys Research Group. 2023. “Overview of Food Patterns Equivalents Database.” USDA Agricultural Research Service. Available online at https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fped-overview/. [Accessed Apr. 4, 2024].

Gao, Z., and T.C. Schroeder. 2009. “Effects of Label Information on Consumer Willingness-to-Pay for Food Attributes.” American Journal of Agricultural Economics 91(3): 795–809. doi: 10.1111/j.1467-8276.2009.01259.x.

Goodwin, B.K., A.F. Ramsey, and J. Chvosta. 2018. Applied Econometrics with SAS: Modeling Demand, Supply, and Risk. Cary, NC: SAS Institute Inc.

Green, R., and J.M. Alston. 1990. “Elasticities in AIDS Models.” American Journal of Agricultural Economics 72(2): 442–445. doi: 10.2307/1242346.

Greene, W.H. 2018. “19.3 Censored Data.” Econometric Analysis, 8th ed. New York, N.Y.: Pearson Education, Inc., pp. 930–948.

Gregory, A.W., and M.R. Veall. 1985. “Formulating Wald Tests of Nonlinear Restrictions.” Econometrica 53(6): 1465–1468. doi: 10.2307/1913221.

Grundy, A. 2022. “Service Annual Survey Shows Continuing Decline in Print Publishing Revenue.” United States Census Bureau. Available online at https://www.census.gov/library/stories/2022/06/internet-crushes-traditional-media.html. [Accessed Nov. 27, 2023].

Hess, S., K.E. Train, and J.W. Polak. 2006. “On the Use of a Modified Latin Hypercube Sampling (MLHS) Method in the Estimation of a Mixed Logit Model for Vehicle Choice.” Transportation Research Part B: Methodological 40(2): 147–163. doi: 10.1016/j.trb.2004.10.005.

Huang, C.J., F.A. Sloan, and K.W. Adamache. 1987. “Estimation of Seemingly Unrelated Tobit Regressions via the EM Algorithm.” Journal of Business & Economic Statistics 5(3): 425–430. doi: 10.2307/1391618.

Jäger, R., C.M. Kerksick, B.I. Campbell, P.J. Cribb, S.D. Wells, T.M. Skwiat, M. Purpura, T.N. Ziegenfuss, A.A. Ferrando, S.M. Arent, A.E. Smith-Ryan, J.R. Stout, P.J. Arciero, M.J. Ormsbee, L.W. Taylor, C.D. Wilborn, D.S. Kalman, R.B. Kreider, D.S. Willoughby, J.R. Hoffman, J.L. Krzykowski, and J. Antonio. 2017. “International Society of Sports Nutrition Position Stand: Protein and Exercise.” Journal of the International Society of Sports Nutrition 14(1). doi: 10.1186/s12970-017-0177-8.

Kang, J. 2021. “Consumers Trade Rib-Eye for Ground Beef as Grocery Prices Rise.” Wall Street Journal, November 8, sec. Markets. Available online at https://www.wsj.com/articles/consumers-trade-rib-eye-for-ground-beef-as-grocery-prices-rise-11636376400. [Accessed Apr. 4, 2024].

Kappeler, R., M. Eichholzer, and S. Rohrmann. 2013. “Meat Consumption and Diet Quality and Mortality in NHANES III.” European Journal of Clinical Nutrition 67: 598–606. doi: 10.1038/ejcn.2013.59.

Kassas, B., and R. Nayga Jr. 2021. “Understanding the Importance and Timing of Panic Buying Among U.S. Households During the COVID-19 Pandemic.” Food Quality and Preference 93. doi: 10.1016/j.foodqual.2021.104240.

Kilders, V., V. Caputo, and J.L. Lusk. 2024. “Consumer Preferences for Food Away From Home: Dine in Versus Delivery.” American Journal of Agricultural Economics 106(2): 496–525. doi: 10.1111/ajae.12428.

Krinsky, I., and A.L. Robb. 1986. “On Approximating the Statistical Properties of Elasticities.” The Review of Economics and Statistics 68(4): 715–719. doi: 10.2307/1924536.

Leontief, W. 1947. “Introduction to a Theory of the Internal Structure of Functional Relationships.” Econometrica 15(4): 361–373. doi: 10.2307/1905335.

Livestock Marketing Information Center. 2023. “Daily, Weekly & Monthly Corn Futures Prices.”

Love, D.C., F. Asche, Z. Conrad, R. Young, J. Harding, E.M. Nussbaumer, A.L. Thorne-Lyman, and R. Neff. 2020. “Food Sources and Expenditures for Seafood in the United States.” Nutrients 12(6): 1810. doi: 10.3390/nu12061810.

Lusk, J.L., and G.T. Tonsor. 2016. “How Meat Demand Elasticities Vary with Price, Income, and Product Category.” Applied Economic Perspectives and Policy 38(4): 673–711. doi: 10.1093/aepp/ppv050.

Lusk, J.L., D. Blaustein-Rejto, S. Shah, and G.T. Tonsor. 2022. “Impact of Plant-Based Meat Alternatives on Cattle Inventories and Greenhouse Gas Emissions.” Environmental Research Letters 17(2): 024035. doi: 10.1088/1748-9326/ac4fda.

Marsh, T.L., T.C. Schroeder, and J. Mintert. 2004. “Impacts of Meat Product Recalls on Consumer Demand in the USA.” Applied Economics 36(9): 897–909. doi: 10.1080/0003684042000233113.

Mazzocchi, M. 2006. “No News Is Good News: Stochastic Parameters versus Media Coverage Indices in Demand Models after Food Scares.” American Journal of Agricultural Economics 88(3): 727–741. doi: 10.1111/j.1467-8276.2006.00891.x.

McDonald, J.F., and R.A. Moffitt. 1980. “The Uses of Tobit Analysis.” The Review of Economics and Statistics 62(2): 318–321. doi: 10.2307/1924766.

McFadden, D. 1973. “Conditional Logit Analysis of Qualitative Choice Behavior.”

Meyersohn, N. 2023. “Americans Have Changed the Way They Exercise. Here’s How Gyms Are Adapting.” CNN, March 1. Available online at https://www.cnn.com/2023/02/28/business/gym-exercise-free-weights-cardio/index.html. [Accessed Nov. 27, 2023].

Morris, M.S., and P.F. Jacques. 2013. “Total Protein, Animal Protein and Physical Activity in Relation to Muscle Mass in Middle-Aged and Older Americans.” British Journal of Nutrition 109(7): 1294–1303. doi: 10.1017/S0007114512003133.

Moschini, G., D. Moro, and R.D. Green. 1994. “Maintaining and Testing Separability in Demand Systems.” American Journal of Agricultural Economics 76(1): 61–73. doi: 10.2307/1243921.

Murphy, J. 2024. “The 10 Ways We Sabotage Our Workouts.” The Wall Street Journal. Available online at https://www.wsj.com/lifestyle/fitness/the-10-ways-we-sabotage-our-workouts-21d50537. [Accessed Apr. 4, 2024].

Naseer, S., and C. St. Aubin. 2023. “Newspapers Fact Sheet.” Pew Research Center. Available online at https://www.pewresearch.org/journalism/fact-sheet/newspapers/. [Accessed Nov. 27, 2023].

National Academies of Sciences, Engineering, and Medicine. 2006. Dietary Reference Intakes: The Essential Guide to Nutrient Requirements. Washington, D.C.: National Academies Press. Available online at http://www.nap.edu/catalog/11537. [Accessed Nov. 25, 2023].

National Center for Health Statistics. 2020. “Dietary Supplement Use 24-Hour - Individual Dietary Supplements, First Day (DS1IDS_J).” National Health and Nutrition Examination Survey. Available online at https://wwwn.cdc.gov/Nchs/Nhanes/2017-2018/DS1IDS_J.htm. [Accessed Apr. 4, 2024].

National Center for Health Statistics. 2024a. “NCHS Research Ethics Review Board (ERB) Approval.” Centers for Disease Control and Prevention. Available online at https://www.cdc.gov/nchs/nhanes/irba98.htm. [Accessed Apr. 4, 2024].

National Center for Health Statistics. 2024b. “NHANES Questionnaires, Datasets, and Related Documentation.” Centers for Disease Control and Prevention. Available online at https://wwwn.cdc.gov/nchs/nhanes/Default.aspx. [Accessed Apr. 4, 2024].

National Center for Health Statistics. 2024c. “Weighting.” Centers for Disease Control and Prevention. Available online at https://wwwn.cdc.gov/nchs/nhanes/tutorials/weighting.aspx. [Accessed Apr. 4, 2024].

Nava, N.J., and D. Dong. 2022. “The Impact of Taxing Sugar-Sweetened Beverages in México: A Censored QUAI Demand System Approach.” Journal of the Agricultural and Applied Economics Association 1(1): 18–32. doi: 10.1002/jaa2.6.

O’Connor, L.E., E.A. Wambogo, K.A. Herrick, R. Parsons, and J. Reedy. 2022. “A Standardized Assessment of Processed Red Meat and Processed Poultry Intake in the US Population Aged ≥2 Years Using NHANES.” The Journal of Nutrition 152(1): 190–199. doi: 10.1093/jn/nxab316.

Pandey, M. 2023. “Strength Training Has Surged in Popularity. Studies Show It Brings Particular Health Benefits.” NBC News, July 25. Available online at https://www.nbcnews.com/health/health-news/strength-training-popular-health-benefits-rcna94678. [Accessed Nov. 27, 2023].

Pasiakos, S.M., S. Agarwal, H.R. Lieberman, and V.L. Fulgoni. 2015. “Sources and Amounts of Animal, Dairy, and Plant Protein Intake of US Adults in 2007–2010.” Nutrients 7(8): 7058–7069. doi: 10.3390/nu7085322.

Paulose-Ram, R., J.E. Graber, D. Woodwell, and N. Ahluwalia. 2021. “The National Health and Nutrition Examination Survey (NHANES), 2021–2022: Adapting Data Collection in a COVID-19 Environment.” American Journal of Public Health 111(12): 2149–2156. doi: 10.2105/AJPH.2021.306517.

Phillips, P.C.B., and J.Y. Park. 1988. “On the Formulation of Wald Tests of Nonlinear Restrictions.” Econometrica 56(5): 1065–1083. doi: 10.2307/1911359.

Phillips, S.M., and R.A. Winett. 2010. “Uncomplicated Resistance Training and Health-Related Outcomes: Evidence for a Public Health Mandate.” Current Sports Medicine Reports 9(4): 208–213. doi: 10.1249/JSR.0b013e3181e7da73.

Piggott, N.E., and T.L. Marsh. 2004. “Does Food Safety Information Impact U.S. Meat Demand?” American Journal of Agricultural Economics 86(1): 154–174.

Poe, G.L., K.L. Giraud, and J.B. Loomis. 2005. “Computational Methods for Measuring the Difference of Empirical Distributions.” American Journal of Agricultural Economics 87(2): 353–365.

Pozo, V.F., G.T. Tonsor, and T.C. Schroeder. 2012. “How Choice Experiment Design Affects Estimated Valuation of Use of Gestation Crates.” Journal of Agricultural Economics 63(3): 639–655. doi: 10.1111/j.1477-9552.2012.00349.x.

ProQuest LLC. 2024. “ProQuest Central.” ProQuest. Available online at https://about.proquest.com/en/products-services/ProQuest_Central/. [Accessed Jun. 20, 2024].

Ramsey, A.F., B. Goodwin, W. Hahn, and M. Holt. 2021. “Impacts of COVID-19 and Price Transmission in U.S. Meat Markets.” Agricultural Economics 52(3): 441–458. doi: 10.1111/agec.12628.

Reynolds, G. 2018. “Lift Weights, Eat More Protein, Especially If You’re Over 40.” The New York Times, February 7. Available online at https://www.nytimes.com/2018/02/07/well/move/lift-weights-eat-more-protein-especially-if-youre-over-40.html. [Accessed Nov. 27, 2023].

Reynolds, G. 2023. “5 Things to Know About Protein.” The Washington Post, May 24. Available online at https://www.washingtonpost.com/wellness/2023/05/24/protein-weight-loss-muscle-facts/. [Accessed Nov. 27, 2023].

Shonkwiler, J.S., and S.T. Yen. 1999. “Two-Step Estimation of a Censored System of Equations.” American Journal of Agricultural Economics 81(4): 972–982. doi: 10.2307/1244339.

Sono, M. 1961. “The Effect of Price Changes on the Demand and Supply of Separable Goods.” International Economic Review 2(3): 239–271. doi: 10.2307/2525430.

Stone, M.H., M. Stone, and W.A. Sands. 2007. Principles and Practice of Resistance Training. Human Kinetics. Available online at https://books.google.com/books?hl=en&lr=&id=TAVtYOrT1G8C&oi=fnd&pg=PP7&dq=resistance+training+definition&ots=BxShO2_RJW&sig=vRALRhqEh0GkMUCr2CxWvKob-Ak#v=onepage&q=resistance%20training%20definition&f=false. [Accessed Jan. 23, 2023].

Taylor, H., G. Tonsor, J. Lusk, and T. Schroeder. 2022. “Benchmarking US Consumption and Perceptions of Beef and Plant-Based Proteins.” Applied Economic Perspectives and Policy 45(1): 22–43. doi: 10.1002/aepp.13287.

Theil, H. 1965. “The Information Approach to Demand Analysis.” Econometrica 33(1): 67–87. doi: 10.2307/1911889.

Thomas, P. 2022. “Egg Prices Jump as Bird Flu Hits Poultry Flocks.” Wall Street Journal, April 2, sec. Business. Available online at https://www.wsj.com/articles/egg-prices-jump-as-bird-flu-hits-poultry-flocks-11648900800. [Accessed Apr. 4, 2024].

Thompson, W.R. 2023. “Worldwide Survey of Fitness Trends for 2023.” ACSM’s Health & Fitness Journal 27(1): 9–18. doi: 10.1249/FIT.0000000000000834.

Tobin, J. 1958. “Estimation of Relationships for Limited Dependent Variables.” Econometrica 26(1): 24–36. doi: 10.2307/1907382.

Tonsor, G.T. 2011. “Consumer Inferences of Food Safety and Quality.” European Review of Agricultural Economics 38(2): 213–235. doi: 10.1093/erae/jbr011.

Tonsor, G.T. 2020. “Meat Demand Monitor - Project Methodology.” AgManager.Info. Available online at https://agmanager.info/livestock-meat/meat-demand/monthly-meat-demand-monitor-survey-data/meat-demand-monitor-project. [Accessed Jan. 29, 2024].

Tonsor, G.T. 2024. “Monthly Survey - December 2023.” AgManager.Info. Available online at https://www.agmanager.info/livestock-meat/meat-demand/monthly-meat-demand-monitor-survey-data/monthly-survey-december-2023. [Accessed May 1, 2024].

Tonsor, G.T., and J.D. Bina. 2023. Assessing Cross-Price Effects of Meat Alternatives on Beef, Pork, and Chicken Retail Demand in 2022. Extension Paper. Purdue University. Available online at https://ag.purdue.edu/cfdas/wp-content/uploads/2023/06/CA1378_061523_Price-Impact-of-Meat-Alternatives-on-Meat-Demand_USDAApproved_logo-added-2.pdf. [Accessed Jul. 3, 2023].

Tonsor, G.T., and N.J. Olynk. 2011. “Impacts of Animal Well-Being and Welfare Media on Meat Demand.” Journal of Agricultural Economics 62(1): 59–72. doi: 10.1111/j.1477-9552.2010.00266.x.

Tonsor, G.T., J. Lusk, and S. Tonsor. 2021. “Meat Demand Monitor During COVID-19.” Animals 11(4): 1040. doi: 10.3390/ani11041040.

Tonsor, G.T., J.L. Lusk, and T.C. Schroeder. 2023. “Market Potential of New Plant-Based Protein Alternatives: Insights from Four US Consumer Experiments.” Applied Economic Perspectives and Policy 45(1): 164–181. doi: 10.1002/aepp.13253.

Tonsor, G.T., J.R. Mintert, and T.C. Schroeder. 2010. “U.S. Meat Demand: Household Dynamics and Media Information Impacts.” Journal of Agricultural and Resource Economics 35(1): 1–17.

Train, K. 2009. Discrete Choice Methods with Simulation, 2nd ed. Cambridge University Press. Available online at https://eml.berkeley.edu/books/choice2.html. [Accessed Dec. 14, 2023].

Tsur, Y. 1983. “On Efficient Estimation of Some Limited Dependent Variables Models.” CUDARE Working Papers. University of California, Berkeley. Available online at https://escholarship.org/content/qt6sd75371/qt6sd75371.pdf.

U.S. Bureau of Economic Analysis. 2023. “Personal Consumption Expenditures: Food.” Available online at https://fred.stlouisfed.org/series/DFXARC1M027SBEA. [Accessed Nov. 28, 2023].

U.S. Bureau of Labor Statistics. 2016. “Sports and Exercise Among Americans.” TED: The Economics Daily. Available online at https://www.bls.gov/opub/ted/2016/sports-and-exercise-among-americans.htm. [Accessed Nov. 27, 2023].

U.S. Bureau of Labor Statistics. 2019. American Time Use Survey - 2018 Results. USDL-19-1003. News Release. U.S. Bureau of Labor Statistics. Available online at https://www.bls.gov/news.release/archives/atus_06192019.pdf.

U.S. Bureau of Labor Statistics. 2020. American Time Use Survey - 2019 Results. USDL-20-1275. News Release. U.S. Bureau of Labor Statistics. Available online at https://www.bls.gov/news.release/archives/atus_06252020.pdf.

U.S. Bureau of Labor Statistics. 2023a. "American Time Use Survey News Release." U.S. Bureau of Labor Statistics. Available online at https://www.bls.gov/news.release/atus.htm. [Accessed Jan. 29, 2024].

U.S. Bureau of Labor Statistics. 2023b. "Energy in U.S. City Average, All Urban Consumers, Not Seasonally Adjusted." Available online at https://beta.bls.gov/dataViewer/view/timeseries/CUUR0000SA0E. [Accessed Nov. 28, 2023].

U.S. Bureau of Labor Statistics. 2023c. "Food in U.S. City Average, All Urban Consumers, Not Seasonally Adjusted." Available online at https://beta.bls.gov/dataViewer/view/timeseries/CUUR0000SAF1. [Accessed Nov. 28, 2023].

U.S. Department of Agriculture Economic Research Service. 2023a. "Avian Flu Losses in 2022 Affected Turkey Breast Prices More Than Whole Hens." USDA Economic Research Service. Available online at http://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=106639. [Accessed Apr. 4, 2024].

U.S. Department of Agriculture Economic Research Service. 2023b. "Avian Influenza Outbreaks Reduced Egg Production, Driving Prices to Record Highs in 2022." USDA Economic Research Service. Available online at http://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=105576. [Accessed Apr. 4, 2024].

U.S. Department of Agriculture Economic Research Service. 2023c. "Historical Monthly Price Spread Data for Beef, Pork, Broilers." Available online at https://www.ers.usda.gov/data-products/meat-price-spreads/. [Accessed Nov. 28, 2023].

U.S. Department of Agriculture Economic Research Service. 2023d. "Meat Supply and Disappearance Tables, Historical." Available online at https://www.ers.usda.gov/data-products/livestock-and-meat-domestic-data/. [Accessed Nov. 28, 2023].

U.S. Department of Agriculture Economic Research Service. 2024. "Cash Receipts by Commodity." Available online at https://data.ers.usda.gov/reports.aspx?ID=17845. [Accessed May 21, 2024].

U.S. Department of Agriculture National Agricultural Statistics Service. 2023. "Quick Stats." National Agricultural Statistics Service. Available online at https://quickstats.nass.usda.gov/?source_desc=CENSUS. [Accessed Nov. 28, 2023].

U.S. Department of Agriculture National Agricultural Statistics Service. 2024. “United States Cattle Inventory Down 2%.” USDA National Agricultural Statistics Service. Available online at https://www.nass.usda.gov/Newsroom/2024/01-31-2024.php. [Accessed Feb. 23, 2024].

U.S. Department of Agriculture, and U.S. Department of Health and Human Services. 2020. Dietary Guidelines for Americans: 2020-2025. 9.

U.S. Department of Agriculture. 2019. “Chicken, Broilers or Fryers, Breast, Meat Only, Cooked, Roasted.” FoodData Central. Available online at https://fdc.nal.usda.gov/fdc-app.html#/food-details/171477/nutrients. [Accessed Nov. 27, 2023].

Van Loo, E.J., V. Caputo, and J.L. Lusk. 2020. “Consumer Preferences for Farm-Raised Meat, Lab-Grown Meat, and Plant-Based Meat Alternatives: Does Information or Brand Matter?” Food Policy 95: 101931. doi: 10.1016/j.foodpol.2020.101931.

Verbeke, W., and R.W. Ward. 2001. “A Fresh Meat Almost Ideal Demand System Incorporating Negative TV Press and Advertising Impact.” Agricultural Economics 25(2–3): 359–374. doi: 10.1111/j.1574-0862.2001.tb00215.x.

Wales, T., and A. Woodland. 1983. “Estimation of Consumer Demand Systems with Binding Non-Negativity Constraints.” Journal of Econometrics 21(3): 263–285. doi: 10.1016/0304-4076(83)90046-5.

Wang, H.H., and P.G. de Beville. 2017. “The Media Impact of Animal Disease on the US Meat Demand.” Agribusiness 33(4): 493–504. doi: 10.1002/agr.21501.

Wang, Y., and M.A. Beydoun. 2009. “Meat Consumption Is Associated With Obesity and Central Obesity Among US Adults.” International Journal of Obesity 33: 621–628. doi: 10.1038/ijo.2009.45.

Wang, Y., M.A. Beydoun, B. Caballero, T.L. Gary, and R. Lawrence. 2010. “Trends and Correlates in Meat Consumption Patterns in the US Adult Population.” Public Health Nutrition 13(9): 1333–1345. doi: 10.1017/S1368980010000224.

Weersink, A., M. von Massow, N. Bannon, J. Ifft, J. Maples, K. McEwan, M. McKendree, C. Nicholson, A. Novakovic, A. Rangarajan, T. Richards, B. Rickard, J. Rude, M. Schipanski, G. Schnitkey, L. Schulz, D. Schuurman, K. Schwartzkopf-Genswein, M. Stephenson, J. Thompson, and K. Wood. 2021. “COVID-19 and the Agri-Food System in the United States and Canada.” Agricultural Systems 188. doi: 10.1016/j.agsy.2020.103039.

Willits-Smith, A., H. Odinga, K. O’Malley, and D. Rose. 2023. “Demographic and Socioeconomic Correlates of Disproportionate Beef Consumption Among US Adults in an Age of Global Warming.” Nutrients 15(17): 3795. doi: 10.3390/nu15173795.

Wilson, J., and G.J. Wilson. 2006. “Contemporary Issues in Protein Requirements and Consumption for Resistance Trained Athletes.” Journal of the International Society of Sports Nutrition 3(1): 7–27. doi: 10.1186/1550-2783-3-1-7.

Wongprawmas, R., G. Pappalardo, M. Canavari, and B. Pecorino. 2016. “Willingness-to-Pay for Multiple Units of Eco-Friendly Wheat-Derived Products: Results From Open-Ended Choice Experiments.” Journal of Food Products Marketing 22(6): 658–682. doi: 10.1080/10454446.2015.1121438.

Wooldridge, J. 2010a. “Econometric Analysis of Cross Section and Panel Data,.” 2nd ed. Cambridge, Massachusetts: The MIT Press, pp. 76–78.

Wooldridge, J. 2010b. “Econometric Analysis of Cross Section and Panel Data,.” 2nd ed. Cambridge, Massachusetts: The MIT Press, pp. 89–114.

Wooldridge, J. 2010c. “Econometric Analysis of Cross Section and Panel Data,.” 2nd ed. Cambridge, Massachusetts: The MIT Press, pp. 671–676.

Yadavalli, A., and K. Jones. 2014. “Does Media Influence Consumer Demand? The Case of Lean Finely Textured Beef in the United States.” Food Policy 49: 219–227. doi: 10.1016/j.foodpol.2014.08.002.

Yahoo! Finance. 2023. “13 Week Treasury Bill (^IRX).” Available online at https://finance.yahoo.com/quote/%5EIRX. [Accessed Nov. 28, 2023].

Zeballos, E., and X. Dong. 2022. “The Effect of COVID-19 on Food Sales.” Applied Economic Perspectives and Policy 44(4): 2131–2144. doi: 10.1002/aepp.13201.

Zeng, L., M. Ruan, J. Liu, P. Wilde, E.N. Naumova, D. Mozaffarian, and F.F. Zhang. 2019. “Trends in Processed Meat, Unprocessed Red Meat, Poultry, and Fish Consumption in the United States, 1999-2016.” Journal of the Academy of Nutrition and Dietetics 119(7): 1085-1098.e12. doi: 10.1016/j.jand.2019.04.004.

Zhao, S., L. Wang, W. Hu, and Y. Zheng. 2023. “Meet the Meatless: Demand for New Generation Plant-Based Meat Alternatives.” Applied Economic Perspectives and Policy 45(1): 4–21. doi: 10.1002/aepp.13232.

Zipf, G., M. Chiappa, K. Porter, Y. Ostchega, B. Lewis, and J. Dostal. 2013. National Health and Nutrition Examination Survey : Plan and Operations, 1999-2010. 1(56). Vital and Health Statistics. National Center for Health Statistics. Available online at https://www.cdc.gov/nchs/data/series/sr_01/sr01_056.pdf.

Appendix A - No Beef with Increased Media: The Impacts of Fitness Media on U.S. Meat Demand

Appendix Table A.1. Seasonality in News Media Indices

	Monthly Average Values		
Month	*Media_Beef*	*Media_Pork*	*Media_Chicken*
January	9.53	5.24	20.70
February	8.87	4.46	18.47
March	9.63	5.10	20.47
April	9.33	4.93	20.23
May	8.93	5.07	21.30
June	8.27	4.50	19.70
July	8.77	4.37	19.87
August	8.43	4.90	20.27
September	7.60	4.59	20.67
October	8.87	4.66	20.87
November	9.80	4.79	19.13
December	8.17	4.34	19.20

Appendix Table A.2. Estimated Expenditure, Compensated Price, and News Media Elasticities (1993–2022)—Adjusted Indices ("AND fat")

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Expenditure	0.4843*[a]	-0.1564[a]	0.2481[a]	1.0148***[a]
Beef Price	-0.4842***[b]	0.0137	-0.1185	0.0051***
Pork Price	0.0079	-0.3326***[b]	0.0268	0.0016**
Chicken Price	-0.0635	0.0250	-0.0633[b]	0.0008
Other Food Price	0.5399***	0.2939**	0.1550	-0.0074***[b]
News Media Elasticities (1993–2002)				
Media_Beef	0.0085	-0.0062	-0.0103	0.0000
Media_Pork	-0.0074	-0.0011	-0.0100	0.0001
Media_Chicken	0.0021	0.0106	0.0064	-0.0001
News Media Elasticities (2003–2012)				
Media_Beef	-0.0029	-0.0040	0.0044	0.0000
Media_Pork	-0.0006	-0.0055	-0.0128**	0.0001
Media_Chicken	0.0160	-0.0151	0.0093	-0.0001
News Media Elasticities (2013–2022)				
Media_Beef	-0.0034	0.0100	-0.0042	0.0000
Media_Pork	0.0128*	0.0014	-0.0014	-0.0001

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Media_Chicken	-0.0120	-0.0227**	-0.0013	0.0002**

Note: Single, double, and triple asterisks (*, **, ***) indicate elasticity estimates that are statistically different than zero at the ten, five, and one percent levels, respectively; [a] indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; [b] indicates compensated own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities are calculated at the mean values of the budget shares. Standard errors and associated *p*-values were obtained from Wald tests on the model parameters.

Appendix Table A.3. Estimated Expenditure, Compensated Price, and News Media Elasticities (1990–2019)

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Expenditure	0.4630*[a]	-0.5269[a]	0.5351	1.0158***[a]
Beef Price	-0.4816***[b]	0.0482	0.0143	0.0042***
Pork Price	0.0279	-0.2448**[b]	0.0212	0.0010
Chicken Price	0.0076	0.0195	-0.0793[b]	0.0002
Other Food Price	0.4461***	0.1770	0.0437	-0.0054***[b]
News Media Elasticities (1990–1999)				
Media_Beef	0.0059	-0.0205	-0.0180	0.0001
Media_Pork	-0.0022	0.0081	0.0044	-0.0001
Media_Chicken	-0.0145	0.0338*	0.0073	-0.0001
News Media Elasticities (2000–2009)				
Media_Beef	-0.0046	-0.0110	-0.0122	0.0002
Media_Pork	0.0192**	-0.0134	0.0065	-0.0001
Media_Chicken	0.0063	0.0143	0.0109	-0.0002
News Media Elasticities (2010–2019)				
Media_Beef	-0.0041	0.0033	-0.0209*	0.0001
Media_Pork	-0.0049	0.0015	-0.0006	0.0000
Media_Chicken	-0.0013	-0.0300*	0.0112	0.0001

Note: Single, double, and triple asterisks (*, **, ***) indicate elasticity estimates that are statistically different than zero at the ten, five, and one percent levels, respectively; [a] indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; [b] indicates compensated own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities are calculated at the mean values of the budget shares. Standard errors and associated *p*-values were obtained from Wald tests on the model parameters.

Appendix Table A.4. Estimated Expenditure, Compensated Price, and News Media Elasticities (1993–2022)—Adjusted Indices (annual rolling sum)

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Expenditure	0.3562[a]	-0.0806[a]	0.2169[a]	1.0158[***a]
Beef Price	-0.5166[***b]	-0.0084	-0.0813	0.0053[***]
Pork Price	-0.0048	-0.3120[***b]	0.0243	0.0016[**]
Chicken Price	-0.0436	0.0227	0.0038[b]	0.0003
Other Food Price	0.5651[***]	0.2977[**]	0.0533	-0.0072[***b]
News Media Elasticities (1993–2002)				
Media_Beef	0.0249	-0.0561	-0.0762	0.0005
Media_Pork	0.0253	-0.0078	0.0372	-0.0004
Media_Chicken	-0.0060	0.0688	-0.0045	-0.0003
News Media Elasticities (2003–2012)				
Media_Beef	0.0408	0.0340	-0.0043	-0.0005
Media_Pork	0.0007	-0.0013	-0.0997[**]	0.0005
Media_Chicken	0.0258	-0.0659	0.0021	0.0001
News Media Elasticities (2013–2022)				
Media_Beef	-0.0079	0.0641	0.0071	-0.0003
Media_Pork	0.0653[***]	0.0271	-0.0165	-0.0007[*]
Media_Chicken	-0.1378[***]	-0.0757	0.0473	0.0015[**]

Note: Single, double, and triple asterisks (*, **, ***) indicate elasticity estimates that are statistically different than zero at the ten, five, and one percent levels, respectively; [a] indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; [b] indicates compensated own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities are calculated at the mean values of the budget shares. Standard errors and associated *p*-values were obtained from Wald tests on the model parameters.

Appendix Table A.5. Estimated Expenditure, Compensated Price, and News Media Elasticities (1993–2022)—Adjusted Indices (cumulative sum)

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Expenditure	0.4230[a]	-0.1063[a]	0.1177[a]	1.0158[***]
Beef Price	-0.4598[***b]	0.0060	-0.1238[*]	0.0049[***]
Pork Price	0.0034	-0.2984[***b]	0.0251	0.0014[*]
Chicken Price	-0.0664[*]	0.0235	0.0580[b]	0.0002
Other Food Price	0.5228[***]	0.2689[*]	0.0408	-0.0066[***b]
News Media Elasticities (1993–2002)				
Media_Beef	0.0505	-0.2436	-0.2209	0.0019
Media_Pork	0.1004	0.0159	-0.0030	-0.0010
Media_Chicken	-0.1268	0.2072	0.2195	-0.0010
News Media Elasticities (2003–2012)				

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Media_Beef	0.2719	0.6733	-0.7533	-0.0024
Media_Pork	-0.5862	-1.0625	-1.2849*	0.0177*
Media_Chicken	0.3788	0.0126	2.2074**	-0.0147
News Media Elasticities (2013–2022)				
Media_Beef	1.1977	1.4919	-1.1530	-0.0135
Media_Pork	0.2039	-0.3446	-1.0662	0.0053
Media_Chicken	-1.8561	-0.2402	2.7386	0.0049

Note: Single, double, and triple asterisks (*, **, ***) indicate elasticity estimates that are statistically different than zero at the ten, five, and one percent levels, respectively; [a] indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; [b] indicates compensated own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities are calculated at the mean values of the budget shares. Standard errors and associated *p*-values were obtained from Wald tests on the model parameters.

Appendix Table A.6. Estimated Expenditure, Compensated Price, and News Media Elasticities (1993–2022)—No Interaction Terms

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Expenditure	0.5097**[a]	-0.0554[a]	0.2662[a]	1.0140***[a]
Beef Price	-0.4499***[b]	0.0562	-0.1001	0.0044***
Pork Price	0.0323	-0.3128***[b]	0.0228	0.0013*
Chicken Price	-0.0537	0.0213	-0.0207[b]	0.0005
Other Food Price	0.4714***	0.2353*	0.0981	-0.0062***[b]
News Media Elasticities (1993–2022)				
Media_Beef	-0.0067	-0.0101	-0.0201***	0.0002**
Media_Pork	-0.0007	-0.0088	0.0039	0.0000
Media_Chicken	-0.0170	-0.0114	0.0016	0.0002

Note: Single, double, and triple asterisks (*, **, ***) indicate elasticity estimates that are statistically different than zero at the ten, five, and one percent levels, respectively; [a] indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; [b] indicates compensated own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities are calculated at the mean values of the budget shares. Standard errors and associated *p*-values were obtained from Wald tests on the model parameters.

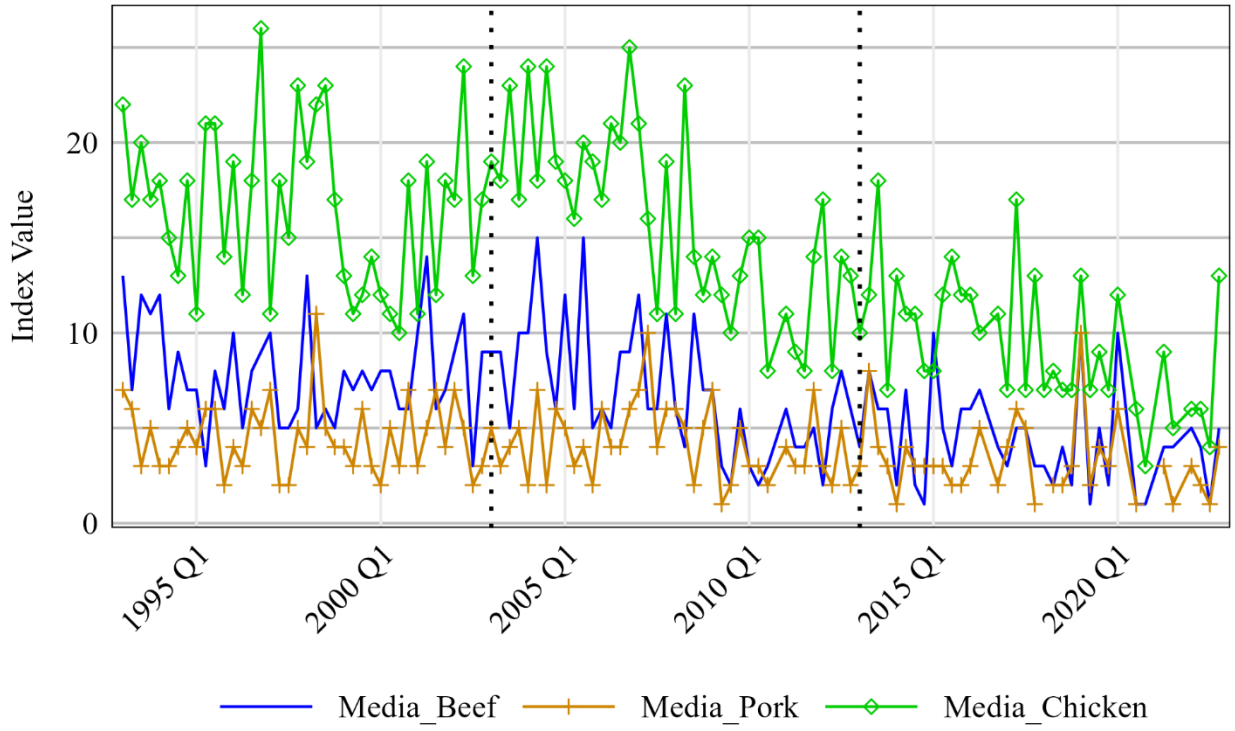
Appendix Table A.7. Estimated Expenditure, Compensated Price, and News Media Elasticities (1993–2022)—Aggregate News Media Index

	Quantity of:			
With respect to:	Beef	Pork	Chicken	Other Food
Expenditure	0.4692**	-0.1009	0.2349	1.0147***
Beef Price	-0.4001***	0.0640	-0.0739	0.0038***
Pork Price	0.0368	-0.2970***	0.0105	0.0012*
Chicken Price	-0.0396	0.0098	0.0200	0.0002
Other Food Price	0.4029***	0.2232*	0.0434	-0.0052***
News Media Elasticities (1993–2002)				
Media_Aggregate	-0.0058	0.0023	-0.0513*	0.0003
News Media Elasticities (2003–2012)				
Media_Aggregate	0.0173	-0.0169	0.0057	-0.0001
News Media Elasticities (2013–2022)				
Media_Aggregate	-0.0821***	-0.0694***	-0.0356	0.0013***

Note: Single, double, and triple asterisks (*, **, ***) indicate elasticity estimates that are statistically different than zero at the ten, five, and one percent levels, respectively; [a] indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; [b] indicates compensated own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities are calculated at the mean values of the budget shares. Standard errors and associated *p*-values were obtained from Wald tests on the model parameters.

Media_Aggregate reflects a news media index constructed as the quarterly sum of news articles including the terms "(protein OR beef OR pork OR chicken) AND (exercise OR fitness OR physical health) NOT government." This index had statistically significant effects on beef, pork, and other food demand in 2013 to 2022. However, the largest percentage change in *Media-_Aggregate* in that decade was -45.5 percent. When multiplied by the news media elasticities, this corresponds to percentage changes in beef, pork, and other food disappearance of 3.74, 3.16, and -0.06 in 2013 to 2022, respectively. Similar to our main conclusions, news media attention to aggregate protein consumption and physical exercise had sporadically statistically significant effects that were economically relevant at only the most extreme quarter-over-quarter changes in news media attention.

Appendix Figure A.1. Species-Specific Quarterly News Media Indices (1993–2022)—Adjusted Indices ("AND fat")



Appendix B - Non-Linear Association of Exercise with Animal Protein Consumption Among U.S. Adults

Appendix Table B.1. Multivariate Tobit Unconditional Marginal Effects on Animal Protein Consumption

	Unconditional Marginal Effect			
Predictor	Beef (g/d)	Pork (g/d)	Poultry (g/d)	Seafood (g/d)
Physical Exercise				
0 min/d	-	-	-	-
	-	-	-	-
1-30 min/d	-1.31	-2.05*	0.36*	7.00*
	[-2.80, 0.17]	[-3.64, -0.46]	[0.21, 0.51]	[2.85, 11.16]
31-60 min/d	-4.86*	-4.07*	0.38*	18.86*
	[-6.90, -2.82]	[-6.17, -1.98]	[0.26, 0.50]	[14.21, 23.52]
61-120 min/d	-6.08*	-3.70*	0.32*	16.55*
	[-8.91, -3.26]	[-6.40, -1.01]	[0.19, 0.44]	[10.48, 22.62]
121-180 min/d	2.40	-4.24	0.14	13.44*
	[-1.35, 6.16]	[-9.47, 0.98]	[-0.32, 0.60]	[1.61, 25.27]
181-240 min/d	-2.78	-10.40*	-0.14	7.46
	[-10.33, 4.78]	[-19.70, -1.09]	[-1.24, 0.96]	[-12.02, 26.93]
241-300 min/d	0.77	-5.65	-0.29	-13.05
	[-12.62, 14.16]	[-23.13, 11.83]	[-4.17, 3.60]	[-60.83, 34.72]
>300 min/d	2.95	-5.32	0.24	1.52
	[-8.67, 14.56]	[-22.32, 11.69]	[-2.03, 2.51]	[-40.06, 43.10]
Survey Cycle				
2007-2008	-	-	-	-
	-	-	-	-
2009-2010	-0.08	0.67	0.09	6.66*
	[-2.08, 1.93]	[-1.46, 2.79]	[-0.16, 0.35]	[0.81, 12.50]
2011-2012	-4.01*	-4.60*	-0.10	2.17
	[-6.26, -1.77]	[-6.98, -2.23]	[-0.41, 0.21]	[-3.78, 8.13]
2013-2014	-7.52*	-1.90	0.14	4.77
	[-9.93, -5.12]	[-4.15, 0.35]	[-0.09, 0.37]	[-1.06, 10.60]
2015-2016	-13.80*	-1.99	-0.08	-12.90*
	[-16.59, -11.02]	[-4.24, 0.26]	[-0.38, 0.23]	[-19.29, -6.50]
2017-2018	-8.79*	-3.64*	0.04	-7.69*
	[-11.30, -6.29]	[-5.93, -1.35]	[-0.23, 0.31]	[-13.89, -1.50]
Gender				
Male	17.55*	14.99*	1.14*	-2.56
	[16.25, 18.85]	[13.69, 16.29]	[0.90, 1.39]	[-5.98, 0.85]

	Unconditional Marginal Effect			
Predictor	Beef (g/d)	Pork (g/d)	Poultry (g/d)	Seafood (g/d)
Female	-	-	-	-
	-	-	-	-
Age				
18-24	-	-	-	-
	-	-	-	-
25-34	1.46	4.68*	0.06	9.03*
	[-0.60, 3.52]	[2.53, 6.83]	[-0.22, 0.34]	[2.59, 15.46]
35-44	3.99*	7.29*	-0.35	18.38*
	[2.12, 5.86]	[5.29, 9.30]	[-0.76, 0.07]	[12.19, 24.57]
45-54	3.39*	8.97*	-1.35*	25.28*
	[1.48, 5.29]	[7.12, 10.83]	[-2.00, -0.69]	[19.35, 31.21]
55-64	2.04	9.64*	-2.29*	36.34*
	[-0.01, 4.09]	[7.76, 11.53]	[-3.14, -1.44]	[30.71, 41.97]
65+	-1.48	10.53*	-4.09*	39.39*
	[-3.75, 0.80]	[8.64, 12.43]	[-5.15, -3.02]	[33.67, 45.11]
Race/Ethnicity				
Non-Hispanic White	-	-	-	-
	-	-	-	-
Non-Hispanic Black	-4.44*	-0.86	-0.17	36.35*
	[-6.62, -2.26]	[-2.89, 1.18]	[-0.67, 0.33]	[31.77, 40.93]
Mexican American	0.00	-9.18*	0.39*	22.35*
	[-2.16, 2.16]	[-12.01, -6.34]	[0.27, 0.52]	[16.54, 28.15]
Other	-6.72*	-1.42	0.47*	37.66*
	[-8.85, -4.60]	[-3.35, 0.51]	[0.34, 0.59]	[33.46, 41.87]
Education				
College Graduate	-4.84*	-6.42*	0.52*	22.84*
	[-7.13, -2.56]	[-8.84, -3.99]	[0.35, 0.69]	[17.33, 28.36]
High School/Some College	2.09*	1.85*	0.67*	5.43*
	[0.37, 3.81]	[0.00, 3.70]	[0.38, 0.96]	[0.31, 10.56]
<High School	-	-	-	-
	-	-	-	-
Annual Household Income				
<$20,000	-	-	-	-
	-	-	-	-
$20,000-$74,999	1.25	1.45	0.29*	13.17*
	[-0.48, 2.99]	[-0.44, 3.33]	[0.03, 0.54]	[7.73, 18.61]
$75,000+	0.18	0.46	0.52*	25.26*
	[-1.75, 2.12]	[-1.63, 2.54]	[0.35, 0.68]	[19.74, 30.78]
Did Not Report	-1.87	-4.41*	0.32*	15.07*
	[-5.34, 1.59]	[-8.31, -0.52]	[0.17, 0.47]	[6.35, 23.78]
n	32,375			

	Unconditional Marginal Effect			
Predictor	Beef (g/d)	Pork (g/d)	Poultry (g/d)	Seafood (g/d)
Log-Likelihood	-605,669			
AIC	1,211,772			

Note: Asterisks (*) indicate a marginal effect that is statistically significant at the 95 percent confidence level. Values in brackets [ ] are 95 percent confidence intervals around the marginal effect, calculated using Krinsky-Robb standard errors. Log-likelihood and AIC values are from the original multivariate Tobit estimation (parameter estimates are not shown).

Appendix Table B.2. Multivariate Tobit Unconditional Marginal Effects on Animal Protein Consumption Cont.

	Unconditional Marginal Effect		
Predictor	Combo (g/d)	Egg (g/d)	Dairy (c/d)
Physical Exercise			
0 min/d	-	-	-
	-	-	-
1-30 min/d	-1.48*	-0.13	-0.03*
	[-2.59, -0.37]	[-1.08, 0.82]	[-0.04, -0.02]
31-60 min/d	-5.10*	1.73*	-0.01*
	[-6.62, -3.59]	[0.65, 2.81]	[-0.03, 0.00]
61-120 min/d	-5.89*	3.64*	-0.07*
	[-7.95, -3.83]	[2.42, 4.86]	[-0.09, -0.05]
121-180 min/d	-5.01*	3.85*	-0.11*
	[-8.77, -1.24]	[1.64, 6.06]	[-0.14, -0.08]
181-240 min/d	0.44	5.03*	-0.08*
	[-4.31, 5.19]	[2.01, 8.04]	[-0.13, -0.03]
241-300 min/d	6.77*	2.98	-0.07
	[0.75, 12.79]	[-4.54, 10.50]	[-0.18, 0.03]
>300 min/d	-8.79	-5.13	0.04
	[-22.05, 4.46]	[-16.56, 6.30]	[-0.03, 0.11]
Survey Cycle			
2007-2008	-	-	-
	-	-	-
2009-2010	-2.67*	0.15	-0.04*
	[-4.32, -1.01]	[-1.18, 1.49]	[-0.05, -0.03]
2011-2012	6.43*	1.14	0.01
	[5.22, 7.63]	[-0.16, 2.43]	[0.00, 0.02]
2013-2014	4.79*	2.69*	0.01*
	[3.49, 6.08]	[1.48, 3.90]	[0.00, 0.03]
2015-2016	6.64*	3.22*	0.05*
	[5.44, 7.83]	[2.04, 4.40]	[0.03, 0.06]
2017-2018	5.53*	3.86*	0.06*
	[4.29, 6.77]	[2.71, 5.01]	[0.05, 0.07]

	Unconditional Marginal Effect		
Predictor	Combo (g/d)	Egg (g/d)	Dairy (c/d)
Gender			
Male	10.80*	3.57*	-0.07*
	[9.89, 11.71]	[2.79, 4.34]	[-0.08, -0.06]
Female	-	-	-
	-	-	-
Age			
18-24	-	-	-
	-	-	-
25-34	0.46	4.95*	0.02*
	[-1.08, 2.01]	[3.76, 6.13]	[0.01, 0.03]
35-44	-0.08	5.21*	0.03*
	[-1.67, 1.51]	[4.04, 6.39]	[0.01, 0.04]
45-54	-2.48*	5.65*	0.03*
	[-4.18, -0.78]	[4.51, 6.80]	[0.02, 0.04]
55-64	-6.70*	6.74*	0.04*
	[-8.59, -4.80]	[5.64, 7.84]	[0.03, 0.05]
65+	-12.01*	6.89*	0.06*
	[-14.09, -9.94]	[5.74, 8.04]	[0.04, 0.07]
Race/Ethnicity			
Non-Hispanic White	-	-	-
	-	-	-
Non-Hispanic Black	-2.02*	2.48*	0.12*
	[-3.48, -0.55]	[1.36, 3.60]	[0.11, 0.12]
Mexican American	1.73*	7.56*	0.07*
	[0.26, 3.20]	[6.65, 8.47]	[0.06, 0.08]
Other	-9.11*	2.00*	0.09*
	[-10.78, -7.43]	[0.93, 3.08]	[0.09, 0.10]
Education			
College Graduate	-4.08*	0.37	-0.04*
	[-5.75, -2.40]	[-0.94, 1.68]	[-0.05, -0.02]
High School/Some College	1.27	-0.40	-0.02*
	[-0.01, 2.56]	[-1.52, 0.72]	[-0.03, -0.01]
<High School	-	-	-
	-	-	-
Annual Household Income			
<$20,000	-	-	-
	-	-	-
$20,000-$74,999	0.51	0.65	0.01*
	[-0.81, 1.82]	[-0.51, 1.82]	[0.00, 0.02]
$75,000+	-1.14	-0.49	0.01
	[-2.64, 0.36]	[-1.80, 0.82]	[0.00, 0.02]

	Unconditional Marginal Effect		
Predictor	Combo (g/d)	Egg (g/d)	Dairy (c/d)
Did Not Report	-1.89	1.33	0.02*
	[-4.50, 0.71]	[-0.61, 3.28]	[0.00, 0.04]
n	32,375		
Log-Likelihood	-605,669		
AIC	1,211,772		

Note: Asterisks (*) indicate a marginal effect that is statistically significant at the 95 percent confidence level. Values in brackets [ ] are 95 percent confidence intervals around the marginal effect, calculated using Krinsky-Robb standard errors. Log-likelihood and AIC values are from the original multivariate Tobit estimation (parameter estimates are not shown).

Appendix C - Impacts of Exercise Pursuits on U.S. Retail Protein Demand

Appendix Table C.1. EM Estimates of Trainee AIDS Parameters (n = 10,323)

	Share Equation							
Parameter	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
α_i	0.798*	-0.139*	0.005	0.000	-0.249*	0.494*	0.367*	-0.276*
	(0.028)	(0.019)	(0.015)	(0.021)	(0.021)	(0.029)	(0.026)	(0.028)
β_i	0.079*	-0.030*	-0.014*	-0.010*	-0.050*	0.042*	0.027*	-0.044*
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)
Price Effects								
Ribeye Steak ($/lb.)	0.024*							
	(0.010)							
Ground Beef ($/lb.)	0.012*	0.021*						
	(0.003)	(0.002)						
Pork Chop ($/lb.)	0.006	-0.006*	0.026*					
	(0.003)	(0.002)	(0.002)					
Bacon Price ($/lb.)	0.010*	-0.006*	-0.005*	0.021*				
	(0.003)	(0.002)	(0.002)	(0.003)				
Chicken Breast ($/lb.)	0.005	-0.008*	-0.006*	-0.007*	0.033*			
	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)			
Plant-Based Patty ($/lb.)	-0.040*	-0.002	-0.007*	0.000	-0.004	0.067*		
	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)	(0.008)		
Shrimp Price ($/lb.)	-0.029*	-0.006*	-0.003	-0.008*	-0.004	-0.017*	0.064*	
	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)	(0.007)	
Beans & Rice ($/lb.)	0.011*	-0.006*	-0.004*	-0.005*	-0.008*	0.004	0.003	0.006*
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Seasonal Effects								
January	-0.011*	-0.003	-0.001	-0.006	-0.003	0.008	0.012*	0.004
	(0.006)	(0.003)	(0.003)	(0.003)	(0.004)	(0.006)	(0.005)	(0.005)
February	-0.005	0.002	-0.007	-0.001	-0.010*	0.006	0.011	0.004
	(0.007)	(0.004)	(0.004)	(0.004)	(0.005)	(0.008)	(0.006)	(0.007)
March	0.005	-0.006	-0.004	-0.004	-0.010*	0.007	0.011	0.001
	(0.007)	(0.004)	(0.004)	(0.004)	(0.004)	(0.007)	(0.006)	(0.007)
April	-0.008	-0.001	0.000	-0.006	-0.005	0.006	0.022*	-0.008
	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.005)
May	-0.008	0.004	-0.002	-0.001	0.000	0.000	0.012*	-0.005
	(0.006)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.006)	(0.005)
June	-0.007	0.004	0.004	-0.011*	0.000	0.007	0.011	-0.007
	(0.006)	(0.003)	(0.003)	(0.003)	(0.005)	(0.006)	(0.006)	(0.005)

	Share Equation							
Parameter	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
July	-0.008	0.000	-0.002	-0.003	-0.002	0.009	0.009	-0.003
	(0.005)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.006)
August	-0.002	-0.002	-0.002	-0.005	-0.004	0.005	0.012*	-0.002
	(0.005)	(0.003)	(0.003)	(0.003)	(0.004)	(0.006)	(0.004)	(0.005)
September	-0.005	0.002	0.005	0.002	0.001	-0.002	0.007	-0.010*
	(0.006)	(0.003)	(0.003)	(0.003)	(0.004)	(0.006)	(0.005)	(0.005)
October	-0.005	-0.001	-0.002	-0.007*	-0.002	0.007	0.015*	-0.004
	(0.006)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.006)	(0.005)
November	0.005	0.001	-0.005	-0.001	-0.001	-0.003	0.011	-0.006
	(0.006)	(0.003)	(0.003)	(0.004)	(0.004)	(0.006)	(0.006)	(0.005)
Physical Effects								
Age (years)	0.000	0.000	0.000*	0.000*	0.000	0.000*	0.001*	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Height (inches)	-0.001	0.000	0.000	0.000	0.001*	0.000	-0.001*	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Weight (pounds)	0.000	0.000*	0.000*	0.000*	0.000	0.000*	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male	0.004	-0.003	0.007*	-0.005*	-0.006*	0.004	-0.011*	0.008*
	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)
Household Income Effects								
Less than $20,000 annually	-0.005	0.001	-0.002	0.002	-0.004	0.004	-0.007*	0.012*
	(0.004)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)
$100,000 or greater annually	0.003	-0.002	-0.001	-0.002	0.000	-0.005	0.005	0.003
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)
Race Effects								
Black	-0.004	-0.008*	-0.008*	-0.007*	-0.003	0.014*	0.006	0.010*
	(0.003)	(0.002)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
Other	0.002	-0.004*	-0.003	-0.008*	0.002	0.009*	0.003	-0.001
	(0.004)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	(0.003)
Regional Effects								
Northeast	0.006	-0.011*	-0.007*	-0.006*	-0.007*	0.011*	0.011*	0.002
	(0.004)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)
South	0.011*	-0.005*	-0.004*	-0.003	-0.005*	-0.001	0.005	0.002
	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
West	0.008*	-0.011*	-0.007*	-0.005*	-0.005	0.008	0.004	0.006
	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	(0.004)
Education Effects								
Some college	0.002	0.000	-0.004*	-0.003	0.002	-0.004	0.003	0.004
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
Bachelor's degree or higher	-0.004	-0.006*	-0.009*	-0.006*	-0.001	0.012*	0.008*	0.006*

	Share Equation							
Parameter	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)
Household Size Effects								
2 people	0.005	0.004	0.002	0.002	0.000	-0.001	-0.012*	0.000
	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)	(0.004)	(0.004)	(0.004)
3 people	0.004	0.006*	0.001	0.003	0.000	-0.004	-0.016*	0.007
	(0.004)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)
4 people	-0.007	0.004	0.001	0.005	0.000	0.003	-0.020*	0.013*
	(0.004)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)
5 or more people	-0.004	0.012*	0.005	0.004	0.003	-0.016*	-0.016*	0.014*
	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
Adj. R^2	0.4575	0.2393	0.1221	0.0584	0.3675	0.3101	0.1110	
Mean Predicted Share	0.2096	0.1037	0.0972	0.0987	0.1145	0.1378	0.1718	0.0673

Note: Asterisks (*) indicate statistical significance at the five percent level. Values in parentheses are bootstrap standard errors. Log-likelihood = 96,202.14.

Appendix Table C.2. EM Estimates of Non-trainee AIDS Parameters (n = 21,271)

	Share Equation							
Parameter	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
α_i	1.014*	-0.213*	-0.075*	-0.095*	-0.309*	0.473*	0.488*	-0.283*
	(0.025)	(0.019)	(0.018)	(0.020)	(0.024)	(0.028)	(0.030)	(0.024)
β_i	0.090*	-0.039*	-0.014*	-0.014*	-0.059*	0.037*	0.044*	-0.046*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Price Effects								
Ribeye Steak ($/lb.)	-0.073*							
	(0.008)							
Ground Beef ($/lb.)	0.019*	-0.028*						
	(0.003)	(0.002)						
Pork Chop ($/lb.)	0.027*	-0.005*	-0.028*					
	(0.003)	(0.002)	(0.003)					
Bacon ($/lb.)	0.029*	-0.001	-0.002	-0.049*				
	(0.003)	(0.002)	(0.002)	(0.003)				
Chicken Breast ($/lb.)	-0.003	-0.003	-0.006*	0.001	-0.003			
	(0.003)	(0.001)	(0.002)	(0.002)	(0.002)			
Plant-Based Patty ($/lb.)	-0.022*	0.002	0.005	0.012*	0.008*	0.006		
	(0.006)	(0.003)	(0.003)	(0.003)	(0.002)	(0.008)		
Shrimp ($/lb.)	0.009	0.014*	0.009*	0.008*	0.004	-0.013*	-0.033*	
	(0.005)	(0.002)	(0.003)	(0.003)	(0.002)	(0.006)	(0.006)	
Beans & Rice ($/lb.)	0.012*	0.002	0.000	0.001	0.001	0.002	0.002	-0.021*
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Seasonal Effects								

	Share Equation							
Parameter	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
January	-0.010*	0.001	0.005	0.009*	0.008	-0.003	0.000	-0.011*
	(0.005)	(0.003)	(0.003)	(0.004)	(0.004)	(0.006)	(0.006)	(0.004)
February	-0.007	0.002	0.002	0.008	0.004	0.005	-0.005	-0.009
	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)	(0.007)	(0.005)
March	-0.008	-0.003	0.007	-0.001	0.004	0.008	0.006	-0.013*
	(0.006)	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)
April	-0.005	-0.005	0.002	0.000	0.002	0.009	0.002	-0.005
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)
May	-0.005	0.001	-0.004	-0.003	0.005	0.003	0.000	0.002
	(0.005)	(0.004)	(0.003)	(0.004)	(0.004)	(0.006)	(0.006)	(0.005)
June	-0.005	0.000	0.002	0.003	0.002	0.003	0.003	-0.008
	(0.005)	(0.004)	(0.003)	(0.004)	(0.004)	(0.005)	(0.006)	(0.004)
July	-0.007	0.001	0.001	0.000	-0.001	0.009	0.003	-0.005
	(0.006)	(0.004)	(0.003)	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)
August	-0.006	0.000	0.001	-0.001	0.005	0.007	0.000	-0.005
	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.005)
September	0.000	0.007	0.004	0.001	0.004	0.001	-0.008	-0.009
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)	(0.005)
October	-0.006	0.001	0.006	0.000	-0.001	0.006	0.002	-0.007
	(0.005)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.004)
November	0.000	0.000	0.005	-0.002	0.000	0.002	0.001	-0.005
	(0.005)	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.005)
Physical Effects								
Age (years)	0.000	0.000	0.000*	0.000	0.000*	-0.001*	0.001*	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Height (inches)	-0.001	0.000	0.000	0.001*	0.000	0.000	-0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Weight (pounds)	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male	0.019*	-0.011*	0.003	-0.006*	-0.009*	0.009*	-0.010*	0.006*
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.003)
Household Income Effects								
Less than $20,000 annually	-0.003	0.000	0.001	0.001	-0.005	0.008*	-0.009*	0.008*
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)
$100,000 or greater annually	0.010*	-0.002	-0.002	-0.006*	-0.006*	-0.004	0.015*	-0.005
	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)
Race Effects								
Black	-0.002	-0.022*	-0.008*	-0.013*	-0.015*	0.021*	0.015*	0.023*
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Other	0.014*	-0.011*	-0.003	-0.007*	-0.014*	0.011*	0.008*	0.001

	Share Equation							
Parameter	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
Regional Effects								
Northeast	0.010*	-0.018*	-0.012*	-0.011*	-0.002	0.009*	0.028*	-0.005
	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
South	0.001	-0.007*	-0.002	-0.001	0.004	0.000	0.007	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
West	0.002	-0.010*	-0.007*	-0.005	0.004	0.011*	0.000	0.005
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Education Effects								
Some college	-0.001	-0.008*	-0.005*	-0.008*	0.000	0.006*	0.016*	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Bachelor's degree or higher	-0.005	-0.020*	-0.007*	-0.018*	-0.005*	0.028*	0.022*	0.005*
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.002)
Household Size Effects								
2 people	-0.006*	0.005*	0.006*	0.008*	0.004	-0.013*	-0.004	0.001
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
3 people	-0.014*	0.009*	0.009*	0.008*	0.010*	-0.011*	-0.019*	0.008*
	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)
4 people	-0.018*	0.014*	0.012*	0.013*	0.010*	-0.020*	-0.020*	0.008*
	(0.004)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)
5 or more people	-0.022*	0.018*	0.015*	0.013*	0.015*	-0.021*	-0.026*	0.008*
	(0.005)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Adj. R^2	0.5327	0.2096	0.0638	0.0733	0.3031	0.2986	0.1940	
Mean Predicted Share	0.1577	0.1404	0.1152	0.1160	0.1551	0.0801	0.1648	0.0717

Note: Asterisks (*) indicate statistical significance at the five percent level. Values in parentheses are bootstrap standard errors. Log-likelihood = 164,691.20.

Appendix Table C.3. Trainee and Non-trainee Expenditure and Hicksian Price Elasticity Estimates (OECE Expenditure < Weekly FAH Expenditure)

	Trainee quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	1.46*+	0.72*+	0.86*+	0.91*+	0.59*+	1.35*+	1.21*+	0.31*+
Prices of:								
Ribeye Steak	-1.29*-	0.50*	0.40*	0.47*	0.49*	-0.21*	-0.01	0.72*
Ground Beef	0.31*	-0.91*-	0.04*	0.05*	-0.03	0.20*	0.15*	-0.09*
Pork Chop	0.22*	0.04*	-0.84*-	0.06*	0.02	0.09*	0.14*	0.00
Bacon	0.26*	0.05*	0.06*	-0.93*	0.03	0.16*	0.09*	-0.01
Chicken Breast	0.35*	-0.03	0.02	0.04	-0.84*-	0.23*	0.19*	-0.19*
Plant-Based Patty	-0.13*	0.21*	0.10*	0.18*	0.21*	-0.71*-	0.00	0.36*
Shrimp	-0.01	0.21*	0.22*	0.14*	0.24*	0.00	-0.71*-	0.38*
Beans & Rice	0.29*	-0.06*	0.00	0.00	-0.11*	0.23*	0.17*	-1.17*-

	Non-trainee quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	1.63*+	0.74*+	0.89*+	0.89*+	0.63*+	1.48*+	1.30*+	0.33*+
Prices of:								
Ribeye Steak	-2.00*-	0.48*	0.50*	0.51*	0.39*	-0.39*	0.03	0.76*
Ground Beef	0.49*	-1.20*-	0.08*	0.12*	0.03*	0.35*	0.33*	0.00
Pork Chop	0.41*	0.06*	-1.25*-	0.10*	0.05*	0.25*	0.22*	0.07*
Bacon	0.41*	0.09*	0.10*	-1.46*-	0.10*	0.38*	0.24*	0.09*
Chicken Breast	0.44*	0.03*	0.07*	0.14*	-1.07*-	0.51*	0.33*	-0.09*
Plant-Based Patty	-0.19*	0.16*	0.15*	0.22*	0.21*	-1.20*	-0.07*	0.25*
Shrimp	0.04	0.37*	0.31*	0.33*	0.33*	-0.16*	-1.29*-	0.43*
Beans & Rice	0.39*	0.00	0.04*	0.06*	-0.04*	0.27*	0.20*	-1.52*-

Note: Asterisks (*) indicate elasticity estimates that are statistically different than zero at the five percent level; superscript "+" indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; superscript "-" indicates Hicksian own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities were calculated at the mean values of the budget shares. Standard errors and associated *p*-values were constructed via bootstrap.

Appendix Table C.4. Trainee and Non-trainee Expenditure and Hicksian Price Elasticity Estimates (OECE Expenditure + $100 < Weekly FAH Expenditure)

	Trainee quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	1.57*+	0.73*+	0.91*+	0.93*+	0.66*+	1.33*+	1.29*+	0.20*+
Prices of:								
Ribeye Steak	-1.81*-	0.45*	0.56*	0.53*	0.49*	-0.07	-0.01	0.61*
Ground Beef	0.36*	-0.99*	0.08	0.17*	0.01	0.24*	0.13*	-0.04
Pork Chop	0.37*	0.07	-1.06*	0.02	0.00	-0.05	0.26*	0.07
Bacon	0.35*	0.14*	0.02	-1.10*	0.04	-0.04	0.22*	0.06
Chicken Breast	0.46*	0.01	0.00	0.05	-0.87*-	0.17	0.30*	-0.16*
Plant-Based Patty	-0.04	0.19*	-0.05	-0.04	0.11	-0.72*	0.07	0.40*
Shrimp	-0.01	0.16*	0.39*	0.32*	0.31*	0.11	-1.19*	0.43*
Beans & Rice	0.33*	-0.03	0.06	0.05	-0.09*	0.35*	0.23*	-1.38*-

	Non-trainee quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	1.73*+	0.75*+	0.90*+	0.91*+	0.64*+	1.47*+	1.39*+	0.40*+
Prices of:								
Ribeye Steak	-2.39*-	0.47*	0.46*	0.48*	0.36*	-0.18	-0.02	0.70*
Ground Beef	0.61*	-1.30*-	0.14*	0.14*	0.10*	0.36*	0.38*	0.05
Pork Chop	0.45*	0.11*	-1.39*-	0.16*	0.07*	0.25*	0.30*	0.10*
Bacon	0.48*	0.11*	0.16*	-1.71*-	0.13*	0.44*	0.40*	0.13*
Chicken Breast	0.52*	0.11*	0.10*	0.18*	-1.12*-	0.49*	0.42*	-0.06
Plant-Based Patty	-0.08	0.13*	0.12*	0.20*	0.15*	-1.47*	-0.04	0.15*
Shrimp	-0.03	0.34*	0.35*	0.47*	0.34*	-0.09	-1.67*-	0.45*
Beans & Rice	0.44*	0.03	0.07*	0.08*	-0.02	0.21*	0.24*	-1.53*-

Note: Asterisks (*) indicate elasticity estimates that are statistically different than zero at the five percent level; superscript "+" indicates expenditure elasticities that are statistically different than 1.0 at the five percent level; superscript "-" indicates Hicksian own-price elasticities that are statistically different than -1.0 at the five percent level. Elasticities were calculated at the mean values of the budget shares. Standard errors and associated *p*-values were constructed via bootstrap.

Appendix Table C.5. *P*-values of One-Sided Hypothesis Tests (OECE Expenditure < Weekly FAH Expenditure)

	Quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	0.000	0.152	0.041	0.785	0.008	0.000	0.000	0.273
Prices of:								
Ribeye Steak	1.000	0.000	0.000	0.000	0.000	0.771	0.218	0.000
Ground Beef	0.702	1.000	0.117	0.034	0.001	0.830	0.000	0.000
Pork Chop	0.015	0.073	1.000	0.041	0.031	0.166	0.040	0.005
Bacon	0.271	0.017	0.044	1.000	0.000	0.288	0.000	0.001
Chicken Breast	1.000	0.001	0.048	0.001	1.000	0.409	0.002	0.000
Plant-Based Patty	0.910	0.006	0.007	0.000	0.000	0.999	0.941	0.149
Shrimp	0.234	0.000	0.003	0.000	0.000	0.869	1.000	0.080
Beans & Rice	0.164	0.000	0.003	0.000	0.001	0.998	0.124	1.000

Note: Each complete combinatorial of elasticity differences contains 10,000 elements (100*100). The proportion of non-negative differences is the *p*-value associated with a one-sided hypothesis test. The null hypothesis is that the difference between trainees' elasticities and non-trainees' is greater than or equal to zero (i.e., trainees' elasticities are more positive). We reject the null hypothesis if the *p*-value is less than or equal to 0.05.

Appendix Table C.6. *P*-values of One-Sided Hypothesis Tests (OECE Expenditure + $100 < Weekly FAH Expenditure)

	Quantity of:							
With respect to:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans & Rice
Expenditure	0.000	0.281	0.562	0.762	0.726	0.004	0.001	0.000
Prices of:								
Ribeye Steak	0.997	0.000	0.117	0.051	0.191	0.632	0.427	0.003
Ground Beef	0.387	1.000	0.164	0.709	0.015	0.761	0.010	0.041
Pork Chop	0.880	0.133	1.000	0.018	0.045	0.039	0.549	0.490
Bacon	0.693	0.639	0.017	1.000	0.006	0.011	0.120	0.183
Chicken Breast	0.988	0.012	0.043	0.006	1.000	0.270	0.306	0.023
Plant-Based Patty	0.680	0.193	0.009	0.003	0.006	0.969	0.781	0.964
Shrimp	0.414	0.000	0.202	0.014	0.020	0.788	0.995	0.473
Beans & Rice	0.160	0.031	0.326	0.080	0.065	1.000	0.452	0.995

Note: Each complete combinatorial of elasticity differences contains 10,000 elements (100*100). The proportion of non-negative differences is the *p*-value associated with a one-sided hypothesis test. The null hypothesis is that the difference between trainees' elasticities and non-trainees' is greater than or equal to zero (i.e., trainees' elasticities are more positive). We reject the null hypothesis if the *p*-value is less than or equal to 0.05.

Appendix D - Do Separability Assumptions Matter in Choice Experiment Research?

Appendix Table D.1. Estimates of Preferred Random Parameters Logit Models

Variable	Base MDM	MDM Variant 1	MDM Variant 2
Means of Alternative-Specific Constants			
Ribeye Steak	6.649* (0.181)	7.382* (0.355)	7.015* (0.328)
Ground Beef	3.824* (0.161)	4.232* (0.332)	4.344* (0.300)
Pork Chop	3.159* (0.162)	3.526* (0.333)	3.697* (0.301)
Bacon	2.920* (0.162)	3.390* (0.333)	3.447* (0.301)
Chicken Breast	3.654* (0.161)	3.993* (0.331)	4.262* (0.300)
Beans and Rice	1.219* (0.164)	1.694* (0.336)	1.800* (0.304)
Plant-Based Patty	1.809* (0.216)	-	2.318* (0.384)
Shrimp	3.820* (0.175)	4.387* (0.349)	-
Eggs	-	2.908* (0.331)	-
Whey Protein	-	-	4.796* (0.432)
Standard Deviations of Alternative-Specific Constants			
Ribeye Steak	-2.574* (0.058)	-2.071* (0.079)	-2.567* (0.096)
Ground Beef	1.007* (0.023)	-0.895* (0.038)	-0.949* (0.037)
Pork Chop	-1.075* (0.028)	1.023* (0.048)	-1.052* (0.047)
Bacon	-0.660* (0.038)	0.652* (0.064)	-0.760* (0.058)
Chicken Breast	1.244* (0.023)	0.992* (0.037)	1.195* (0.037)
Beans and Rice	1.745* (0.040)	1.601* (0.060)	-1.907* (0.067)
Plant-Based Patty	-3.231* (0.097)	-	-3.142* (0.160)
Shrimp	2.101* (0.055)	1.858* (0.087)	-
Eggs	-	-1.108* (0.038)	-
Whey Protein	-	-	-2.818* (0.198)
Linear Price Effect	-0.473* (0.004)	-0.467* (0.006)	-0.461* (0.006)
Gender			
Male	0.182* (0.039)	0.080 (0.078)	0.210* (0.064)
Female	-	-	-
Age (years)			
18-24	-	-	-
25-34	-0.033 (0.164)	-0.833* (0.334)	-0.313 (0.303)
35-44	-0.491* (0.153)	-0.704* (0.324)	-0.730* (0.287)
45-54	-0.917* (0.151)	-1.270* (0.319)	-1.211* (0.286)
55-64	-1.092* (0.149)	-1.398* (0.315)	-1.507* (0.283)
65+	-1.275* (0.151)	-1.631* (0.317)	-1.786* (0.285)
Race/Ethnicity			
White	-	-	-

Variable	Base MDM	MDM Variant 1	MDM Variant 2
Black	0.169* (0.062)	0.217 (0.117)	-0.063 (0.095)
Other	0.048 (0.064)	0.183 (0.128)	-0.134 (0.104)
Annual Household Income			
$20,000 and under	-	-	-
$20,001-$100,000	0.289* (0.054)	0.483* (0.101)	0.219* (0.087)
$100,000 and over	0.332* (0.072)	0.541* (0.141)	0.256* (0.117)
Education			
High school or lower	-	-	-
Some college	-0.034 (0.049)	0.042 (0.094)	0.011 (0.081)
Bachelor's or higher	-0.029 (0.055)	0.211 (0.109)	-0.097 (0.088)
Census Region			
Midwest	-0.064 (0.056)	-0.159 (0.110)	-0.004 (0.099)
Northeast	0.081 (0.061)	0.258* (0.123)	-0.292* (0.099)
South	0.161* (0.053)	0.201 (0.103)	-0.080 (0.087)
West	-	-	-
Diet			
Regularly consumes meat	-	-	-
Flexitarian	-0.680* (0.056)	-0.843* (0.106)	-0.806* (0.099)
Vegetarian	-0.863* (0.121)	-1.023* (0.211)	-0.962* (0.197)
Vegan	-0.497* (0.133)	-1.855* (0.200)	-0.386 (0.261)
Other	-0.472* (0.079)	-0.264 (0.157)	-0.684* (0.112)
Number of observations	54,324	19,602	19,431
Log-likelihood	-85,275	-33,086	-29,640
AIC	170,622	66,244	59,352
BIC	170,942	66,528	59,635

Note: Asterisks (*) indicate statistical significance at the five percent level or lower. Values in parentheses are standard errors.

Appendix Table D.2. Base MDM Arc Elasticity Estimates

		Quantity of:								
Price of:	Change of:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans and Rice	Opt-Out
Ribeye Steak	-50%	-10.32	0.74	0.76	0.80	0.71	0.63	0.73	0.72	0.81
	-40%	-9.28	0.67	0.68	0.73	0.63	0.56	0.66	0.64	0.74
	-30%	-8.12	0.59	0.60	0.64	0.55	0.49	0.57	0.56	0.66
	-20%	-6.94	0.50	0.52	0.56	0.46	0.42	0.49	0.47	0.57
	-10%	-5.82	0.42	0.43	0.47	0.38	0.36	0.41	0.39	0.49
	+10%	-3.95	0.29	0.30	0.32	0.26	0.24	0.27	0.26	0.34
	+20%	-3.24	0.24	0.24	0.27	0.21	0.20	0.22	0.22	0.28
	+30%	-2.68	0.20	0.20	0.22	0.17	0.17	0.18	0.18	0.23
	+40%	-2.24	0.16	0.17	0.18	0.15	0.14	0.15	0.15	0.19
	+50%	-1.89	0.14	0.14	0.16	0.12	0.12	0.12	0.13	0.16

		Quantity of:								
Price of:	Change of:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans and Rice	Opt-Out
Ground Beef	-50%	0.42	-1.57	0.54	0.59	0.48	0.40	0.48	0.49	0.60
	-40%	0.41	-1.53	0.53	0.58	0.47	0.38	0.47	0.47	0.59
	-30%	0.39	-1.49	0.51	0.57	0.45	0.37	0.45	0.46	0.59
	-20%	0.38	-1.45	0.50	0.56	0.44	0.36	0.44	0.45	0.57
	-10%	0.36	-1.40	0.48	0.54	0.42	0.34	0.42	0.43	0.56
	+10%	0.33	-1.29	0.45	0.51	0.39	0.31	0.39	0.40	0.53
	+20%	0.32	-1.24	0.43	0.49	0.37	0.29	0.37	0.38	0.51
	+30%	0.30	-1.18	0.41	0.47	0.35	0.28	0.35	0.36	0.49
	+40%	0.28	-1.12	0.39	0.45	0.33	0.26	0.34	0.34	0.47
	+50%	0.27	-1.07	0.37	0.43	0.31	0.25	0.32	0.32	0.45
Pork Chop	-50%	0.27	0.35	-2.42	0.41	0.32	0.26	0.32	0.32	0.42
	-40%	0.26	0.33	-2.29	0.39	0.30	0.24	0.30	0.30	0.40
	-30%	0.24	0.31	-2.17	0.37	0.29	0.23	0.28	0.28	0.38
	-20%	0.22	0.29	-2.04	0.35	0.27	0.21	0.27	0.27	0.36
	-10%	0.21	0.27	-1.91	0.34	0.25	0.20	0.25	0.25	0.34
	+10%	0.18	0.24	-1.67	0.30	0.22	0.17	0.22	0.22	0.30
	+20%	0.17	0.22	-1.55	0.28	0.20	0.16	0.20	0.20	0.28
	+30%	0.15	0.21	-1.44	0.26	0.19	0.15	0.19	0.19	0.26
	+40%	0.14	0.19	-1.34	0.24	0.17	0.13	0.17	0.17	0.25
	+50%	0.13	0.18	-1.25	0.23	0.16	0.12	0.16	0.16	0.23
Bacon	-50%	0.20	0.27	0.29	-3.84	0.24	0.19	0.24	0.25	0.34
	-40%	0.18	0.25	0.27	-3.50	0.22	0.18	0.22	0.22	0.31
	-30%	0.17	0.22	0.24	-3.17	0.20	0.16	0.20	0.20	0.29
	-20%	0.15	0.20	0.22	-2.87	0.18	0.14	0.18	0.18	0.26
	-10%	0.13	0.18	0.20	-2.59	0.16	0.13	0.16	0.16	0.24
	+10%	0.11	0.15	0.16	-2.11	0.13	0.10	0.13	0.13	0.20
	+20%	0.10	0.13	0.15	-1.90	0.12	0.09	0.12	0.12	0.18
	+30%	0.09	0.12	0.13	-1.72	0.11	0.08	0.11	0.11	0.16
	+40%	0.08	0.11	0.12	-1.56	0.10	0.08	0.10	0.10	0.15
	+50%	0.07	0.10	0.11	-1.41	0.09	0.07	0.09	0.09	0.13
Chicken Breast	-50%	0.36	0.45	0.48	0.51	-1.20	0.35	0.42	0.43	0.53
	-40%	0.35	0.45	0.47	0.51	-1.18	0.35	0.41	0.42	0.52
	-30%	0.35	0.44	0.46	0.50	-1.16	0.34	0.40	0.41	0.52
	-20%	0.34	0.43	0.45	0.49	-1.14	0.33	0.39	0.40	0.51
	-10%	0.32	0.42	0.44	0.48	-1.11	0.32	0.38	0.39	0.50
	+10%	0.30	0.39	0.42	0.46	-1.05	0.30	0.35	0.36	0.48
	+20%	0.29	0.38	0.41	0.45	-1.02	0.29	0.34	0.35	0.47
	+30%	0.28	0.37	0.39	0.44	-0.98	0.27	0.33	0.34	0.46
	+40%	0.27	0.35	0.38	0.42	-0.95	0.26	0.32	0.33	0.44
	+50%	0.26	0.34	0.37	0.41	-0.91	0.25	0.30	0.31	0.43

Price of:	Change of:	Quantity of: Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Shrimp	Beans and Rice	Opt-Out
Plant-Based Patty	-50%	0.17	0.19	0.19	0.21	0.18	-6.55	0.17	0.18	0.21
	-40%	0.15	0.16	0.17	0.18	0.16	-5.74	0.15	0.15	0.19
	-30%	0.13	0.14	0.15	0.16	0.14	-5.00	0.13	0.13	0.17
	-20%	0.11	0.12	0.13	0.14	0.12	-4.35	0.11	0.11	0.14
	-10%	0.10	0.11	0.11	0.12	0.10	-3.77	0.10	0.10	0.13
	+10%	0.07	0.08	0.08	0.09	0.08	-2.85	0.07	0.07	0.10
	+20%	0.06	0.07	0.07	0.08	0.07	-2.48	0.06	0.06	0.08
	+30%	0.06	0.06	0.06	0.07	0.06	-2.17	0.06	0.05	0.07
	+40%	0.05	0.05	0.06	0.06	0.05	-1.91	0.05	0.05	0.07
	+50%	0.04	0.05	0.05	0.06	0.04	-1.68	0.04	0.04	0.06
Shrimp	-50%	0.31	0.38	0.39	0.42	0.35	0.30	-7.27	0.37	0.43
	-40%	0.28	0.34	0.35	0.38	0.31	0.26	-6.46	0.33	0.39
	-30%	0.24	0.30	0.31	0.33	0.27	0.23	-5.68	0.29	0.35
	-20%	0.21	0.26	0.27	0.29	0.23	0.19	-4.94	0.25	0.30
	-10%	0.18	0.22	0.23	0.26	0.20	0.16	-4.27	0.22	0.27
	+10%	0.13	0.16	0.17	0.19	0.15	0.12	-3.15	0.16	0.20
	+20%	0.12	0.14	0.15	0.17	0.13	0.10	-2.70	0.14	0.17
	+30%	0.10	0.12	0.13	0.14	0.11	0.08	-2.32	0.12	0.15
	+40%	0.09	0.11	0.11	0.12	0.09	0.07	-2.01	0.10	0.13
	+50%	0.07	0.09	0.10	0.11	0.08	0.06	-1.75	0.09	0.11
Beans and Rice	-50%	0.09	0.11	0.12	0.13	0.10	0.08	0.11	-1.16	0.13
	-40%	0.09	0.11	0.11	0.12	0.10	0.08	0.11	-1.12	0.13
	-30%	0.08	0.11	0.11	0.12	0.10	0.08	0.10	-1.08	0.12
	-20%	0.08	0.10	0.11	0.12	0.09	0.07	0.10	-1.04	0.12
	-10%	0.08	0.10	0.10	0.11	0.09	0.07	0.09	-1.01	0.12
	+10%	0.07	0.09	0.09	0.10	0.08	0.06	0.09	-0.93	0.11
	+20%	0.07	0.09	0.09	0.10	0.08	0.06	0.08	-0.90	0.10
	+30%	0.06	0.08	0.09	0.10	0.08	0.06	0.08	-0.86	0.10
	+40%	0.06	0.08	0.08	0.09	0.07	0.06	0.08	-0.83	0.10
	+50%	0.06	0.08	0.08	0.09	0.07	0.05	0.07	-0.80	0.09

Appendix Table D.3. MDM Variant 1 Arc Elasticity Estimates

Price of:	Change of:	Quantity of: Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Eggs	Shrimp	Beans and Rice	Opt-Out
Ribeye Steak	-50%	-14.43	0.80	0.82	0.84	0.79	0.78	0.79	0.78	0.86
	-40%	-12.71	0.70	0.72	0.75	0.69	0.69	0.69	0.68	0.76
	-30%	-10.79	0.60	0.62	0.64	0.58	0.58	0.59	0.57	0.66
	-20%	-8.89	0.49	0.51	0.53	0.48	0.48	0.48	0.47	0.55
	-10%	-7.14	0.39	0.42	0.43	0.38	0.39	0.39	0.37	0.45

Price of:	Change of:	Quantity of: Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Eggs	Shrimp	Beans and Rice	Opt-Out
	+10%	-4.46	0.25	0.26	0.27	0.24	0.24	0.24	0.23	0.28
	+20%	-3.54	0.19	0.21	0.22	0.19	0.19	0.19	0.18	0.23
	+30%	-2.84	0.16	0.17	0.17	0.15	0.15	0.15	0.15	0.18
	+40%	-2.32	0.13	0.14	0.14	0.12	0.13	0.12	0.12	0.15
	+50%	-1.93	0.11	0.12	0.12	0.10	0.10	0.10	0.10	0.12
Ground Beef	-50%	0.42	-1.79	0.49	0.52	0.47	0.46	0.45	0.44	0.54
	-40%	0.40	-1.74	0.48	0.51	0.45	0.44	0.44	0.43	0.53
	-30%	0.39	-1.68	0.46	0.50	0.44	0.42	0.42	0.41	0.51
	-20%	0.37	-1.61	0.45	0.48	0.42	0.41	0.41	0.40	0.50
	-10%	0.35	-1.54	0.43	0.46	0.40	0.39	0.39	0.38	0.48
	+10%	0.32	-1.40	0.39	0.42	0.37	0.35	0.35	0.34	0.44
	+20%	0.30	-1.33	0.37	0.40	0.35	0.33	0.33	0.32	0.42
	+30%	0.28	-1.26	0.35	0.38	0.33	0.31	0.31	0.30	0.40
	+40%	0.27	-1.19	0.33	0.36	0.31	0.30	0.30	0.29	0.38
	+50%	0.25	-1.12	0.31	0.35	0.29	0.28	0.28	0.27	0.36
Pork Chop	-50%	0.27	0.31	-2.68	0.34	0.30	0.29	0.29	0.29	0.35
	-40%	0.26	0.29	-2.52	0.33	0.28	0.27	0.28	0.27	0.33
	-30%	0.24	0.27	-2.35	0.31	0.26	0.25	0.26	0.25	0.31
	-20%	0.22	0.25	-2.19	0.29	0.24	0.23	0.24	0.23	0.29
	-10%	0.20	0.23	-2.04	0.27	0.23	0.22	0.22	0.22	0.27
	+10%	0.17	0.20	-1.75	0.23	0.19	0.19	0.19	0.19	0.24
	+20%	0.16	0.19	-1.62	0.22	0.18	0.17	0.18	0.17	0.22
	+30%	0.15	0.17	-1.49	0.20	0.16	0.16	0.16	0.16	0.20
	+40%	0.14	0.16	-1.38	0.18	0.15	0.15	0.15	0.15	0.19
	+50%	0.13	0.15	-1.28	0.17	0.14	0.13	0.14	0.14	0.18
Bacon	-50%	0.21	0.25	0.26	-3.95	0.24	0.23	0.24	0.23	0.29
	-40%	0.19	0.22	0.24	-3.58	0.22	0.21	0.21	0.21	0.27
	-30%	0.17	0.20	0.21	-3.23	0.20	0.19	0.19	0.19	0.24
	-20%	0.15	0.18	0.19	-2.91	0.18	0.17	0.17	0.17	0.22
	-10%	0.14	0.16	0.17	-2.62	0.16	0.15	0.16	0.15	0.20
	+10%	0.11	0.13	0.14	-2.12	0.13	0.12	0.13	0.12	0.16
	+20%	0.10	0.12	0.13	-1.91	0.12	0.11	0.11	0.11	0.15
	+30%	0.09	0.11	0.12	-1.72	0.10	0.10	0.10	0.10	0.13
	+40%	0.08	0.10	0.10	-1.56	0.09	0.09	0.09	0.09	0.12
	+50%	0.07	0.09	0.09	-1.41	0.09	0.08	0.08	0.08	0.11
Chicken Breast	-50%	0.36	0.42	0.43	0.46	-1.52	0.40	0.39	0.39	0.47
	-40%	0.35	0.41	0.42	0.45	-1.47	0.38	0.38	0.38	0.46
	-30%	0.34	0.39	0.40	0.44	-1.43	0.37	0.36	0.37	0.45
	-20%	0.32	0.38	0.39	0.42	-1.38	0.36	0.35	0.35	0.44
	-10%	0.31	0.37	0.38	0.41	-1.33	0.35	0.34	0.34	0.42

Price of:	Change of:	Quantity of: Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Eggs	Shrimp	Beans and Rice	Opt-Out
	+10%	0.28	0.34	0.35	0.38	-1.23	0.32	0.31	0.31	0.39
	+20%	0.27	0.32	0.33	0.37	-1.17	0.30	0.29	0.30	0.38
	+30%	0.26	0.31	0.32	0.35	-1.12	0.29	0.28	0.28	0.36
	+40%	0.25	0.29	0.30	0.33	-1.07	0.27	0.27	0.27	0.35
	+50%	0.23	0.28	0.29	0.32	-1.02	0.26	0.25	0.25	0.33
Eggs	-50%	0.15	0.17	0.18	0.19	0.17	-0.64	0.16	0.16	0.20
	-40%	0.15	0.17	0.17	0.19	0.17	-0.63	0.16	0.16	0.19
	-30%	0.15	0.17	0.17	0.19	0.16	-0.62	0.16	0.16	0.19
	-20%	0.15	0.16	0.17	0.18	0.16	-0.61	0.15	0.15	0.19
	-10%	0.14	0.16	0.17	0.18	0.16	-0.60	0.15	0.15	0.18
	+10%	0.14	0.15	0.16	0.17	0.15	-0.58	0.15	0.14	0.18
	+20%	0.13	0.15	0.16	0.17	0.15	-0.57	0.14	0.14	0.18
	+30%	0.13	0.15	0.15	0.17	0.14	-0.55	0.14	0.14	0.17
	+40%	0.13	0.15	0.15	0.16	0.14	-0.54	0.14	0.14	0.17
	+50%	0.13	0.14	0.15	0.16	0.14	-0.53	0.13	0.13	0.17
Shrimp	-50%	0.33	0.36	0.38	0.40	0.35	0.35	-8.67	0.36	0.41
	-40%	0.29	0.32	0.33	0.35	0.31	0.30	-7.57	0.32	0.36
	-30%	0.25	0.27	0.29	0.31	0.26	0.26	-6.52	0.27	0.31
	-20%	0.21	0.23	0.25	0.26	0.22	0.22	-5.57	0.23	0.27
	-10%	0.18	0.20	0.21	0.22	0.19	0.19	-4.72	0.20	0.23
	+10%	0.13	0.14	0.15	0.16	0.13	0.13	-3.36	0.14	0.16
	+20%	0.11	0.12	0.13	0.14	0.11	0.11	-2.84	0.12	0.14
	+30%	0.09	0.10	0.11	0.12	0.10	0.10	-2.41	0.10	0.12
	+40%	0.08	0.09	0.09	0.10	0.08	0.08	-2.07	0.08	0.10
	+50%	0.07	0.07	0.08	0.09	0.07	0.07	-1.78	0.07	0.09
Beans and Rice	-50%	0.09	0.10	0.11	0.11	0.10	0.10	0.10	-1.27	0.12
	-40%	0.09	0.10	0.10	0.11	0.09	0.09	0.10	-1.22	0.11
	-30%	0.08	0.09	0.10	0.10	0.09	0.09	0.09	-1.17	0.11
	-20%	0.08	0.09	0.09	0.10	0.09	0.09	0.09	-1.12	0.10
	-10%	0.08	0.09	0.09	0.10	0.08	0.08	0.09	-1.08	0.10
	+10%	0.07	0.08	0.08	0.09	0.08	0.08	0.08	-0.99	0.09
	+20%	0.07	0.07	0.08	0.08	0.07	0.07	0.08	-0.95	0.09
	+30%	0.06	0.07	0.08	0.08	0.07	0.07	0.07	-0.91	0.08
	+40%	0.06	0.07	0.07	0.08	0.07	0.07	0.07	-0.87	0.08
	+50%	0.06	0.07	0.07	0.07	0.06	0.06	0.07	-0.83	0.08

Appendix Table D.4. MDM Variant 2 Arc Elasticity Estimates

Price of:	Change of:	Quantity of: Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Whey Protein	Beans and Rice	Opt-Out
Ribeye Steak	-50%	-9.86	0.72	0.73	0.77	0.69	0.62	0.67	0.68	0.79
	-40%	-8.86	0.65	0.66	0.70	0.61	0.55	0.60	0.60	0.72
	-30%	-7.76	0.57	0.58	0.62	0.53	0.49	0.53	0.52	0.64
	-20%	-6.65	0.49	0.50	0.54	0.45	0.42	0.46	0.45	0.56
	-10%	-5.60	0.41	0.42	0.46	0.38	0.36	0.40	0.37	0.48
	+10%	-3.85	0.28	0.29	0.32	0.26	0.25	0.28	0.25	0.34
	+20%	-3.18	0.24	0.24	0.27	0.21	0.20	0.23	0.21	0.28
	+30%	-2.64	0.20	0.20	0.22	0.18	0.17	0.19	0.17	0.24
	+40%	-2.22	0.16	0.16	0.19	0.15	0.14	0.16	0.14	0.20
	+50%	-1.88	0.14	0.14	0.16	0.12	0.12	0.14	0.12	0.17
Ground Beef	-50%	0.41	-1.56	0.53	0.57	0.47	0.39	0.48	0.46	0.59
	-40%	0.39	-1.52	0.52	0.57	0.46	0.38	0.47	0.45	0.59
	-30%	0.38	-1.48	0.51	0.56	0.45	0.37	0.45	0.43	0.58
	-20%	0.36	-1.44	0.49	0.54	0.43	0.35	0.44	0.42	0.57
	-10%	0.35	-1.39	0.48	0.53	0.42	0.34	0.43	0.40	0.55
	+10%	0.32	-1.28	0.44	0.49	0.38	0.31	0.39	0.37	0.52
	+20%	0.30	-1.23	0.42	0.48	0.37	0.30	0.38	0.35	0.50
	+30%	0.29	-1.17	0.41	0.46	0.35	0.28	0.36	0.33	0.48
	+40%	0.27	-1.11	0.39	0.44	0.33	0.27	0.34	0.32	0.46
	+50%	0.26	-1.06	0.37	0.42	0.31	0.25	0.32	0.30	0.44
Pork Chop	-50%	0.26	0.35	-2.34	0.40	0.32	0.25	0.30	0.31	0.41
	-40%	0.25	0.33	-2.22	0.38	0.30	0.24	0.28	0.29	0.39
	-30%	0.23	0.31	-2.10	0.36	0.28	0.22	0.27	0.27	0.38
	-20%	0.22	0.29	-1.98	0.34	0.27	0.21	0.25	0.26	0.36
	-10%	0.20	0.28	-1.86	0.32	0.25	0.19	0.24	0.24	0.34
	+10%	0.18	0.24	-1.62	0.29	0.22	0.17	0.20	0.21	0.30
	+20%	0.16	0.23	-1.52	0.27	0.20	0.16	0.19	0.19	0.28
	+30%	0.15	0.21	-1.41	0.25	0.19	0.14	0.18	0.18	0.26
	+40%	0.14	0.20	-1.32	0.24	0.18	0.13	0.17	0.17	0.25
	+50%	0.13	0.18	-1.22	0.22	0.16	0.12	0.15	0.16	0.23
Bacon	-50%	0.21	0.28	0.29	-3.55	0.25	0.20	0.25	0.24	0.34
	-40%	0.19	0.25	0.27	-3.26	0.23	0.18	0.23	0.22	0.31
	-30%	0.17	0.23	0.25	-2.98	0.21	0.16	0.21	0.20	0.29
	-20%	0.16	0.21	0.22	-2.71	0.19	0.15	0.19	0.18	0.26
	-10%	0.14	0.19	0.20	-2.46	0.17	0.13	0.17	0.16	0.24
	+10%	0.12	0.16	0.17	-2.03	0.14	0.11	0.14	0.13	0.20
	+20%	0.10	0.14	0.15	-1.84	0.13	0.10	0.13	0.12	0.18
	+30%	0.09	0.13	0.14	-1.67	0.11	0.09	0.12	0.11	0.17
	+40%	0.09	0.12	0.13	-1.52	0.10	0.08	0.11	0.10	0.15

Price of:	Change of:	Quantity of: Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Whey Protein	Beans and Rice	Opt-Out
	+50%	0.08	0.11	0.12	-1.39	0.09	0.07	0.10	0.09	0.14
Chicken Breast	-50%	0.37	0.47	0.49	0.52	-1.15	0.38	0.41	0.42	0.54
	-40%	0.36	0.47	0.48	0.51	-1.13	0.37	0.41	0.42	0.54
	-30%	0.36	0.46	0.48	0.51	-1.11	0.36	0.40	0.41	0.53
	-20%	0.35	0.45	0.47	0.50	-1.09	0.35	0.39	0.40	0.53
	-10%	0.34	0.44	0.46	0.49	-1.07	0.34	0.38	0.39	0.52
	+10%	0.31	0.42	0.44	0.47	-1.01	0.32	0.36	0.36	0.50
	+20%	0.30	0.41	0.42	0.46	-0.98	0.31	0.35	0.35	0.49
	+30%	0.29	0.39	0.41	0.45	-0.95	0.30	0.34	0.34	0.47
	+40%	0.28	0.38	0.40	0.43	-0.92	0.29	0.33	0.33	0.46
	+50%	0.27	0.37	0.38	0.42	-0.89	0.28	0.31	0.31	0.45
Plant-Based Patty	-50%	0.16	0.18	0.18	0.20	0.17	-6.74	0.20	0.17	0.20
	-40%	0.14	0.16	0.16	0.17	0.15	-5.88	0.18	0.15	0.18
	-30%	0.12	0.14	0.14	0.15	0.13	-5.11	0.16	0.13	0.15
	-20%	0.11	0.12	0.12	0.13	0.11	-4.42	0.14	0.11	0.13
	-10%	0.09	0.10	0.10	0.11	0.10	-3.83	0.12	0.10	0.12
	+10%	0.07	0.08	0.08	0.08	0.07	-2.88	0.09	0.07	0.09
	+20%	0.06	0.07	0.07	0.07	0.06	-2.51	0.08	0.06	0.08
	+30%	0.05	0.06	0.06	0.06	0.06	-2.20	0.07	0.06	0.07
	+40%	0.04	0.05	0.05	0.06	0.05	-1.93	0.06	0.05	0.06
	+50%	0.04	0.05	0.05	0.05	0.04	-1.70	0.05	0.04	0.05
Whey Protein	-50%	0.21	0.26	0.26	0.28	0.24	0.22	-30.77	0.24	0.29
	-40%	0.16	0.20	0.20	0.22	0.18	0.17	-23.40	0.18	0.22
	-30%	0.12	0.15	0.14	0.16	0.13	0.13	-17.41	0.13	0.17
	-20%	0.09	0.11	0.11	0.12	0.10	0.10	-12.75	0.10	0.13
	-10%	0.07	0.08	0.08	0.09	0.07	0.07	-9.28	0.07	0.09
	+10%	0.03	0.04	0.04	0.05	0.04	0.04	-5.03	0.04	0.05
	+20%	0.03	0.03	0.03	0.04	0.03	0.04	-3.80	0.03	0.04
	+30%	0.02	0.03	0.02	0.03	0.02	0.03	-2.96	0.02	0.03
	+40%	0.02	0.02	0.02	0.02	0.02	0.02	-2.37	0.02	0.02
	+50%	0.01	0.02	0.02	0.02	0.01	0.02	-1.95	0.02	0.02
Beans and Rice	-50%	0.10	0.12	0.12	0.13	0.11	0.10	0.11	-1.05	0.14
	-40%	0.09	0.12	0.12	0.13	0.11	0.10	0.11	-1.02	0.14
	-30%	0.09	0.11	0.12	0.13	0.10	0.09	0.11	-0.99	0.13
	-20%	0.09	0.11	0.11	0.12	0.10	0.09	0.10	-0.96	0.13
	-10%	0.08	0.11	0.11	0.12	0.10	0.09	0.10	-0.93	0.12
	+10%	0.08	0.10	0.10	0.11	0.09	0.08	0.09	-0.86	0.12
	+20%	0.07	0.10	0.10	0.11	0.09	0.08	0.09	-0.84	0.11
	+30%	0.07	0.09	0.10	0.10	0.08	0.08	0.08	-0.81	0.11
	+40%	0.07	0.09	0.09	0.10	0.08	0.07	0.08	-0.78	0.11

		Quantity of:								
Price of:	Change of:	Ribeye Steak	Ground Beef	Pork Chop	Bacon	Chicken Breast	Plant-Based Patty	Whey Protein	Beans and Rice	Opt-Out
	+50%	0.07	0.09	0.09	0.10	0.08	0.07	0.08	-0.75	0.10