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No Beef with Increased Media: The Impacts of Fitness Media on US Meat Demand

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Economic research has not assessed the relationship between physical exercise and protein consumption, which is frequently discussed across media platforms. This study uses news articles related to physical exercise to construct fitness-related media indices. Incorporating these indices and national prices and disappearance for meat from 1993 to 2022, a Rotterdam demand model was used to estimate news media elasticities. We find little evidence that news media attention to physical exercise has direct or spillover effects on beef, pork, or chicken consumption. Further, news media information does not shift demand for food into or out of the aggregate meat complex.

Key words: physical exercise, protein, Rotterdam

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 (US 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).[1] 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 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 research in this area, our objective is to quantify how news media discussing that relationship has impacted US demand for meat from 1993 to 2022.

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 US Department of Agriculture Dietary Guidelines for Americans (US Department of Agriculture and US Department of Health and Human Services, 2020). The

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

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%) 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 g 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-lb individual (roughly 81.6 kg) would be recommended to consume 65.3 g of protein per day based on this RDA. As an example, this equates to 0.46 lb (211 g) of boneless, skinless, and roasted chicken breast (US 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 1.2–2.2 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 1.4–2.0 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 Academies of Sciences, Engineering, and Medicine (2006), consumption of 1.2–2.2 g/kg would entail a 180-lb exercising individual eating 98.0–179.6 g of protein per day. This corresponds to between 0.70–1.28 lb (316–579 g) of boneless, skinless, and roasted chicken breast (US Department of Agriculture, 2019), substantially higher consumption than that recommended for an individual of similar weight who does not exercise.

The extent to which health-focused US 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, 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 US demand for beef, pork, and chicken at a national level. As no data collection effort has been conducted to track US 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.[2] 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.

[2] 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.

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 (2001) likewise incorporated a media index in an AIDS framework to evaluate the impacts of negative television press on the demand for fresh meat in Belgium. In contrast to Burton and Young (1996), their media index was a sum of negative television news reports less positive news reports and was compared to actual television advertising expenses. Simulating the impact of negative television 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 precommitted 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 those created by 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 US meat demand.

Marsh, Schroeder, and Mintert (2004) again used Burton and Young's (1996) linear aggregation approach to construct news media indices with a focus on the impact of product recall information on US demand for beef, pork, and poultry. Own- and cross-commodity impacts of media coverage were assessed with Piggott 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's (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 US meat demand. Other approaches have since been developed to estimate meat demand response to media information; these have varied in functional forms and commodities analyzed (Yadavalli and Jones, 2014; Wang and De Beville, 2017). In general, these studies have 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

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

where u denotes utility, $\boldsymbol{x}$ 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 $\boldsymbol{H}$ 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 $\boldsymbol{H}$. 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 affect not only substitution patterns between meat proteins but also substitution into or out of the meat complex entirely.[3] 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 0 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's (1964) and Theil's (1965) Rotterdam model is estimated with the model's share equations:

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

where $\overline{w}_{it} = 0.5(w_{i,t} - w_{i,t-1})$ is the average budget share of the ith good ($i = 1, \ldots, n$); Δ is the first difference operator; x_{it} is the per capita consumption of good i in time t; $\Delta\ln(\overline{q}_t)$ is the Divisia volume index, where $\Delta\ln(\overline{q}_t) = \sum_{j=1}^{n}\overline{w}_{it}\Delta\ln(x_{it})$; 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 mth 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 jth equation was dropped to avoid singularity of the variance–covariance matrix of error terms. Coefficients for the jth 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

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

and ensure that the sum of budget shares across all included goods always equal 1. Homogeneity and symmetry restrictions are imposed by

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

Homogeneity of degree 0 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.

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

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

$$\eta_i = \frac{\beta_i}{w_i} \text{ and } \varepsilon_{ij} = \frac{c_{ij}}{w_i}, \tag{5}$$

while shift, or media, elasticities are

$$K_{iml} = \frac{\delta_{im} + \theta_{iml}}{w_i}, \tag{6}$$

which, through incorporating interactions of media index terms with categorical decade terms, allows demand sensitivity to media information to vary over time. Using equation (6), $K_{im0} = \delta_{im}/w_i$ 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 0). 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 include (i) a null correction matrix which restricts all elements to be 0 (i.e., there is no autocorrelation correction; $\rho_{ij} = 0 \forall ij$), (ii) a diagonal correction matrix which restricts off-diagonal elements to be 0 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 in which all elements are allowed to differ individually from 0 ($\rho_{ij} \neq 0 \forall ij$). 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 used to provide our results. Based on the sequence of tests discussed previously, we treated prices and expenditure as predetermined (i.e., exogenous) over the study period and did not include off-diagonal autocorrelation correction elements in our modeling.

Wald tests on media-related parameters were 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 would not be overly useful in this assessment. We further used the variance of Wald-type test statistics to obtain standard errors for all elasticity estimates. Gregory and Veall (1985) and Phillips and Park (1988) noted 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 was 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 US Bureau of Labor Statistics (BLS) retail price data (US Department of Agriculture, 2023a). Monthly retail prices were aggregated to quarterly prices by taking a simple average and were then deflated by the US Bureau of Labor Statistics (2023b) consumer price index (CPI) for food. Beef, pork, and chicken quantities are quarterly retail weight per capita disappearance (in pounds) obtained from the US Department of Agriculture (2023b). 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 US 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, are from the US Bureau of Labor Statistics (2023a) CPI for energy series, a Yahoo! Finance (2023) archive of closing values for the 13-week treasury bill, a Livestock Marketing Information Center (2023) aarchive 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 (US Department of Agriculture, 2023c).[4]

[4] The AMS_3658 report was formerly the SJ_LS711 report. Meat production data were obtained from the USDA National Agricultural Statistics Service Quick Stats database.

Media Indices

ProQuest Central (ProQuest LLC, 2024) was used to construct indices capturing public news information on the relationship between meat consumption and physical exercise. Three indices were created and are included in equation (2) as H_m. We limited data collection to articles appearing in the ProQuest Central US Major Dailies database, which 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 US Major Dailies database, we capture news media information that is accessible to most US residents while omitting information from smaller local news outlets that (i) is of little relevance on a national scale, (ii) is burdensome—if not infeasible—to collect, and (iii) 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 often require paid subscriptions, we 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).[5] 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 US 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* for 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, which had been present in our initial search efforts.[6]

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 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 (0.41–0.48), easing concern that news articles are being captured in multiple indices to a substantial

[5] "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 whether 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.

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

Table 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	54
Pork news media index	13.88	4.50	2	27
Chicken news media index	60.22	12.69	32	97

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

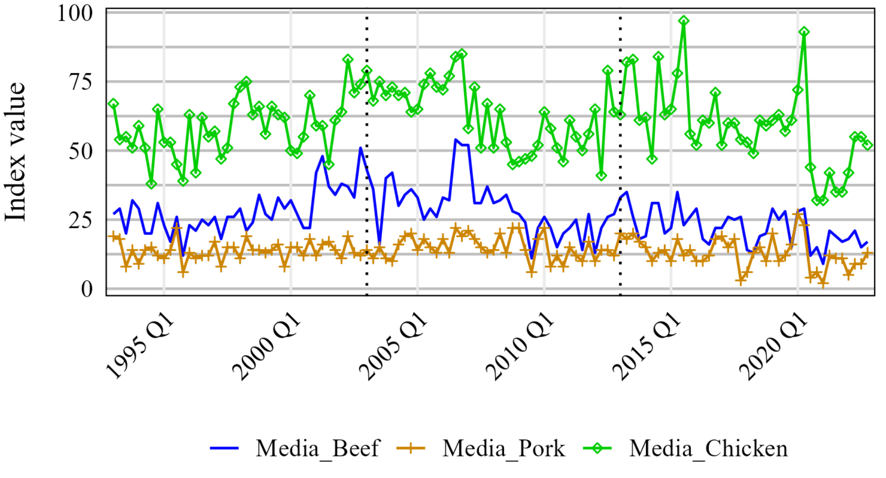

Figure 1. Species-Specific Quarterly News Media Indices, 1993–2022

degree.[7] Ultimately, the main interest is in net effects on aggregate beef, pork, and chicken demand, making the narrower distinctions of directionality and multiprotein information beyond the scope of this study.

Descriptive Statistics

Table 1 reports descriptive statistics for real retail meat prices, per capita meat disappearance, and news media indices. In real terms, beef, pork, and chicken prices averaged $2.12/lb, $1.50/lb, and $0.86/lb, respectively, from 1993 through 2022. Per capita disappearance averaged 15.5 lb, 12.5 lb, and 20.6 lb per quarter for beef, pork, and chicken, respectively, over the same period.

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

[7] 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 2. Coefficient Estimates of Rotterdam Model, Quarterly Data, 1993–2022 (N = 120)

	Share Equation		
Dependent Variable	**Beef**	**Pork**	**Chicken**
Intercept	−3.70E−04*** (5.00E−05)	4.60E−04*** (3.10E−05)	−1.80E−04*** (2.80E−05)
Expenditure	4.21E−03* (2.17E−03)	−4.60E−04 (1.42E−03)	9.69E−04 (1.37E−03)
Beef Price	−3.94E−03*** (5.74E−04)		
Pork Price	4.16E−04 (3.61E−04)	−1.66E−03*** (5.22E−04)	
Chicken Price	−4.30E−04 (3.61E−04)	1.84E−04 (4.14E−04)	−1.80E−04 (6.36E−04)
Other Food Price	3.95E−03*** (8.21E−04)	1.06E−03 (6.90E−04)	4.26E−04 (7.66E−04)
Quarter 1 Dummy	2.95E−04*** (7.70E−05)	−8.90E−04*** (4.50E−05)	2.74E−04*** (3.40E−05)
Quarter 2 Dummy	8.23E−04*** (5.70E−05)	−6.40E−04*** (3.80E−05)	3.22E−04*** (3.60E−05)
Quarter 3 Dummy	3.79E−04*** (7.90E−05)	−2.90E−04*** (4.80E−05)	2.10E−04*** (3.70E−05)
Decade Dummy (2003–2012)	−3.00E−05 (3.10E−05)	−2.00E−05 (2.10E−05)	−3.00E−05 (2.40E−05)
Decade Dummy (2013–2022)	−3.06E−06 (3.20E−05)	8.37E−06 (2.20E−05)	−1.21E−06 (2.40E−05)
Media_Beef	−2.00E−05 [δ_{11}] (1.30E−04)	−1.20E−04 [δ_{21}] (8.40E−05)	−1.20E−04 [δ_{31}] (7.70E−05)
Media_Pork	5.60E−05 [δ_{12}] (9.80E−05)	6.70E−05 [δ_{22}] (6.20E−05)	5.60E−05 [δ_{32}] (5.20E−05)
Media_Chicken	−9.00E−05 [δ_{13}] (1.85E−04)	1.58E−04 [δ_{23}] (1.17E−04)	−4.00E−05 [δ_{33}] (1.03E−04)
Media_Beef × Decade (2003–2012)	−1.20E−04 [θ_{11_1}] (1.62E−04)	1.09E−04 [θ_{21_1}] (1.05E−04)	3.20E−05 [θ_{31_1}] (9.50E−05)
Media_Pork × Decade (2003–2012)	5.00E−05 [θ_{12_1}] (1.36E−04)	−1.80E−04** [θ_{22_1}] (8.60E−05)	−7.00E−05 [θ_{32_1}] (7.30E−05)
Media_Chicken × Decade (2003–2012)	1.81E−04 [θ_{13_1}] (2.77E−04)	−2.10E−04 [θ_{23_1}] (1.73E−04)	1.34E−04 [θ_{33_1}] (1.42E−04)
Media_Beef × Decade (2013–2022)	−1.00E−05 [θ_{11_2}] (1.70E−04)	7.80E−05 [θ_{21_2}] (1.10E−04)	3.00E−05 [θ_{31_2}] (1.01E−04)
Media_Pork × Decade (2013–2022)	−1.10E−04 [θ_{12_2}] (1.16E−04)	−1.20E−04 [θ_{22_2}] (7.40E−05)	−4.00E−05 [θ_{32_2}] (6.30E−05)
Media_Chicken × Decade (2013–2022)	−2.00E−04 [θ_{13_2}] (2.47E−04)	−3.50E−04** [θ_{23_2}] (1.60E−04)	4.00E−05 [θ_{33_2}] (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)
Adjusted R^2	0.71	0.88	0.55
Log-likelihood value	2,664.34		

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level. Values in parenthesis are standard errors. Values in square brackets are news media-related parameter names. The default (i.e., dropped) quarter dummy is Quarter 4, while the default decade dummy is the 1993–2002 period.

experienced a value of 0 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 depicts values of the beef, pork, and chicken news media indices over time.

Index values vary over time for each species, prompting the inclusion of decade and decade–media interaction regressors in equation (2).[8] *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 average article counts of 13.7, 15.0, and 13.0 per quarter in the same decades. *Media_Chicken*, though still declining in the 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, 2003–2012, 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 available in Table S1 in the online supplement (see www.jareonline.org).

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 2 presents 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 that the model captures 72%, 88%, and 55% 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.

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. Table 3 presents the results of the Wald tests. From the estimates for *Media_Beef*, *Media_Pork*, and *Media_Chicken* shown in Table 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 3 results indicate these influences were likewise not statistically different from 0 in the succeeding 2 decades (5% confidence level).

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 $\delta_{11} + \theta_{11\_2} + \delta_{12} + \theta_{12\_2} + \delta_{13} + \theta_{13\_2} = 0$ 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.

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[8] We elected to use broad decade and decade–media interactions rather than shorter time intervals to (i) reduce model complexity and retain degrees of freedom when conducting Hausman specification tests and (ii) bypass potential endogeneity of interval selection and media impacts (e.g., the 5-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.

Table 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
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	$\delta_{33} + \theta_{33\_1} = 0$	0.372
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

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%, respectively. The remainder of this study focuses on the elasticity estimates, presented in Table 4.

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 0 at a confidence level of at least 10%. 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 5% level of confidence, with beef, pork, and other food being statistically different than 0. 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 0 and only at the 10% level of confidence. In the 2003–2012 period, a 1% increase in news media articles related to pork and physical exercise was associated with a 0.02% decrease in national pork disappearance. This

Table 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	−0.009	0
News media elasticities, 2003–2012				
Media_Beef	−0.0157	−0.0014	−0.0181	0.0002
Media_Pork	0.0116	−0.0208*	−0.002	0
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*	−0.001	0.0005*

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% 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.
[a]Indicates expenditure elasticities that are statistically different than 1.0 at the 5% level.
[b]Indicates compensated own-price elasticities that are statistically different than -1.0 at the 5% level.

result indicates a multidirectional 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 that 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, 0.

While news media elasticity estimates were only periodically statistically significant (10% 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%), which, when multiplied by the corresponding news media elasticity for pork, yielded a 4.16% reduction in national pork disappearance. Of note, however, is the small number of articles included in *Media_Pork* in Quarters 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% (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%, respectively. The corresponding increase in other food disappearance over the same quarters was relatively smaller in magnitude, at just 0.04%. 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 US meat industry. We emphasize, however, that the results of this study indicate only sporadic news media influence on meat demand (at the 10% 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 30 years of price and disappearance data prior to the 2019 coronavirus (i.e., COVID-19) pandemic.[9] Tables S2 and S3 in the online supplement report the elasticity estimates derived from these alternative Rotterdam specifications. 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—must be present in the article. Supplementary Figure S1 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.[10] The second alternative maintained the original news media indices but differed in the period of analysis. Specifically, data from 1990–2019 were used 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 (10% 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 chicken 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).

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[9] Additional sensitivity assessments included (i) constructing news media indices as an annual rolling sum of articles, (ii) constructing news media indices as a cumulative sum of articles, (iii) omitting decade and news media interaction terms, and (iv) using an "aggregate" media index that included all articles related to protein, beef, pork, or chicken and exercise. These results are in Tables S4–S7 in the online supplement.

[10] The adjusted beef and pork news media indices experienced values of 0 in five quarters in the 1993–2022 period. For these quarters, 0 values were replaced with values of 1. 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 United States 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) that the cross-commodity impact of physical exercise- and chicken-related news media on the demand for pork was statistically significant (10% confidence) in the 2013–2022 period but not economically meaningful, (ii) that other own- and cross-commodity impacts of exercise-related news media were absent, and (iii) that news media information on physical exercise and meat consumption did not shift US 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 to be 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 US 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 0 effects.

Leveraging available data on national US meat purchases and media information, this study provides the first known economic assessment of physical exercise-related news media and its impact on US 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 US 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.

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References

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

Berndt, E. R., and N. E. Savin. 1975. "Estimation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances." *Econometrica* 43(5-6):937–957. doi: 10.2307/1911336.

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.

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.

Condor, B. 1995, April 19. "Protein's Winning Ways." *Chicago Tribune.* Available online at https://www.chicagotribune.com/1995/04/19/proteins-winning-ways/.

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

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.

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

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

Grundy, A. 2022. "Service Annual Survey Shows Continuing Decline in Print Publishing Revenue." Available online at https://www.census.gov/library/stories/2022/06/internet-crushes-traditional-media.html.

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):20. doi: 10.1186/s12970-017-0177-8.

Livestock Marketing Information Center. 2023. "Daily, Weekly & Monthly Corn Futures Prices." Available online at https://lmic.info/.

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.

Meyersohn, N. 2023, February 28. "Americans Have Changed the Way They Exercise. Here's How Gyms Are Adapting." *CNN.* Available online at https://www.cnn.com/2023/02/28/business/gym-exercise-free-weights-cardio/index.html.

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.

Naseer, S., and C. St. Aubin. 2023, November 10. "Newspapers Fact Sheet." *Pew Research Center.* Available online at https://www.pewresearch.org/journalism/fact-sheet/newspapers/.

National Academies of Sciences, Engineering, and Medicine. 2006. *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*. National Academies Press. doi: 10.17226/11537.

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

Phillips, P. C. B., and J. Y. Park. 1988. "On the Formulation of Wald Tests of Nonlinear Restrictions." *Econometrica* 56(5):1065. 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. doi: 10.1111/j.0092-5853.2004.00569.x.

ProQuest LLC. 2024. "ProQuest Central." Available online at https://about.proquest.com/en/products-services/ProQuest_Central/.

Reynolds, G. 2018, February 7. "Lift Weights, Eat More Protein, Especially if You're over 40." *New York Times* Available online at https://www.nytimes.com/2018/02/07/well/move/lift-weights-eat-more-protein-especially-if-youre-over-40.html.

———. 2023, May 24. "5 Things to Know about Protein." *Washington Post* Available online at https://www.washingtonpost.com/wellness/2023/05/24/protein-weight-loss-muscle-facts/.

Stone, M. H., M. Stone, and W. A. Sands. 2007. *Principles and Practice of Resistance Training*. Human Kinetics.

Theil, H. 1965. "The Information Approach to Demand Analysis." *Econometrica* 33(1):67. doi: 10.2307/1911889.

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.

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. doi: 10.22004/ag.econ.61056.

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.

US Bureau of Economic Analysis. 2023. "Personal Consumption Expenditures: Food." Available online at https://fred.stlouisfed.org/series/DFXARC1M027SBEA [Accessed November 28, 2023].

US Bureau of Labor Statistics. 2016, August 4. "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.

———. 2023a. "Energy in U.S. City Average, All Urban Consumers, Not Seasonally Adjusted." Available online at https://data.bls.gov/timeseries/CUUR0000SA0E [Accessed November 28, 2023].

———. 2023b. "Food in U.S. City Average, All Urban Consumers, Not Seasonally Adjusted." Available online at https://data.bls.gov/timeseries/CUUR0000SAF1 [Accessed November 28, 2023].

US Department of Agriculture. 2019. "Chicken, Broilers or Fryers, Breast, Meat Only, Cooked, Roasted." Available online at https://fdc.nal.usda.gov/fdc-app.html#/food-details/171477/nutrients [Accessed November 27, 2023].

———. 2023a. "Historical Monthly Price Spread Data for Beef, Pork, Broilers." USDA Economic Research Service. Available online at https://www.ers.usda.gov/data-products/meat-price-spreads/ [Accessed November 28, 2023].

———. 2023b. "Meat Supply and Disappearance Tables, Historical." USDA Economic Research Service. Available online at https://www.ers.usda.gov/data-products/livestock-and-meat-domestic-data/ [Accessed November 28, 2023].

———. 2023c. "QuickStats." USDA National Agricultural Statistics Service. Available online at https://quickstats.nass.usda.gov/?source_desc=CENSUS [Accessed November 28, 2023].

US Department of Agriculture, and US Department of Health and Human Services. 2020. *Dietary Guidelines for Americans, 2020–2025*, 9 ed. Washington, DC: US Department of Agriculture.

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.

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.

Weersink, A., M. Von Massow, N. Bannon, J. Ifft, J. Maples, K. McEwan, M. G. 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* 188:103039. doi: 10.1016/j.agsy.2020.103039.

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. doi: 10.1186/1550-2783-3-1-7.

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 November 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.

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Online Supplement: No Beef with Increased Media: The Impacts of Fitness Media on US Meat Demand

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Table S1. 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

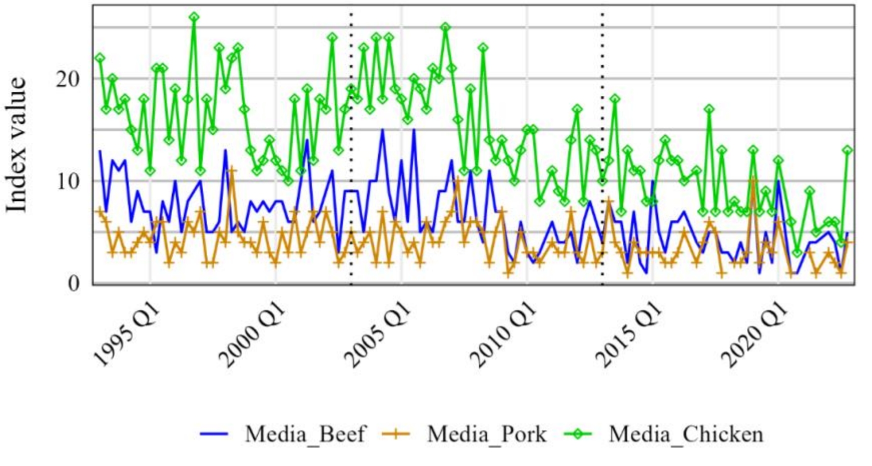

Figure S1. Species-Specific Quarterly News Media Indices, 1993–2022—Adjusted Indices (“AND fat”)

The material contained herein is supplementary to the article named in the title and published in the *Journal of Agricultural and Resource Economics* (*JARE*).

Table S2. 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
Media_Chicken	−0.0120	−0.0227**	−0.0013	0.0002**

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% 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.

[a] Indicates expenditure elasticities that are statistically different than 1.0 at the 5% level.

[b] Indicates compensated own-price elasticities that are statistically different than -1.0 at the 5% level.

Table S3. 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

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% 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.

[a] Indicates expenditure elasticities that are statistically different than 1.0 at the 5% level.

[b] Indicates compensated own-price elasticities that are statistically different than -1.0 at the 5% level.

Table S4. 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**

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% 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.

[a] Indicates expenditure elasticities that are statistically different than 1.0 at the 5% level.

[b] Indicates compensated own-price elasticities that are statistically different than -1.0 at the 5% level.

Table S5. 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)				
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

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% 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.
[a] Indicates expenditure elasticities that are statistically different than 1.0 at the 5% level.
[b] Indicates compensated own-price elasticities that are statistically different than -1.0 at the 5% level.

Table S6. 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

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% 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.
[a] Indicates expenditure elasticities that are statistically different than 1.0 at the 5% level.
[b] Indicates compensated own-price elasticities that are statistically different than -1.0 at the 5% level.

Table S7. 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***

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% 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.
[a] Indicates expenditure elasticities that are statistically different than 1.0 at the 5% level.
[b] Indicates compensated own-price elasticities that are statistically different than -1.0 at the 5% level.

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%. 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.