

U.S. Meat Demand: Household Dynamics and Media Information Impacts

Glynn T. Tonsor, James R. Mintert, and Ted C. Schroeder

This article uses national, quarterly data to examine U.S. meat demand using the Rotterdam model. We investigate the effect of multiple information indices linking different health concerns with diet, changes in household dynamics, and meat recall information. Medical journal articles linking iron, zinc, and protein with health and diet increase beef and poultry demand, whereas articles dealing with fat, cholesterol, and diet concerns reduce beef demand. Increasing consumption of food away from home enhances pork and poultry demand while reducing beef demand. Combined, these results provide a more complete and current understanding of the impact of multiple information factors faced by U.S. consumers.

Key words: Atkins diet, female workforce, food away from home, food safety, health concerns, meat recalls, U.S. meat demand

Introduction

Meat demand is complex, multi-faceted, and evolving as new and important demand drivers develop over time. A number of factors combine to shape consumer meat demand, including traditional economic determinants such as relative prices and consumer income, as well as nontraditional determinants such as emerging health, nutrition, diet, and food safety information; changing product characteristics, new product developments or offerings; and shifts in consumer demographics and lifestyles. Over time, new dimensions of demand may arise and the relative importance of determinants ultimately may change in response to new information. For example, discovering new health benefits accruing from consuming a product may alter the structure of empirical demand estimates. Ongoing demand estimation is important for informed policy decision making and for industry stakeholder strategic management because of the dynamic nature of meat demand determinants.

The purpose of this study is to provide a comprehensive and updated assessment of quarterly U.S. consumer meat demand determinants. We consider changes in meat demand as information on human health impacts of zinc, iron, and protein from meat consumption has become more prevalent. In addition, we estimate the impacts on meat demand of information regarding low-carbohydrate diets.

A large body of research has considered various meat demand shifters, including effects of food safety and product recall news (Piggott and Marsh, 2004; Marsh, Schroeder, and Mintert, 2004; Burton and Young, 1996); health and related diet information (Adhikari et al.,

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2006; Kinnucan et al., 1997; Miljkovic and Mostad, 2005; Rickertsen, Kristofersson, and Lothe, 2003; Brown and Schrader, 1990; Chang and Kinnucan, 1991; Capps and Schmitz, 1991); generic advertising (Brester and Schroeder, 1995; Kinnucan et al., 1997; Rickertsen, 1998; Piggott et al., 1996; Park and Capps, 2002); pre-committed demand (Piggott and Marsh, 2004; Tonsor and Marsh, 2007); and structural changes (Eales and Unnevehr, 1988; Rickertsen, 1996; Moschini and Meilke, 1989; Davis, 1997).

In recent years, substantial changes in potentially important meat demand determinants have occurred. For example, low-carbohydrate diets were the focus of much media attention and became very popular in the late 1990s and early 2000s, with relatively few adherents prior to the mid-1990s. Moreover, published information linking meat consumption with nutritional benefits of zinc, iron, and protein intake has increased. Conversely, record numbers of meat recalls and other related food safety events have raised consumer concerns about meat product safety. Also, increased demand for convenience foods and growth in food-away-from-home consumption are affecting consumer eating choices (Capps, Tedford, and Havlicek, 1985; Byrne, Capps, and Saha, 1996). Understanding how new information on different topics impacts meat demand is important for both policy and industry production decisions. Our study estimates the impacts of these factors on the demand for meat by U.S. consumers.

We provide a brief review of relevant prior research and develop a conceptual model underlying this research in the next section. The empirical model and a description of the data used for the analysis follow. The results of the study are then presented. We conclude with an overview of the implications of our research.

Literature Review

Several studies have considered food safety and health information effects on meat demand. Using food safety indices constructed from popular press newspaper articles, Piggott and Marsh (2004) found small, contemporaneous effects of food safety events on U.S. meat demand. Marsh, Schroeder, and Mintert (2004) estimated a Rotterdam model incorporating Food Safety Inspection Service (FSIS) recall information and found a small, but statistically significant decline in meat demand and an increase in demand for non-meat goods following meat recalls. Ishida, Ishikawa, and Fukushima (2010) compared the impact of bovine spongiform encephalopathy (BSE) and avian flu on Japanese meat demand by examining gradual demand shift patterns using an almost ideal demand system (AIDS). Japanese demand for beef and chicken declined following BSE and bird flu scares, respectively, and the demand for pork and fish increased. In summary, existing work suggests food safety events have had statistically significant impacts on meat demand. The most recent analyses of U.S. consumers, however, only incorporated data through 1999. An increase in food safety events in recent years suggests a need for an updated assessment of food safety impacts on meat demand.

A large body of work also indicates that health information has had a significant impact on food demand. For example, Adhikari et al. (2006), Brown and Schrader (1990), Capps and Schmitz (1991), Kinnucan et al. (1997), Chang and Kinnucan (1991), and Rickertsen, Kristofersson, and Lothe (2003) all used published medical research to build indices that proxy health information to which consumers have been exposed. Kinnucan et al. (1997), Capps and Schmitz (1991), and Brown and Schrader (1990) found statistically significant effects from cholesterol information on U.S. meat and egg demand, respectively. Chang and Kinnucan (1991) observed that cholesterol information reduced Canadian demand for butter. Adhikari

et al. (2006) found cholesterol information reduced U.S. demand for beef and pork and increased the demand for chicken. Rickertsen, Kristofersson, and Lothe (2003) concluded that chicken demand in Finland, Norway, and Sweden increased as information about cholesterol was more widely disseminated. Using a range of time-series methods (e.g., cointegration, vector error correction, causality tests), Miljkovic and Mostad (2005) found media attention emphasizing low-carbohydrate diets had longer-lasting impacts on beef demand than corresponding media articles focusing on low-fat/low-cholesterol diets.

The thrust of most research regarding health information and meat demand has been on estimating the effects of cholesterol information. Other health issues, such as the benefits of zinc, iron, and protein in diets, have not been included in meat demand analyses, which provides additional motivation for the present study.

Limitations of previous research are twofold. First, the previously noted studies assumed separability of meat demand from “other food” or “non-food” categories. This separability assumption causes adding-up restrictions to implicitly force health information that may enhance demand for one product to reduce the demand of another. Consequently, health information estimates are precluded from having similar impacts across multiple meat products. Second, Adhikari et al. (2006) noted the need for additional research regarding the joint effects of both cholesterol information (as in the above cited studies) and carbohydrate information. Although joint effects were considered by Miljkovic and Mostad (2005), they were not incorporated into a demand system framework. Hence, interrelationships of cholesterol information and carbohydrate information with meat and non-meat demands have been ignored. Our model builds upon prior research and takes these concerns into account by providing a joint evaluation of food safety on multiple meat products and health information factors. These issues are addressed through their inclusion in a demand system framework across meat, non-meat food, and non-food goods.

Kalwij and Salverda (2007) found changes in Norwegian consumer demand patterns to be significantly influenced by household characteristics. Increases in the proportion of employed women with young children significantly affected total budget shares allocated to food and beverages as well as to food consumed away from home. Manrique and Jensen (1997) reported Spanish household expenditures for convenience meats were higher among two-income households. Moreover, Horton and Campbell (1991) found food-away-from-home (FAFH) expenditures represented a larger proportion of food budgets for Canadian households with women employed outside the home. Using annual data from 1960 to 1998 and a linear approximation to the AIDS model, McGuirk et al. (1995) concluded that annual U.S. demand for poultry was enhanced by increasing female workforce participation, primarily at the expense of beef demand. We are unaware of any studies using more recent data or more flexible demand models to examine the impact of female workforce participation or FAFH consumption trends on U.S. meat demand.

Conceptual Model

Let the utility function for any given consumer be well-behaved and represented by $U(\mathbf{x}, \mathbf{q})$, where \mathbf{x} is the vector of quantities consumed and \mathbf{q} is a vector of quality perceptions reflecting available information. We assume the consumer utility maximization problem is given by:

$$(1) \quad \underset{\mathbf{x}, \lambda}{\text{Max}} U(\mathbf{x}, \mathbf{q}) + \lambda(M - \mathbf{p}'\mathbf{x}),$$

where λ is the Lagrange multiplier, M is total expenditure, and \mathbf{p} is a vector of prices.

In the spirit of Mojduska and Caswell (2000), Foster and Just (1989), and Piggott and Marsh (2004), we assume that publicly available information impacts consumer perceptions of product quality. In our analysis of U.S. meat demand, this information may include media or medical information regarding health concerns posed by meat consumption (\mathbf{H}) or government recall announcements regarding the safety of different meat products (\mathbf{R}). As previously noted, Stewart et al. (2005) warned against omitting consumer preferences for convenience in evaluating the demand for food products. Accordingly, we assume that consumer characteristics (\mathbf{C}) associated with product convenience and the value of their time may impact budget allocations. Combining these points with the equation (1) first-order conditions yields the Marshallian demand for good i : $[\mathbf{x}_i^m(\mathbf{p}, M, \mathbf{H}, \mathbf{R}, \mathbf{C})]$.

Empirical Application

The primary factors for model selection include both theoretical and feasible empirical components. In our application, we use the absolute-price version of the Rotterdam model consisting of five equations associated with beef, pork, poultry, non-meat food, and non-food demands.¹ The Rotterdam model has been widely used in meat demand analysis (Kinnucan et al., 1997; Marsh, Schroeder, and Mintert, 2004; Brester and Schroeder, 1995) and is of particular interest here because it easily accommodates inclusion of multiple covariates. The Rotterdam model can be estimated to satisfy adding-up, homogeneity, and symmetry restrictions suggested by demand theory. Furthermore, Kastens and Brester (1996) argued that the Rotterdam may outperform the AIDS model in out-of-sample forecasting accuracy.

Following previous research, the model incorporates variables to control for price, expenditure, and seasonality. Moreover, our empirical model follows the conceptual model above and includes demand shifters that reflect publicly available information regarding health concerns (\mathbf{H}), food safety meat recall announcements (\mathbf{R}), and consumer preferences for convenient food products (\mathbf{C}).² In particular, the i th equation of our estimated model is given by:

$$(2) \quad w_i \Delta \ln(x_i) = a_{io} + \sum_{j=1}^3 d_{ij} D_j + \sum_{j=1}^n c_{ij} \Delta \ln(p_j) + \beta_i \Delta \ln(\bar{q}) + \sum_{k=1}^K \sum_{l=0}^L \lambda_{ikl} \Delta \ln(Z_{kl}) + v_i,$$

where w_i is budget share of the i th good ($i = 1, \dots, 5$); Δ is the standard first-difference operator [e.g., $\Delta \ln(Y_t) = \ln(Y_t) - \ln(Y_{t-1})$ for any variable Y]; x_i is per capita consumption of good i ; D_j is a quarterly dummy variable included for seasonality; p_j is the price of the j th good; $\Delta \ln(\bar{q})$ is the Divisia volume index [$\Delta \ln(\bar{q}) = \sum_{j=1}^n w_j \Delta \ln(x_j)$]; Z_{kl} represents the k th exogenous demand shifter (i.e., \mathbf{H} , \mathbf{R} , and \mathbf{C}) with lag length of l ; v_i is a random error term; and a_{io} , d_{ij} , c_{ij} , β_i , and λ_{ikl} are parameters to be estimated.

¹ In this specification, lamb, veal, finfish, and shellfish fall into the *non-meat food* category. Separate equations more narrowly evaluating these products are not incorporated in the demand system to maintain a more parsimonious model. Moreover, quarterly disappearance data on these products consistent with data available for beef, pork, and poultry are difficult to obtain and suspect in quality (Tonsor and Marsh, 2007; Schroeder et al., 2001; Kinnucan et al., 1997).

² We chose not to incorporate generic advertising and promotion, as previous research applying similar demand system approaches to disappearance data has found small, insignificant effects on U.S. meat demand (Brester and Schroeder, 1995). Nonetheless, we recognize the potential for omitted variable bias and present our results and inferences as being conditional on our estimated model specification.

Similar to Marsh, Schroeder, and Mintert's (2004) application, the approach of including non-meat food and non-food in the demand system allows for reallocation of expenditures across meat, non-meat, and non-food products. Moreover, by assuming meat products are not separable, our model provides expenditure elasticities which are closer approximations to income elasticities. In contrast, a model that assumes meat demand is separable (i.e., Ishida, Ishikawa, and Fukushige, 2010; Tonsor and Marsh, 2007) effectively imposes the restriction that each shifter has a net zero effect across meat products. This situation clearly is undesirable given the diversity of shift variables incorporated in our model.

A common practice in demand system estimation is to delete one share equation (usually the broadest category) from the empirical model to avoid singularity in the estimated error variance-covariance matrix. The parameters of this omitted equation are recovered using adding-up restrictions. In addition, symmetry and homogeneity restrictions are imposed as maintained assumptions to ensure the demand model is consistent with economic theory. Adding-up restrictions are imposed by:

$$(3) \quad \sum_{i=1}^N c_{ij} = 0, \quad \sum_{i=1}^N \beta_i = 1, \quad \sum_{i=1}^N \lambda_{ikl} = 0, \quad \text{and} \quad \sum_{i=1}^N d_{ij} = 0.$$

Homogeneity and symmetry are imposed by:

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

Equations (2)–(4) generate compensated price, income, and shift elasticities given, respectively, by (Marsh, Schroeder, and Mintert, 2004):

$$(5) \quad \varepsilon_{ij} = \frac{c_{ij}}{w_i}, \quad \eta_i = \frac{\beta_i}{w_i}, \quad \text{and} \quad \kappa_{ikl} = \frac{\sum_{l=0}^L \lambda_{ikl}}{w_i}.$$

Using equation (5), κ_{ik0} yields a short-run (i.e., current period) elasticity estimate and κ_{ikL} yields a long-run elasticity estimate associated with an equilibrium value of Z_{kl} over time.

Hausman specification tests are used to determine if prices and meat expenditures are endogenous (Eales and Unnevehr, 1993; Stockton, Capps, and Bessler, 2008; Thurman, 1987). Specifically, we estimate the Rotterdam model in two ways. First, the right-hand-side variables are assumed to be predetermined and the model is estimated using iterative seemingly unrelated regression (ITSUR). Second, the right-hand-side variables are assumed to be endogenous and the model is estimated using iterative three-stage least squares (IT3SLS). The IT3SLS approach requires instrumental variables that may be associated with endogenous prices and total expenditure. Following Eales and Unnevehr (1993), Capps et al. (1994), and Kinnucan et al. (1997), we use lagged prices and quantities, total per capita expenditure, an energy price index, the price of corn received by producers, weekly wages of meat packing plant workers, 90-day Treasury bill yields, U.S. population, meat processed from animal carcasses, and lagged media indices (Z_{kl}) as instruments. The null hypothesis of price exogeneity was rejected. As such, all presented results are obtained from IT3SLS estimation.

Data

The demand model is estimated using quarterly data for beef, pork, poultry, non-meat food, and all other goods from 1982 through 2007. Summary statistics of select data used in estimation of the model are presented in table 1. The beef, pork, and poultry quantity variables represent quarterly retail weight per capita disappearance (pounds). Per capita disappearance averaged 17.3, 12.7, and 21.3 lbs./capita/quarter, respectively, for beef, pork, and poultry. Beef, pork, and poultry prices are quarterly average retail prices (\$/pound). Chicken and turkey were aggregated to form one poultry variable (Marsh, Schroeder, and Mintert, 2004). Accordingly, poultry price reflects total expenditure on chicken and turkey divided by per capita poultry disappearance. All beef, pork, and poultry quantity and price series were obtained from the U.S. Department of Agriculture's Economic Research Service (USDA/ERS, 2004).

Our demand system specification includes two aggregate commodities (non-meat food and all other goods) which, while subject to aggregation bias (limiting value of corresponding elasticities), results in an unconditional demand model improving insights on the commodities of core interest (beef, pork, and poultry). Corresponding price and quantity indices were derived following Eales and Unnevehr (1993), Wang and Bessler (2003), and Bryant and Davis (2008).³ Non-meat food expenditures are calculated as total food expenditures less beef, pork, and poultry expenditures. Non-meat food quantity is specified as total food quantity (total food expenditures divided by the consumer price index for food) less the sum of beef, pork, and poultry quantities. Non-meat food price is the ratio of non-meat food expenditures to non-meat food quantity. The quantity of all other goods is calculated as the ratio of non-food expenditures to the consumer price index for all items less food. The price of all other goods is represented by the consumer price index for all items less food. Total consumption expenditure and total food expenditure series were obtained from the U.S. Department of Commerce, Bureau of Economic Analysis (USDC/BEA, 2009). All consumer price indices were obtained from the U.S. Department of Labor, Bureau of Labor Statistics (BLS).

Binkley's (2006) analysis suggested a significant, positive correlation between consumer stated preferences for convenience and food purchased away from home. Food-away-from-home (*FAFH*) consumption as a percentage of food expenditures increased steadily during the study period, rising from 41% in 1982 to 48% in 2007. Moreover, female workforce participation has frequently been used as a proxy for time value (e.g., Becker, 1965; Nayga, 1996; Byrne, Capps, and Saha, 1996). Female labor force participation increased from 52% in 1982 to about 60% in 1998, but has been relatively stable since the late 1990s. Therefore, we include variables accounting for food consumption away from home and household characteristics (*C*) as proxies for the demand for convenience. Specifically, we include a *FAFH* series obtained from BEA, and the percentage of females employed in the labor force (*Female*) obtained from BLS.

³ Each of these calculations was made on a per capita basis to be consistent with beef, pork, and poultry measures (Bryant and Davis, 2008). Derivation of price or quantity data from alternative sources for different share equations in demand systems is common in applications with less restrictive separability assumptions (e.g., Marsh, Schroeder, and Mintert, 2004; Eales and Unnevehr, 1993; Wang and Bessler, 2003). As in other applications, we recognize the potential for our chosen derivations to impact subsequent results and inferences.

Table 1. Summary Statistics of Quarterly Data Used to Estimate Demand, 1982–2007

Variable	Average	Std. Dev.	Minimum	Maximum
Beef Consumption (lbs./capita)	17.3	1.3	15.0	20.8
Pork Consumption (lbs./capita)	12.7	0.7	11.4	14.3
Poultry Consumption (lbs./capita)	21.3	3.6	13.7	27.0
Retail Beef Price (\$/lb.) ^a	2.04	0.18	1.70	2.50
Retail Pork Price (\$/lb.) ^a	1.57	0.13	1.36	2.02
Retail Poultry Price (\$/lb.) ^a	0.67	0.08	0.53	0.86
Food Away from Home (<i>FAFH</i>), %	45.0	1.8	40.6	47.5
Females in Labor Force (<i>Female</i>), %	57.8	2.3	51.8	60.2
Fat, Cholesterol, Heart Disease, Arteriosclerosis (<i>FCHA</i>) Index ^b	48.5	19.5	18.0	93.0
Zinc, Iron, Protein (<i>ZIP</i>) Index ^b	306.5	120.6	146.0	615.0
Net Atkins, High Protein, Low Carbohydrate (<i>nAtk</i>) Index ^{b,c}	35.8	93.6	-195.3	457.6
Beef Food Safety Recalls (<i>Beef_FS</i>)	3.8	3.2	0.0	15.0
Pork Food Safety Recalls (<i>Pork_FS</i>)	2.7	2.4	0.0	11.0
Poultry Food Safety Recalls (<i>Poultry_FS</i>)	2.6	2.4	0.0	9.0

^a Inflation-adjusted dollars (deflated by CPI, 1982–1984 = 100).

^b Details on construction of each media information index are provided in the appendix.

^c The net Atkins index is negative when articles favorable to beef demand are outnumbered by those detrimental to beef demand.

To capture information about health- and diet-related impacts of meat consumption on meat demand (**H**), we also created a series of media and medical journal information indices. Consistent with the variety of information sources available to consumers, several sources were used to develop the indices depending on the type of information being measured. Following previous research (Piggott and Marsh, 2004; Brown and Schrader, 1990), the Lexis-Nexis and Medline databases were used to construct three indices representing public information. Specific key word phrases used for each index are provided in the appendix.

The first index uses Medline articles on links between fat, cholesterol, heart disease, arteriosclerosis, and diet (*FCHA*). The second index uses the Medline database to obtain articles linking zinc, iron, or protein to diet (*ZIP*). Medline searches focused on published English medical journal articles related to each topic. The rationale for using medical journals to develop these indices was that the primary source of information about health issues related to heart disease and diet is physicians (Adhikari et al., 2006; Miljkovic and Mostad, 2005). Similarly, we anticipated that emerging information regarding human nutrition and meat consumption would first be published in medical journals, then read and interpreted by physicians and dietitians who, in turn, would disseminate this information to their clientele. In this context, medical journals were viewed as a primary source for subsequent articles appearing in the popular press on this topic.

The third index is comprised of major newspaper articles on Atkins, high-protein, or low-carbohydrate diets as identified by the Lexis-Nexis database. Popular press articles were used to measure consumer interest in low-carbohydrate diets, rather than medical journals, because of the large volume of mass media information published on this topic. The Lexis-Nexis search identified a marked divergence over time in the nature of published articles on these diets. Articles focusing on these diets were overwhelmingly positive in the late 1990s and early 2000s, whereas a far larger number of negative articles were published after 2003. To

capture the disparity in positive versus negative information surrounding these diets, we followed Brown and Schrader (1990) and developed a “net Atkins” index (*nAtk*), which is the number of articles promoting low-carbohydrate diets minus those focusing on the potential adverse health impacts of such diets.

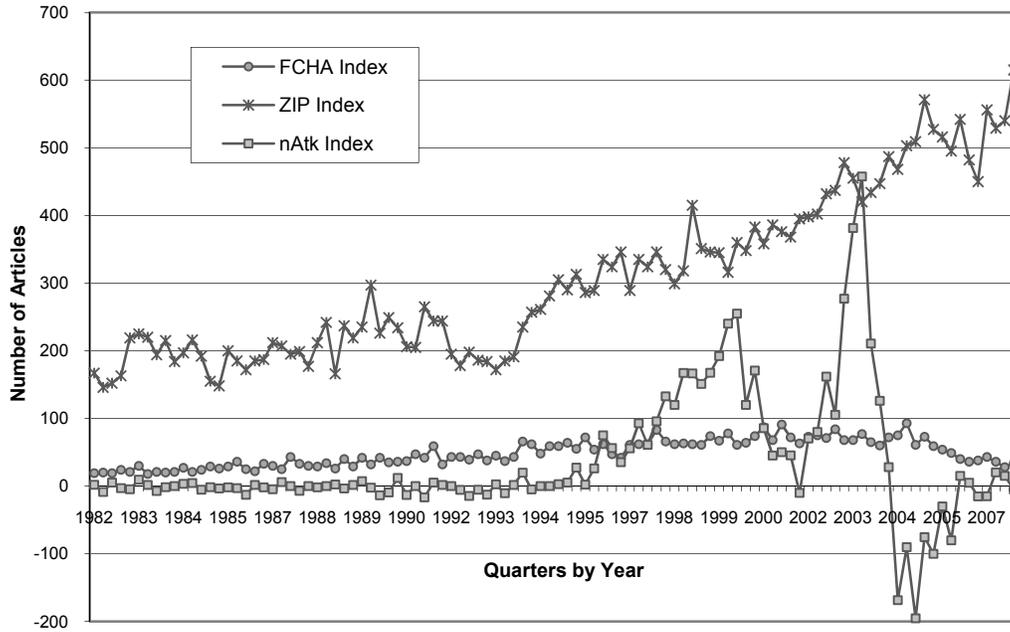
Figure 1 illustrates the three health and diet information indices over the sample period. The *ZIP* index increased steadily over time, from 167 journal articles in 1982(1) to 615 articles in 2007(4). The *FCHA* index increased from 19 journal articles in 1982(1) to a maximum of 93 articles in 2004(4), although it subsequently declined to 34 articles in 2007(4). The net Atkins (*nAtk*) index increased from 1982–2003, and peaked in 2003(3) at 458 popular press articles. The changing nature of public information regarding Atkins and related diets is reflected in the sharp reversal of this index, which bottomed at –195 articles (i.e., articles raising health concerns about low-carbohydrate diets outnumbered articles supporting these diets) in 2005(1).

Food safety indices (**R**) were developed using the procedure of Marsh, Schroeder, and Mintert (2004), which counts the number of meat recalls publicly reported by the U.S. Department of Agriculture’s Food Safety Inspection Service (FSIS).⁴ Meat recalls are used as proxies for food safety information because a recall represents a failure of the meat food safety system and, as such, may represent a threat to human health. Because recalls are publicly announced and widely reported by broadcast, print, and internet media, they directly mirror information consumers receive about such food safety events. We added class I and class II recalls over each quarter, creating separate food safety recall counts for beef, pork, and poultry. Class I recalls represent a health hazard whereby there is a “reasonable probability that eating the food will cause health problems or death,” and class II recalls have a “remote probability of adverse health consequences from eating the food” (USDA/FSIS, 2008).

Marsh, Schroeder, and Mintert (2004) found significant cross-commodity impacts from meat recalls, suggesting that recall effects by species might vary and might have differing spillover effects. Thus, food safety indices were developed by species. FSIS recalls for beef, pork, and poultry averaged 3.8, 2.7, and 2.6 per quarter, respectively, over the 1982–2007 period (table 1). Figure 2 presents the variability of all three recall indices over the sample period. Each recall count increased in level and variability during the 2000–2007 period relative to the 1982–1999 period. Beef recalls reached record levels in 2007, with 15 recalls occurring during the fourth quarter.

Estimation of the Rotterdam model required all variables to have positive values over all observations because of logarithmic transformations. Therefore, we added 1 to each FSIS recall (because the value was zero for some quarters) and 200 to the net Atkins media article series (because it had one value as small as –195). These adjustments ensure that all explanatory variables are globally positive. Alternative approaches were considered, including replacing all zeros with 10% of their geometric mean or with 0.01 in the FSIS series and adding 196, 300, or 400 to the Atkins index. These alternative approaches yielded very similar results. Our procedure follows that of Brester and Schroeder (1995) and Schroeder (1992). Although commonly employed in the literature, Schroeder cautions that this adjustment does introduce a small estimation bias.

⁴ We also considered Lexis-Nexis based food safety article indices (following Piggott and Marsh, 2004). However, examination of resulting indices raised concerns about excessive double-counting of food safety events in multiple meat indices. Combined with the notion of FSIS recalls being widely publicized themselves, we chose to follow the Marsh, Schroeder, and Mintert (2004) procedure. A reviewer also pointed out the double-counting issue could be present in our *FCHA*, *ZIP*, and *nAtk* indices. A review of individual articles in these indices suggests this is not a problem in our application. Nonetheless, future work using similar media indices should carefully consider the issue of double-counting articles.



Note: Construction of the three media information indices is described in the appendix.

Figure 1. Media indices, 1982–2007

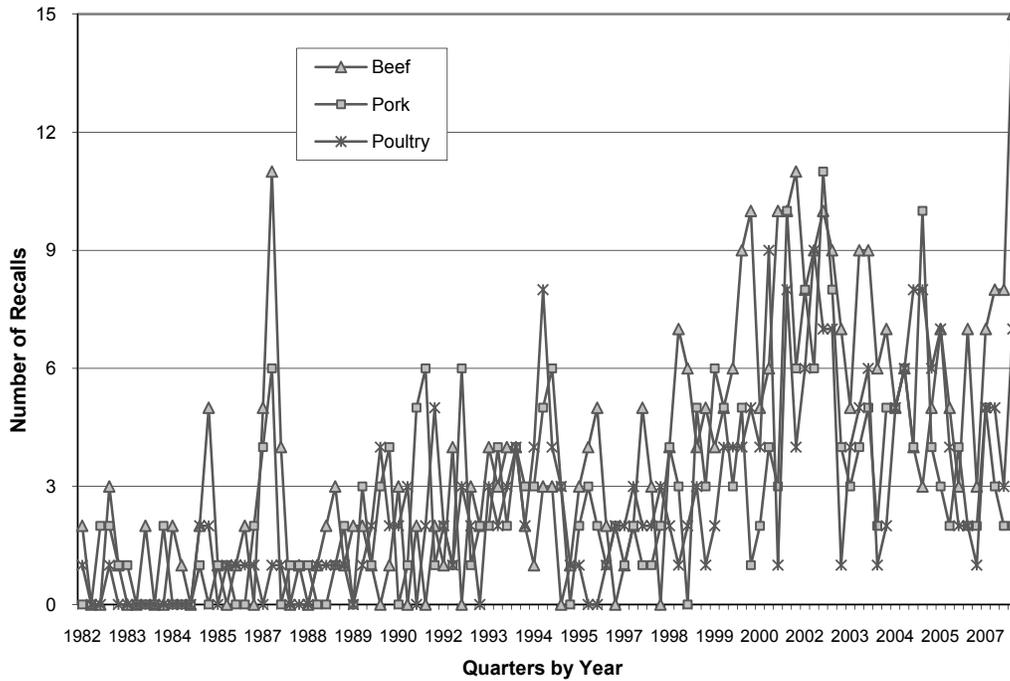


Figure 2. Food Safety Inspection Service recalls (class I and II), 1982–2007

Results

The empirical analysis was conducted through an iterative procedure of multiple model estimations with a range of likelihood-ratio tests employed. Adjusted likelihood-ratio tests were used to compare alternative model specifications (Bewley, 1986). While traditional likelihood-ratio tests rely on asymptotic assumptions, the adjusted likelihood-ratio test statistics do not. Models were estimated with lag lengths of zero to three quarters for each exogenous demand shifter

$$Z_{kl} = [FCHA, ZIP, nAtk, Beef_FS, Pork_FS, Poultry_FS, FAFH, Female].$$

After an array of likelihood-ratio tests, it was determined that only FSIS recalls had statistically significant lagged impacts. Moreover, a sequence of models was estimated for all combinations of demand shifter subsets (e.g., one model omitted female employment to test joint significance). Following these iterations, the final model incorporated contemporaneous effects for all variables in addition to one- and two-quarter lagged effects for all three FSIS recall variables.

With homogeneity and symmetry imposed, IT3SLS estimates were calculated while deleting one equation to avoid singularity of the error covariance matrix. The parameters of this omitted equation were recovered using the Engel aggregation (adding-up) restrictions discussed previously in the modeling section.

Following Piggott and Marsh (2004), Holt and Goodwin (1997), and Tonsor and Marsh (2007), three different Berndt and Savin (1975) autocorrelation corrections were evaluated. These three corrections consisted of: (a) a correction matrix (null matrix) restricting all elements to zero (specifying no autocorrelation correction, $\rho_{ij} = 0 \forall ij$); (b) a correction matrix (diagonal matrix) with all off-diagonal elements restricted to zero and all diagonal elements to be identical ($\rho_{ij} = 0 \forall i \neq j$ and $\rho \neq 0 \forall i = j$); and (c) a correction matrix (complete matrix) allowing all elements to differ individually from zero ($\rho_{ij} \neq 0 \forall ij$).⁵ In our application, both the no-autocorrelation correction (null matrix) and identical diagonal element correction (diagonal matrix) specifications were rejected in favor of the correction matrix (complete matrix) with all elements allowed to vary individually from zero.⁶

The estimated coefficients are reported in table 2. Goodness of fit, as measured by R^2 values, indicates the model captured 73%, 86%, 86%, and 37%, respectively, of the in-sample variation of beef, pork, poultry, and other food goods. The weaker fit of the other food goods equation probably reflects the selection of exogenous shift variables based on their relevance to meat demand rather than their ability to explain shifts in the demand for other food goods. The three meat share equations fit the data similarly to those of previous studies. Curvature restrictions are satisfied (at the data means), as the estimated price coefficient matrix is negative semidefinite.

The Rotterdam model's coefficient estimates are of limited value except for calculating elasticities. Therefore, we focus on the model's estimated elasticities (table 3). It can be misleading to simply examine elasticity point estimates without consideration of their statistical

⁵ Here, i and j denote commodities and not time periods.

⁶ This finding is consistent with Tonsor and Marsh (2007) and Holt and Goodwin (1997). Nevertheless, presence of autocorrelation may indicate potential model misspecification, and future work should consider alternative functional forms and covariate mixes.

Table 2. Coefficient Estimates of Rotterdam Model, Quarterly Data, 1982–2007

Dependent Variable	Demand Equation			
	Beef	Pork	Poultry	Other Food
<i>Beef Price</i>	-9.30E-04* (2.56E-04)			
<i>Pork Price</i>	3.60E-05 (1.29E-04)	-9.00E-04* (1.36E-04)		
<i>Poultry Price</i>	-9.00E-05 (1.04E-04)	1.00E-05 (8.40E-05)	-8.00E-05 (1.03E-04)	
<i>Other Food Price</i>	-1.40E-04 (1.21E-03)	1.10E-04 (8.33E-04)	3.42E-04 (6.40E-04)	-4.44E-02* (1.80E-02)
<i>FCHA Index</i>	-5.00E-05* (2.80E-05)	-2.85E-06 (1.90E-05)	-3.31E-06 (1.60E-05)	4.45E-04 (3.90E-04)
<i>ZIP Index</i>	5.50E-05 (5.10E-05)	-3.00E-05 (3.40E-05)	3.90E-05 (3.00E-05)	-1.60E-04 (7.30E-04)
<i>nAtk Index</i>	1.70E-05 (1.10E-05)	-5.68E-06 (7.67E-06)	-2.92E-06 (6.86E-06)	1.51E-04 (1.59E-04)
<i>FAFH</i>	-3.52E-03* (1.24E-03)	2.16E-03* (7.89E-04)	1.57E-03* (6.34E-04)	2.54E-02 (1.78E-02)
<i>Female</i>	-1.23E-03 (1.37E-03)	-9.50E-04 (8.26E-04)	4.81E-04 (6.69E-04)	-5.39E-03 (2.12E-02)
<i>Beef_FS (lag = 0)</i>	-2.00E-05 (1.10E-05)	-8.73E-06 (6.89E-06)	6.21E-06 (5.35E-06)	-3.10E-04* (1.53E-04)
<i>Pork_FS (lag = 0)</i>	-4.00E-05* (1.30E-05)	5.41E-06 (8.04E-06)	3.78E-07 (6.59E-06)	2.61E-04 (1.75E-04)
<i>Poultry_FS (lag = 0)</i>	2.00E-05 (1.30E-05)	-5.84E-07 (7.96E-06)	2.02E-06 (6.07E-06)	-2.50E-04 (1.81E-04)
<i>Beef_FS (lag = 1)</i>	-1.53E-06 (1.20E-05)	6.57E-07 (7.72E-06)	5.78E-06 (5.67E-06)	-3.80E-04* (1.65E-04)
<i>Pork_FS (lag = 1)</i>	-7.74E-06 (1.30E-05)	-1.00E-05 (8.72E-06)	-9.46E-06 (6.38E-06)	2.94E-04 (1.88E-04)
<i>Poultry_FS (lag = 1)</i>	8.37E-06 (1.40E-05)	2.39E-06 (8.80E-06)	4.75E-06 (6.62E-06)	-8.00E-05 (1.97E-04)
<i>Beef_FS (lag = 2)</i>	-3.00E-05* (1.10E-05)	1.10E-05 (7.20E-06)	5.65E-06 (6.20E-06)	-2.00E-04 (1.50E-04)
<i>Pork_FS (lag = 2)</i>	-7.09E-06 (1.30E-05)	1.79E-06 (8.72E-06)	1.71E-06 (7.83E-06)	7.00E-06 (1.74E-04)
<i>Poultry_FS (lag = 2)</i>	-1.00E-05 (1.30E-05)	7.91E-07 (8.97E-06)	5.26E-06 (7.60E-06)	-1.50E-04 (1.79E-04)
<i>Intercept</i>	-1.20E-04* (1.50E-05)	8.50E-05* (1.00E-05)	4.30E-05* (9.32E-06)	3.97E-04* (2.11E-04)
<i>Quarter 1 Dummy</i>	1.00E-04* (2.40E-05)	-1.90E-04* (1.60E-05)	-1.10E-04* (1.60E-05)	-1.90E-04 (2.93E-04)
<i>Quarter 2 Dummy</i>	2.08E-04* (2.50E-05)	-1.00E-04* (1.60E-05)	-3.95E-06 (1.10E-05)	-4.30E-04 (3.18E-04)
<i>Quarter 3 Dummy</i>	1.35E-04* (2.40E-05)	-5.00E-05* (1.70E-05)	-3.00E-05* (1.70E-05)	-2.20E-04 (2.93E-04)
<i>Expenditures</i>	2.03E-03* (1.02E-03)	2.00E-05 (6.13E-04)	-4.70E-04 (4.88E-04)	6.40E-02* (1.66E-02)
<i>R² Value</i>	73.1%	85.6%	86.0%	37.2%
<i>Log-Likelihood Value = 3,309.349</i>				

Notes: An asterisk (*) denotes statistical significance at the 10% level or higher. Values in parentheses are standard errors. Autocorrelation coefficients are not presented, but are available from the authors upon request.

Table 3. Estimated Compensated Elasticities for Demand Model, Quarterly Data, 1982–2007

With Respect to:	Quantity of:				
	Beef	Pork	Poultry	Other Food	Non-Food Goods
<i>Beef Price</i>	-0.4199** ^a	0.0296	-0.1113	-0.0009	0.0013
<i>Pork Price</i>	0.0163	-0.7396** ^a	0.0124	0.0007	0.0009
<i>Poultry Price</i>	-0.0406	0.0082	-0.0990 ^a	0.0023	-0.0002
<i>Other Food Price</i>	-0.0632	0.0904	0.4230	-0.2978** ^a	0.0521**
<i>Non-Food Price</i>	0.5075	0.6114*	-0.2251	0.2957**	-0.0540** ^a
<i>Expenditures</i>	0.9148**	0.0164 ^b	-0.5813 ^b	0.4295** ^b	1.1036** ^b
<i>FCHA Index</i>	-0.0226**	-0.0023	-0.0041	0.0030*	-0.0005
<i>ZIP Index</i>	0.0248*	-0.0247	0.0482*	-0.0011	0.0001
<i>nAtk Index</i>	0.0077**	-0.0047	-0.0036	0.0010	-0.0002
<i>FAFH</i>	-1.5893**	1.7768**	1.9419**	0.1706**	-0.0303**
<i>Female</i>	-0.5554	-0.7807*	0.5949	-0.0362	0.0084
— Short-Run Recall Elasticities —					
<i>Beef_FS</i>	-0.0090**	-0.0072*	0.0077*	-0.0021**	0.0004**
<i>Pork_FS</i>	-0.0181**	0.0044	0.0005	0.0018**	-0.0003**
<i>Poultry_FS</i>	0.0090**	-0.0005	0.0025	-0.0017**	0.0003**
— Long-Run Recall Elasticities —					
<i>Beef_FS</i>	-0.0233**	0.0024	0.0218**	-0.0060**	0.0011**
<i>Pork_FS</i>	-0.0248**	-0.0023	-0.0091	0.0038**	-0.0006*
<i>Poultry_FS</i>	0.0083	0.0021	0.0149	-0.0032*	0.0005

Notes: Single, and double asterisks (*,**) denote elasticities significantly different from 0 at the 15% and 10% levels, respectively; ^a denotes own-price elasticities significantly greater than -1.0 at the 10% level; ^b denotes income elasticities significantly different from 1.0 at the 10% level. Elasticities are calculated at the mean values of the explanatory variables. All *p*-values were obtained using Krinsky-Robb bootstrapping procedures.

significance (Tonsor and Marsh, 2007). Accordingly, a Krinsky-Robb (1986) simulation-based evaluation of elasticities was conducted. These tests evaluated whether each elasticity estimate differed from zero and, in the case of own-price and expenditure elasticities, whether it was statistically different from -1.0 and 1.0 (to assess the nature of elastic/inelastic demand and normal/inferior goods), respectively. For this procedure, we generated 10,000 values of each elasticity estimate using random draws from a multivariate normal distribution based on the model's estimated coefficients and variance terms. The proportion of observations in this distribution with values greater than the critical value (i.e., 0, 1.0, or -1.0) is the *p*-value associated with the one-sided hypothesis test that each elasticity estimate is greater than this critical value.

Table 3 reveals that many of the elasticity measures are statistically different from hypothesized values. Own-price compensated elasticity estimates are -0.420, -0.740, -0.099, -0.298, and -0.054 for beef, pork, poultry, other food, and non-food goods, respectively. Each own-price elasticity estimate is significantly greater than -1.0, and all except poultry are significantly different from zero (at the 0.05 level). Our findings of pork as the most elastic and poultry the most inelastic demand of the meat goods are consistent with results reported by Tonsor and Marsh (2007) and Brester and Schroeder (1995). Other food and non-food demands are found to be less price sensitive than beef, pork, or poultry, supporting the findings

of Brester and Schroeder (1995) and Marsh, Schroeder, and Mintert (2004). None of the cross-price elasticity estimates for the three evaluated meats are significantly different from zero (in accord with Marsh, Schroeder, and Mintert, 2004). Each of the expenditure elasticity estimates is statistically different from 1.0, with the exception of beef. As in other applications using a Rotterdam specification (Wang and Bessler, 2003; Brester and Schroeder, 1995; Marsh, Schroeder, and Mintert, 2004), beef and pork are normal goods.

The impacts of the three health information indices included in the model vary across information source and product. Only contemporaneous effects from the health information indices were significant, suggesting the impact of health information on consumer demand for meat decays rapidly. Finding contemporaneous, but not statistically significant, lingering health information effects on meat demand is consistent with prior studies (e.g., Kinnucan et al., 1997). Nonetheless, future work is encouraged to examine the underlying reasons that health information does not sustain longer-term effects on meat demand.

Increased information regarding links between fat, cholesterol, heart disease, arteriosclerosis, and diet (*FCHA*) reduced beef demand (-0.023 elasticity) and increased demand for other food goods (0.003 elasticity). The negative impact on beef demand is consistent with prior findings of Adhikari et al. (2006) and Kinnucan et al. (1997).

Beef and poultry demand benefited (0.025 and 0.048 elasticities, respectively) from information regarding health benefits associated with zinc, iron, or protein (*ZIP*) in diets. The finding that poultry demand was relatively more impacted by *ZIP* than beef demand was surprising. Furthermore, beef demand responded positively to the publication of net positive information associated with Atkins, high-protein, or low-carbohydrate diets (*nAtk*). Conversely, beef demand declined in response to net negative information about such diets (0.008 elasticity). This finding is consistent with results reported by Miljkovic and Mostad (2005) regarding the impact of media attention to low-carbohydrate diets on beef demand.

While the health and diet information elasticity estimates are small, the large changes in these variables during the study period reveal they had substantial impacts on demand. For instance, the cholesterol and heart disease index (*FCHA*) increased by 389% over the 1982(1) to 2004(4) period (figure 1). Given the elasticity estimate of -0.023 , this implies a beef demand reduction of about 9%, representing approximately one-third of the estimated 28% beef demand reduction experienced over the 1982–2004 period as measured by the Beef Demand Index (Mintert, 2009). Conversely, the 268% increase in zinc, iron, and protein information (*ZIP*) between 1982(1) and 2007(4) enhanced beef and poultry demand by about 7% and 13%, respectively. The low-carbohydrate diet information index (*nAtk*) increased by 245% from 1998(1) to 2003(3), only to decline precipitously after 2003(3) (and actually fell below zero in 2005). The media frenzy associated with low-carbohydrate diets increased beef demand by nearly 2% from 1998(1) to 2003(3). However, the rapid shift away from positive to negative information regarding low-carbohydrate diets reduced beef demand by approximately 0.8% over the 2003(4) to 2007(4) period.

Significant changes occurred during the study period in food-away-from-home consumption (*FAFH*) and in female workforce participation (*Female*), reflecting, to some extent, increasing desires of consumers for convenience and the value of their time. Over the sample period, *FAFH* and *Female* increased by approximately 17% and 16%, respectively (table 1), suggesting U.S. consumers were interested in devoting less time to food preparation at home.

Results indicate that increases in *FAFH* expenditures substantially benefited pork and poultry demand at the expense of beef demand. As shown by the elasticity estimates, a 1% increase in food-away-from-home consumption increased pork and poultry demand by about

1.8% and 1.9%, respectively, but reduced beef demand by about 1.6% (table 3). Our model does not directly explain why increasing consumption of food away from home led to increases in poultry and pork demand and decreases in beef demand. One hypothesis worthy of future research is that shifts in menu items (relative changes in new beef, pork, and poultry products) over time may underlie this finding.

Increasing employment of females outside the home led to a reduction in pork demand but did not have a statistically significant impact on beef or poultry demand. The 16% increase in female employment from 1982 to 2007 reduced pork demand by about 12%.⁷ Unfortunately, our aggregate disappearance data-based analysis is unable to definitively explain *why* consumption of food away from home and employment of women produce these effects. Given the meat industry's inability to influence consumption of food away from home or female employment trends, additional work is needed to determine *why* these trends are influential. Future research, possibly utilizing scanner or household-level data, might provide more clarity regarding the occurrence of these impacts.

The final set of exogenous shifters in our model is the FSIS recall indices specific to each meat product. Marsh, Schroeder, and Mintert (2004) and Piggott and Marsh (2004) found that estimated food safety effects are small relative to price, expenditure, and household dynamic effects. Our analysis rejects the hypothesis of cross-species spillover effects (e.g., beef recall effects on pork demand) being jointly zero. This finding supports using species-specific measures of food safety, rather than a single, aggregate food safety measure in demand analyses.

Nearly all of the estimated long-run recall effects are larger than contemporaneous effects. As observed in table 3, beef consumption is the only meat product statistically impacted by its own recalls (-0.009 and -0.023 short- and long-run elasticities, respectively). This result differs from Marsh, Schroeder, and Mintert (2004) who found beef demand to be unaffected by beef recalls. Beef demand is notably more sensitive to both own-product and spillover effects from recalls of other meats. Beef recalls cause poultry demand to increase contemporaneously, and even more so over longer periods. A 10% increase in beef recalls reduces beef demand by 0.2% and increases poultry demand by 0.2% in the long run. Conversely, beef and pork recalls appear to exert negative spillover effects on each other, as pork recalls adversely affect beef demand.

Conclusions and Implications

Our analysis provides insights into the effects of media attention to multiple health issues and diet linkages on meat demand. In addition to prices and expenditures, multiple factors, including government food recalls, published articles on health and diet issues, and changing household characteristics, impact meat demand.

New consumer information regarding links between meat consumption and human health provides an important set of demand determinants. Links among fat, cholesterol, heart disease, or arteriosclerosis; iron, zinc, or protein and meat consumption; Atkins, high-protein, or low-carbohydrate diets all have statistically significant impacts on meat demand. In particular, beef demand declined in response to information linking fat and cholesterol to

⁷ The presented impacts of *FAFH* and *Female* are insensitive to the inclusion or omission of each other. Moreover, these impacts are insensitive to omission of the presented food safety and/or health information variables. The correlations of variables as they entered the Rotterdam model are available from the authors upon request and document that *FAFH* and *Female* are uncorrelated in the estimated model.

heart disease. Additionally, both beef and poultry demand benefited from medical literature linking iron, zinc, or protein with meat consumption.

Given that food quality is influenced by multiple sources of information and differs across heterogeneous consumers, the meat industry would be well served to routinely investigate the impact of contemporaneous issues (i.e., Atkins diet) on meat demand. For instance, media information indices beyond those considered here are worthy of investigation. These may include indices of articles linking cancer concerns with meat consumption or discussions of animal welfare and handling. Moreover, additional measures of changing household demand for product convenience could be incorporated in future research as they become available. Future research using scanner or other household-level data could be valuable in more narrowly identifying specific determinants of changes in meat demand. For example, research identifying specific grocery buying habits, employment status, types of restaurants visited, household menu selections, and food-away-from-home decisions may provide additional valuable insights about the impacts of household characteristics on meat demand. In addition, as producer groups adjust the amount and allocations of generic advertising efforts, our analysis could be expanded to evaluate corresponding impacts on U.S. meat demand. Finally, if additional data on U.S. lamb, veal, finfish, and shellfish consumption become available, an evaluation of information effects (including food safety and health) on these products would be beneficial.

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Appendix: Media Information Search Details

Presented below is an outline of the media information searches that were conducted to build the indices used in the estimation of the Rotterdam model. To keep each search more relevant to food demand issues, we included "and diet" in each search. Acronyms consistent with our estimation results are given in parentheses.

1. **Health: Fat, Cholesterol, Heart Disease, Arteriosclerosis (FCHA)**

- *Key Words*: "(fat or cholesterol) and (heart disease or arteriosclerosis) and (diet)"
- This search was conducted using the Medline database selecting English language medical journal articles. These key words follow those used by Rickertsen, Kristofersson, and Lothe (2003).

2. **Health: Atkins (Atk)**

- *Key Words*: "(Atkins or high protein or low carbohydrate) and (diet)"
- This search was conducted using the Lexis-Nexis database of media articles of major U.S. newspapers.

3. **Nutrition: Zinc, Iron, Protein (ZIP)**

- *Key Words*: "(zinc or iron or protein) and (diet)"
- This search was conducted using the Medline database selecting English language medical journal articles.