U.S. Beef Demand Drivers and Enhancement Opportunities

Abstract

This publication uses national, quarterly data to examine U.S. meat demand using the Rotterdam model. The analysis provides insights into beef demand and previously unexamined topics including the effect of multiple information indices linking different health concerns with diet, changes in household dynamics, and meat recall information.

Estimation results confirmed that consumer expenditures are a very important beef demand determinant, which means that beef demand is sensitive to the strength of the U.S. economy. Results also indicate consumers respond to the receipt of information about beef and nutrition. For example, publication of medical journal articles linking iron, zinc, and protein with health and diet increase beef demand whereas publication of articles dealing with fat, cholesterol, and diet concerns reduce beef demand.

Overall, model results also suggest that beef demand suffered, and poultry demand benefitted, as U.S. consumers' demand for more convenient meat products increased. In particular, as U.S. consumers consumption of food away from home increased, beef demand declined. Consumers are also sensitive to food safety. When USDA Food Safety Inspection Service beef product recalls increase, beef demand declines. Moreover, beef product recalls have a significant positive spillover effect on poultry demand, suggesting that consumers shift away from beef and toward poultry products in response to beef food safety recalls.

In summary, this research provides a more complete understanding of the influence multiple information factors have on consumer demand for beef. Future research could explore the use of additional media indices focusing on animal welfare, environmental concerns, and other aspects of human health to estimate their impact on beef demand. Additionally, future research should also consider the use of scanner data to obtain better measures of prices paid by consumers for meat products and to more narrowly identify some of the specific determinants of the findings from this study.

Introduction

Large shifts in domestic beef demand have had substantial effects on the beef industry. Before the late 1970s, growth in the U.S. economy and rising consumer incomes supported consistent beef demand growth. In response to growing product demand, the beef industry increased in size. About 1980, however, domestic retail beef demand weakened and declined every year through 1998. The long-run decline in retail beef demand contributed to a reduction in cattle industry size, particularly in relation to competing meat sectors. In 1999, following nearly 20 consecutive years of decline, domestic beef demand began to strengthen. From the late 1990s through 2004, the Choice domestic retail beef demand index increased from a low of 50 to a peak of 63, before weakening again from 2005 through 2008 (Figure 1).

Designing programs to increase domestic retail beef demand requires a comprehensive understanding of the underlying factors that caused beef demand to decline precipitously during the 1980s and 1990s. Likewise, it is important to determine what caused beef demand increases from the late 1990s through 2004. Increasing consumer demand for beef requires concerted effort by all vertical segments of the production, processing, and marketing chain as there are myriad opportunities to improve product quality, food safety, and diversity of product offerings. How the industry collectively responds to these challenges will determine the success or failure of demand enhancement initiatives.

A wealth 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 and new product developments or offerings; and shifts in consumer demographics and lifestyles. Over time, new dimensions of demand arise and the relative importance of determinants can change as new information enters the market.

For example, discovering new health benefits of consuming a product may alter the structure of empirical demand estimates. Because of the dynamic nature of meat demand determinants, ongoing demand estimation is important for informed policy decision making and for industry stakeholder strategic management.

This study provides an updated assessment of factors influencing quarterly U.S. consumer demand for beef. To assess the relative effect various factors have on beef demand, a demand model was built to estimate the effects of beef, competing meat, and other goods prices; consumer expenditures; published information on food safety, health, and nutrition related to meat consumption; female labor force participation; and expenditures on food consumed away from home. Unique to this study is analysis regarding how meat demand has changed as information on human health impacts of zinc, iron, and protein from meat consumption has become more prevalent, and new information regarding the impacts on meat demand associated with low-carbohydrate diets. Quarterly data from 1982 through 2007 were used to estimate the model. Estimates obtained from the model provide measures of expected effects from changes in each of the demand drivers.

The next section of this report provides a brief review of relevant prior research. It then proceeds to develop the conceptual model underlying this research, followed by the empirical model and a description of the data used for the analysis. Finally, results and conclusions from the study are presented. [1]

A summary version of this publication is available at www.agmanager.info

Figure 1. *Retail Choice Beef Domestic Demand Index Annual, 1980–2008.*
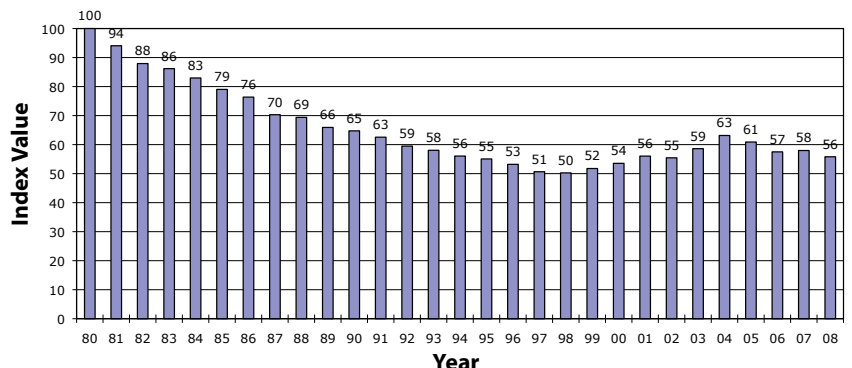
Source: USDA, Department of Commerce, &
James Mintert, Department of Ag. Economics, Kansas State University

U.S. Beef Demand Drivers and Enhancement Opportunities 1

Literature Review

A large body of research has focused on meat demand shifters. Factors that have been examined include effects of food safety and product recall news (Piggott and Marsh, 2004; Marsh, Schroeder, and Mintert, 2004; Schroeder, Marsh, and Mintert, 2000; Burton and Young, 1996); health and related diet information (Adhikari et al., 2006; Kinnucan et al., 1997; Miljkovic and Mostad, 2005; Rickertsen, Kristofersson, and Lothe, 2003; Brown and Schrader, 1990; Chang and Kinnucan, 1991; Capps, Jr. and Schmitz, 1991); generic advertising (Brester and Schroeder, 1995; Kinnucan et al., 1997; Rickertsen, 1998; Piggott et al., 1996; Park and Capps, Jr., 2002); pre-committed demand (Piggott and Marsh, 2004; Tonsor and Marsh, 2007); and structural changes in consumer demand (Eales and Unnevehr, 1988; Rickertsen, 1996; Moschini and Meilke, 1989; Davis, 1997).

In recent years, substantial changes in potentially important meat demand determinants have taken place that merit investigation. For example, low-carbohydrate diets were the focus of much media attention and became popular in the late 1990s and early 2000s, with relatively few adherents before the mid-1990s. Moreover, there also has been a rise in published information linking meat consumption with the nutritional benefits of increased zinc, iron, and protein intake. Additionally, record numbers of meat recalls and related other food safety events have raised consumer concerns about meat product safety. Understanding how new information on different topics and from varied sources effects meat demand is important for both policy and industry production decisions. Changing economic conditions such as continued growth in demand for food that is convenient to consume and long-term growth in food away from home consumption are affecting consumer eating choices (Capps, Jr., Tedford, and Havlicek, 1985; Byrne, Capps, Jr., and Saha, 1996).

Our study estimates the influences of these factors on the demand for meat by U.S. consumers.

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 on U.S. meat demand from food safety events. 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 nonmeat goods following meat recalls. Ishida, Ishikawa, and Fukushige (2008) compared the impact of BSE and Bird Flu on Japanese meat demand by examining gradual demand shift patterns using the Almost Ideal Demand System. Japanese demand for beef and chicken declined following BSE and Bird Flu scares, respectively, and the demand for pork and fish increased.

Using a range of time series methods (e.g., cointegration, vector error correction, causality tests), Miljkovic and Mostad (2005) found media attention on low-carbohydrate diets had longer-lasting impacts on beef demand than corresponding media articles regarding low-fat/low-cholesterol diets. 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) 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) found cholesterol information reduced

Canadian demand for butter. Adhikari et al. (2006) found cholesterol information reduced U.S. demand for beef and pork and increased chicken demand. Rickertsen, Kristofersson, and Lothe (2003) concluded that chicken demand in Finland, Norway, and Sweden increased as information about cholesterol was more widely disseminated.

Limitations of previous research are twofold. First, all six of the previously noted studies assumed that meat demand is separable from 'other food' or 'non-food' categories. The separability assumption implicitly forces health information to enhance demand for one included product at the expense of another, when the adding-up restriction from demand theory is imposed. This effectively precludes health information from having similar impacts across multiple meat products. Second, Adhikari et al. (2006) noted the need for additional work considering the joint effects of both cholesterol information (as in the above noted studies) and carbohydrate information. These joint effects were examined by Miljkovic and Mostad (2005), but not in a demand system framework. Hence, interrelationships of cholesterol information and carbohydrate information with meat and nonmeat demands have not been studied. Our model builds upon prior research and addresses these concerns by providing a joint evaluation of food safety on multiple meat products and multiple health information factors in a demand system framework incorporating meat, nonmeat food, and nonfood goods.

Household dynamics have been found to affect consumer demand by various researchers. For example, Kalwij and Salverda (2007) concluded that increases in the proportion of employed Norwegian 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) found Spanish household expenditures for convenience meats were higher among two-income households. Moreover, Horton and Campbell (1991) found food-away-from-home (FAFH) expenditures were a larger proportion of food budgets in Canadian households with women employed outside the home. Using annual data from 1960 to 1998 and a linear approximation to the Almost Ideal Demand System model, McGuirk et al. (1995) found annual U.S. demand for poultry increased as female work force participation increased, primarily at the expense of beef demand. These studies, some of which are more than a decade old, suggest a comprehensive examination of U.S. meat demand that incorporates female work force participation, food-away-from-home consumption trends, food safety, and health information in a demand system framework using recent data is overdue.

Conceptual Model

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

$$Max_{x,\lambda}\, U(\mathbf{x}, \mathbf{q}) + \lambda(M - \mathbf{p'x}) \qquad (1),$$

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 affects consumer perceptions of product quality. In the 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 affect budget allocations. Combining these points with equation (1), the first-order conditions yield the Marshallian demand for good $i(\mathbf{x}_i^m(\mathbf{p}, M, \mathbf{H}, \mathbf{R}, \mathbf{C}))$.

Empirical Application

The primary issues of consideration in model selection include both theoretical and feasible empirical components. In this application, the absolute-price version of the Rotterdam model, comprised of five equations associated with beef, pork, poultry, nonmeat food, and nonfood demands is used.[2] 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 that may be highly correlated in levels, but not in first differences. The Rotterdam model maintains flexibility while simultaneously satisfying the adding-up, homogeneity, and symmetry restrictions in accordance with demand theory. Furthermore, Kastens and Brester (1996) indicated that the Rotterdam model might outperform the Almost Ideal Demand System model in out-of-sample forecasting accuracy.

Following previous research, the model incorporates variables to control for price, expenditure, and seasonality. Moreover, the empirical model follows the conceptual model above by including shifters reflecting publicly available information regarding health concerns from meat consumption ($\mathbf{H}$), government recall announcements regarding the safety of different meat products ($\mathbf{R}$), and consumer preferences for convenience in food products ($\mathbf{C}$). In particular, the ith equation of our estimated model is given by:

$$w_i \Delta \ln x_i = a_{io} + \sum_{j=1}^{3} d_{ij} D_j + \sum_{j=1}^{n} c_{ij} \Delta \ln p_j$$

$$+ \beta_i \Delta \ln \bar{q} + \sum_{k=1}^{K} \sum_{l=0}^{L} \lambda_{ikl} \Delta \ln Z_{kl} + v_i \qquad (2)$$

where w_i is budget share of the ith good ($i=1,\ldots,5$), 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 jth good, $\Delta \ln \bar{q}$ is Divisia volume index $[\Delta \ln \bar{q} = \sum_{j=1}^{n} w_i \Delta \ln(x_i)]$, Z_{kl} represents the kth exogenous 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; λ_{ikl} are parameters to be estimated.

Similar to Marsh, Schroeder, and Mintert's (2004) application, the more flexible approach of including nonmeat food and nonfood in the demand system allows for shift variables to more than simply reallocate expenditures across meat products. The inclusion of nonmeat food

and nonfood in the demand system allows us to examine not only within-meat influences of incorporated shifters, but also implications with respect to nonmeat food and nonfood demand. Moreover, by *not* assuming meat products are separable the model provides expenditure elasticities that are closer approximations to income elasticities. In contrast, models that assume meat demand is separable (i.e., Piggott and Marsh, 2004; Ishida, Ishikawa, and Fukushige, 2007; Tonsor and Marsh, 2007), effectively impose the restriction that each shifter has a net zero effect across meat products. This situation clearly is undesirable given the diversity of shifter variables incorporated in the model.

As is common in demand system estimations, one share equation (all other goods) from our demand model is deleted from the system before estimation to avoid singularity in the estimated variance-covariance matrix of the error terms. The parameters of this omitted equation are recovered using the adding-up restrictions. In addition the adding-up restrictions, symmetry, and homogeneity restrictions are imposed as maintained assumptions to ensure the demand model is consistent with economic theory. Adding-up conditions are imposed by requiring:

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

Homogeneity and symmetry are imposed by:

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

Combined, equations (2) – (4) lead to compensated price, income, and shifter elasticities given by (Marsh, Schroeder, and Mintert, 2004):

$$\varepsilon_{ij} = \frac{c_{ij}}{w_i}, \ \eta_\iota = \frac{\beta_i}{w_i}$$

and

$$\kappa_{ikl} = \frac{\sum_{l=0}^{L} \lambda_{ikl}}{w_i}$$

respectively. $\quad (5)$

Given concerns with endogeneity of prices and/or quantities in meat demand models, (e.g., Eales and Unnevehr, 1993; Stockton, Capps, and Bessler, 2008), the approach followed by Thurman (1987) was used and Hausman specification tests were conducted. More specifically, the Rotterdam model was estimated in two ways. First, the right-hand-side variables were assumed to be predetermined and the model was estimated using Iterative Seemingly Unrelated Regression (ITSUR) techniques. Second, the right-hand-side variables were assumed to be endogenous and Iterative Three Stage Least Squares (IT3SLS) methods were used for estimation. The IT3SLS approach requires instrumental variables that may be associated with endogeneity of prices and total expenditure. Instruments employed, following those used by Eales and Unnevehr (1993), Capps et al (1994), and Kinnucan et al. (1997), include lagged prices and quantities, total per capita expenditure, a price index for energy, 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}). Since the null hypothesis of price exogeneity was rejected, reported results reflect use of the IT3SLS estimation technique.

Data

The demand model is estimated with quarterly data comprised of beef, pork, poultry, nonmeat 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 correspond to quarterly per capita disappearance, in retail weight (pounds/capita). Per capita consumption averaged 21.3, 17.3, and 12.7 lbs/capita/quarter, respectively for poultry, beef, and pork (Table 1). 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 consumption. All beef, pork, and poultry quantity and price series were obtained from the United States Department of Agriculture's Economic Research Service (USDA-ERS).

Unlike other studies, the complete demand system specification includes two aggregate commodities, nonmeat food and all other goods. Derivation of corresponding price and quantity indices for these two aggregate commodities were developed following Eales and Unnevehr (1993), Wang and Bessler (2003), and Bryant and Davis (2008).[3] Nonmeat food expenditures are identified as total food expenditures, less beef, pork, and poultry expenditures. Nonmeat food quantity is specified as total food quantity (proxied as total food expenditures divided by food's consumer price index) less the sum of beef, pork, and poultry quantities. Nonmeat food price is the ratio of nonmeat food expenditures to nonmeat food quantity. All other goods prices are proxied by the consumer price index for all items, less food. Thus, the quantity of all other goods is calculated as the ratio of nonfood expenditures to the consumer price index for all items, less food. Total consumption expenditure and total food expenditure series were obtained

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 (*FAFH*) (%)	45.0	1.8	40.6	47.5
Female in Labor Force (*Female*) (%)	57.8	2.3	51.8	60.2
Fat, Cholesterol, Heat Disease, Arteriosclerosis (*FCHA*) Index[b]	48.5	19.5	18.0	93.0
Zinc, Iron, Protein (*ZIP*) Index[b]	306.5	120.6	146.0	615.0
Net Atkins, High Protein, Low Carbohydrates (*nAtk*) Index[b,c]	35.8	93.6	-195.3	457.6
Beef Food Safety Recalls (*Beef_FS*)	3.8	3.2	0.0	15.0
Pork Food Safety Recalls (*Pork_FS*)	2.7	2.4	0.0	11.0
Poultry Food Safety Recalls (*Poultry_FS*)	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 Appendix A.*

[c] *The Atkins net index is negative when articles favorable to beef demand are outnumbered by those detrimental to beef demand.*
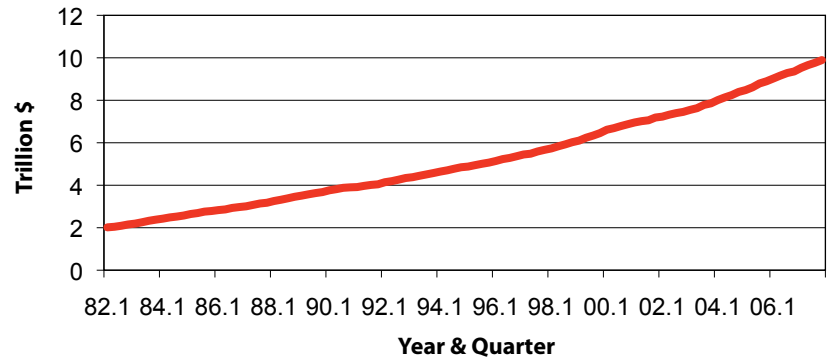
from the Bureau of Economic Analysis (BEA) (Figure 2). All consumer price indices were obtained from the Bureau of Labor Statistics (BLS).

To proxy changing demands for food convenience and household dynamics (**C**), variables accounting for food consumption away from home and female workforce participation were employed. In particular, a food away from home (*FAFH*) series, obtained from BEA, and the percentage of females employed in the labor force (*Female*), obtained from BLS, are included in the model specification. Binkley's (2006) analysis suggested a significant, positive correlation between consumers stated preferences for convenience and food purchased away from home. Moreover, female workforce participation has frequently been used as a proxy for valuation of consumer's time (i.e., Becker, 1965; Nayga, 1996; Byrne, Capps, and Saha, 1996). *FAFH* consumption as a percentage of food expenditures increased steadily during the study period, rising from 41 percent in 1982 to 52 percent in 2007 (Figure 3). Female labor force participation increased from 52 percent in 1982 to about 60 percent in 1998, but has been relatively stable since the late 1990s (Figure 4).

A series of media and medical journal information indices were created to capture the impact of health and diet information on meat demand (**H**). Consistent with the diversity in information sources available to consumers, different 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 individual indices capturing public information. Specific key word phrases used to develop each index are provided in Appendix A.
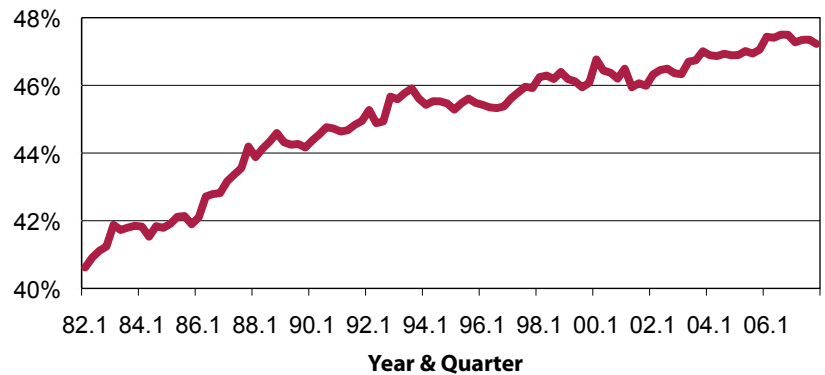
The first index captures Medline articles on links between fat, cholesterol, heart disease, arteriosclerosis, and diet (*FCHA)* (Figure 5). The second index

Figure 2. *Personal Consumption Expenditures Quarterly at Annual Rate, Seasonally Adjusted, 1982–2007.*
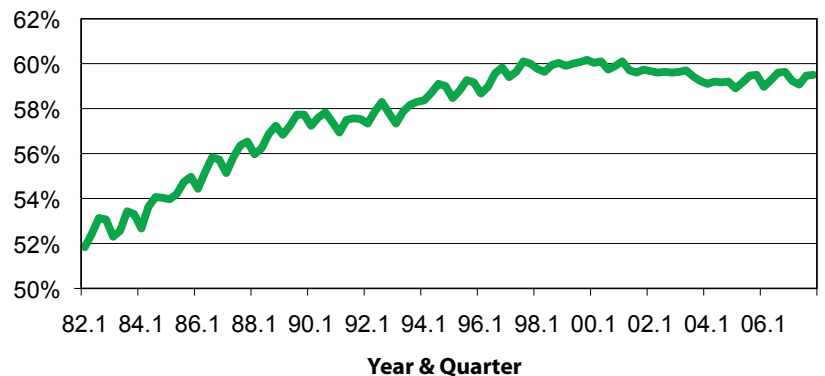

Source: Bureau of Economic Analysis

Figure 3. *Percentage of Food Consumed Away From Home Quarterly, 1982–2007.*

Source: U.S. Department of Commerce

Figure 4. *Percent of Females Employed Outside the Home Quarterly, 1982–2007.*

Source: U.S. Department of Commerce

searched the Medline database for articles regarding links between zinc, iron, or protein and diet (*ZIP*) (Figure 6). These indices were constructed by searching Medline for 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

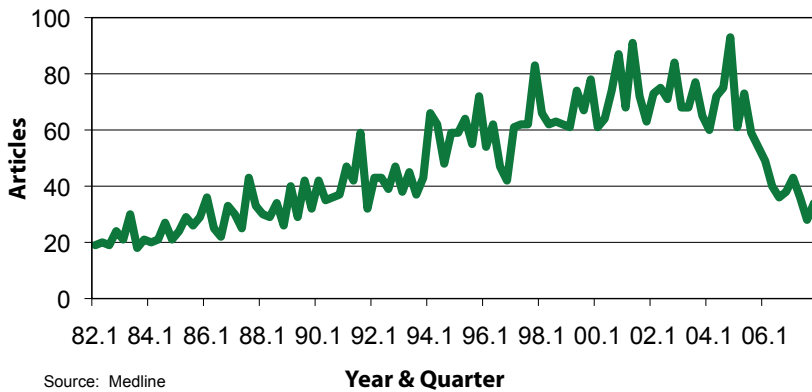**Figure 5.** *Articles Published Referencing Heart Disease & Diet Medical Journals, Quarterly, 1982–2007.*

Source: Medline

Figure 6. *Articles Published Referencing Zinc or Iron or Protein & Diet U.S. Newspapers, Quarterly, 1982–2007.*
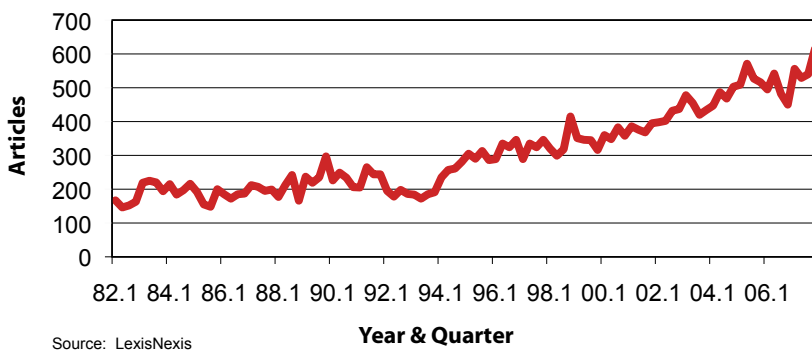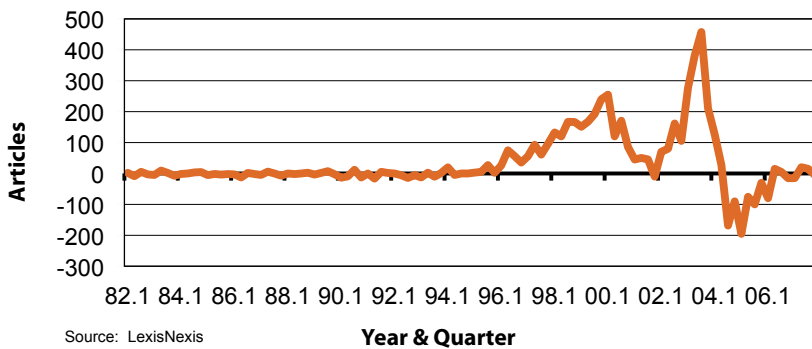

Source: LexisNexis

Figure 7. *Net Articles Published Referencing Atkins Diet Positive Minus Negative Articles, U.S. Newspapers, Quarterly, 1982–2007.*

Source: LexisNexis

physicians (Adhikari et al., 2006; Miljkovic and Mostad, 2005). Similarly, it was anticipated that emerging information regarding human nutrition and meat consumption would first be published in medical journals, read and interpreted by physicians and dieticians who, in turn, would transmit this information to their clientele. In this context, medical journals were viewed as a primary information source for subsequent articles that appeared in the popular press on this topic.

The third index is comprised of major newspaper articles on Atkins, high protein, or low carbohydrate diets identified via the Lexis-Nexis database (Figure 7). Popular press articles were used to measure consumer interest in low-carbohydrate diets, as opposed to medical journals, because of the large volume of mass media information published on this topic, much of which did not originate in medical journals. 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.

The *zinc, iron, protein* index increased steadily over time from 167 journal articles in the first quarter of 1982 to 615 articles in the fourth quarter of 2007. The *FCHA* index increased from 19 journal articles in the first quarter of 1982 to a maximum of 93 articles in fourth quarter of 2004, although it subsequently declined to 34 articles in the fourth quarter of 2007. The net Atkins (*nATK*) index increased from 1982 to 2003 and peaked in the third quarter of 2003 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, as the number of articles raising concerns about low carbohydrate diets outnumbered articles supporting these diets by 195 articles during the first quarter of 2005.

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 United States Department of Agriculture Food Safety Inspection Service (FSIS).[4] Meat recalls are employed as a proxy 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. Since recalls are publicly announced and widely reported by broadcast, print, and Internet media, they directly mirror information consumers receive about such food safety events. Class I and class II recalls were added for each quarter to create separate food safety recall counts for beef, pork, and poultry. Class I recalls occur when FSIS concludes a health hazard exists with a "reasonable probability that eating the food will cause health problems or death." Class II recalls take place when FSIS identifies a health hazard with a "remote probability of adverse health consequences from eating the food" (USDA, FSIS).

Food safety indices were developed by species because Marsh, Schroeder, and Mintert (2004) found significant cross-commodity effects from meat recalls, which suggests that direct and spillover recall effects differ by species. FSIS recalls for beef, pork, and poultry averaged 3.8, 2.7, and 2.6 per quarter, respectively, over the 1982 to 2007 period (Table 1). Figure 8 documents variability in beef recalls during the sample period. Each recall count increased in level and variability during the period 2000 to 2007 relative to the period 1982 to 1999. Importantly, beef recalls reached record levels in 2007 with 15 recalls during the fourth quarter. The variability in recalls provides further

Figure 8. *Beef Food Safety Class I & II Recalls, Quarterly, 1982-2007.*
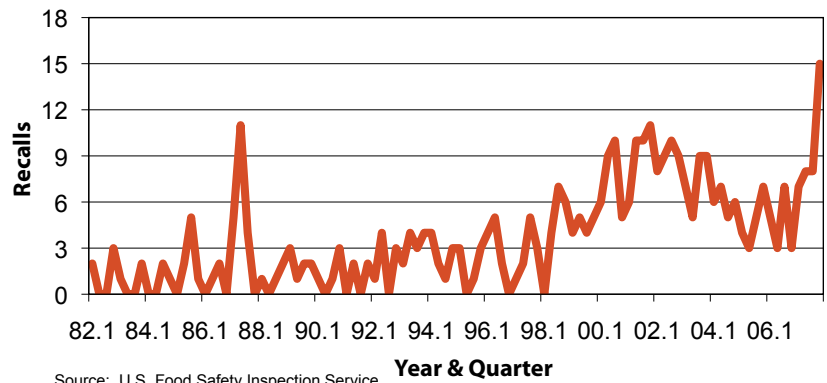
Source: U.S. Food Safety Inspection Service

evidence of the need to provide a current examination of food safety impacts on meat demand to update related literature (i.e., Piggott and Marsh, 2004; Marsh, Schroeder, and Mintert, 2004).

Estimation of the Rotterdam model required all variables to have positive values over all observations because of logarithmic transformations. Therefore, 1 was added to each FSIS recall (because the value was zero for some quarters) and 200 was added to the Atkins Net media article series (because it had one value as small as -195). These adjustments ensure that all the explanatory variables were globally positive in value, making possible natural logarithm calculations. Alternative adjustments were considered, including replacing all zeros with 10 percent 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 similar results. This procedure follows that of Brester and Schroeder (1995) and Schroeder (1992). Although commonly employed in the literature, this adjustment does introduce a small bias in the resulting estimates (Schroeder, 1992).

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 0 to 3 quarters for each exogenous 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 omitting each variable or set of variables considered (i.e., significance of female employment or joint significance of FSIS recalls). Following these evaluations, the final presented model incorporates contemporaneous effects for all variables, in addition to 1 and 2 quarter lagged effects for all three FSIS recall variables.

With homogeneity and symmetry imposed, IT3SLS estimates were calculated while dropping one equation to avoid singularity of the error covariance matrix. The parameters of this omitted equation are obtained by using the Engel aggregation (adding-up) restrictions discussed 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: (1) a correction matrix (null matrix) restricting all elements to zero (specifying no autocorrelation correction, $\rho_{ij} = 0 \ \forall_{ij}$); (2) 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 $\rho_{ij} \neq 0 \ \forall_{i=j}$); and (3) a correction matrix (complete matrix) allowing all elements to differ individually from zero ($\rho_{ij} \neq 0 \ \forall_{ij}$).[5] 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 model coefficients are reported in Table 2. Goodness-of-fit, as measured by R-squared values, indicates the model captured 73 percent, 86 percent, 86 percent, and 37 percent, respectively, of the in-sample variation of beef, pork, poultry, and other food goods. The weaker fit of the other food goods equation is reflective of the fact that exogenous shifter variables were selected based on their relevance to meat demand, not demand for other food goods. The fits for the three meat share equations are consistent with existing studies. Curvature is satisfied by the estimated model as the price coefficient matrix is negative semidefinite.

Rather than discuss the estimated coefficients, which are individually of limited value, estimated elasticities implied by the model are focused on (Table 3). It also may be misleading to simply examine elasticity point estimates without consideration of their statistical significance (Tonsor and Marsh, 2007). Accordingly, a Krinsky-Robb (1986) bootstrapping 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, respectively. This procedure generated 1,000 values of each elasticity estimate, using bootstrapping drawings from a multivariate normal distribution parameterized using the estimated coefficients and variance terms from the model. The proportion of observations in this distribution with values greater than

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

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

Notes: Standard errors are in parentheses. * denotes coefficient estimates that are statistically significant at the 10% level or higher. Log-likelihood value is 3,309.349.

R-square statistics of the beef, pork, poultry, and other food shares are 73.1%, 85.6%, 86.0%, and 37.2%, respectively. Autocorrelation coefficients are not presented, but are available upon request.

the critical value (e.g., 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 elasticities are estimated at -0.420, -0.740, -0.099, -0.298, and -0.054 for beef, pork, poultry, other food, and nonfood goods, respectively. Each own-price elasticity estimate is significantly greater than -1.0 and all except poultry are significantly different from zero (0.05 level). The finding of pork as the most elastic and poultry the most inelastic demand of the meat goods is consistent with Tonsor and Marsh (2007) and Brester and Schroeder (1995). Finding other food and nonfood demands to be less price sensitive than beef and pork, is consistent with Brester and Schroeder (1996) and Marsh, Schroeder, and Mintert, (2004). Each cross-price elasticity estimate for the three evaluated meats is not significantly different from zero (as in Marsh, Schroeder, and Mintert, 2004). Each of the expenditure elasticity estimates statistically differs 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), the estimates indicate that beef and pork are normal goods and poultry is an inferior good.

The affects of the three health information indices included in the model vary across information source and product. Important to note is the fact that only contemporaneous effects from the health information indices were significant, suggesting that the impact of health information on consumer demand for meat declines rapidly. Increasing availability of 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).

Beef and poultry demand benefited (0.025 and 0.048 elasticities, respectively) from increasing availability of information regarding health benefits associated with zinc, iron, or protein (*ZIP*) in diets. Furthermore, beef demand responded positively to the publication of net positive information regarding Atkins, high protein, or low carbohydrate diets (*nATK*), and likewise, declined when net negative information about such diets was disseminated (0.008 elasticity).

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

Table 3. *Estimat ed Compensated Elasticities for Demand Model, Quarterly Data 1982-2007.*

Quantity of:

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

Note: Elasticities are calculated at the mean values of the explanatory variables. All *p*-values were obtained using Krinsky-Robb bootstrapping procedures.
*, ** denote elasticities significantly different from 0 at the 15% and 10% level, 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.

> *… the increase in food-away-from-home expenditures substantially benefited demand for pork and poultry, at the expense of the demand for beef.*

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

Model results indicate the increase in *FAFH* expenditures substantially benefited demand for pork and poultry, at the expense of the demand for beef. Elasticity estimates reveal that a 1 percent increase in food away from home consumption increased pork and poultry demand by about 1.8 percent and 1.9 percent, respectively, but reduced beef demand by about 1.6 percent. Although the model does not directly provide insight regarding why increasing consumption of food away from

… in quarters when food safety recalls increase markedly, as they did in 2007, recalls can lead to a decided reduction in beef demand.

home led to increases in poultry and pork demand and decreases in beef demand, one possible explanation is a shift in menu items over time. Rapid proliferation of new poultry menu items throughout the study period, compared to a much smaller number of new beef menu items, could be responsible for the poultry and beef results. Left unexplained, however, is the reason why pork demand benefitted from increasing away from home consumption since, unlike, poultry, there has not been a notable increase in new pork menu items.

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. Examining the data from 1982 to 2007, the 16 percent increase in female employment reduced pork demand by about 12 percent. Combined, these results suggest that U.S. consumers view poultry (and possibly pork) products (in aggregate) as being more convenient than beef products.[7] Unfortunately, the aggregate disappearance data based analysis is unable to further explain *why* foods away from home consumption and employment of women have these effects. Given the meat industry's inability to influence consumption of food away from home or female employment trends, additional work is needed regarding *why* these trends are influential. Future research, possibly using scanner or household-level

data, might provide more clarity regarding why these impacts are occurring.

The final set of exogenous shifters evaluated in the model is the FSIS recall indices specific to each meat product. As found by Marsh, Schroeder, and Mintert (2004) and Piggott and Marsh (2004), the estimated food safety effects are small, particularly relative to price, expenditure, and household dynamic effects. Nearly all of the estimated long-run recall effects are larger than contemporaneous effects. Beef consumption is the only meat product statistically impacted by its own recalls (-0.009 and -0.023 short- and long-run elasticities, respectively). However, it's important to note that in quarters when food safety recalls increase markedly, as they did in 2007, recalls can lead to a decided reduction in beef demand. This result differs from that of Marsh, Schroeder, and Mintert (2004) who concluded that beef recalls did not have a statistically significant affect on beef demand. Beef demand is notably more sensitive to both own-product and spillover effects from recalls of other meats. Poultry demand actually increases when beef recalls occur. A 10 percent increase in beef recalls reduces beef demand by 0.2 percent and increases poultry demand by 0.2 percent, in the long run. Conversely, beef and pork recalls appear to exert negative spillover effects on each other as increasing pork recalls adversely affects demand for beef.

Conclusions and Implications

The analysis provides insights into previously unexamined topics including media attention to multiple health issues and diet linkages. In summary, the results suggest that in addition to prices and expenditures, multiple factors, including food safety recalls, published articles on health and diet issues, and changing household dynamics affect meat demand.

New information available to consumers regarding how meat consumption affects 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 carbohydrates and human nutrition all have significant effects on meat demand. In particular, beef demand declined in response to publication of information linking fat and cholesterol to heart disease. Additionally, both beef and poultry demand benefited from publication of medical literature linking iron, zinc, or protein with meat consumption.

The effect of changing U.S. household dynamics, namely food away from home consumption and female workforce participation, on meat demand were also examined. The trend toward a higher portion of household food expenditures being allocated to goods consumed away from home substantially increased pork and poultry demand at the expense of beef demand. In addition, increasing employment of women outside the home had a negative impact on pork demand. Overall, these results suggest poultry demand benefited, and beef demand suffered, as U.S. consumers' demand for more convenient meat products increased.

U.S. Department of Agriculture Food Safety Inspection Service (FSIS) meat recalls also were examined for both own-good and spillover effects on other meats. Recalls have both contemporaneous and longer-run direct adverse impacts on consumer demand. Beef demand is harmed by FSIS recalls and both beef and pork recalls reduce beef consumption. Moreover, beef recalls have a significant positive spillover effect on poultry demand, suggesting that consumers shift away from beef and toward poultry products in response to beef food safety recalls.

Given that meat demand 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 discussing animal welfare and handling. Moreover, additional measures of changing household dynamics (i.e., factors influencing demand for product convenience, or ease of preparation) could be incorporated in future research as they become available. Future work using scanner or other household-level data also could be valuable in more narrowly identifying the specific determinants of the findings from this study, which are based on aggregate disappearance data. For instance, research identifying the specific grocery buying habits and types of restaurants visited (and preferably menu items selected) of households varying in employment and food away from home status would provide additional valuable insights on the effects of ever-changing household dynamics on meat demand. In addition, as producer groups adjust the amount and allocations of generic advertising efforts, the analysis could be expanded to evaluate corresponding effects on U.S. meat demand. Finally, as additional data on U.S. lamb, veal, and fish consumption becomes available, evaluation of information effects (including food safety and health) on these products might also provide valuable insights.

… these results suggest poultry demand benefited, and beef demand suffered, as U.S. consumers' demand for more convenient meat products increased.

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Endnotes

[1] Readers interested in a less detailed summary of this study should read the four-page fact sheet entitled "U.S. Beef Demand Drivers and Enhancement Opportunities: A Research Summary" by James Mintert, Glynn Tonsor, and Ted Schroeder. The fact sheet can be accessed at *http://www.agmanager.info/livestock/marketing/bulletins_2/industry/demand/Beef_Demand_Drivers_January_2009.pdf*.

[2] In this specification, lamb, veal, and fish 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, accurate quarterly disappearance data on these products consistent with that available for beef, pork, and poultry is difficult to obtain(Tonsor and Marsh, 2007; Schroeder et al. 2001; Kinnucan et al, 1997).

[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 (i.e.,

Marsh, Schroeder, and Mintert, 2004; Eales and Unnevehr, 1993; Wang and Bessler, 2003).

[4] Also considered were 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.

[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).

[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 Appendix presents the correlation of variables as they entered the Rotterdam model given by equation (2), documenting that FAFH and Female are uncorrelated in the estimated model.

Appendix A

We present 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 provided 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 keywords 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.

Appendix B.

Correlation of the Exogenous Shifter Variables Used in the Rotterdam Model.

	Beef_FS	Pork_FS	Poultry_FS	FCHA	ZIP	nATK	FAFH	Female
Beef_FS	1.00							
Pork_FS	-0.20*	1.00						
Poultry_FS	0.01	0.15	1.00					
FCHA	0.01	0.00	0.06	1.00				
ZIP	-0.05	0.11	-0.10	-0.02	1.00			
nATK	0.02	0.10	-0.06	0.18	0.10	1.00		
FAFH	-0.02	-0.21	0.10	-0.18*	-0.08	0.03	1.00	
Female	0.01	-0.03	0.07	-0.16*	-0.04	0.10	0.01	1.00

Note: Presented figures are correlation coefficients of the first differenced, natural logarithms of all eight shifter variables incorporated in the Rotterdam model.
* denotes correlation coefficients significantly different from zero at the 10% level.

Appendix C.

Sample Summary of Beef Demand Elasticity Estimates.

Study	Years	Frequency	Beef Own-Price	Pork Price	Poultry Price	Income or Expenditure
Tonsor & Marsh, 2007	1976-2001	Quarterly	-0.23	0.32	0.14	0.89[a]
Marsh, Schroeder, and Mintert, 2004	1982-1998	Quarterly	-0.78	0.02	-0.02	0.59[b]
Piggott & Marsh, 2004	1982-1999	Quarterly	-0.32	0.21	0.12	1.11[a]
Boetel & Liu, 2003	1976-2000	Quarterly	-0.44	0.20	0.10	0.85[a]

This table presents a sample of beef demand elasticity estimates from research published since 2000. Please see page 12 of Schroeder, Marsh, and Mintert (2000) for a similar summary of ten studies published before 2000. Here a and b denote meat expenditure and total expenditure elasticities, respectively.

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