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Food Safety and Habits in U.S. Meat Demand under Rational Expectations*

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June 2006

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, California, July 23-26, 2006

*We thank Nick Piggott, Wally Thurman, and Barry Goodwin for helpful comments. All errors are our own.
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Abstract

A consumer life-cycle demand system is built to investigate the presence of rational habits and the effects of food safety information on U.S. meat consumption. Information extracted from the popular press coverage of food safety events is used to approximate consumers' "true" perception of food safety. At quarterly frequencies, U.S. meat demand is found to be intertemporally nonseparable. During the post-1998 period, habit persistence is found to dominate inventory adjustment in beef demand. In general, food safety information is found to adversely affect meat demand. The ongoing research focuses on numerical simulations of consumer responses to alternative food safety event scenarios to evaluate the economic significance of food safety information and habit formation in U.S. meat demand.

Keywords: food safety, habit persistence, meat demand.

1 Introduction

Every year in the United States foodborne diseases cause thousands of premature deaths and cost society billions of dollars (USDA, 2000). Sporadic outbreaks of food contamination are the subject of public attention and may adversely affect consumer demand for the implicated food products. Although foodborne pathogens have been found in a myriad of food types, meat products remain a major source. It is of considerable importance not only to academics but also to the food industry and public policy-makers whether food safety information has short- and long-run effects on consumer demand. The purpose of this paper is to empirically investigate, using a demand system with rational habit persistence, the effects of meat recalls and news media coverage of food contamination outbreaks on U.S. consumption of beef, pork and poultry products.

A small but growing economic literature examines the impact of food safety events on consumer demand. Burton and Young (1996) built indices of media coverage of bovine spongiform encephalopathy (BSE) by counting the number of newspaper articles that mentioned BSE. When these indices were incorporated in a demand system, statistically significant impacts of BSE articles on beef and other meats were detected. Henson and Mazzocchi (2002) examined security price data of a number of food manufacturers that were publicly traded on the London Stock Exchange. Their results indicated that the public announcement of a possible link between BSE and a new variant of its human equivalent Creutzfeldt-Jacob disease (CJD) by the British government in 1996 negatively affected beef product manufacturers but profited manufacturers of other meats. Similar results were reported using U.S. data. Thomsen and McKenzie (2001) found that a class 1 meat recall resulted in a 1.5-3% loss in shareholder wealth, while less serious hazards had no discernible adverse impact on stock market returns of the implicated food company.

Several studies show that the effects of food safety on U.S. meat demand have been small in magnitude relative to price and health effects. Dahlgran and Fairchild (2002) constructed an adverse publicity index of salmonella contamination of chicken using multiple sources of TV and print news. Their results indicated that consumer response to chicken contamination publicity was small and short-lived with less than 1% reduction in consumption at the height of the exposure. Flake and Patterson (1999) studied the impact of beef safety information on meat demand in a system of demand framework. Their food safety information index was based on the number of Associated Press articles on *Escherichia coli* (*E. coli*), salmonellosis and BSE. They found that

the negative effect of beef safety stories on beef consumption was small (when compared to health effect) and only marginally statistically significant. The analysis by Piggott and Marsh (2004) is the first demand study that incorporated multiple food safety indices constructed individually for beef, pork and poultry. In contrast to earlier studies, they were able to investigate both the own- and cross-effects of food safety indices on meat types. While statistically significant food safety effects were detected, their economic significance appeared to be modest relative to price and expenditure effects. These results were confirmed by Marsh, Schroeder and Mintert (2004) who found small effects of meat product recalls on U.S. meat demand.

Traditionally, most studies of meat consumption have followed the static demand system paradigm in that the consumption decisions are functions of current prices, income, and possibly a few other demographic and health variables. Exceptions include Pope, Green and Eales (1980) and Holt and Goodwin (1997) where dynamic aspects of meat demand were explored by testing for the existence of habit formation. In these studies, the household is backward-looking in that habits play a passive role and do not alter the duality theorems of standard static optimization. This type of habits is called myopic habits. In contrast to the existing literature on meat demand, the estimation in this paper is based on the optimality conditions derived from an intertemporal optimization problem with rational expectations assumed.

The construction of a meat demand model under rational expectations is implicitly motivated by the Lucas (1976) critique which contends that the parameters of conventional macroeconomic models rest critically on parameters dictating agents' expectation processes and are possibly unstable in a varying economic environment. To overcome this problem, some empirical studies focus on the estimation of "deep" behavioral parameters that have explicit structural interpretations. In the case of meat consumption, expectations are important for modeling habitual demand while almost irrelevant for demand models that are intertemporally separable (Zhen and Wohlgenant, 2005).

Food safety and habit persistence are not two unrelated issues that may be treated separately. Habituation of demand provides a convenient tool with which consumption dynamics could be rationalized. Under habit persistence, food scares that may have a short-lived direct impact on demand could have protracted indirect effects by changing the level of habit stock.

More importantly, if meat consumption is habit-forming, rational consumers respond more to permanent food safety shocks than to transitory shocks. But this distinction is not implied by a

reduced-form myopic demand model with habit persistence.

The contribution of this paper is at least two-fold. First, newspaper articles are differentiated by their contents, an improvement over existing meat safety indices in the literature. Second, a rational habit persistence model is estimated with meat data. The estimated structural parameters can then be used to simulate demand responses to price and food safety shocks under different expectations schemes.

The plan of this paper is as follows. In section 2, a theory of consumer response to food safety information under rational habit persistence is described. In section 3 we discuss the data used in our empirical analysis with special attention to the food safety data. In section 4 the econometric technique used to obtain estimates of preference parameters is outlined, and then, empirical results are presented and discussed. Finally, section 5 provides concluding remarks.

2 Theoretical Model

2.1 Intertemporal nonseparable preferences

The simplest way to introduce time-nonseparable preferences is to let current consumption depend on consumption in the previous period. It is the most common approach to consumption dynamics in the literature on habit persistence (e.g., Becker, Grossman and Murphy, 1994; Dynan, 2000). Under uncertainty, the representative household maximizes at period t the present value of a lifetime utility

$$\max_{X_t} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u_{\tau}(X_{\tau}, X_{\tau-1}, Z_{\tau}) \quad (1)$$

where u_{τ} is the within-period utility at period τ , X_{τ} is a vector of N consumption goods (e.g., meats) at τ , E_t is the expectation operator conditional on information available at time t , and β is the discount factor. The vector Z_{τ} contains variables that measure the quality aspects of the goods at τ . The idea is to let $X_{\tau-1}$ be the vector of habit stock variables to proxy past consumption experience. Implicit in (1) is the assumption that other goods are weakly separable from the X vector of commodities that are potentially habit-forming. The budget constraint is

$$\sum_{\tau=t}^{\infty} (1 + r_{\tau})^{\tau-t} (Y_{\tau} + P'_{\tau} X_{\tau} - y_{\tau}) = W_t \quad (2)$$

where r_{τ} is the riskless interest rate between periods τ and $\tau + 1$, Y_{τ} represents expenditures on all other goods at τ , P_{τ} is the price vector corresponding to X_{τ} , y_{τ} is the household income at period

τ , and W_t is the present value of lifetime assets at t .

The marginal utility of good i ($i = 1, \dots, N$) implied by the assumed utility structure is

$$MU_{it} = \frac{\partial u_t}{\partial x_{it}} + \beta E_t \left[\frac{\partial u_{t+1}}{\partial x_{it}} \right]. \quad (3)$$

Thus, with intertemporally nonseparable preferences, the marginal utility of x equals the marginal utility of current consumption plus its discounted marginal effect on the utility in the next period. It distinguishes a rational household from a myopic one because the rational household is aware of the impact of its current consumption on future utilities and makes explicit use of this information when optimizing intertemporally, while the myopic household is ignorant of such information.

Maximize the lifetime utility function (1) subject to the budget constraint (2). The first-order conditions (FOC) of the representative household choosing optimally to allocate consumption over time are

$$\frac{1}{p_{it}} MU_{it} = \lambda_t \text{ for } i = 1, \dots, N \quad (4)$$

where p_i is the price of good i , λ_t is the marginal utility of wealth at t . Although λ_t is unobservable, using the FOC for the 1st good to eliminate λ_t from other FOCs yields

$$\frac{1}{p_{1t}} MU_{1t} = \frac{1}{p_{jt}} MU_{jt} \text{ for } j = 2, \dots, N. \quad (5)$$

Equation (5) is the Euler equation that will be used to form the basis of our empirical work.

Habit persistence requires that consumption be positively related across periods. Becker and Murphy (1988) proved that, for consumption to be habitual, consumption in the previous period must have a positive marginal effect on the marginal utility of current consumption. In the context of partial derivatives, this implies $\frac{\partial u_\tau}{\partial x_\tau \partial x_{\tau-1}} > 0$. This positive marginal effect may come from a variety of potential sources such as learning-by-doing or cost-of-adjustment. Whatever causes the habit, the degree of a habit is an increasing function of, *inter alia*, the magnitude of this marginal effect.

2.2 Effects of food safety and health information on consumption

In a theoretical paper, Zhen and Wohlgenant (2005) studied the impacts of adverse food safety and health information on consumer demand of meat, using a direct quadratic utility function augmented with habit and food safety variables. Theoretical findings that may have important bearing on our empirical analysis are described below.

Let Z contain indices of public information on the product safety of X , with the index z_i linked to the quality of good i . The index could be a measure of the extensiveness of product recalls or intensity of media reports of food contaminations. A higher value of z_i indicates increased adverse publicity on the quality of good i implying $\frac{\partial u_r}{\partial x_r \partial z_i} < 0$ (see, for example, Piggott and Marsh). If preferences are time-separable, z_i would have the immediate and full effect on x_i by reducing the level of its consumption. However, if consumption of x_i is habitual, the effect of an increase in z_i on x_i has several dimensions. Consumption responses to a change in product quality are different between in the short run and in the long run. For a transitory increase in z_i , holding the increment in z_i constant, the size of the immediate drop in consumption of x_i is an increasing function of the expected duration of the adverse publicity. In the long run, x_i returns to its equilibrium level before the negative quality shock. On the other hand, the quality deterioration that is expected to be permanent would gradually reduce x_i to a new long-run equilibrium at a lower level. The sluggish adjustment in x_i causes its long-run response to be larger than its short-run response, and this difference increases with the degree of habit persistence. The cross-effects of food safety events on other goods depend on the nature of these goods (substitutes or complements) and would be interesting to investigate in the empirical analysis.

Using some forms of consumer cholesterol awareness index, several static demand system approaches have found statistically significant negative/positive impacts of this health hazard on demand for beef /poultry and sometimes pork (e.g., McGuirk et al. 1995; Kinnucan et al. 1997). Dahlgran and Fairchild and Piggott and Marsh noted that cholesterol related health effects require long-term and repeated consumption, unlike food safety effects that would result in sudden and acute illness. If this is true, it is plausible that the health effects would express themselves through the habit stock term X_{t-1} . Arguably, increased cholesterol information may have reduced/increased the marginal effect of past consumption on the marginal utility of current consumption of red/white meat. The strength of a habit for red/white meat could have consequently declined/increased over time.

3 Description of the Data

3.1 Food safety indices

We follow the mass-media index approach often pursued in the literature. To explore the news content of the popular press coverage of food safety, our food safety indices are based on full-text articles and abstracts from four US-based newspapers—*Christian Science Monitor*, *New York Times*, *Wall Street Journal*, and *Washington Post*. These newspapers are selected because they are available for searching during the entire sample period (1980(3) to 2005(4)). The search engine used was LexisNexis Academic. Keywords searched were specified in Piggott and Marsh, which were *food safety* or *contamination* or *product recall* or *outbreak* or *salmonella* or *listeria* or *E. Coli* or *trichinae* or *staphylococcus* or *foodborne*. Based on this pool of articles, the search was narrowed down to individual meats. The keywords *beef* or *hamburger* or *meat*, *pork* or *ham* or *meat*, and *poultry* or *chicken* or *turkey* or *meat* were used to locate articles related to beef, pork, and poultry food safety, respectively. Every article was read to determine its pertinence to food safety with irrelevant ones dropped from the information base. Articles regarded as being positive about a meat species were separated from negative articles. Depending on our objective judgement of the likelihood that the article would adversely affect consumer demand for a meat species, negative articles were assigned a score of 0, 0.25, 0.5 or 0.75, with 0 being the least likely and 0.75 the most likely. Similarly, all positive articles were also scored. For each meat type, quarterly negative-news indices (NIDX) were constructed by adding up scores on negative articles, and positive-news indices (PIDX) by adding up scores on positive articles, related to this meat. Figure 1 plots these data series for the 1980(3)-2005(4) period.

Over the entire sample, beef on average suffered a higher degree of negativity than pork or poultry on average. The NIDX takes a mean of 11.24 for beef, 4.03 for pork, and 6.67 for poultry. But this is not the case during the 1980-1992 subsample period. In fact, from 1980 to 1992, poultry safety attracted more media attention than beef and pork. The NIDX values for beef, pork and poultry in the 1980-1992 period are 2.78, 2.38 and 3.52, respectively. In the first quarter of 1993 an outbreak of *E. coli* bacteria poisoning traced to hamburgers at a fast-food chain in the Northwest received intense media coverage and caused beef NIDX to peak at 45.75. This incident ignited heavy criticism over the soundness of the nation’s meat and poultry inspection system that brought the pork NIDX to its maximum at 20.75 and poultry NIDX to one of its highest at 23. This event

became a vital catalyst to USDA's implementation of the Pathogen Reduction/Hazard Analysis and Critical Control Point (PR/HACCP) system for meat and poultry inspection in the late 1990s. The 1997(3) peak in beef NIDX was due to a massive recall of 25 million pounds of ground beef in the midwest U.S. Media reports of beef safety surged drastically in 2003(4) and 2004(1) when the first case of BSE in U.S. was discovered in Washington state.

The poultry NIDX reached one of its highest levels at 24.25 when fear of listeria contamination prompted gigantic recall of chicken and turkey products in the fourth quarter of 2002. A peak score of 34.5 coincides with the outbreak of avian flu in Asia in 2004(1). The highest poultry NIDX (37.75) occurred in the last quarter of 2005 following warnings of potential international bird flu pandemic.

Unlike beef and poultry, pork received less media attention partly because it was less often implicated in large-scale outbreaks than beef and poultry. However, listeria and other bacteria contaminations have been traced to products with pork as the ingredient from time to time.

In contrast to the number of negative news reports that constantly made the headlines, articles that can be classified as being positive occurred rather sporadically. Both poultry and pork received some degree of positive media coverage in 1996 when a new variant of CJD was first linked to eating contaminated beef, and during the 2003(4)-2004(1) period in the midst of the first U.S. mad cow case. In addition, some of the non-zero beef, pork and poultry PIDXs during the late 1990s were a result of favorable coverage following the implementation of the PR/HACCP system.

3.2 Meat data

Quarterly meat data during the 1980(3)-2004(4) period are used in the empirical analysis. The disappearance data published in the United States Department of Agriculture (USDA) Economic Research Service (ERS) *Red Meats Yearbook* and *Poultry Yearbook* are taken to be the basic consumption quantity data for the period 1982-2003. Data for 2004 and 2005 are from the February 2006 issue of ERS *Livestock, Dairy, and Poultry outlook*. The beef price is the average retail price of choice beef. The pork price is the average retail price of pork. Following the procedure specified in Piggott and Marsh, the poultry price is a weighted average of chicken and turkey retail prices. Quantity data are converted to retail weight using the conversion factors available online from the ERS *Food Consumption Data System*. Population data used to convert aggregate quantities to per

capita values are mid-quarter total U.S. population from the Department of Commerce, Bureau of Economic Analysis (BEA).

Figure 2 illustrates the real quarterly per capita expenditures on beef, pork and poultry. Seasonality is apparent in all three series. Beef expenditure peaks in the second and third quarter corresponding with the summer grilling season. For poultry, expenditure is the highest in the fourth quarter partly because of the high demand around Thanksgiving. Pork expenditure also reaches its highest level in the fourth quarter, partly because demand for hams is strong during the winter holiday season.

Apart from seasonality, meat expenditures appear to trend differently before and after 1998. This is most evident for beef but less obvious for poultry and pork. In 1998, beef expenditure reversed its nearly two-decade downward trend and continued to rise until the end of the sample. One probable explanation is that the high protein-low carbohydrate diet fad may have shifted consumer preferences toward meat products.

4 Empirical Specification and Results

4.1 Direct translog preferences

For this study, a flexible direct translog utility function augmented to include habits is used to describe the household preferences over consumption goods 1 (beef), 2 (pork) and 3 (poultry)

$$u_t = \sum_{i=1}^3 a_i \ln x_{it} + \frac{1}{2} \sum_{i=1}^3 \sum_{j=1}^3 b_{ij} \ln x_{it} \ln x_{jt} + \sum_{i=1}^3 b_i \ln x_{it} \ln x_{it-1} \quad (6)$$

where a_i , b_{ij} and b_i are parameters to be estimated. Christensen and Manser (1977) estimated U.S. consumer preferences for meats with a static direct translog utility function. The last term on the right-hand-side of equation (6) is responsible for capturing any potential intertemporal non-separability in the preferences. Meghir and Weber (1996) and Carrasco, Labeaga and López-Salido (2005)¹ used the same preferences structure to test for intertemporal nonseparable preferences with U.S. and Spanish micro data, respectively. Following the discussion in section 2, habit persistence implies $b_i > 0$ while durability or inventory adjustment² implies $b_i < 0$. If $b_i = 0 \forall i$ time separable

¹Note that the parameter estimates interpreted by Carrasco, Labeaga and López-Salido as evidence of habit formation are actually evidence of inventory adjustment. This is because their results imply negative marginal effect of past consumption on the marginal utility of current consumption—an indication of inventory adjustment.

²In this paper, the terms inventory adjustment and durability are used interchangeably.

preferences follow. Habits may arise because it is costly for the household to adjust consumption in response to changes in the economic environment. These costs may involve the cost of learning and perfecting new recipes and any psychological disutilities from switching to new cuisine. Conversely, inventory adjustment may be a result of hoarding on the part of the household to take advantage of supermarket specials or an appetite for food diversities. Finally, additive separability for any two goods (i, j) is implied if $b_{ij} = 0$. It is important to test habit formation in meat consumption in a demand system framework as all empirical studies of meat demand decisively reject separabilities across meat types.

To incorporate the effects of food safety information on the household preferences, the parameter a_i is further specified to be a linear function of the household's perception of meat safety. That is,

$$a_i = a_{i0} + a_{i1}bs_t + a_{i2}ps_t + a_{i3}cs_t \quad (7)$$

where bs_t , ps_t and cs_t are, respectively, consumer perceptions of the safety of beef, pork and poultry. Because there is no way to determine *a priori* the most appropriate way of representing these perception variables with our news indices. We examine the performance of a few alternative representations in more detail in the model results section.

4.2 Estimation strategy

When estimating a dynamic rational expectations model, the Generalized Method of Moments (GMM) of Hansen (1982) is the natural choice. Use the direct utility function (6) to parameterize the marginal utility of consumption (3)

$$MU_{it} = \frac{a_{it}}{m_{it}} + \sum_{j=1}^3 b_{ij} \frac{\ln x_{jt}}{m_{it}} + b_i \frac{\ln x_{it-1}}{m_{it}} + \beta E_t \left[b_i \frac{\ln x_{it+1}}{m_{it}} \right] \quad (8)$$

for $i = 1, 2$ and 3 . Next, use (8) and (5) to derive an estimable form of the FOC

$$\begin{aligned} e_{it} = & \left[\frac{a_{1t}}{m_{1t}} + \sum_{j=1}^3 b_{1j} \frac{\ln x_{jt}}{m_{1t}} + b_1 \frac{\ln x_{1t-1}}{m_{1t}} + b_1 \beta \frac{\ln x_{1t+1}}{m_{1t}} \right] \\ & - \left[\frac{a_{it}}{m_{it}} + \sum_{j=1}^3 b_{ij} \frac{\ln x_{jt}}{m_{it}} + b_i \frac{\ln x_{it-1}}{m_{it}} + b_i \beta \frac{\ln x_{it+1}}{m_{it}} \right] \end{aligned} \quad (9)$$

for i equal to 2 (pork) and 3 (poultry), where m_i is the expenditure on the i th meat. The expectations in (5) are replaced by realizations less innovations. These innovations are expectation errors

made in the household intertemporal consumption decision process, and are contained in the error term e_{it} . The parameters of good 1 (beef) appear in both equations with a_{10} normalized to 1. The model is linear conditional upon the discount factor. Because a linear model is easier to handle, we decide not to estimate β but fix it at 0.98.

In addition, there is another justification for preserving the linearity of the regression. Since seasonally unadjusted data are used for estimation, seasonality has to be taken care of. If the transformed variables in (9) are better characterized as nonstationary seasonal processes, seasonal differencing is more appropriate. At quarterly frequencies, this amounts to fourth-differencing the transformed variables in (9) which is feasible because of the linearity of the regression.

Under uncertainty and assuming rational expectations, the error term $\Delta_4 e_{it} = e_{it} - e_{it-4}$ that contains the innovations is orthogonal to variables in the information set (Ω_t) as of period t . That is, when evaluated at the true parameter values,

$$E[(\Delta_4 e_{2t} \ \Delta_4 e_{3t})' | \Omega_t] = 0. \quad (10)$$

The instrumental variables in the information set include choice variables dated $t - 1$ and earlier, demand shifters and prices dated t and earlier. Furthermore, e_{it} is serially uncorrelated since it is in the information set at period $t + 1$. The moment conditions used by the GMM estimation of parameters can be summarized as

$$E[(\Delta_4 e_{2t} \Delta_4 z'_{2t} \ \Delta_4 e_{3t} \Delta_4 z'_{3t})'] = 0 \quad (11)$$

where $\Delta_4 z_{2t}$ and $\Delta_4 z_{3t}$ are the corresponding vectors of fourth-differenced instruments.

Note that every variable in (9) is divided by an expenditure at t . Therefore, all of the transformed variables are endogenous and have to be instrumented. To imitate the variables in (9) as closely as possible, the list of instruments includes food safety variables dated t and $t - 1$ and quantities demanded at $t - 2$, all of which were first divided by expenditures dated $t - 2$ and then fourth-differenced. The beef/pork and beef/poultry equations were estimated jointly imposing equality of the beef parameters across equations and $b_{ij} = b_{ji}$.

4.3 Results and discussion

There are many ways in which the newspaper indices discussed earlier could be used to represent consumers' perception of meat safety. Because there is no clear *a priori* reason for preferring one

to the other, we report parameter estimates using two alternative combinations of indices, denoted by mode 1 and 2, to proxy the bs , ps , and cs variables in (7).

In mode 1, bs_t (or ps_t or cs_t) is the square root of the beef (or pork or poultry) NIDX at t net of the square root of the beef (pork/poultry) PIDX at t . Following Flake and Patterson, the media indices were introduced in square root form to account for the diminishing marginal effect of information. Mode 1 imposes the restriction that positive media has a quantitative identical but opposite effect on consumption than negative media. The construction of mode 2 is similar to mode 1 except that the PIDXs were not used. It follows from the hypothesis that “good” news has no effect on consumer demand.

An empirical issue in conducting GMM estimation is to choose the lag order of the error term when estimating the variance-covariance matrix of the moment conditions. According to the rational expectation hypothesis, the forecast error e_{it} is serially uncorrelated. Thus, strict adherence to economic theory suggests that the lag order should be zero. However, depending on model specification and data, this theoretical restriction may not be upheld in empirical applications. An alternative is to let data decide the appropriate lag length using, for instance, the heteroscedasticity and autocorrelation consistent (HAC) covariance estimator of Newey and West (1987). We follow the latter solution method and investigate the correlation structure of the estimated error term.

The coefficient estimates and standard errors reported in table (1) are the optimal two-step GMM estimates obtained by exploiting the Newey and West covariance estimator in the second step. Hansen’s J is a test for overidentifying restrictions. It is asymptotically $\chi^2(q-k)$ distributed, where q is the number of moment conditions and k is the number of model parameters. It is a test of the extent to which the error term $\Delta_4 e_{it}$ is orthogonal to the instruments. There are 24 instruments in each z_{it} ($i = 2, 3$) resulting in a total of 48 moment conditions. The test statistics are 13.97 for mode 1 and 14.85 for mode 2, which should be compared to a χ^2 with 13 degrees of freedom. The 10% critical value is 19.81. Thus, neither mode is statistically rejected.

The likelihood ratio test statistics of the null that food safety information at $t - 1$ does not directly influence consumption decision at t are 22.3 for mode 1 and 32.6 for mode 2. These statistics are $\chi^2(9)$ distributed under the null, which is rejected at 1% level for both modes. It is not feasible to test further lags in food safety information, because this will result in too many moment conditions relative to the sample size.

Our *a priori* expectation is that the own-effects of food safety information are negative, while the cross-effects are less obvious. Inspecting the estimated parameters on food safety information indicates that only three out of eighteen parameters are precisely estimated in mode 1. These results suggest that the own- and cross-effects of beef safety information at t are negative. We refrain from drawing inferences on the own- and cross-effects of pork and poultry safety information, because these food safety coefficient estimates are not statistically different from zero.

The estimated food safety coefficients in mode 2 follow the similar pattern. In terms of the effects of contemporary food safety information, only the own- and cross-effects of beef safety are negative and statistically significant. The effects of pork and poultry safety information are not precisely estimated. Interestingly, according to the results in mode 2, pork safety information at $t - 1$ has statistically significant direct negative effects on demands for beef, pork, and poultry at t . Because relatively few articles contained in the pork media index were exclusively about pork safety, it is not clear from these results whether concerns over pork safety spill over into the demand for beef and poultry.

If adverse health information reduces the degree of habit persistence of red meat, then the low carb-high protein movement popular during the past a few years may have increased the degree of habits for red meat. To exploit this hypothesis, a dummy variable, D98, that is equal to zero prior to 1998 and one thereafter is included in the model. It interacts with the a_{i0} 's in (7) and with the b_i 's in (6). The former interaction is intended to capture changes in the intercepts, while the latter is designed to approximate any potential shift in the degree of habit persistence. At quarterly frequencies, both mode 1 and 2 point an increase in the degree of beef habit around 1998. However, no statistically significant changes in pork and poultry habits are found. If the low carb-high protein fad was the sole rationale for the estimated increase in beef habit, we would expect that the degree of habit persistence for pork should also increase. For instance, the Atkins Diet recommends consumption of bacon. It is conjectured that improvement in beef quality partly due to the USDA certification program in the 1990s may have contributed to the increase in the degree of beef habit.

Fourth-differencing appears to be sufficient to render the $\Delta_4 e_{it}$'s white noise. Graphical inspection of the error terms in mode 1 and 2 shows that the assumption of homoscedastic innovation may be difficult to maintain. Table (2) reports the standard Lagrange Multiplier tests for the absence

of ARCH effects. Under the null the test statistic $ARCH(\kappa)$ is $\chi^2(\kappa)$ distributed where κ is the lag order of the ARCH effect. These test results confirm the presence of conditional heteroscedasticity in all residual series. Also reported in table (2) are Ljung-Box test results for autocorrelation in the error terms. The test statistic $LB(\kappa)$ is $\chi^2(\kappa)$ distributed under the null of no serial correlation, where κ is the lag order of the serial correlation. The Ljung-Box test may show spurious evidence of serial correlation when the series is conditionally heteroscedastic. Diebold's (1987) correction for ARCH effects was applied to the calculation of these Ljung-Box statistics. The corrected Ljung-Box statistic with eight lags cannot reject the null of no serial correlation for the $\Delta_4 e_{it}$'s at the 10% level.

5 Concluding Remarks

The objective of this paper has been to test for rational habit formation and the effects of food safety information on U.S. meat consumption. We consider a multiple-good version of the household preferences allowing for intertemporal nonseparabilities. Under rational expectations the representative household maximizes the life-time utility taking into account the effects of its current consumption decisions upon future utilities. Habits provide such a mechanism through which current levels of consumption could affect future utilities. To investigate the effects of food safety information on meat demand, food safety news articles from the popular press were compiled into information indices. These indices are then used to approximate the "true" consumer perceptions of food safety.

U.S. quarterly data on meat consumption are used to estimate the model. The degree of habit persistence for beef increased around 1998, while there were no discernible shifts in the degree of habits for pork and poultry. During the post-1998 period habit persistence dominates inventory adjustment in beef consumption. It implies that the long-run price and quality elasticities of beef are larger than their short-run counterparts. However, the intertemporal optimization nature of the consumer's problem means that these elasticities cannot be easily calculated. In fact, the consumer's problem is highly non-linear and has to be solved numerically. Once this step is complete, consumption responses to price and food safety shocks can be simulated under various expectations schemes.

In the empirical analysis, we have specified that only one-period lagged levels of consumption enter the current utility function and hoped this would be enough to capture habit formation in

meat demand at quarterly frequencies. Although this is consistent with the approach followed by most studies on habit formation under rational expectations, it is not innocuous. It is plausible that consumption at nearby dates is substitutable (durable) while habits develop over a longer time span. In Becker and Murphy, it was shown that the degree of habit persistence is positively related to the rate at which the habit stock depreciates. Becker (1996) defined traditions as mild habits whose habit stocks depreciate more slowly and are likely to be related to behaviors in the more distant past. In the case of food, the rate of depreciation of its habit stock may be quite low compared to substances that are clearly addictive to many people, such as cigarettes. For instance, once the household learns a new recipe, its knowledge capital may not quickly dissipate. It follows that it is desirable to account for consumption experiences in the more distant past than just one quarter ago.

Therefore, a more fruitful formulation of the problem may be to explicitly model short-run durabilities and long-run habit formation (see, for example, Heaton, 1995). This requires additional lags of consumption to enter the utility function. As Heaton pointed out, these additional terms imply a larger MA structure in the error term of (9). It makes the estimation of the asymptotic covariance matrix of the GMM estimator more difficult. A practical solution to this problem is to follow Heaton (1995)'s Simulated Methods of Moments approach. Exploration of this possibility is outside of the scope of this paper but is on our research agenda.

Finally, it is important to realize that our results are conditional on the chosen functional form. Future research should consider other specifications of the utility function and the way that food safety variables enter the household preferences.

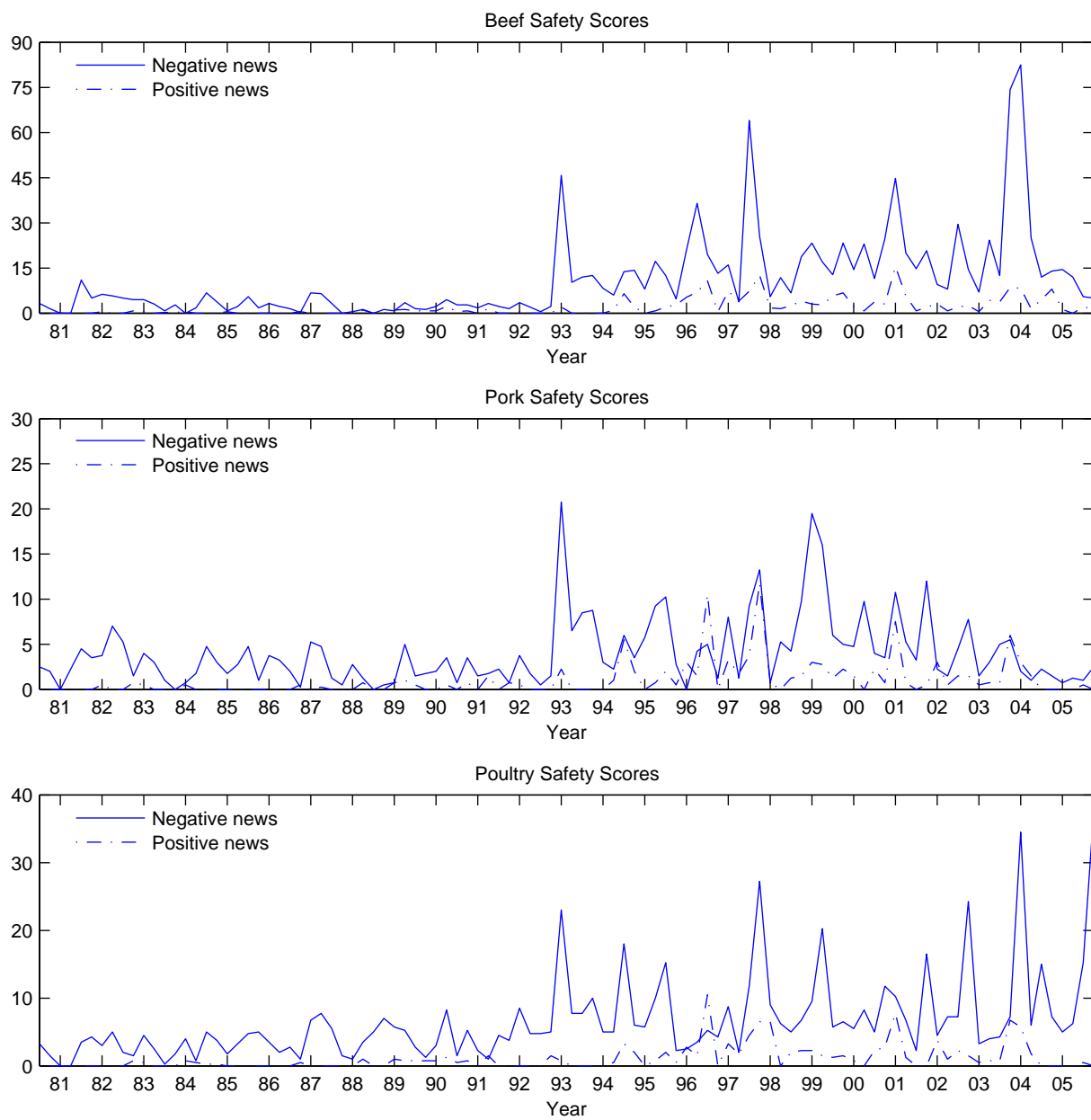


Figure 1: U.S. quarterly meat safety indices

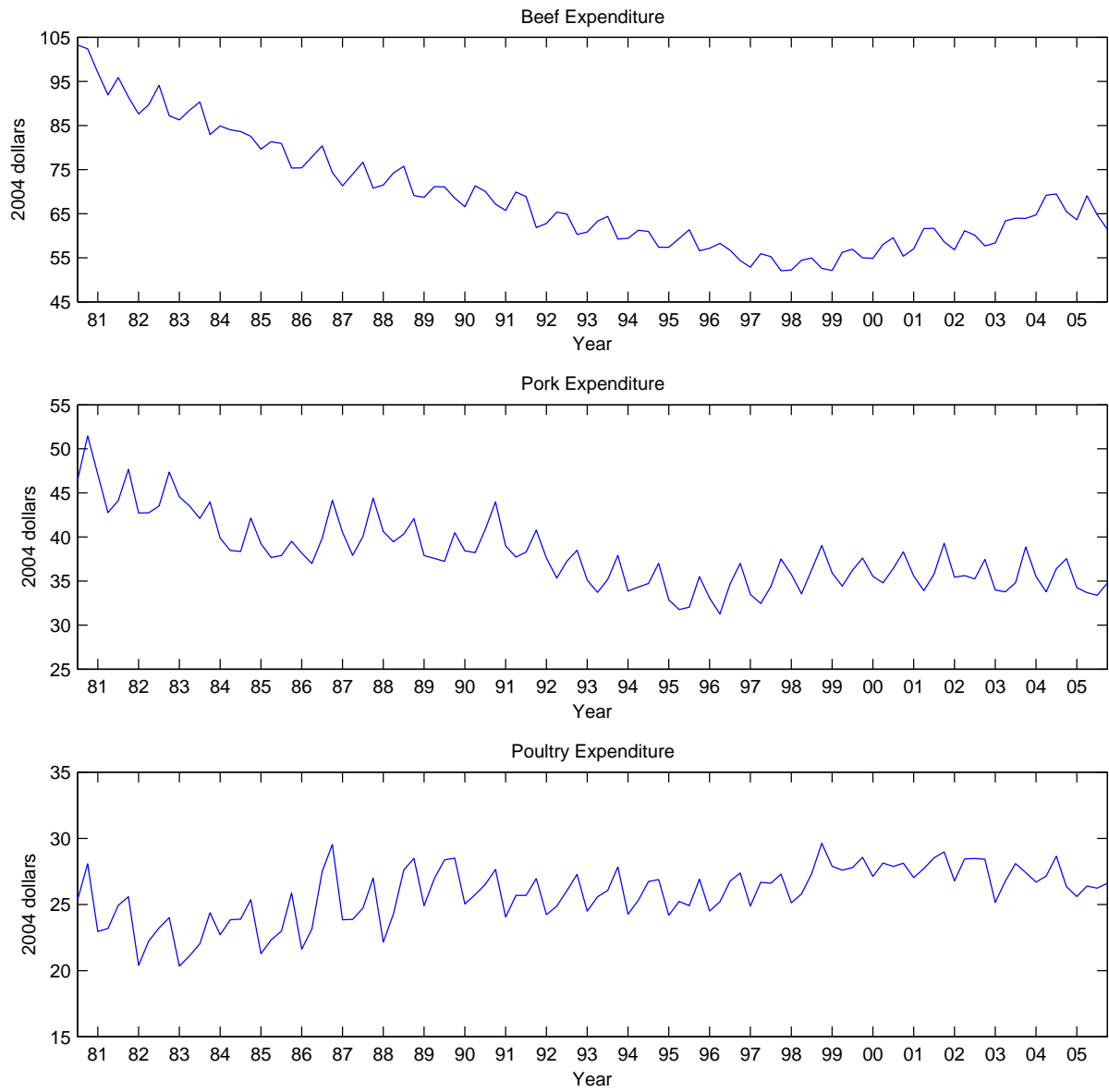


Figure 2: U.S. quarterly per capita real meat expenditures

Table 1: GMM estimates

	mode 1			mode 2		
	Beef	Pork	Poultry	Beef	Pork	Poultry
bf safety(t)	-0.440** (0.122)	-0.256** (0.073)	-0.192** (0.055)	-0.213** (0.077)	-0.126** (0.045)	-0.093** (0.035)
pk safety(t)	0.297 (0.198)	0.191 (0.115)	0.136 (0.082)	0.185 (0.125)	0.114 (0.077)	0.084 (0.056)
pl safety(t)	0.174 (0.141)	0.101 (0.082)	0.074 (0.058)	0.071 (0.113)	0.043 (0.066)	0.024 (0.050)
bf safety($t - 1$)	0.006 (0.110)	0.006 (0.064)	0.005 (0.047)	0.014 (0.076)	0.002 (0.044)	0.009 (0.034)
pk safety($t - 1$)	-0.206 (0.158)	-0.128 (0.091)	-0.094 (0.065)	-0.384* (0.183)	-0.226* (0.101)	-0.176* (0.076)
pl safety($t - 1$)	-0.010 (0.142)	-0.048 (0.082)	-0.040 (0.058)	0.024 (0.128)	0.021 (0.073)	0.007 (0.052)
beef	-16.305** (1.115)			-15.611** (0.948)		
pork	-9.494** (0.342)	-5.161** (0.464)		-9.732** (0.338)	-5.874** (0.304)	
poultry	-7.475** (0.308)	-3.982** (0.256)	-3.053** (0.747)	-7.303** (0.247)	-3.932** (0.277)	-3.143** (0.495)
habit	-1.197 (0.677)	-0.250 (0.406)	-0.062 (0.337)	-1.504** (0.585)	0.046 (0.249)	0.064 (0.238)
habit*D98	2.337* (1.079)	0.347 (0.357)	-0.048 (0.299)	2.541** (0.833)	-0.086 (0.349)	-0.206 (0.246)
const	100 (—)	53.231** (2.834)	41.362** (2.088)	100 (—)	54.261** (1.806)	40.435** (1.831)
const*D98	-11.804 (6.349)	-1.057 (1.819)	0.820 (2.012)	-12.936** (4.885)	1.127 (1.800)	1.782 (1.673)
Hansen's J	13.97			14.85		
LR	22.26			32.63		
bandwith	0			2		

Note: The parameters and standard errors (in parentheses) are multiplied by 100 to facilitate presentation. *Denotes significance at the 5% level. **Denotes significance at the 1% level.

Table 2: Analysis of the residuals

		$ARCH(2)$	$ARCH(4)$	$LB(4)$	$LB(8)$
mode 1	$\Delta_4 e_{2t}$	16.7**	16.4**	8.7	12.1
	$\Delta_4 e_{3t}$	17.4**	17.8**	3.7	5.8
mode 2	$\Delta_4 e_{2t}$	10.1**	16**	9.3	10.5
	$\Delta_4 e_{3t}$	15.4**	25.8**	5.9	9

Note: *Denotes significance at the 5% level. **Denotes significance at the 1% level.

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