Food Safety and Intertemporally Nonseparable Preferences in U.S. Meat Consumption

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Abstract

A consumer life-cycle demand system is constructed to investigate the presence of rational habits and effects of food safety information on U.S. meat consumption. Based on previous studies, information on meat recalls and media coverage of food safety events is used to measure consumer perception of meat quality. At quarterly frequencies, U.S. meat demand is found to be intertemporally nonseparable, although there is mixed evidence on whether inventory effects dominate habit formation or vice versa. In general, food safety information is found to adversely affect meat demand, but some of our results are not consistent with a priori expectations. The ongoing research focuses on numerical simulations of consumer responses to alternative food safety 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.

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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 to be informed 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. 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 ealier 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) that 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 a function of current prices and 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 interpretation. 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 consumption 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.

The paper is organized 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 simpliest way to introduce time-nonseparable preferences is to let current consumption depend on consumption in last 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

$$\max_{X_t} \mathrm{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} u_\tau(X_\tau, X_{\tau-1}, Z_\tau) \tag{1}$$

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

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

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 ($i = 1, ..., N$) implied by the assumed utility structure is

$$MU_{it} = \frac{\partial u_t}{\partial x_{it}} + \beta \mathrm{E}_t\left[\frac{\partial u_{t+1}}{\partial x_{it}}\right]. \tag{3}$$

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

$$\frac{1}{p_{it}}MU_{it} = \lambda_t \text{ for } i = 1, ..., N \tag{4}$$

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

$$\frac{1}{p_{1t}}MU_{1t} = \frac{1}{p_{jt}}MU_{jt} \text{ for } j = 2, ..., N. \tag{5}$$

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. For example, 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 $\frac{\partial u_\tau}{\partial x_\tau \partial z_i} < 0$ (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 in the short run than 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 lower level at a new long-run equilibrium. The sluggish adjustment in x_i causes its long-run response to be larger than its short-run response, and the difference increases with the degree of habit persistence. This said about the own-effects of quality shocks on the level of consumption, its cross-effects on other goods depend on the nature of these other 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

Two alternative measures of food safety were applied to the econometric models. One uses information on U.S. meat product recalls monitored by the United States Department of Agriculture (USDA)—Food Safety Inspection Service (FSIS). The other follows the mass-media index approach often taken in the literature. We now discuss the designs of the two food safety data sets in turn.

A meat product recall is a voluntary action by a firm to withdraw products from the market when a problem is identified after they leave the processing facility. All raw meat and poultry products sold in interstate and foreign commerce are inspected by FSIS. In case that a recall is initiated, FSIS issues a press release and a Recall Notification Report posted on its website. The agency also notifies the public along with state and local authorities in the affected regions. Depending on the severity of the threat to human health, each recall is categorized into one of the three classifications. Class 1 recalls refer to cases in which serious health consequences are probable. Class 2 recalls include cases in which the probabilities of serious health hazards are remote. Products implicated in Class 3 recalls involve no human health risks. The federal recall data collected by Marsh, Schroeder and Mintert were updated to 2004. Quarterly data on the number of beef, pork and poultry (chicken and turkey) recalls during the 1982(1)-2004(4) period are shown in Figure 1.

This recall data set makes no distinction across the three recall classes, neither does it include recalls in which the specific meat species were not identified. All three meat types display an upward trend over time. On average, beef, pork and poultry had 3.89, 2.58 and 2.32 recalls per quarter, respectively. The largest number of recalls for beef occurred in the 4th quarter of 2001 when 24 cases were incurred. In 2002(2) pork was implicated in 10 cases resulting in its largest number of recalls in a single quarter. Poultry recalls peaked in 2002(2) and 2004(4) with 9 cases in each quarter.

To explore the news contents of the new articles, our food safety news sources were based on four US-based newspapers—*Christian Science Monitor*, *New York Times*, *Wall Street Journal*, and *Washington Post*. These newspapers were chosen because they were available for searching during the entire sample period. News reports germane to food safety were searched for in the LexisNexis Academic using the keywords 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 and the particular meat with irrelevant ones dropped from the information base. Using objective judgement of the probability that it would adversely affect consumer demand for a meat species, each article was assigned a score of 0, 0.25, 0.5 or 0.75. Negative scores indicate that the news may *positively* affect demand for a particular meat type. Quarterly food safety indices were built individually for beef, pork, and poultry by linearly aggregating their corresponding scores. The final indices may be positive or negative in a particular quarter with positive values indicating net adverse media coverage for the interested meat and negative values indicating net favorable news coverage. Figure 2 plots these data series for the 1982(1)-2004(4) period.

Over the entire sample, beef safety induced higher incidences of concerns than pork or poultry on average. The mean index value is 9.71 for beef, 3.11 for pork and 5.36 for poultry. But this is not the case during the 1982-1992 subsample period. In fact, from 1982 to 1992, poultry safety attracted more media attention than beef and pork. The index values for beef, pork and poultry in the 1982-1992 period are 2.35, 2.14 and 3.40, respectively. In the first quarter of 1993 an outbreak of E. coli bacteria poisoning traced to hamburger at a fast-food chain in the Northwest received intense media coverage and caused the beef index to peak at 43.75. This incident ignited heavy criticism over the soundness of the nation's meat and poultry inspection system that brought the pork index to its maximum at 18.5 and poultry index to one of its highest at 22.25. This event became a vital catalyst to USDA's implementation of the Pathogen Reduction/Hazard Analysis and Critical Control Point system for meat and poultry inspection in the late 1990s. The 1997(3) peak in safety index 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 index reached its second highest level at 22.75 when fear of listeria contamination prompted gigantic recall of chicken and turkey products, the largest in U.S. history, in the fourth quarter of 2002. A peak score of 28.75 in poultry index coincides with the outbreak of avian flu in Asia in 2004(1).

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. Both poultry and pork received some degree of positive media coverage in 1996 when a new variant of CJD was first linked to eating of contaminated beef, and in 2003(4)-2004(1) in the midst of the first U.S. mad cow case. Recall that negative scores were assigned to articles with positive contents, the negative values in 1996 for poultry and pork indices and in 2004 for pork index were a direct result of these positive news reports.

3.2 Meat data

Quarterly meat data during the 1982(1)-2004(4) period were 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* were taken to be the basic consumption quantity data for the period 1982-2003. Data for 2004 were from the November 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 were 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 ones were mid-quarter total U.S. population from the Department of Commerce, Bureau of Economic Analysis(BEA).

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)

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

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 nonseparability in the preferences. Meghir and Weber (1996) and Carrasco, Labeaga and López-Salido (2005)[1] used similar preferences structure to (6) to test for intertemporal nonseparable preferences using U.S. and Spanish micro data, respectively. Following the discussion in section 2, habit persistence implies $b_i > 0$ while durability or inventory adjustment[2] implies $b_i < 0$. If $b_i = 0 \; \forall i$ time separable preferences follow. Habits arise because it is costly for the household to deviate from the levels of consumption in last period. These costs may involve the cost of learning and perfecting new recipes and any psychological disutilities from switching to new cuisine. Conversely, inventory adjustment

[1] Note 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.

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

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.

The parameters a_i, b_{ij} and b_i are specified to be linear functions of a vector of time-varying demand shifters. That is,

$$a_i = a_i^0 + a_i^{*'} d_t, \;\; b_{ij} = b_{ij}^0 + b_{ij}^{*'} g_t, \text{ and } b_i = b_i^0 + b_i^{*'} h_t \tag{7}$$

where a_i^*, b_{ij}^* and b_i^* are vectors of constants and d, g and h vectors of demand shifters. The list of candidate exogenous demand shifters includes: three quarterly dummies (D1, D2, D3), beef (BS), pork (PS) and poultry (CS) safety indices, and the logarithm of a time trend (Trend). Importantly, we do not explicitly model the adverse health effect of cholesterol and fats on red meats. Instead, a naïve approach is taken by including Trend to approximate the effects of any deterministic (health and demographic) trend that may have affected consumer preferences. The demand shifters used in specifying d are D1, D2, D3, Trend, BS, PS and CS, in specifying g are BS, PS and CS, and in specifying h is Trend.

4.2 Estimation strategy

When estimating a dynamic rational expectations model, the Generalized Method of Moments (GMM) of Hansen (1982) seems to be a natural choice. Use the direct utility function

(6) to parameterize the marginal utility of consumption (3)

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

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

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

for i equal to 2 (pork) and 3 (poultry), where m_i is the expenditure on the ith 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) appears in both equations with a_{10} normalized to 1.

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

$$\mathrm{E}\left[(e_{2t} \; e_{3t})' | I_t \right] = 0. \tag{10}$$

The instrumental variables in the information set include choice variables dated $t-1$ and earlier and demand shfiters 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

$$\mathrm{E}\left[(e_{2t} z_{2t}' \; e_{3t} z_{3t}')' \right] = 0 \tag{11}$$

where z_{2t} and z_{3t} are corresponding vectors of instruments.

To induce stationarity in regressors and instruments, the beef/pork equation (9) and beef/poultry equation (9) were first-differenced and so were the instruments. The first-differenced e_{it} has a MA(1) structure and is orthogonal to demand shifters dated t and earlier and to choice variables dated $t-2$ and earlier. In addition to the stationarity argument, there is another reason for proceeding with the first-differenced model. Heien and Durham (1991) argued that aggregate time-series consumption data tend to overstate the degree of habit formation, because these data often exhibit spurious serial correlation that may not be an accurate reflection of actual consumer behavior. Auld and Grootendorst (2004) found that, for rational addiction models, estimation in differences renders better small-sample properties than in levels whenever this spurious moderate to high serial correlation exists in consumption series.

Note that all variables in (9) are divided by current period expenditures that make every transformed variable endogenous. To imitate the variables in (9) as closely as possible, instruments included demand shifters dated t and levels of consumption dated $t-2$, all of which were divided by expenditures dated $t-2$ before they were first-differenced. The beef/pork and beef/poultry equations were estimated jointly imposing equality of the beef parameters across equations and $b_{ij} = b_{ji}$. Conditional on the discount factor β the estimation is linear. We did not attempt to estimate β. Instead, it was fixed to a quarterly rate of 0.99.

4.3 Results and discussion

The optimal two-step GMM estimates reported in table 1 were obtained by exploiting the heteroscedasticity and autocorrelation consistent (HAC) covariance estimator of Newey and West (1987) [3]. The "Recall" and "Media" columns report parameter estimates with the recall and newspaper index data as the food safety variables, respectively. Logarithms of contemporary media indices were used in the Meida model to account for the diminishing marginal effects of news on food safety if any. The J-stat on the last row refers to the Hansen's test for overidentifying restrictions. It is asymptotically χ^2 distributed with $q - k$ degrees of freedom, where q is the number of population moment conditions and k is the number of parameters. It is a test of the extent to which the error term e_{it} is orthogonal to the instrument set. There are 39 instruments in each z_{it} $(i = 2, 3)$ resulting in a total of 78 population moment conditions. The test statistics are 14.765 for the Recall model and 10.304 for the Media model, respectively, which should be compared to a χ^2 with 25 degrees of freedom. The 10% critical value is approximately 33.2. It implies that the orthogonality restrictions are not rejected for either model with the chosen instrument set.

The dynamic effects are determined by the coefficients on "Habit" and "Habit*Trend" in table 1, where "Habit*Trend" denotes the interactions between habits and logarithms of time trends. The sum of the coefficients on "Habit" and "Habit*Trend" is the value of b_i in (6). In table 1 all parameter estimates associated with the dynamic effects are statistically

[3] We also experimented the iterated GMM estimator by iterating the weighting matrix. But the weighting matrix failed to converge in some cases. Moreover, the standard errors of the estimates of the parameters are conspicuously too small as the number of iteration increases.

significant at least at the 10% level. The quarterly meat data are disappearance data that do not necessarily measure actual househould meat intakes. The estimated values of b_i are therefore the net effects of habit formation and inventory adjustment.

The evolution of the estimated b_i's of the Recall model over time are plotted in figure 3. Negative values suggest inventory adjustment while positive numbers are indications of habit persistence. Our parameter estimates imply that habit persistence dominated durability in quarterly beef consumption data until around 1986 after which durability was the predominant factor. For pork demand, habit persistence has dominated durability since 1991 at quarterly frequencies. For poultry, durability was always the dominant force although the degree of durability has been decreasing over time. Note that although these habit parameters are statistically significant, their magnitudes are small when compared to the coefficient estimates on current levels of consumption (b_{ij}'s). As to what caused the dynamic patterns in the coefficients on beef, pork and poultry habit terms is not clear to us. It could be in line with the argument that adverse health information has reduced beef habit but raised pork and poultry habits. But the data do not allow one to test for this against alternative hypotheses. The parameter estimates for b_i's of the Media model are qualitatively similar to those of the Recall model except that pork demand is now only marginally habitual at the end of the sample.

To test if lagged food safety information has impacts on meat demand, the one-period lags of food safety variables were included in the model. Multicollinearities in the data and instrument matrices preclude us from estimate the coefficients on contemporary and lagged food safety information simultaneously. Results from the Recall and Media models where only one-quarter lagged food safety indices were used are reported in table 2. The J-stat is 15.286 for the Recall model and 18.713 for the Media model, implying that the overidentifying restrictions are not rejected at the conventional levels. With regard to the dynamic effects, the relevant coefficients are statistically significant at the 5% level for the Recall model but are not precisely estimated for the Media model except for the interaction term between beef habit and time that is statistically significant at the 5% level. The estimated b_i's of the Recall model are plotted in figure 4. In constrast to figure 3 pork and poultry are close to being intertemporally separable at the end of the sample, although time is still important in diminishing the dominance of inventory adjustment effects over time. For beef demand, consistent with the results from models using contemporary food safety indices, inventory adjustment dominates habit formation at the end of sample. Just because pork and poultry are almost intertemporally separable near the end of sample does not mean that the demand for these two goods can be modeled as static thereafter. The statistically significant estimates of b_{ij}'s in tables 1 and 2 indicate nonseparability across beef, pork and poultry in the within-period utility. Since beef is not time-separable in all model specifications, demands for pork and poultry are (indirectly) dynamic through their within-period nonseparability with beef.

Habit formation and inventory adjustment are two forms of time-nonseparable preferences that have different short- and long-run implications. While habit formation suggests that demand should respond more to permanent changes more in the long run than in the short run, the opposite is true for inventory adjustment. Wohlgenant and Hahn (1982) found that inventory adjustment dominated habit persistence in beef and pork consumption data at monthly frequencies and demands for them were more own-price elastic in the short run than in the long run. Under rational expectations, households with inventory adjustment dominating habit persistence in their preferences respond more to price changes that are expected to be temporary than to price changes believed to be more permanent. This statement is made without formal proof. But the intuition is straightforward. The household has the flexibility to consume the meat right away or to put it into the refrigerator. The household do not purchase as much as it would have if the price cut is expected to stay for some more time because meats are perishable.

Because of the significant iteractions between food safety indices and levels of consumption, there is no guarantee that the marginal effect of a food safety index on the marginal utility of a particular meat type will take the same sign across observations. It is therefore necessary to calculate the effects of food safety variables on the marginal utilities of meats at every data points. Our a priori expectation is that the own-effect of food safety information should be negative while its cross-effects on other meats are less clear.

The marginal effects of an increase in a food safety index on the marginal utilities of beef, pork and poultry were calculated for every model of tables 1 and 2 at every data point. The results from this excercise are summaried in tables 3 and 4. The "+" and "−" signs indicate whether the average marginal effect of a food safety index on a particular meat type is positive or negative. The number in parentheses records the number of observations at which the corresponding marginal effect takes the reported sign. There are a total of 92 observations. For instance, according to table 4 the average marginal effect of an increase in the contemporary beef safety media index on the marginal utility of beef is negative, and there are 90 out of 92 observations at which this marginal effect is negative.

The upshot from examining tables 3 and 4 is that several of the specified models do not offer completely satisfactory description of the effects of food safety information on meat demand. The estimated average own-effects of contemporary poultry recalls and pork news and one-quarter lagged beef and poultry news are positive, inconsistent with our a priori expectations. These results are difficult to explain. It could be an indication of the inadequacies of the model specifications.

To check if our results are sensitive to the methods used in constructing the media indices, the data set used in Piggott and Marsh was extended to 2004. This data set is based on a much larger pool of newspapers[4]. But indices in this data set were not weighted based on the news contents. The results did not change qualitatively and so were not reported here.

5 Concluding Remarks

The objective of this paper was to test for rational habit formation and food safety effects in U.S. meat consumption. We considered a multiple-good version of the household preferences allowing for intertemporal nonseparabilities. Under rational expectations the representative household maximizes its life-time utility function taking into account the effects of its current consumption decisions upon future utilities. Habits provide such a mechanism through which

[4]Depending on the time periods, it contains a maximum of 47 English language newspapers worldwide.

current levels of consumption could affect future utilities. To investigate the effects of food safety information on meat demand, information on meat recalls and news coverage of food safety was taken to measure consumer perception of meat quality.

U.S. quarterly data on meat consumption were applied to the model. Point estimates of coefficients on habit terms are somewhat sensitive to the choice of food safety variables and whether current or lagged food safety variables are used. Interestingly, statistically significant interactions between habits and logarithms of time trends were detected in all specifications. Based on the parameter estimates, time played significant role in reducing the strength of habit persistence in beef demand and in raising the degree of habits in pork and poultry demands. When evaluated at the end of our sample, durability was found to dominate habit formation in beef and poultry demands; depending on which food safety variables were used, pork demand was either habitual or close to being intertemporally separable at the end of our sample.

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.

As to the effects of food safety information on U.S. meat demand, we found statistically significant evidence that it adversely affects meat consumption. Overall, the specification with one-period lagged information on meat recalls provides the best results in terms of its consistency with our a priori expectations that such information should reduce the marginal utility of meat. Given that intertemporal nonseparability is statistically significant, it is inappropriate to calculate elasticities based on formulars for static demand systems. The representative household in this paper is faced with an intertemporal optimization problem with three decision variables (current levels of consumption of the three meats) and four state variables (three one-peirod lags of consumption and the present value of lifetime wealth). Numerical solution is needed to assess the short- and long-run demand responses to alternative food safety scenarios. This is part of our ongoing research.

Last but certainly not least, 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 demand shifters enter the household preferences.

Table 1: Estimated coefficients for the demand system with habits and contemporary food safety information

	Recall			Media		
	Beef	Pork	Poultry	Beef	Pork	Poultry
Beef	-0.1809**			-0.1853**		
	(0.0034)			(0.0018)		
Pork	-0.0937**	-0.0508**		-0.0997**	-0.0554**	
	(0.0024)	(0.0047)		(0.0020)	(0.0026)	
Poultry	-0.0604**	-0.0322**	-0.0273**	-0.0605**	-0.0350**	-0.0305**
	(0.0018)	(0.0010)	(0.0023)	(0.0013)	(0.0009)	(0.0023)
Beef*BS	0.0080**			0.0027		
	(0.0018)			(0.0067)		
Pork*BS	0.0051**	0.0027**		0.0050	0.0027	
	(0.0010)	(0.0006)		(0.0037)	(0.0021)	
Poultry*BS	0.0030**	0.0018**	0.0012**	0.0003	0.0015	-0.0003
	(0.0006)	(0.0003)	(0.0002)	(0.0029)	(0.0016)	(0.0013)
Beef*PS	-0.0075**			0.0014		
	(0.0028)			(0.0080)		
Pork*PS	-0.0022	-0.0011		-0.0017	-0.0010	
	(0.0016)	(0.0010)		(0.0045)	(0.0028)	
Poultry*PS	-0.0016	-0.0009	-0.0010*	0.0001	0.0000	0.0015
	(0.0011)	(0.0006)	(0.0005)	(0.0032)	(0.0018)	(0.0015)
Beef*CS	0.0049			0.0368**		
	(0.0032)			(0.0066)		
Pork*CS	0.0025	0.0020*		0.0220**	0.0124**	
	(0.0019)	(0.0012)		(0.0040)	(0.0026)	
Poultry*CS	0.0009	0.0006	0.0001	0.0151**	0.0084**	0.0051**
	(0.0014)	(0.0008)	(0.0006)	(0.0027)	(0.0016)	(0.0012)
BS	-0.0446**	-0.0268**	-0.0166**	-0.0218	-0.0260	-0.0039
	(0.0092)	(0.0052)	(0.0031)	(0.0370)	(0.0207)	(0.0164)
PS	0.0300**	0.0108	0.0090	0.0027	0.0087	-0.0038
	(0.0153)	(0.0088)	(0.0062)	(0.0434)	(0.0250)	(0.0183)

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Table 1 –Continued

	Recall			Media		
	Beef	Pork	Poultry	Beef	Pork	Poultry
CS	-0.0230	-0.0140	-0.0044	-0.2084**	-0.1207**	-0.0804**
	(0.0178)	(0.0105)	(0.0077)	(0.0369)	(0.0225)	(0.0151)
Trend	-0.0120**	-0.0063**	-0.0007	-0.0085**	-0.0043**	0.0004
	(0.0020)	(0.0009)	(0.0005)	(0.0020)	(0.0009)	(0.0004)
Habit	0.0232**	-0.0159**	-0.0113**	0.0269**	-0.0092**	-0.0078**
	(0.0049)	(0.0021)	(0.0020)	(0.0045)	(0.0014)	(0.0015)
Habit*Trend	-0.0081**	0.0045**	0.0023**	-0.0083*	0.0022**	0.0006*
	(0.0011)	(0.0005)	(0.0005)	(0.0010)	(0.0004)	(0.0003)
1st Quarter	-0.0050**	-0.0021**	-0.0017**	-0.0075**	-0.0035**	-0.0026**
	(0.0011)	(0.0007)	(0.0005)	(0.0010)	(0.0006)	(0.0004)
2nd Quarter	-0.0034**	-0.0019**	-0.0017**	-0.0068**	-0.0032**	-0.0029**
	(0.0008)	(0.0005)	(0.0004)	(0.0006)	(0.0004)	(0.0003)
3rd Quarter	0.0023**	0.0010	0.0009**	-0.0016	-0.0005	-0.0003
	(0.0010)	(0.0006)	(0.0004)	(0.0006)	(0.0004)	(0.0003)
Constant	1	0.5165**	0.3439**	1	0.5449**	0.3602**
	(—)	(0.0164)	(0.0103)	(—)	(0.0106)	(0.0091)
J-stat	14.765			10.304		

Note: Standard errors in parentheses, * and ** denote statistical significance at 10% and 5% levels, respectively

Table 2: Estimated coefficients for the demand system with habits and one-quarter lagged food safety information

	Recall			Media		
	Beef	Pork	Poultry	Beef	Pork	Poultry
Beef	-0.1781**			-0.1946**		
	(0.0022)			(0.0028)		
Pork	-0.1025**	-0.0591**		-0.0989**	-0.0438**	
	(0.0028)	(0.0035)		(0.0024)	(0.0042)	
Poultry	-0.0651**	-0.0351**	-0.0246**	-0.0590**	-0.0336**	-0.0241**
	(0.0019)	(0.0011)	(0.0021)	(0.0022)	(0.0022)	(0.0030)
Beef*BS	0.0014			0.0616**		
	(0.0024)			(0.0157)		
Pork*BS	0.0015	0.0008		0.0362**	0.0209**	
	(0.0015)	(0.0010)		(0.0090)	(0.0055)	
Poultry*BS	0.0006	0.0007	0.0001	0.0216**	0.0136**	0.0093**
	(0.0011)	(0.0007)	(0.0005)	(0.0065)	(0.0037)	(0.0027)
Beef*PS	0.0058*			-0.0173		
	(0.0035)			(0.0134)		
Pork*PS	0.0041**	0.0026**		-0.0042	-0.0040	
	(0.0020)	(0.0013)		(0.0077)	(0.0048)	
Poultry*PS	0.0030**	0.0017**	0.0013**	-0.0035	-0.0014	-0.0024
	(0.0014)	(0.0008)	(0.0006)	(0.0058)	(0.0034)	(0.0024)
Beef*CS	0.0157**			0.0065		
	(0.0057)			(0.0111)		
Pork*CS	0.0095**	0.0045**		-0.0028	-0.0040	
	(0.0030)	(0.0016)		(0.0066)	(0.0042)	
Poultry*CS	0.0058**	0.0033**	0.0015*	0.0014	-0.0011	0.0007
	(0.0020)	(0.0012)	(0.0009)	(0.0048)	(0.0029)	(0.0020)
BS	-0.0100	-0.0085	-0.0040	-0.3310**	-0.1963**	-0.1238**
	(0.0139)	(0.0086)	(0.0064)	(0.0864)	(0.0503)	(0.0359)
PS	-0.0365*	-0.0237**	-0.0168**	0.0667	0.0240	0.0192
	(0.0192)	(0.0113)	(0.0076)	(0.0747)	(0.0441)	(0.0323)

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Table 2 –Continued

	Recall			Media		
	Beef	Pork	Poultry	Beef	Pork	Poultry
CS	-0.0876**	-0.0493**	-0.0300**	-0.0135	0.0227	-0.0024
	(0.0300)	(0.0163)	(0.0115)	(0.0625)	(0.0377)	(0.0268)
Trend	-0.0055*	-0.0031**	-0.0001	-0.0024	-0.0005	0.0010
	(0.0031)	(0.0015)	(0.0008)	(0.0029)	(0.0014)	(0.0007)
Habit	0.0325**	-0.0114**	-0.0058**	0.0054	0.0021	0.0005
	(0.0050)	(0.0023)	(0.0014)	(0.0070)	(0.0027)	(0.0022)
Habit*Trend	-0.0090**	0.0026**	0.0012**	-0.0056**	-0.0008	-0.0005
	(0.0011)	(0.0008)	(0.0003)	(0.0017)	(0.0008)	(0.0004)
1st Quarter	-0.0082**	-0.0041**	-0.0031**	-0.0085**	-0.0041**	-0.0033**
	(0.0009)	(0.0006)	(0.0004)	(0.0013)	(0.0008)	(0.0006)
2nd Quarter	-0.0062**	-0.0034**	-0.0025**	-0.0053**	-0.0018**	-0.0022**
	(0.0009)	(0.0005)	(0.0005)	(0.0010)	(0.0006)	(0.0005)
3rd Quarter	-0.0020**	-0.0011*	-0.0007*	-0.0047**	-0.0012	-0.0016**
	(0.0008)	(0.0006)	(0.0004)	(0.0013)	(0.0008)	(0.0006)
Constant	1	0.5637**	0.3561**	1	0.4955**	0.3286**
	(—)	(0.0150)	(0.0080)	(—)	(0.0174)	(0.0121)
J-stat	15.286			18.713		

Note: Standard errors in parentheses, * and ** denote statistical significance at 10% and 5% levels, respectively

Table 3: Estimated marginal effects of recalls on marginal utilities of meats

	Contemporary recalls			One-quarter lagged recalls		
Marginal utility	Beef	Pork	Poultry	Beef	Pork	Poultry
Beef	−	−	+	−	−	−
	(46)	(92)	(86)	(92)	(87)	(88)
Pork	+	−	+	−	−	−
	(44)	(92)	(73)	(92)	(82)	(89)
Poultry	+	−	+	−	−	−
	(50)	(92)	(90)	(92)	(81)	(89)

Table 4: Estimated marginal effects of food safety news on marginal utilities of meats

	Contemporary news			One-quarter lagged news		
Marginal utility	Beef	Pork	Poultry	Beef	Pork	Poultry
Beef	−	+	−	+	−	+
	(90)	(92)	(74)	(65)	(92)	(92)
Pork	+	+	−	+	−	+
	(92)	(92)	(70)	(66)	(92)	(92)
Poultry	−	+	−	+	−	+
	(91)	(92)	(76)	(64)	(92)	(92)

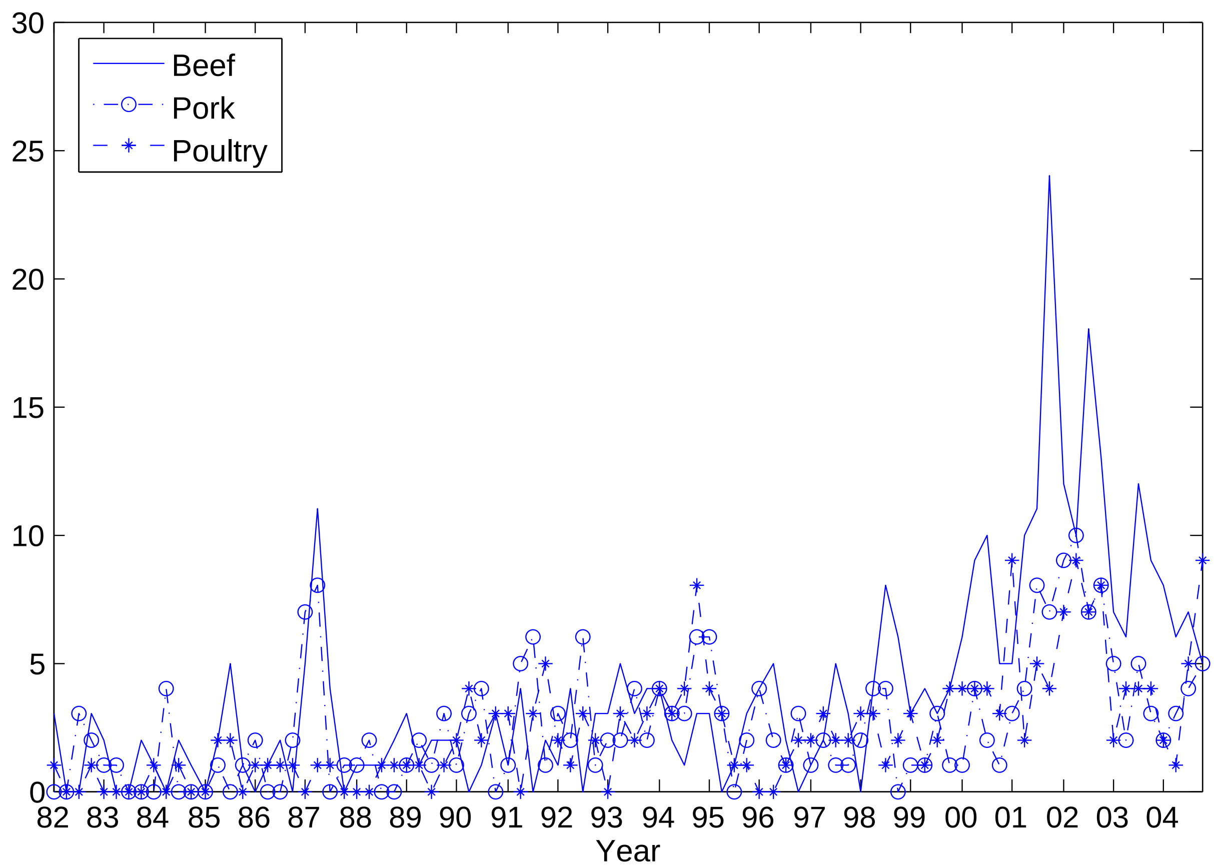

Figure 1: Quarterly number of beef, pork and poultry recalls.

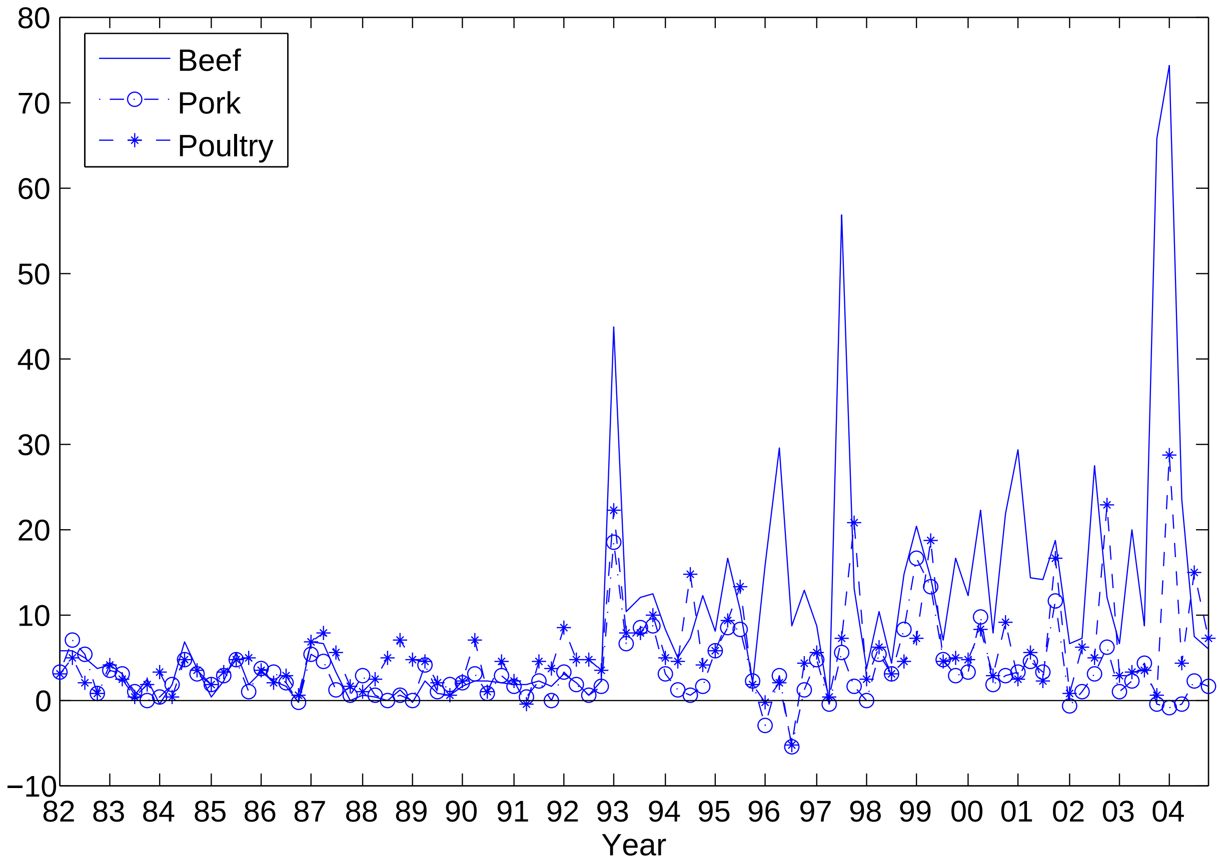

Figure 2: Quarterly beef, pork and poultry safety media indices.

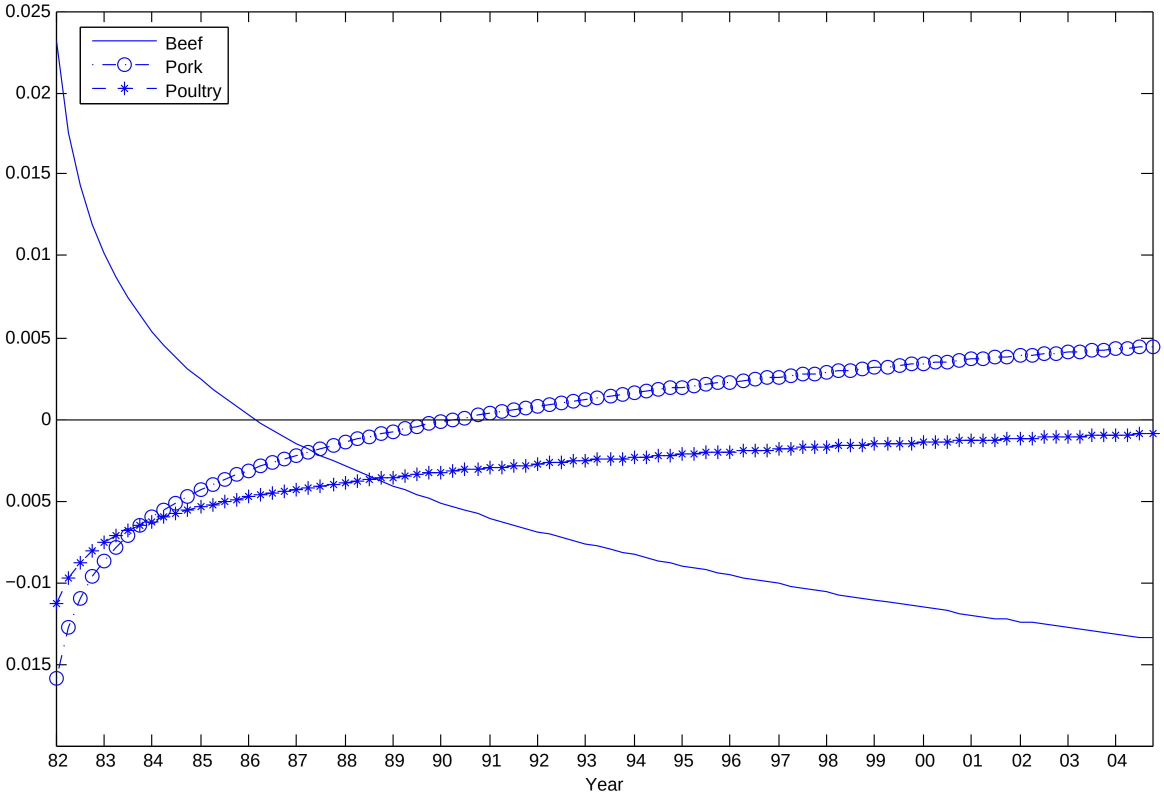

Figure 3: Estimated coefficients on habit terms from the model with contemporary recalls.

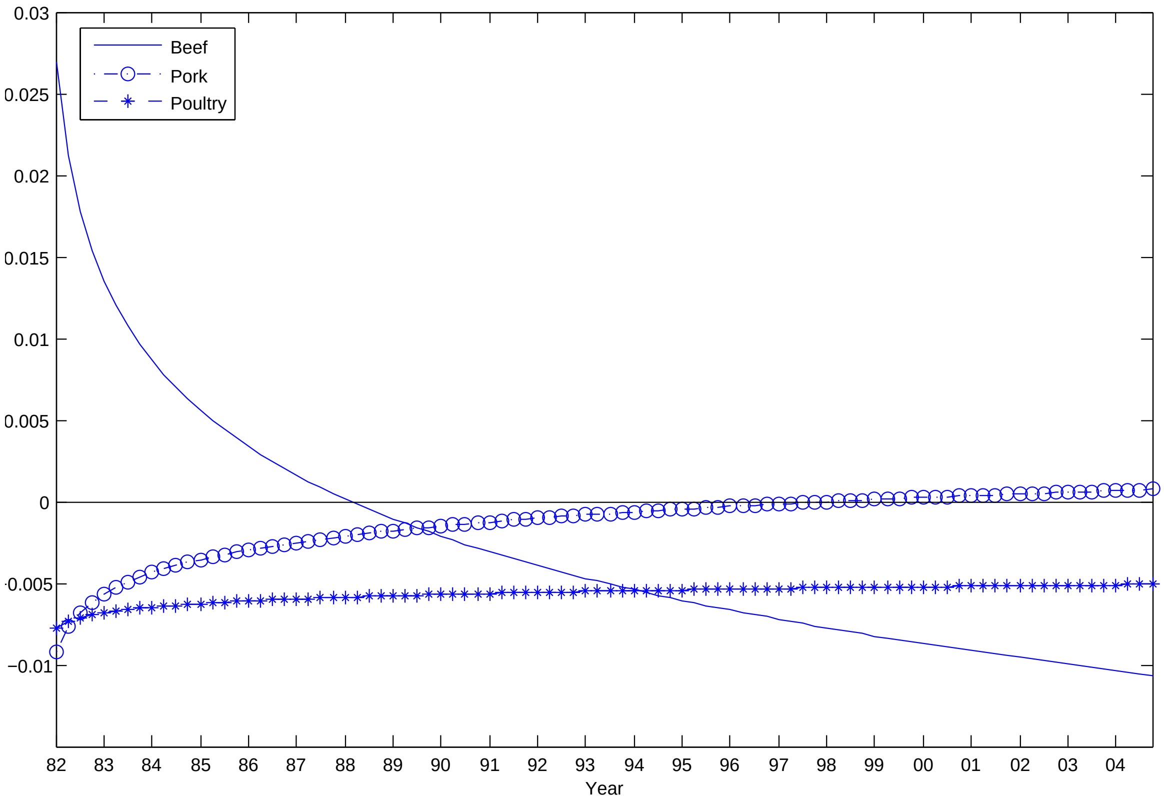

Figure 4: Estimated coefficients on habit terms from the model with one-quarter lagged recalls.

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