Do marketing margins change with food scares? Examining the effects of food recalls and disease outbreaks in the US red meat industry

Oral Capps, Jr.
Agribusiness, Food and Consumer Economics Research Center
Department of Agricultural Economics
Texas A&M University
ocapps@tamu.edu

Sergio Colin-Castillo
Centro de Investigaciones Socioeconómicas – CISE
Universidad Autónoma de Coahuila
scolin_mx@yahoo.com

Manuel A. Hernandez
Markets, Trade and Institutions Division
International Food Policy Research Institute – IFPRI
m.a.hernandez@cgiar.org

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ABSTRACT

This paper examines the impact of food scares on marketing margins in the US beef and pork industries. We analyze how market stresses induced by different food recalls and disease outbreaks affect price spreads and the extent of price transmission at the slaughter-to-wholesale and wholesale-to-retail levels. We use monthly data for the period 1986–2008. The results indicate that marketing margins are differentially affected by FSIS recalls and BSE outbreaks at different levels of the beef and pork marketing chain, although the effects are generally quite modest. Only BSE discoveries in the United States considerably affect marketing margins in the beef industry, specifically at the wholesale-to-retail level. We also find that food safety incidents have minor cross-industry and cross-country effects on marketing margins.

Keywords: Marketing margins, price transmission, food recalls, BSE outbreaks, red meat industry
JEL code: Q13, L11, L13

1. INTRODUCTION

This paper examines the effect of food safety incidents on marketing margins in the US beef and pork industry at farm-wholesale-retail levels. In particular, we evaluate how market stresses induced by Food Safety Inspection Service (FSIS) recalls and Bovine Spongiform Encephalopathy (BSE) outbreaks affect price margins at the farm-to-wholesale and wholesale-to-retail levels. We also examine the extent of price transmission along the marketing channel during food scares. We use monthly data for the period 1986–2008.

Both FSIS recalls and BSE outbreaks capture variations in food safety conditions. The recalls are related to food contamination and the outbreaks to animal disease situations. Among food recalls, class I recalls are the most dangerous. FSIS defines a class I recall as a recall that involves a health hazard situation in which there is a reasonable probability that eating the food product will lead to health problems or even result in death. BSE or "mad cow disease" is a progressive, fatal disease of the nervous system of cattle. The exact cause of BSE is unknown, but it is associated with the presence of an abnormal protein (prion) and currently there is no treatment or vaccine for the disease.

Since food recalls and disease outbreaks may occur simultaneously across time, some confounded effect is expected between food contamination and animal disease. It is important, then, to isolate the impact of each variable when examining the effects of food recalls and disease outbreaks. In this study, we consider three different types of FSIS recalls: (1) recalls due to pathogenic bacteria or *class I bacterial*; (2) the rest of class I recalls that originate, for example, due to allergenic ingredients or underprocessing (hereafter called *class I other*); and (3) *national recalls* that are effective in all of the states in the United States and are not necessarily a class I recall. Additionally, we consider three BSE events in the United States and thirteen BSE

cases in Canada. We also account for immediate and delayed effects of food recalls and BSE outbreaks on marketing margins.

The paper is intended to contribute to the literature in several ways. First, we assess the impact of food safety issues on the price margins of red meat, particularly of beef and pork which are the two main red meats produced and consumed in the United States. Previous research on the effects of food safety concerns has mainly focused on meat demand and prices. Marsh et al. (2004), for example, found that recall events in the United States significantly affect the demand for meat. Pigott and Marsh (2004) concluded that the demand response to food safety concerns is small compared to price effects. Marsh et al. (2008) reported a minor short-term price effect on US cattle prices due to the two BSE events that occurred in North America in 2003. In the United Kingdom, Leeming and Turner (2004) found that the BSE outbreak in 1996 significantly reduced the price of beef. This study specifically examines the impact of food safety concerns on price spreads in the beef and pork meat industries at the slaughter-to-wholesale and wholesale-to-retail levels.

Second, we jointly explore two types of food scares, FSIS recalls and BSE outbreaks, over a period of 22 years. Marketing margins in the meat industry have been analyzed rather extensively, but only a few studies have used this approach to evaluate the effect of food scares.[1] Further, these studies have generally focused on specific events. McKenzie and Thomsen (2001) evaluated the impact of recalls for E-coli on the beef marketing channel in the United States and found that price responses at the wholesale level do not transmit back to the farm level. Sanjuan

[1] Most studies on marketing margins focus on the effects of market concentration, marketing costs, retail demand and farm input supply (see, e.g., Wohlgenant & Mullen, 1987; Capps et al., 1995; Brester & Marsh, 2001; Marsh & Brester, 2004; and Armah, 2007).

and Dawson (2003) and Lloyd et al. (2006) analyzed the effect of the 1996 BSE-U.K. outbreak on price margins in the beef sector and found a differentiated impact on retailers and producers. Prices at the producer level fell by more than double compared to those at the retail level. Saghaian (2007) examined the impact of the BSE discovery in 2003 in the United States on the beef marketing chain and also found a differentiated impact on producers and retailers. This BSE event resulted in a widening of price margins, pointing also to imperfect price transmission in the industry. More recently, Dhoubhadel et al. (2009) evaluated the effect of different food safety incidents on the beef marketing channel. Contrary to BSE discoveries, recall variables did not have a statistically significant impact on price spreads. This study, however, does not properly account for variations in the severity of the recalls. Hassouneh et al. (2010) also found that BSE scares affect beef retailers and producers differently in the Spanish bovine market. Unlike the aforementioned studies, our analysis considers jointly the potential differentiated effects of different FSIS recalls and BSE outbreaks on marketing margins in the beef and pork industries.

Finally, we model price spreads for beef and pork to account for any underlying correlation or substitution effects across these red meat markets during food scare events.[2] We also account for BSE discoveries in the United States and Canada to assess any cross-country effect, considering the closeness of these two markets and their similar meat production systems. Cross-country effects of food scares on marketing margins have not been studied in much detail. Previous studies have shown that BSE outbreaks in Canada and the United States had significant effects on trade, production costs and prices of US cattle and beef (Coffey et al., 2005; Mathews

[2] Uncovering potential cross-industry effects with other meat products are beyond the scope of the present study. We focus on the two main red meat products, which are direct, close substitutes of each other and are frequently handled by the same agents across the marketing channel.

et al., 2006; Marsh et al., 2008). Beyond North America, Park et al. (2008) found important effects of BSE discoveries in the United States on the Korean meat market, increasing the retail price margin relative to the farm and wholesale levels. This study specifically accounts for the impact of BSE outbreaks in both the United States and Canada on the US market seeking to capture any cross-country effect.

Overall, the analysis of marketing margins is useful to identify the underlying factors that are significant to explain variations in price spreads along the marketing channel. This paper aims to uncover any differentiated, cross-industry and cross-country effects of food safety incidents on different levels of the beef and pork marketing chain. Importantly, in this undertaking we disentangle the impacts of food recalls from BSE outbreaks. Our results also intend to provide valuable information to policymakers by identifying the most vulnerable agents in the marketing channel during periods of food safety concern, thereby aiding policymaking in these periods.

We find that marketing margins in the United States are differentially affected by food recalls and disease outbreaks at different levels of the beef and pork marketing channel. The effects, however, are generally quite modest and not statistically significant. Only a BSE outbreak in the United States significantly affects marketing margins in the beef industry, widening the wholesale-to-retail margin by more than one third of the average margin. Food scares also have minor cross-industry and cross-country effects on margins. Price transmission along the beef and pork marketing channel is similarly only affected during outbreaks in the United States at the wholesale-to-retail level, which could point toward potential market power exertion by retailers, who usually handle both beef and pork, during and immediately following an outbreak.

The remainder of the paper is organized as follows. In Section 2, we present the empirical model. In Section 3, we describe the data used in the analysis. The estimation results are presented and discussed in Section 4. Concluding remarks are made in Section 5.

2. EMPIRICAL MODEL

Marketing margins are the result of demand and supply factors, marketing costs and the degree of marketing channel competition (Marsh & Brester, 2004). Margins reflect aggregate firm behavior at different levels of the supply chain. Two marketing margin models that have been widely used in the literature are the Markup Price (MP) model, proposed by Waugh (1964), and the Relative Price Spread (RPS) model developed by Wohlgenant and Mullen (1987). In the MP model, the relationship between farm and retail prices can be depicted accurately only if changes occur in either supply or demand, but not in both (Gardner, 1975). The RPS model, in contrast, allows for simultaneous changes in demand and supply conditions by relating the price spread to industry output and marketing input prices. This characteristic of the RPS model is theoretically appealing.

In particular, the RPS model can be derived from an industry-wide specification of derived demand by processors for farm output. An important assumption of the model is that farm output is predetermined with respect to price from one period to another because of biological lags in the production process. This feature permits to model farm prices as a function of the quantity processed, wholesale prices, and marketing costs. Subsequently, it is possible to derive marketing margin relationships (see Wohlgenant & Mullen, 1987; Capps et al., 1995).

Under the RPS approach, then, the farm-to-retail price margin M_{fr} is modeled as $M_{fr} = P_r f(Q, C/P_r)$, where $M_{fr} = P_r - P_f$, P_f is the farm price, P_r is the retail price, f represents the marginal cost of marketing services, Q is the quantity of the agricultural commodity processed and C is a vector of marketing costs. This relationship implies that shifts in retail demand and farm supply have two possible avenues of influence on the farm-retail price spread: quantity of output and/or retail price. Increases in output and in relative marketing costs lead, then, to a higher relative price spread. As shown by Wohlgenant and Mullen (1987), the empirical analogue of the RPS model can be represented by

$$M_{frt} = b_1 P_{rt} + b_2 P_{rt} Q_t + b_3 IC_t + e_t \qquad (1)$$

where IC is a marketing cost index, b_i, i = 1,..., 3 are parameters to be estimated, and e corresponds to the error or distribution term.

Our model is based on the empirical analogue of the RPS model, which allows for a joint analysis of shifts in retail demand and farm supply and eliminates the need for a more elaborate simultaneous equation model of the beef and pork industries. We augment the RPS model by including dummy variables for different types of FSIS recalls and BSE outbreaks. This variant allows us to examine the impact of food scare events on the beef and pork marketing channel in the US market. Similar to Capps et al. (1995), we further decompose the farm-to-retail margin into slaughter-to-wholesale and wholesale-to-retail segments for a more complete understanding of the effect of food scares at different levels of the supply chain.

In particular, the following model is specified for the analysis of the beef and pork price margins,

$$
\begin{aligned}
M_{swt} &= \alpha_1 P_{wt} + \alpha_2 P_{wt} Q_{wt} + \alpha_3 IC_{wt} + \sum_{i=0}^{3} \gamma_{1i} R^{b}_{S,t-i} + \sum_{i=0}^{3} \gamma_{2i} R^{p}_{S,t-i} + \sum_{i=0}^{3} \gamma_{3i} BSE^{U}_{t-i} \\
&\quad + \sum_{i=0}^{3} \gamma_{4i} BSE^{C}_{t-i} + u_{1t} \\
M_{wrt} &= \beta_1 P_{rt} + \beta_2 P_{rt} Q_{rt} + \beta_3 IC_{rt} + \sum_{i=0}^{3} \delta_{1i} R^{b}_{S,t-i} + \sum_{i=0}^{3} \delta_{2i} R^{p}_{S,t-i} + \sum_{i=0}^{3} \delta_{3i} BSE^{U}_{t-i} \\
&\quad + \sum_{i=0}^{3} \delta_{4i} BSE^{C}_{t-i} + u_{2t}
\end{aligned}
\tag{2}
$$

M_{swt} and M_{wrt} are the slaughter-to-wholesale and wholesale-to-retail price margins for beef (pork) at month *t* in price equivalent retail weight terms (cents per pound); P_{wt} and P_{rt} are the wholesale and retail prices of beef (pork) in cents per pound; Q_{wt} and Q_{rt} correspond to per capita beef (pork) consumption at the wholesale and retail level of the marketing chain; IC_{wt} and IC_{rt} are wholesale and retail marketing cost indexes associated with the food industry; $R^{b}_{S,t-i}$ and $R^{p}_{S,t-i}$, i=0, …, 3, are dummy variables to indicate recalls for beef and pork reported by FSIS, where $S = \{Class\ I\ Bacterial, Class\ I\ Other, National\}$; and BSE^{U}_{t-i} and BSE^{C}_{t-i} are indicator variables of BSE outbreaks in the United States and Canada. The parameters of interest are $\gamma_{1i}, \gamma_{2i}, \gamma_{3i}, \gamma_{4i}, \delta_{1i}, \delta_{2i}, \delta_{3i}$, and δ_{4i}, which capture any immediate and delayed effects of food recalls and disease outbreaks on different levels of the beef and pork marketing channel as well as any cross-industry and cross-country effects.

BSE outbreaks are distinguished from recall cases to avoid any potential confounding of their effects (since both events may occur simultaneously). We include BSE discoveries in both the United States and Canada to account for any cross-country effects. Further, the indicators associated with food recalls in pork are included in the marketing margin equations for beef and

vice versa, to uncover any cross-industry effects. We consider up to three lags for the different food recall and disease outbreak variables to control for immediate and delayed effects of these food scare events on the respective marketing margins.[3] The three-month lag specification also is in line with the work of Schlenker and Villas-Boas (2009), who found that the effects of the BSE discovery in 2003 on the beef industry persisted for three months in the United States. For robustness, an alternative specification is also considered in which the immediate and delayed effects are modeled through a polynomial distributed lag (PDL) process of second degree and three lags, constraining both the near and far end of the distribution to zero.

The system of equations for beef and pork marketing margins previously described is estimated by an iterative seemingly unrelated regression (SUR) procedure to account for contemporaneous correlations along the marketing channel of each industry and across industries. Given that the explanatory variables are not the same in each equation, gains in estimation efficiency can also be expected relative to Ordinary Least Squares (OLS). In addition, autoregressive (AR) error terms are included in the estimation process to control for serial correlation. Time trend variables and quarterly dummies are further included to account for technological changes and/or changes in dietary preferences across time and to account for seasonal fluctuations in meat demand.[4]

Additionally, we derive elasticities of price transmission (EPTs) to evaluate the extent of price transmission along the beef and pork marketing channel, particularly during food scares. The EPT estimates the responsiveness of downstream prices due to changes in upstream prices in

[3] Additional lags were found to be insignificant.

[4] The trend variables pertain to the use of a time trend and the square of the time trend to control for possible nonlinear relationships.

the marketing channel (Capps et al., 1995). An EPT close to zero suggests no transmission of price signals along the segments of the marketing chain, which may be attributed to imperfect competition; an EPT close to one suggests an equal response transmission from upstream to downstream prices, which is consistent with perfect competition. Finally, an EPT considerably greater than one signals over-response of downstream prices to changes in upstream prices. Overreaction of downstream prices to an initial increase in upstream prices could point to imperfect competition, but this is not necessarily the case when there is a decrease in upstream prices.

We derive EPTs at the slaughter-to-wholesale level, $EPT_{sw} = (\partial P_w / \partial P_s) \times (P_s / P_w)$, and at the wholesale-to-retail level, $EPT_{wr} = (\partial P_r / \partial P_w) \times (P_w / P_r)$, but these elasticities are assumed not to change with food safety incidents. To analyze price transmission effects during specific incidences of market stress induced by food scares, we modify equation (2) by interacting the dummy variables for FSIS recalls and BSE discoveries with the relevant downstream price term. To avoid degrees-of-freedom problems, immediate and delayed effects of food safety incidents on marketing margins are further modeled through a PDL process of second degree and three lags. This specification also allows both for direct effects of food scares on marketing margins and for indirect effects through wholesale and retail prices.[5] Formally, the following model (hereafter called the interaction model) is specified as,

[5] Alternatively, wholesale and retail prices have a differentiated effect on the corresponding marketing margins due to food scare events.

$$
\begin{aligned}
M_{swt} &= \theta_1 P_{wt} + \theta_2 P_{wt} Q_{wt} + \theta_3 IC_{wt} + \sum_{i=0}^{3} \kappa_{1i} R^{b}_{S,t-i} + \sum_{i=0}^{3} \kappa_{2i} R^{p}_{S,t-i} + \sum_{i=0}^{3} \kappa_{3i} BSE^{U}_{t-i} \\
&\quad + \sum_{i=0}^{3} \kappa_{4i} BSE^{C}_{t-i} + (FS_t \times P_{wt})\kappa_5 + \upsilon_{1t} \\
M_{wrt} &= \lambda_1 P_{rt} + \lambda_2 P_{rt} Q_{rt} + \lambda_3 IC_{rt} + \sum_{i=0}^{3} \tau_{1i} R^{b}_{S,t-i} + \sum_{i=0}^{3} \tau_{2i} R^{p}_{S,t-i} + \sum_{i=0}^{3} \tau_{3i} BSE^{U}_{t-i} \\
&\quad + \sum_{i=0}^{3} \tau_{4i} BSE^{C}_{t-i} + (FS_t \times P_{rt})\tau_5 + \upsilon_{2t}
\end{aligned}
\tag{3}
$$

where FS_t is a vector containing all the indicator variables, immediate and delayed, for the different food scares considered in the analysis: FSIS beef recalls (class I bacterial, class I other, national), FSIS pork recalls (class I bacterial, class I other, national), BSE outbreaks in the United States and BSE outbreaks in Canada.

3. DATA

To conduct the analysis, we use monthly national data for the period January 1986 through December 2008. Prices and quantities were obtained from the red meat yearbook archives, published online by the US Department of Agriculture (USDA). The wholesale and retail marketing cost indexes were derived based on data used by the Economic Research Service (ERS)-USDA to construct their food marketing cost index, published online in the agricultural outlook tables. The data are from the Bureau of Labor Statistics (BLS). Data for FSIS recalls and BSE outbreaks were obtained from the recall case archive of FSIS and official reports from the

Foreign Agricultural Service (FAS), most of them available online.[6] For further details on the sources consulted, refer to Table A.1 in the Appendix.

Beef and pork prices are in cents per pound of retail weight equivalent and were deflated using the consumer price index (1982-84=100), city average, published by the BLS. Quantities are in pounds per capita to account for population growth over the period of analysis.[7] Slaughter quantity is the quantity bought by slaughter plants from farmers, equal to the average light weight of cattle (hogs) slaughtered under federal inspection multiplied by the commercial cattle (hog) slaughtered. Wholesale quantity is the carcass sold by slaughter plants to fabricating plants (commercial production), while retail quantity is the quantity bought by retail stores to be sold to consumers. More specifically, the retail quantity is constructed based on the disappearance of beef and pork, equal to commercial production, plus imports, less exports, plus beginning stocks, less ending stocks; this quantity is then multiplied by a conversion factor to obtain a corresponding retail weight equivalent for both beef and pork.[8]

The wholesale marketing cost index (1982-84=100) is the weighted average of earnings of production and nonsupervisory workers in food manufacturing and wholesaling, rail freight index for food and producer price index for energy. The retail marketing cost index (1982-84=100) is the weighted average of earnings of nonsupervisory workers in food retailing, rail freight index for food and producer price index for energy. These data series constitute the basis

[6] Information on FSIS recalls prior to 1992 was generously provided by Dr. Ted Schroeder from Kansas State University. A special thanks also to Dr. Victoria Salin from Texas A&M University who provided the data for the period 1993-1997.

[7] Population estimates were obtained from the U.S. Census Bureau. We find qualitatively similar results when considering total quantity instead of per capita quantity.

[8] The conversion factors used are 0.74 for cattle and 0.77 for hog, based on the factors used by USDA reports.

of the Food Marketing Cost Index, a monthly wholesale and retail index for food marketing costs reported by ERS-USDA.[9] The weights used are based on the relative importance given by USDA to wages, transportation and energy in the construction of their index.

We distinguish between beef and pork FSIS recalls and consider, given their importance, three categorical variables for each type of meat: class I bacterial, class I other and national. As indicated above, class I recalls are for dangerous or defective products that could cause serious health problems or death. These recalls may originate due to pathogenic bacteria such as *E.Coli, Salmonella, Listeria Staphylococcus* and *Trichinae* (class I bacterial) or due to other factors such as allergenic ingredients or underprocessing (class I other). A national recall is effective across all of the 52 states in the United States and is not necessarily a class I recall.[10]

BSE cases in the United States occurred in December 2003 (Washington), June 2005 (Texas) and March 2006 (Alabama). BSE cases in Canada occurred in May 2003, January 2005, January, April, July and August 2006, February, May and December 2007, and February, June, August and November 2008.

Table 1 provides summary statistics of the variables used in the analysis. On average, beef price margins are very similar to pork margins both at the slaughter-to-wholesale level (17 versus 19 cents per pound on a retail weight basis) and at the wholesale-to-retail level (79 versus 78 cents per pound). In terms of prices, beef prices are higher than pork prices, but these differences decrease as we move downstream along the marketing chain. Regarding food safety

[9] Special thanks are owed to Dr. Howard Elitzak, agricultural economist from ERS-USDA, for sharing the inputs, weights and part of the data series used to construct the Food Marketing Cost Index.

[10] The inclusion of these types of recalls is also based on previous work by Marsh et al. (2004) and Salin et al. (2006).

incidents, there is a much higher occurrence of class I bacterial recalls in both beef and pork, relative to other recalls and BSE discoveries in the United States and Canada.

Figure 1 shows beef and pork price margins for the whole sample period. In the case of beef, the wholesale-to-retail margin has shown a slight upward trend, increasing from around 75 cents (per pound) in 1986 to 95 cents in 2008. The slaughter-to-wholesale margin, in contrast, has remained around 17 cents during the same period. In the case of pork, the wholesale-to-retail margin has also shown a small upward trend, although in recent years the price margin appears to have declined: the margin increased from around 68 cents in 1986 to 90 cents in 2002 and then decreased to 80 cents in 2008. Similar to the case of beef, the pork slaughter-to-wholesale margin has been rather stable, fluctuating around its mean (19 cents) in past years. Note also that while wholesale-to-retail margins in both industries have shown important variations across time, slaughter-to-wholesale margins exhibit some seasonality. All of these patterns suggest, then, the necessity of controlling for possible trend and seasonal effects in our analysis.

Figure 2 reports the recorded cases of beef and pork FSIS recalls (class I bacterial, class I other, or national) and BSE outbreaks in the United States and Canada during the last decade. The figure clearly shows the higher incidence of beef and pork recalls (in that order) relative to BSE discoveries. Figure 3 further plots the beef and pork marketing margins together with the recorded cases of BSE outbreaks.[11] In general, wholesale-to-retail margins appear to be more responsive to food safety incidents (BSE outbreaks) than slaughter-to-wholesale margins, providing some evidence of potential impacts of food scares on marketing margins.

[11] For clarity of exposition, we do not include the recorded cases of food recalls in the figure since these are more recurrent than the BSE outbreaks.

4. EMPIRICAL RESULTS

In this section, we formally examine the impact of FSIS recalls and BSE outbreaks on beef and pork marketing margins, as well as their effects on the extent of price transmission along the marketing channel.

Table 2 presents the SUR estimates for the system of marketing margins described in equation (2) and corrected for autocorrelation. The correction for serial correlation involves an autoregressive process of order 3. The Portmanteau system residual test for autocorrelation, reported at the bottom of the table, does not reject the null hypothesis of no residual autocorrelations, once the AR(3) process in the disturbance terms are accounted for.[12] The Likelihood Ratio test for the diagonality of the variance-covariance matrix, reported also at the bottom of the table, rejects the null hypothesis of zero correlation among the disturbances of the specified marketing margins equations, confirming gains in estimation efficiency relative to OLS. Similarly, joint significance tests for trend, trend squared and quarterly dummies for each equation in the system indicate (at the 1% level) the importance of accounting for a (nonlinear) time trend and seasonality when modelling beef and pork marketing margins. Overall, the goodness-of-fit statistics show that the variables included in the model account for 74–88% of the variation in marketing margins at the slaughter-to-wholesale and wholesale-to-retail levels of the beef and pork industry in the United States.

The associated coefficients for the corresponding downstream prices and prices interacted with quantities generally have a positive sign and are significant at a 5% or 10% level across all

[12] The adjusted *Q*-statistic reported is for no residual autocorrelation up to 6 lags. Similar results are found when considering up to 12 lags.

beef and pork marketing margins. The only exception is the negative effect of wholesale pork prices on the slaughter-to-wholesale margin, suggesting that when wholesale prices are high, slaughter prices are even higher. In terms of marginal effects reported in Table 3, the change in the slaughter-to-wholesale margin due to a 10-cent increase in the wholesale price is equal to 1.7 cents (per pound) for beef and -1.6 cents in pork (at the sample means), while the change in the wholesale-to-retail margin due to a 10-cent increase in the retail price is equal to 5.2 cents for beef and 4.7 cents for pork.[13] In terms of elasticities, we find that the beef marketing margins are more price-elastic than the pork marketing margins. At the sample means, a 10% increase in the wholesale price of beef leads to a 11.4% increase in the slaughter-to-wholesale margin, while a 10% increase in the retail price of beef leads to a 12.9% increase in the wholesale-to-retail margin; in the case of pork, a 10% increase in wholesale and retail prices results in a 6% decrease and a 9.2% increase in the respective margins.

Regarding the effect of variations in the quantity consumed, marketing margins are not very responsive to changes in per capita beef and pork consumption. A 10% increase in the quantity consumed at the wholesale level only gives rise to a 3.9% increase in the beef slaughter-to-wholesale margin and to a 3.3% increase in the pork margin; at the retail level, there is only a (statistically significant) 0.5% increase in the pork wholesale-to-retail margin. Marketing costs, in turn, curiously have a negative effect on beef marketing margins and do not affect pork margins. A 10% increase in the wholesale marketing cost index leads to a 5.5% decrease in the beef slaughter-to-wholesale margin, while a 10% increase in the retail marketing cost index leads to a 6.4% decrease in the wholesale-to-retail margin.

[13] The marginal effect of a unit change in the wholesale price on the slaughter-to-wholesale margin, for example, is obtained as follows: $\partial M_{sw}/\partial P_w = \hat{\alpha}_1 + \hat{\alpha}_2 \times \overline{Q}_w$, where $\overline{Q}_w$ is the average per capita wholesale quantity.

Turning to our variables of interest, we allow for both immediate and delayed effects of food recalls and disease outbreaks on the beef and pork marketing margin, as noted previously. The results reveal a differentiated impact of the different types of FSIS recalls and BSE discoveries, in terms of direction, magnitude and statistical significance, on the slaughter-to-wholesale and wholesale-to-retail margins, although in most cases, the effects are quite modest. As shown in Table 3, beef and pork recalls do not have a statistically significant influence on the corresponding beef and pork marketing margins. We do find, however, cross-industry effects of beef recalls on pork margins, but not vice versa. In particular, a class I beef recall originated due to pathogenic bacteria has a cumulative effect over a period of three months of about 1.4 cents on the pork slaughter-to-wholesale margin (or 7.2% of the average pork slaughter-to-wholesale margin).[14] Similarly, a national beef recall has a cumulative effect of 1.9 cents on the pork slaughter-to-wholesale margin (or 10.1% of the average margin). These results imply that these two types of beef recalls, bacterial and national cases, could marginally favor pork wholesalers relative to slaughterhouses. Wholesalers, who are more concentrated, could be obtaining further advantages than slaughterhouses during market stresses in the beef industry.

Regarding disease outbreaks, a BSE discovery in the United States significantly influences the beef wholesale-to-retail margin. The effect is much higher than any of the other effects resulting from food safety incidents on the beef and pork marketing channel. A BSE outbreak in the United States widens the beef wholesale-to-retail margin by 29.7 cents over a period of three months; this is equivalent to 37.6% of the average beef wholesale-to-retail margin. Hence a BSE discovery in the United States clearly favors beef retailers relative to wholesalers or, alternatively, less affects retailers as compared to wholesalers, which is also in

[14] The cumulative effect is the sum of the immediate and three lagged effects reported in Table 2.

line with the apparent higher oligopsony market power enjoyed by retailers that has been addressed in other related studies (see, e.g., Marsh & Brester, 2004; Armah, 2007). A BSE outbreak in Canada, in turn, has a minor effect on the pork slaughter-to-wholesale US margin; more specifically, a disease outbreak in the neighboring country results in a 3.4 cent decrease in the pork slaughter-to-wholesale margin (or 18% of the average margin), although this result is not robust to an alternative specification as discussed next.

For robustness, an alternative model specification is estimated in which the immediate and delayed effects of FSIS recalls and BSE discoveries are modeled using a polynomial distributed lag (PDL) process of second degree and three lags, constraining the near and far end of the distribution to zero. The full estimation results are reported in Table A.2 in the Appendix. The estimated coefficients are comparable, in terms of both magnitude and statistical significance, to our base results (see Table 2).

Table 4 confirms that the marginal effects (and elasticities) of prices, quantity consumption, marketing costs and, in particular, the cumulative effects of food recalls and disease outbreaks on the slaughter-to-wholesale and wholesale-to-retail margins are very similar to our original results. This finding suggests that the results are robust with respect to an alternative (polynomial) specification of immediate and delayed effects of food safety incidents on the beef and pork marketing channel. The only major difference between the results in Table 3 and Table 4 pertains to the lack of statistical significance of the effect of BSE outbreaks in Canada on the pork slaughter-to-wholesale margin.

We also estimate EPTs to examine the extent of price transmission along the beef and pork marketing channel. Recall that the elasticity of price transmission measures the responsiveness of downstream prices to changes in upstream prices. In the case of our base

model, the EPTs do not change with food scare events since

$EPT_{sw} = \left(1/(1-\hat{\alpha}_1 - \hat{\alpha}_2\overline{Q}_w)\right)\times\left(\overline{P}_s/\overline{P}_w\right)$ and $EPT_{wr} = \left(1/(1-\hat{\beta}_1 - \hat{\beta}_2\overline{Q}_r)\right)\times\left(\overline{P}_w/\overline{P}_r\right)$, where

$\overline{P}_s, \overline{P}_w, \overline{P}_r, \overline{Q}_w$, and $\overline{Q}_r$ denote average prices and quantities.

The estimated elasticities, presented in the top panel of Table 5, indicate that price changes at the slaughter level in the beef marketing channel are fully transmitted (all else equal) to the wholesale level, suggesting a perfect competition situation ($EPT_{sw} = 1.025$). Price changes at the beef wholesale level, in turn, are slightly more than fully transmitted to the retail level. A 10% increase in wholesale price leads to a 12.4% increase in retail price. A different pattern emerges when analyzing price transmission in the pork marketing channel. Prices are less than fully transmitted both from hog slaughterhouses to wholesalers and from wholesalers to retailers. A 10% increase in slaughter price only results in a 6.4% increase in wholesale price, while a 10% increase in wholesale price leads to a 9.2% increase in retail price. A possible explanation for this breakdown in price transmission could be the lower volume and lower importance that wholesalers and retailers attach to marketing pork, relative to marketing beef. Note also that similar results are obtained when modelling the effects of recalls and outbreaks as a PDL process.

To examine whether these elasticities of price transmission change during food safety incidents, we further estimate an interaction model, summarized in equation (3), where the derived EPTs are allowed to vary with FSIS recalls and BSE outbreaks. The full estimation results are presented in Table A.3 in the Appendix. The estimated coefficients are qualitatively similar to our original estimates (when comparable). Under this specification, the EPT from slaughter-to-wholesale is given by $EPT_{sw} = \left(1/(1-\hat{\theta}_1 - \hat{\theta}_2\overline{Q}_w - FS\hat{\kappa}_5)\right)\times\left(\overline{P}_s/\overline{P}_w\right)$, while the EPT

from wholesale-to-retail is equal to $EPT_{wr} = \left(1/(1-\hat{\lambda}_1 - \hat{\lambda}_2\overline{Q}_r - FS\hat{\tau}_5)\right)\times\left(\overline{P}_w/\overline{P}_r\right)$, where the vector FS contains the indicator variables (immediate and delayed) for the different food recalls and disease outbreaks considered in the analysis. We set each indicator variable to one to estimate the EPT during the corresponding food scare event and to zero to derive the EPT when there is no occurrence of the event.

The estimated elasticities are reported in the bottom panel of Table 5. Immediate corresponds to the elasticity during the month in which the recall or outbreak occurs, while delayed is the elasticity one month after the food safety incident occurred. It follows that price transmission along the beef and pork marketing channel is not affected by most food safety incidents: the EPTs, both immediate and delayed, do not generally vary with the occurrence of food scares. This result is in line with the modest effects of all food scare events on marketing margins, except for BSE outbreaks in the United States, as discussed earlier. Precisely, the only significant change in elasticities for beef occurs during a disease outbreak in the United States, which further increases the elasticity of price transmission at the wholesale-to-retail level: from 1.18 to 2.11 during the month of the outbreak and to 3.50 one month later. Interestingly, a BSE discovery in the United States also results in considerable overreaction of retail pork prices to potential changes in wholesale prices. The EPT increases from 0.82 to 1.93 during the month of the outbreak and to 6.06 one month later. This result provides further evidence toward the potential market power exertion enjoyed by retailers, who usually handle both beef and pork and who could take advantage of market stresses induced by disease outbreaks in the red meat industry.

In sum, the results indicate that marketing margins are differentially affected by FSIS recalls and BSE outbreaks at different levels of the beef and pork marketing channel, although

the effects are generally quite modest and not statistically significant. Only a BSE discovery in the United States has an economically significant impact on the wholesale-to-retail margin in the beef industry, favoring retailers. Food safety incidents also have minor cross-industry effects (from beef to pork) and cross-country effects (from Canada to the United States) on marketing margins. The extent of price transmission along the beef and pork marketing channel is similarly only affected by BSE outbreaks in the United States, specifically at the wholesale-to-retail level.

5. CONCLUDING REMARKS

This study has examined the effect of FSIS recalls and BSE outbreaks on marketing margins and the extent of price transmission at the slaughter-to-wholesale and wholesale-to-retail levels in the US beef and pork industry. We account for three different types of food recalls and allow for cross-industry effects of recalls and cross-country effects of disease outbreaks. We further allow for immediate and delayed effects of food scares on marketing margins, considering that adjustments are not necessarily made instantaneously to such events.

The results indicate that only a BSE discovery in the United States has an important and statistically significant effect on the wholesale-to-retail margin in the beef industry, in favor of retailers. The corresponding price margin increases by almost 30 cents, equivalent to 37% of the average margin. There are also modest cross-industry and cross-country effects. Interestingly, a BSE discovery in the United States further increases the extent of price transmission from wholesalers to retailers for both beef and pork. These findings could point toward potential market power exertion enjoyed by retailers during and immediately after an outbreak, as these

retailers typically handle both beef and pork and could take advantage of specific market stresses in the industry due to their oligopsony market power.

For policymakers concerned with assessing the impact of food safety events on prices along the red meat marketing channel, this research provides some insight about the more and less vulnerable agents along the channel during periods of food safety concern. In particular, the results indicate that specific attention should be placed to retailers during and a couple of months after a disease outbreak in the country. Their apparent higher market power could aid them to better cope with a major food safety concern such as a BSE outbreak, but to the detriment of other agents along the marketing channel. The results also suggest that some attention should be paid to the behavior of pork wholesalers after bacterial and national beef recalls, although the implications are not as strong as in the case of a BSE outbreak.

Finally, we recognize some limitations in the analysis. We use food recall and disease outbreak information from the FSIS recall case archive and FAS official reports. Consumers, however, may not be aware of such reported cases unless the media publicizes them. As shown by Schlenker and Villas-Boas (2009), media can play an important role in consumers' reaction to food safety incidents and consequently on how marketing margins could be affected by these incidents. It is possible that several food recalls did not catch the public attention, which could explain to some extent the limited effect of recalls on the beef and pork marketing margins. Additionally, our analysis is at the national level and several FSIS recalls are at the state or regional level, which could also affect our results. Future research should also incorporate price asymmetries into the analysis of price transmission during food scares to shed more light on potential market power exertion along the beef and pork marketing channel, particularly among retailers. Certainly, a decreasing price may produce a different effect on the marketing chain than

an increasing price, which could bring additional information to further improve the policy-making process during food safety concerns.

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FIGURE 1. Beef and pork marketing margins for slaughter-to-wholesale and wholesale-to-retail, 1986-2008

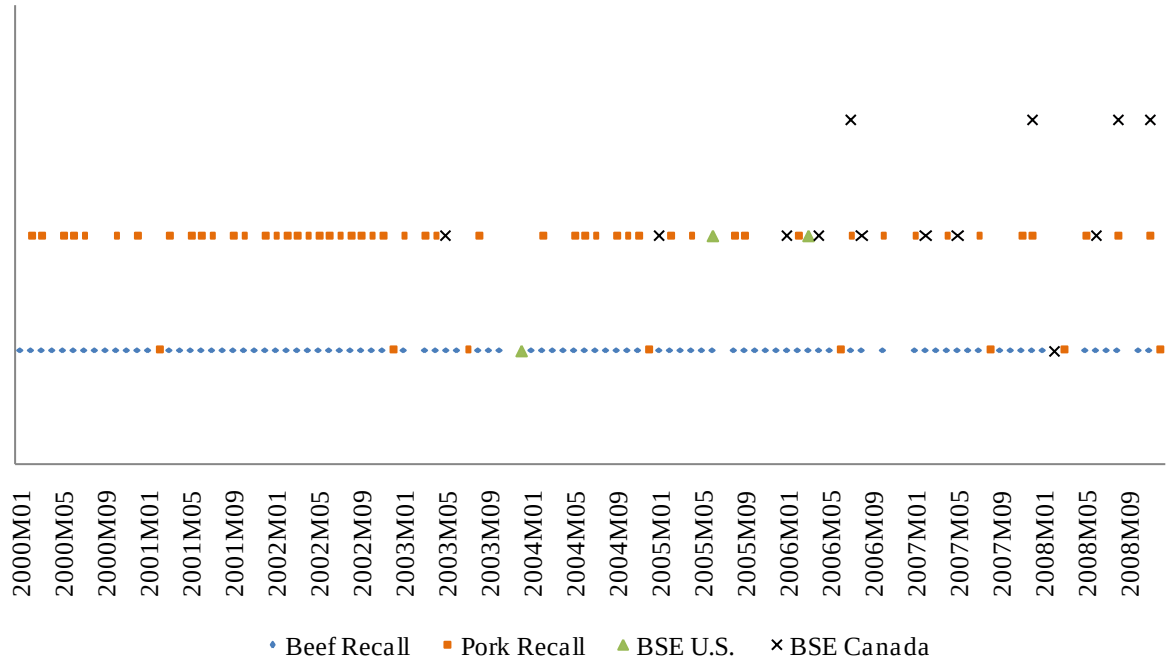

FIGURE 2. FSIS recalls and BSE outbreaks, 2000-2008

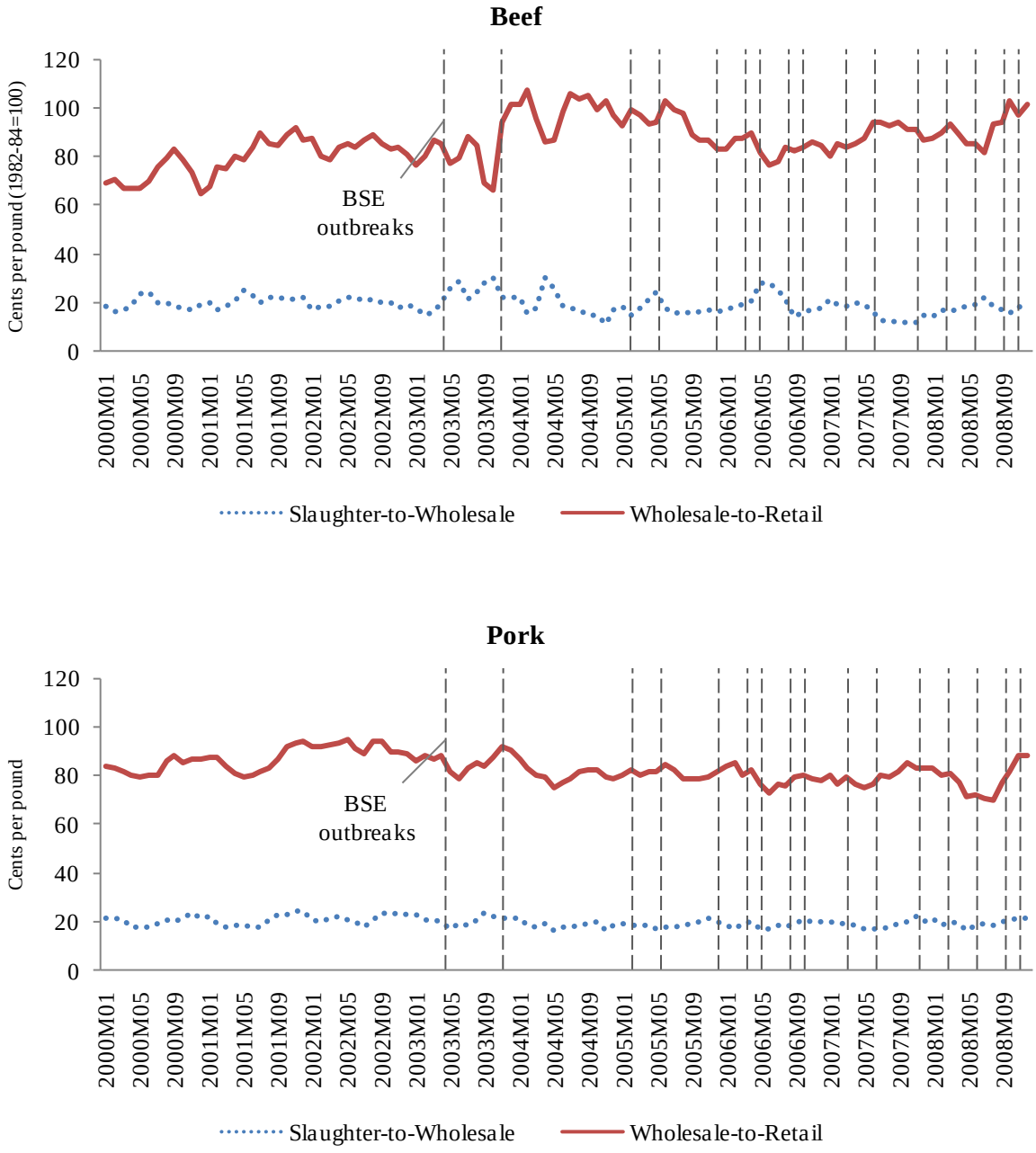

FIGURE 3. Beef and pork marketing margins for slaughter-to-wholesale and wholesale-to-retail, and BSE outbreaks, 2000-2008

TABLE 1. Summary statistics

Variable	Mean	SD	Min.	Max.
Margins (cents per pound, 1982-84=100)				
Beef, slaughter-to-wholesale	17.14	3.75	9.10	30.10
Beef, wholesale-to-retail	78.98	9.45	56.00	107.60
Beef, slaughter-to-retail	96.12	10.32	76.10	124.40
Pork, slaughter-to-wholesale	18.91	3.31	11.50	31.60
Pork, wholesale-to-retail	77.86	7.99	53.20	95.80
Pork, slaughter-to-retail	96.77	10.24	64.70	127.40
Prices (cents per pound, 1982-84=100)				
Beef, slaughter	100.76	16.55	74.70	135.70
Beef, wholesale	117.91	16.46	90.60	155.70
Beef, retail	196.88	15.26	167.60	234.00
Pork, slaughter	54.16	16.93	17.90	109.10
Pork, wholesale	73.08	15.42	49.50	126.40
Pork, retail	150.93	12.03	131.10	186.90
Per capita quantity (pounds)				
Beef, slaughter	12.80	1.00	10.00	15.30
Beef, wholesale	7.68	0.60	6.00	8.90
Beef, retail	5.94	0.43	4.70	7.20
Pork, slaughter	7.64	0.66	6.00	9.50
Pork, wholesale	5.58	0.53	4.30	7.10
Pork, retail	4.22	0.30	3.50	4.90
Food Marketing Cost Index (1982-84=100)				
Wholesale Index	1569.94	267.22	1180.75	2287.61
Retail Index	1415.27	219.01	1124.70	2030.66
Food Recalls and Disease Outbreaks				
Beef Recall I Bacterial	0.47	0.50	0.00	1.00
Beef Recall I Other	0.06	0.23	0.00	1.00
Beef Recall National	0.16	0.36	0.00	1.00
Pork Recall I Bacterial	0.32	0.47	0.00	1.00
Pork Recall I Other	0.12	0.32	0.00	1.00
Pork Recall National	0.04	0.19	0.00	1.00
BSE US	0.01	0.10	0.00	1.00
BSE Canada	0.05	0.21	0.00	1.00
Observations				276

Note: All margins and prices are in retail weight equivalent. For further description of the variables and their sources, refer to Table A.1.

TABLE 2. Marketing margins' regressions

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Price	0.109**	0.521**	-0.241**	0.445**
	(0.028)	(0.056)	(0.034)	(0.054)
Price x Per Capita Quantity	0.007**	0.000	0.015**	0.006*
	(0.002)	(0.002)	(0.004)	(0.004)
Marketing Cost Index	-0.006*	-0.036**	0.008	-0.011
	(0.003)	(0.010)	(0.008)	(0.008)
Beef Recall I Bacterial	0.339	0.382	0.327	-0.102
	(0.290)	(0.555)	(0.264)	(0.452)
Beef Recall I Bacterial (-1)	-0.117	-0.785	0.336	-0.332
	(0.365)	(0.734)	(0.319)	(0.582)
Beef Recall I Bacterial (-2)	-0.086	-1.228*	0.180	-0.986*
	(0.364)	(0.732)	(0.320)	(0.577)
Beef Recall I Bacterial (-3)	0.336	-0.647	0.519**	0.045
	(0.296)	(0.569)	(0.264)	(0.456)
Beef Recall I Other	-0.857	1.051	0.035	-0.979
	(0.543)	(1.022)	(0.490)	(0.823)
Beef Recall I Other (-1)	-1.364**	-0.474	0.143	0.312
	(0.682)	(1.372)	(0.592)	(1.072)
Beef Recall I Other (-2)	-0.532	-2.475*	0.489	0.143
	(0.676)	(1.351)	(0.574)	(1.060)
Beef Recall I Other (-3)	0.049	-1.889*	0.799	-0.011
	(0.546)	(1.052)	(0.490)	(0.844)
Beef Recall National	0.523	-0.186	0.675**	-0.779
	(0.346)	(0.667)	(0.317)	(0.545)
Beef Recall National (-1)	0.169	1.589*	0.658*	-0.341
	(0.407)	(0.817)	(0.356)	(0.660)
Beef Recall National (-2)	0.010	0.655	0.331	0.199
	(0.406)	(0.822)	(0.354)	(0.656)
Beef Recall National (-3)	-0.152	0.048	0.253	0.248
	(0.351)	(0.676)	(0.318)	(0.549)
Pork Recall I Bacterial	-0.390	0.450	-0.115	-0.857**
	(0.265)	(0.512)	(0.239)	(0.411)
Pork Recall I Bacterial (-1)	0.067	0.077	-0.336	-0.863
	(0.334)	(0.678)	(0.289)	(0.534)
Pork Recall I Bacterial (-2)	0.813**	0.629	-0.192	0.025
	(0.340)	(0.691)	(0.294)	(0.549)
Pork Recall I Bacterial (-3)	0.916**	0.033	-0.059	0.170
	(0.265)	(0.517)	(0.238)	(0.415)

TABLE 2. continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Pork Recall I Other	-0.717**	0.313	0.215	-0.411
	(0.364)	(0.699)	(0.326)	(0.553)
Pork Recall I Other (-1)	-0.474	0.579	-0.214	-1.287*
	(0.459)	(0.921)	(0.390)	(0.703)
Pork Recall I Other (-2)	0.206	-0.168	0.645*	-0.577
	(0.454)	(0.912)	(0.389)	(0.697)
Pork Recall I Other (-3)	-0.189	-0.082	-0.119	-0.802
	(0.350)	(0.673)	(0.316)	(0.533)
Pork Recall National	-0.128	2.884**	-0.270	-0.151
	(0.682)	(1.283)	(0.581)	(0.997)
Pork Recall National (-1)	0.620	2.184	-0.080	-0.260
	(0.884)	(1.757)	(0.744)	(1.353)
Pork Recall National (-2)	0.306	-0.846	0.166	-0.554
	(0.878)	(1.745)	(0.758)	(1.360)
Pork Recall National (-3)	-0.339	-2.285*	0.065	-0.436
	(0.675)	(1.277)	(0.606)	(1.026)
BSE Outbreak US	-0.697	6.377**	0.001	-0.036
	(1.117)	(2.192)	(1.004)	(1.671)
BSE Outbreak US (-1)	-0.723	10.992**	0.567	-0.430
	(1.410)	(2.825)	(1.198)	(2.094)
BSE Outbreak US (-2)	-0.346	10.207**	-1.363	-2.091
	(1.398)	(2.783)	(1.193)	(2.084)
BSE Outbreak US (-3)	-0.944	2.119	-0.788	-2.173
	(1.068)	(2.049)	(0.975)	(1.607)
BSE Outbreak Canada	0.649	0.240	-0.794	0.368
	(0.608)	(1.167)	(0.543)	(0.924)
BSE Outbreak Canada (-1)	0.026	1.571	-0.900	0.686
	(0.855)	(1.723)	(0.736)	(1.318)
BSE Outbreak Canada (-2)	-0.872	1.910	-1.022	-0.260
	(0.859)	(1.737)	(0.746)	(1.355)
BSE Outbreak Canada (-3)	-0.447	-0.381	-0.686	0.858
	(0.622)	(1.210)	(0.557)	(0.968)
Trend	0.554	3.119**	-5.698**	3.397**
	(0.381)	(0.882)	(1.083)	(0.680)
Trend squared	0.003	-0.038	0.156**	-0.077**
	(0.013)	(0.032)	(0.031)	(0.026)

TABLE 2. continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
First Quarter	-1.301**	-1.792**	-0.085	-0.420
	(0.399)	(0.766)	(0.733)	(0.637)
Second Quarter	0.452	-1.745**	-0.375	-0.898
	(0.428)	(0.814)	(0.585)	(0.714)
Third Quarter	0.106	1.633**	-0.176	-0.168
	(0.377)	(0.714)	(0.447)	(0.657)
AR(1)	0.890**	1.020**	0.931**	1.027**
	(0.063)	(0.062)	(0.062)	(0.062)
AR(2)	-0.238**	-0.302**	-0.119	-0.103
	(0.084)	(0.086)	(0.085)	(0.090)
AR(3)	0.144**	0.144**	0.190**	-0.069
	(0.066)	(0.061)	(0.065)	(0.064)
R-squared	0.779	0.868	0.743	0.881
Durbin-Watson Statistic	2.013	1.992	2.013	2.027
Diagonality of Covariance Matrix Test:				
Likelihood Ratio statistic				655.345
p-value				0.000
Portmanteau Autocorrelation Test:				
Adjusted *Q*-statistic (6 lags)				128.020
p-value				0.117
Total System Observations				1,104

Notes: SE are reported in parentheses. Asterisk (*) and double asterisk (**) denote coefficients significant at 10% and 5% respectively.

TABLE 3. Marginal and cumulative effects and elasticities in the beef and pork marketing chain

	Beef				Pork			
	Slaughter-to-Wholesale		Wholesale-to-Retail		Slaughter-to-Wholesale		Wholesale-to-Retail	
	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity
Marginal effect								
Price	0.166**	1.143**	0.518**	1.292**	-0.156**	-0.602**	0.472**	0.915**
Per Capita Quantity	0.870**	0.390**	-0.092	-0.007	1.119**	0.330**	0.979*	0.053*
Marketing Cost Index	-0.006*	-0.548*	-0.036**	-0.638**	0.008	0.679	-0.011	-0.203
Cumulative effect								
Beef Recall I Bacterial	0.471		-2.277		1.361*		-1.375	
Beef Recall I Other	-2.705		-3.787		1.466		-0.535	
Beef Recall National	0.549		2.106		1.916**		-0.674	
Pork Recall I Bacterial	1.406		1.190		-0.703		-1.525	
Pork Recall I Other	-1.175		0.643		0.526		-3.076	
Pork Recall National	0.459		1.937		-0.119		-1.402	
BSE Outbreak US	-2.709		29.696**		-1.584		-4.729	
BSE Outbreak Canada	-0.644		3.340		-3.401*		1.653	

Notes: Asterisk (*) and double asterisk (**) denote estimates significant at 10% and 5% respectively. The cumulative effect for the food recalls and disease outbreaks is the sum of current and lagged effects. The marginal effects (when applicable) and elasticities are evaluated at the sample means.

TABLE 4. Marginal and cumulative effects and elasticities in the beef and pork marketing chain, polynomial distributed lag

	Beef				Pork			
	Slaughter-to-Wholesale		Wholesale-to-Retail		Slaughter-to-Wholesale		Wholesale-to-Retail	
	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity
Marginal effect								
Price	0.164**	1.125**	0.488**	1.216**	-0.169**	-0.654**	0.462**	0.896**
Per Capita Quantity	0.855**	0.383**	-0.136	-0.010	1.057**	0.312**	1.043*	0.056*
Marketing Cost Index	-0.006*	-0.546*	-0.030**	-0.531**	0.007	0.583	-0.010	-0.179
Cumulative effect								
Beef Recall I Bacterial	0.876		-1.885		1.444*		-0.932	
Beef Recall I Other	-1.481		-1.721		1.681		-0.824	
Beef Recall National	0.696		0.116		1.875**		-1.061	
Pork Recall I Bacterial	1.275		0.655		-0.697		-1.508	
Pork Recall I Other	-0.825		0.134		0.744		-2.570	
Pork Recall National	-0.386		0.787		0.461		-3.099	
BSE Outbreak US	-2.834		28.723**		-0.204		-6.648	
BSE Outbreak Canada	-0.450		1.485		-3.245		1.418	

Notes: Asterisk (*) and double asterisk (**) denote estimates significant at 10% and 5% respectively. The effect of food recalls and BSE outbreaks are modeled using a polynomial distributed lag (PDL) specification of second degree with three lags and constraining both the near and far end of the distribution to zero. The cumulative effect for the food recalls and disease outbreaks is the sum of current and lagged effects. The marginal effects (when applicable) and elasticities are evaluated at the sample means.

TABLE 5. Elasticity of price transmission (EPT) in the beef and pork marketing chain

A. Base Model				
	Original Model		Polynomial Distributed Lag	
	Beef	Pork	Beef	Pork
Slaughter-to-Wholesale	1.025	0.641	1.022	0.634
Wholesale-to-Retail	1.243	0.917	1.169	0.900

B. Interaction Model with Polynomial Distributed Lag						
	Beef Recall I Bacterial		Beef Recall I Other		Beef Recall National	
	Beef	Pork	Beef	Pork	Beef	Pork
Slaughter-to-Wholesale						
No Recall	1.002	0.721	1.082	0.693	1.058	0.685
Immediate	1.035	0.708	1.126	0.682	1.091	0.691
Delayed	1.053	0.701	1.090	0.676	1.108	0.695
Wholesale-to-Retail						
No Recall	1.056	0.903	1.247	0.879	1.176	0.827
Immediate	1.117	0.877	1.225	0.772	1.219	0.850
Delayed	1.149	0.865	1.074	0.727	1.242	0.862
	Pork Recall I Bacterial		Pork Recall I Other		Pork Recall National	
	Beef	Pork	Beef	Pork	Beef	Pork
Slaughter-to-Wholesale						
No Recall	1.056	0.710	1.065	0.697	1.079	0.687
Immediate	1.073	0.697	1.096	0.685	1.102	0.701
Delayed	1.082	0.691	1.113	0.679	1.113	0.708
Wholesale-to-Retail						
No Recall	1.198	0.863	1.224	0.894	1.232	0.796
Immediate	1.205	0.851	1.199	0.814	1.115	1.172
Delayed	1.209	0.846	1.187	0.779	1.064	1.534
	BSE Outbreak US		BSE Outbreak Canada			
	Beef	Pork	Beef	Pork		
Slaughter-to-Wholesale						
No Outbreak	1.082	0.694	1.060	0.684		
Immediate	1.102	0.623	1.174	0.711		
Delayed	1.112	0.592	1.240	0.726		
Wholesale-to-Retail						
No Outbreak	1.180	0.818	1.185	0.818		
Immediate	2.114	1.933	1.299	0.949		
Delayed	3.498	6.058	1.365	1.032		

Notes: All elasticities are significant at the 5% level. The elasticities are evaluated at the sample mean. Immediate corresponds to the elasticity during the month where the recall or outbreak occurs while delayed corresponds to the elasticity one month after the food safety incident occurred. The polynomial distributed lag (PDL) process is of second degree with three lags and constraining both the near and far end of the distribution to zero.

APPENDIX

TABLE A.1. Sources of information

Variable	Description	Source
Prices: Cents per pound. Retail weight equivalent (beef, pork)		US Department of Agriculture (USDA), Economic Research Service (ERS) Red Meat Yearbooks www.ers.usda.gov/Data/MeatPriceSpreads
- Slaughter	Net farm value	
- Wholesale	Wholesale value	
- Retail	Retail value. Average price reported by the Bureau of Labor Statistics (BLS)	
Quantities: millions of pounds (beef, pork)		US Department of Agriculture (USDA), Economic Research Service (ERS), Red Meat Yearbooks www.ers.usda.gov/Data
- Slaughter	Average light weight of cattle (hog) slaughtered under Federal Inspection x Commercial cattle (hog) slaughter	
- Wholesale	Commercial production (carcass weight)	
- Retail	Estimated Retail Disappearance = (Commercial production + Imports - Exports + Beginning stock - Ending stock) x Conversion factor from carcass to retail weight equivalent Conversion factor equal to 0.74 for cattle and equal to 0.77 for hog	
Food Marketing Cost Index		US Department of Agriculture (USDA), Economic Research Service (ERS), Agricultural Outlook www.ers.usda.gov/publications/AgOutlook Bureau of Labor Statistics (BLS) www.bls.gov
- Wholesale Index	Weighted average of earnings of production workers in in food manufacturing and nonsupervisory workers in wholesaling, rail freight rate index for food and producer price index for energy	
- Retail Index	Weighted average of earnings of nonsupervisory workers in food retailing, rail freight rate index for food and producer price index for energy Weights based on those used by USDA to construct the Food Marketing Cost Index	
Food Recalls	Beef, Pork Class I, Bacterial and National Recall Cases	US Department of Agriculture (USDA), Food Safety and Inspection Service (FSIS) Recall Case Archive http://www.fsis.usda.gov/fsis_recalls/ Archives from Dr. Schroeder (Kansas State University) and Dr. Salin (Texas A&M University)
Disease Outbreaks	Bovine Spongiform Encephalopathy (BSE) Outbreaks in the US and Canada	US Department of Agriculture (USDA), Foreign Agricultural Service (FAS), Bovine Spongiform Encephalopathy www.fas.usda.gov/dlp/bse/bse.html
Consumer Price Index	City average, not seasonally adjusted, 1982-84=100	Bureau of Labor Statistics (BLS) www.bls.gov
Population	Resident population estimates	US Census Bureau www.census.gov/popest

TABLE A.2. Marketing margins' regressions, polynomial distributed lag

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Price	0.108**	0.491**	-0.250**	0.433**
	(0.028)	(0.055)	(0.034)	(0.054)
Price x Per Capita Quantity	0.007**	-0.001	0.014**	0.007*
	(0.002)	(0.002)	(0.004)	(0.004)
Marketing Cost Index	-0.006*	-0.030**	0.007	-0.010
	(0.003)	(0.010)	(0.008)	(0.008)
Beef Recall I Bacterial	0.175	-0.377	0.289*	-0.186
	(0.193)	(0.387)	(0.164)	(0.323)
Beef Recall I Bacterial (-1)	0.263	-0.566	0.433*	-0.280
	(0.290)	(0.580)	(0.246)	(0.484)
Beef Recall I Bacterial (-2)	0.263	-0.566	0.433*	-0.280
	(0.290)	(0.580)	(0.246)	(0.484)
Beef Recall I Bacterial (-3)	0.175	-0.377	0.289*	-0.186
	(0.193)	(0.387)	(0.164)	(0.323)
Beef Recall I Other	-0.296	-0.344	0.336	-0.165
	(0.356)	(0.715)	(0.300)	(0.593)
Beef Recall I Other (-1)	-0.444	-0.516	0.504	-0.247
	(0.534)	(1.072)	(0.451)	(0.890)
Beef Recall I Other (-2)	-0.444	-0.516	0.504	-0.247
	(0.534)	(1.072)	(0.451)	(0.890)
Beef Recall I Other (-3)	-0.296	-0.344	0.336	-0.165
	(0.356)	(0.715)	(0.300)	(0.593)
Beef Recall National	0.139	0.023	0.375**	-0.212
	(0.216)	(0.434)	(0.179)	(0.365)
Beef Recall National (-1)	0.209	0.035	0.562**	-0.318
	(0.324)	(0.650)	(0.268)	(0.548)
Beef Recall National (-2)	0.209	0.035	0.562**	-0.318
	(0.324)	(0.650)	(0.268)	(0.548)
Beef Recall National (-3)	0.139	0.023	0.375**	-0.212
	(0.216)	(0.434)	(0.179)	(0.365)
Pork Recall I Bacterial	0.255	0.131	-0.139	-0.302
	(0.188)	(0.373)	(0.157)	(0.311)
Pork Recall I Bacterial (-1)	0.382	0.196	-0.209	-0.452
	(0.281)	(0.559)	(0.236)	(0.467)
Pork Recall I Bacterial (-2)	0.382	0.196	-0.209	-0.452
	(0.281)	(0.559)	(0.236)	(0.467)
Pork Recall I Bacterial (-3)	0.255	0.131	-0.139	-0.302
	(0.188)	(0.373)	(0.157)	(0.311)

TABLE A.2. continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Pork Recall I Other	-0.165	0.027	0.149	-0.514
	(0.263)	(0.519)	(0.219)	(0.419)
Pork Recall I Other (-1)	-0.248	0.040	0.223	-0.771
	(0.395)	(0.778)	(0.328)	(0.629)
Pork Recall I Other (-2)	-0.248	0.040	0.223	-0.771
	(0.395)	(0.778)	(0.328)	(0.629)
Pork Recall I Other (-3)	-0.165	0.027	0.149	-0.514
	(0.263)	(0.519)	(0.219)	(0.419)
Pork Recall National	-0.077	0.157	0.092	-0.620
	(0.451)	(0.871)	(0.373)	(0.705)
Pork Recall National (-1)	-0.116	0.236	0.138	-0.930
	(0.677)	(1.306)	(0.559)	(1.057)
Pork Recall National (-2)	-0.116	0.236	0.138	-0.930
	(0.677)	(1.306)	(0.559)	(1.057)
Pork Recall National (-3)	-0.077	0.157	0.092	-0.620
	(0.451)	(0.871)	(0.373)	(0.705)
BSE Outbreak US	-0.567	5.744**	-0.041	-1.330
	(0.779)	(1.562)	(0.636)	(1.217)
BSE Outbreak US (-1)	-0.850	8.617**	-0.061	-1.994
	(1.168)	(2.344)	(0.954)	(1.826)
BSE Outbreak US (-2)	-0.850	8.617**	-0.061	-1.994
	(1.168)	(2.344)	(0.954)	(1.826)
BSE Outbreak US (-3)	-0.567	5.745**	-0.041	-1.330
	(0.779)	(1.562)	(0.636)	(1.217)
BSE Outbreak Canada	-0.090	0.297	-0.649	0.284
	(0.475)	(0.938)	(0.403)	(0.752)
BSE Outbreak Canada (-1)	-0.135	0.446	-0.973	0.425
	(0.713)	(1.407)	(0.605)	(1.128)
BSE Outbreak Canada (-2)	-0.135	0.446	-0.973	0.425
	(0.713)	(1.407)	(0.605)	(1.128)
BSE Outbreak Canada (-3)	-0.090	0.297	-0.649	0.284
	(0.475)	(0.938)	(0.403)	(0.752)
Trend	0.533	2.906**	-5.266**	3.375**
	(0.381)	(0.816)	(1.099)	(0.668)
Trend squared	0.003	-0.034	0.158**	-0.079**
	(0.013)	(0.030)	(0.030)	(0.025)

TABLE A.2. continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
First Quarter	-1.035**	-2.160**	-0.392	-0.339
	(0.406)	(0.771)	(0.729)	(0.647)
Second Quarter	0.707	-1.841**	-0.577	-1.053
	(0.438)	(0.840)	(0.587)	(0.720)
Third Quarter	0.272	1.105	-0.160	-0.119
	(0.375)	(0.717)	(0.436)	(0.629)
AR(1)	0.849**	0.940**	0.894**	0.958**
	(0.062)	(0.062)	(0.061)	(0.062)
AR(2)	-0.198**	-0.232**	-0.076	-0.027
	(0.079)	(0.082)	(0.081)	(0.087)
AR(3)	0.134**	0.128**	0.183**	-0.087
	(0.062)	(0.059)	(0.063)	(0.064)
R-squared	0.748	0.851	0.721	0.868
Durbin-Watson Statistic	2.008	1.984	2.031	2.024
Diagonality of Covariance Matrix Test:				
Likelihood Ratio statistic				487.542
p-value				0.000
Portmanteau Autocorrelation Test:				
Adjusted *Q*-statistic (6 lags)				115.989
p-value				0.081
Total System Observations				1,104

Notes: SE are reported in parentheses. Asterisk (*) and double asterisk (**) denote coefficients significant at 10% and 5% respectively. The effect of food recalls and BSE outbreaks are modeled using a polynomial distributed lag (PDL) specification of second degree with three lags and constraining both the near and far end of the distribution to zero.

TABLE A.3. Marketing margins' regressions, interaction model with polynomial distributed lag

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Price	0.010	0.428**	-0.073*	0.418**
	(0.037)	(0.066)	(0.042)	(0.060)
Price x Per Capita Quantity	0.008**	-0.001	0.014**	0.007*
	(0.002)	(0.002)	(0.004)	(0.004)
Marketing Cost Index	0.004	-0.019	0.017**	-0.006
	(0.004)	(0.012)	(0.003)	(0.009)
Beef Recall I Bacterial	-3.019**	-6.156	1.779*	2.271
	(1.178)	(4.124)	(0.926)	(3.691)
Beef Recall I Bacterial (-1)	-4.529**	-9.234	2.669*	3.406
	(1.767)	(6.186)	(1.389)	(5.537)
Beef Recall I Bacterial (-2)	-4.529**	-9.234	2.669*	3.406
	(1.767)	(6.186)	(1.389)	(5.537)
Beef Recall I Bacterial (-3)	-3.019**	-6.156	1.779*	2.271
	(1.178)	(4.124)	(0.926)	(3.691)
Beef Recall I Other	-0.835	10.426	1.710	10.924
	(2.676)	(11.738)	(1.793)	(9.866)
Beef Recall I Other (-1)	-1.253	15.639	2.565	16.386
	(4.015)	(17.607)	(2.689)	(14.799)
Beef Recall I Other (-2)	-1.253	15.639	2.565	16.386
	(4.015)	(17.607)	(2.689)	(14.799)
Beef Recall I Other (-3)	-0.835	10.426	1.710	10.924
	(2.676)	(11.738)	(1.793)	(9.866)
Beef Recall National	-2.448	-3.554	-0.219	-2.480
	(2.086)	(5.279)	(1.657)	(8.145)
Beef Recall National (-1)	-3.673	-5.330	-0.328	-3.720
	(3.129)	(7.919)	(2.486)	(12.217)
Beef Recall National (-2)	-3.673	-5.330	-0.328	-3.720
	(3.129)	(7.919)	(2.486)	(12.217)
Beef Recall National (-3)	-2.448	-3.554	-0.219	-2.480
	(2.086)	(5.279)	(1.657)	(8.145)
Pork Recall I Bacterial	-1.243	-0.397	1.287	0.951
	(1.263)	(4.617)	(0.938)	(3.971)
Pork Recall I Bacterial (-1)	-1.864	-0.596	1.930	1.426
	(1.895)	(6.925)	(1.408)	(5.956)
Pork Recall I Bacterial (-2)	-1.864	-0.596	1.930	1.426
	(1.895)	(6.925)	(1.408)	(5.956)
Pork Recall I Bacterial (-3)	-1.243	-0.397	1.287	0.951
	(1.263)	(4.617)	(0.938)	(3.971)

TABLE A.3. continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Pork Recall I Other	-2.895*	2.246	1.432	7.668*
	(1.703)	(6.630)	(1.130)	(4.198)
Pork Recall I Other (-1)	-4.343*	3.370	2.149	11.502*
	(2.555)	(9.945)	(1.695)	(6.297)
Pork Recall I Other (-2)	-4.343*	3.370	2.149	11.502*
	(2.555)	(9.945)	(1.695)	(6.297)
Pork Recall I Other (-3)	-2.895*	2.246	1.432	7.668*
	(1.703)	(6.630)	(1.130)	(4.198)
Pork Recall National	-1.871	11.006	-1.253	-29.448
	(3.477)	(10.778)	(4.093)	(21.145)
Pork Recall National (-1)	-2.806	16.508	-1.881	-44.172
	(5.215)	(16.168)	(6.140)	(31.718)
Pork Recall National (-2)	-2.806	16.508	-1.881	-44.172
	(5.215)	(16.168)	(6.140)	(31.718)
Pork Recall National (-3)	-1.871	11.006	-1.254	-29.448
	(3.477)	(10.778)	(4.093)	(21.145)
BSE Outbreak US	-1.452	-40.252*	7.947	-49.753
	(7.460)	(22.707)	(8.981)	(43.462)
BSE Outbreak US (-1)	-2.178	-60.378*	11.920	-74.629
	(11.191)	(34.061)	(13.471)	(65.194)
BSE Outbreak US (-2)	-2.178	-60.378*	11.920	-74.629
	(11.191)	(34.061)	(13.471)	(65.194)
BSE Outbreak US (-3)	-1.452	-40.252*	7.947	-49.753
	(7.460)	(22.707)	(8.981)	(43.462)
BSE Outbreak Canada	-8.854	-8.946	-3.298	-11.283
	(5.054)	(19.525)	(3.159)	(18.434)
BSE Outbreak Canada (-1)	-13.281	-13.419	-4.947	-16.924
	(7.581)	(29.287)	(4.739)	(27.651)
BSE Outbreak Canada (-2)	-13.281	-13.419	-4.947	-16.924
	(7.581)	(29.287)	(4.739)	(27.651)
BSE Outbreak Canada (-3)	-8.854	-8.946	-3.298	-11.283
	(5.054)	(19.525)	(3.159)	(18.434)
Beef Recall I Bacterial x Price	0.027**	0.031	-0.020	-0.016
	(0.010)	(0.021)	(0.013)	(0.025)
Beef Recall I Bacterial (-1) x Price	0.041**	0.046	-0.030	-0.024
	(0.015)	(0.032)	(0.019)	(0.037)
Beef Recall I Bacterial (-2) x Price	0.041**	0.046	-0.030	-0.024
	(0.015)	(0.032)	(0.019)	(0.037)
Beef Recall I Bacterial (-3) x Price	0.027**	0.031	-0.020	-0.016
	(0.010)	(0.021)	(0.013)	(0.025)

TABLE A.3. continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Beef Recall I Other x Price	0.004	-0.051	-0.018	-0.076
	(0.022)	(0.058)	(0.025)	(0.067)
Beef Recall I Other (-1) x Price	0.006	-0.077	-0.027	-0.115
	(0.033)	(0.087)	(0.038)	(0.101)
Beef Recall I Other (-2) x Price	0.006	-0.077	-0.027	-0.115
	(0.033)	(0.087)	(0.038)	(0.101)
Beef Recall I Other (-3) x Price	0.004	-0.051	-0.018	-0.076
	(0.022)	(0.058)	(0.025)	(0.067)
Beef Recall National x Price	0.024	0.018	0.010	0.016
	(0.019)	(0.027)	(0.027)	(0.056)
Beef Recall National (-1) x Price	0.036	0.027	0.016	0.023
	(0.029)	(0.041)	(0.040)	(0.084)
Beef Recall National (-2) x Price	0.036	0.027	0.016	0.023
	(0.029)	(0.041)	(0.040)	(0.084)
Beef Recall National (-3) x Price	0.024	0.018	0.010	0.016
	(0.019)	(0.027)	(0.027)	(0.056)
Pork Recall I Bacterial x Price	0.013	0.003	-0.019	-0.008
	(0.011)	(0.024)	(0.013)	(0.026)
Pork Recall I Bacterial (-1) x Price	0.019	0.004	-0.029	-0.012
	(0.016)	(0.035)	(0.019)	(0.040)
Pork Recall I Bacterial (-2) x Price	0.019	0.004	-0.029	-0.012
	(0.016)	(0.035)	(0.019)	(0.040)
Pork Recall I Bacterial (-3) x Price	0.013	0.003	-0.019	-0.008
	(0.011)	(0.024)	(0.013)	(0.026)
Pork Recall I Other x Price	0.023	-0.010	-0.018	-0.054*
	(0.014)	(0.033)	(0.015)	(0.028)
Pork Recall I Other (-1) x Price	0.034	-0.015	-0.028	-0.080*
	(0.021)	(0.050)	(0.022)	(0.042)
Pork Recall I Other (-2) x Price	0.034	-0.015	-0.028	-0.080*
	(0.021)	(0.050)	(0.022)	(0.042)
Pork Recall I Other (-3) x Price	0.023	-0.010	-0.018	-0.054*
	(0.014)	(0.033)	(0.015)	(0.028)
Pork Recall National x Price	0.016	-0.051	0.021	0.195
	(0.031)	(0.053)	(0.064)	(0.143)
Pork Recall National (-1) x Price	0.024	-0.077	0.031	0.293
	(0.047)	(0.080)	(0.095)	(0.215)
Pork Recall National (-2) x Price	0.024	-0.077	0.031	0.293
	(0.047)	(0.080)	(0.095)	(0.215)
Pork Recall National (-3) x Price	0.016	-0.051	0.021	0.195
	(0.031)	(0.053)	(0.064)	(0.143)

TABLE A.3. continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
BSE Outbreak US x Price	0.014	0.224**	-0.123	0.341
	(0.066)	(0.110)	(0.147)	(0.305)
BSE Outbreak US (-1) x Price	0.021	0.336**	-0.184	0.512
	(0.099)	(0.165)	(0.220)	(0.457)
BSE Outbreak US (-2) x Price	0.021	0.336**	-0.184	0.512
	(0.099)	(0.165)	(0.220)	(0.457)
BSE Outbreak US (-3) x Price	0.014	0.224**	-0.123	0.341
	(0.066)	(0.110)	(0.147)	(0.305)
BSE Outbreak Canada x Price	0.078*	0.044	0.042	0.082
	(0.044)	(0.096)	(0.052)	(0.131)
BSE Outbreak Canada (-1) x Price	0.117*	0.067	0.063	0.122
	(0.067)	(0.145)	(0.077)	(0.196)
BSE Outbreak Canada (-2) x Price	0.117*	0.067	0.063	0.122
	(0.067)	(0.145)	(0.077)	(0.196)
BSE Outbreak Canada (-3) x Price	0.078*	0.044	0.042	0.082
	(0.044)	(0.096)	(0.052)	(0.131)
Trend	0.308	2.727**	-0.856**	3.060**
	(0.426)	(0.790)	(0.324)	(0.662)
Trend squared	-0.005	-0.043	0.003	-0.077**
	(0.014)	(0.030)	(0.010)	(0.024)
First Quarter	-0.848**	-1.900**	-0.686*	-0.178
	(0.397)	(0.781)	(0.390)	(0.641)
Second Quarter	0.773*	-1.690**	-0.640	-1.184*
	(0.418)	(0.828)	(0.437)	(0.718)
Third Quarter	0.444	1.115	-0.199	-0.068
	(0.355)	(0.712)	(0.407)	(0.627)
AR(1)	0.874**	0.954**	0.830**	0.936**
	(0.063)	(0.066)	(0.061)	(0.063)
AR(2)	-0.222**	-0.251**	-0.161*	-0.026
	(0.080)	(0.087)	(0.080)	(0.089)
AR(3)	0.177**	0.124**	0.046	-0.070
	(0.062)	(0.061)	(0.062)	(0.065)
R-squared	0.772	0.858	0.712	0.873
Durbin-Watson Statistic	1.985	1.980	1.983	1.991
Diagonality of Covariance Matrix Test:				
Likelihood Ratio statistic				568.596
p-value				0.000
Portmanteau Autocorrelation Test:				
Adjusted *Q*-statistic (6 lags)				127.048
p-value				0.131
Total System Observations				1,104

Notes: SE are reported in parentheses. Asterisk (*) and double asterisk (**) denote coefficients significant at 10% and 5% respectively. The effect of food recalls and BSE outbreaks are modeled using a polynomial distributed lag (PDL) specification of second degree with three lags and constraining both the near and far end of the distribution to zero.