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## **Measuring the Impact of a BSE Announcement on U.S. Retail Beef Sales: A Time-Series Analysis**

**Christian S. L. Crowley and Yoshiaki Shimazaki**

On December 23, 2003, Agriculture Secretary Ann M. Veneman announced that the United States Department of Agriculture had diagnosed the first U.S. case of bovine spongiform encephalopathy (BSE), commonly known as “mad cow disease.” This study uses supermarket sales data to analyze the effect of the BSE announcement on U.S. retail beef sales, finding a statistically significant disruption of sales. In addition, we develop a forecast of retail beef sales revenues in the hypothetical absence of BSE. The forecast implies that the BSE announcement may have reduced domestic retail beef revenues in excess of \$11 billion in the post-BSE period.

**Key Words:** ARIMA models, BSE, mad cow disease, U.S. retail beef sales

On December 23, 2003, according to the USDA Newsroom (2003), Agriculture Secretary Ann M. Veneman announced that the United States Department of Agriculture had diagnosed the first U.S. case of bovine spongiform encephalopathy (BSE), commonly known as “mad cow disease.” This disease of cattle had previously been found to be the precursor of Creutzfeldt-Jakob disease (CJD), an invariably fatal brain-wasting disease in humans. USDA’s Food Safety and Inspection Service (2004) reports that this single case of BSE resulted in nearly 38,000 pounds of beef being recalled as a safety measure to prevent the BSE agent from entering the U.S. food supply.

This analysis examines the effects of unanticipated announcements, such as the discovery of BSE in the U.S. domestic cattle herd, by studying retail beef purchases in the periods before and after the announcement. Piggott and Marsh (2004) provide a brief survey of the literature on demand effects of food safety announcements, highlighting several recent papers with a focus on the U.S. meat market. Lusk and Schroeder (2002) found that beef recalls have a marginal impact on futures prices,

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and Thomsen and McKenzie (2001) observed that recalls lead to small losses for meat processing shareholders, indicating a market anticipation of an adverse impact on demand.

McKenzie and Thomsen (2001) summarize the effects of health-related announcements on beef demand, concluding that while the effects of announcements concerning food-related long-term health risks such as increased cholesterol levels can be seen in low-frequency (quarterly or annual) data, studies using high-frequency (daily) data yielded mixed results. These authors use event study methodology to show that announcements about foodborne pathogens have stronger effects when the disease in question is a serious one (i.e., Class 1 recalls), and when the product at risk is more susceptible to becoming tainted, such as ground beef for *E. Coli*.

Dahlgran and Fairchild (2002) concluded that consumers tend to forget about adverse publicity concerning meat safety, and eventually return to established patterns of meat consumption. Results of our analysis reveal that U.S. retail beef sales suffered significant disruption following the BSE announcement. This disruption seems to have had a persistent level effect, shifting beef sales to a lower level in the post-BSE period, in contrast to the results reported by Dahlgran and Fairchild. The month-to-month variations in retail beef sales, however, did appear to return to their normal pattern about two months after the announcement. These persistently low sales have most likely resulted in a loss of retail beef revenue, which we estimate may be on the order of \$11.1 billion over the post-BSE period.

The remainder of the paper is organized into eight major sections. First, background is provided through an introduction to BSE and a summary of the international experience with the disease. Next, the sources are given for the data sets used in the study, followed by a description of the data via an overview of the U.S. retail beef market before and after the BSE announcement. An economic interpretation of the shock is then presented, highlighting the nature of the post-December 2003 structural shift. In the methodology section, we develop the ARIMA model used in investigating the nature of the shock associated with the discovery of BSE, and the next section describes an experiment with event study modeling techniques for this episode. The revenue effects of the BSE announcement are then investigated by considering what revenues might have been in the absence of a BSE announcement. The final section offers concluding remarks and a summary of our findings.

## **Background**

Bovine spongiform encephalopathy (BSE), commonly known as mad cow disease, is a progressive neurological disorder of cattle caused by an agent present in the tissues of infected animals. BSE affects a cow's central nervous system, leading to the development of spongy lesions on the brain. The Federal Interagency Working Group (2003) reports that BSE has been a concern internationally since the UK experienced a BSE epidemic, which peaked in 1993 with roughly 1,000 new bovine cases per week. The U.S. Centers for Disease Control and Prevention (CDC) reported in 2004 that the outbreak may have resulted from feeding cattle with meat-

and-bone meal derived from sheep infected with scrapie, a fatal degenerative disease affecting the central nervous system of sheep and goats.

BSE and scrapie are both characterized as a transmissible spongiform encephalopathy (TSE), according to online information provided by the USDA's Animal and Plant Health Inspection Service (2004). TSEs are the subject of increased attention and concern because of the link between BSE in cattle and variant Creutzfeldt-Jakob disease (vCJD, commonly referred to as simply CJD) in humans.<sup>1</sup> In 2004, an update on BSE and CJD by the U.S. Centers for Disease Control and Prevention cited considerable epidemiological and causal evidence pointing to BSE exposure as the source of CJD. CJD, like other TSEs, is a degenerative brain disease that is invariably fatal. The BSE agent has been found in the brain, spinal cord, retina, dorsal root ganglia, distal ileum, and bone marrow of infected cattle. In addition, Japan's Ministry of Agriculture, Forestry, and Fisheries reported in a November 2004 press release that the BSE agent was found in nerves in the muscle tissue of a 94-month old cow—documenting the first time the BSE agent has been observed in muscle tissue, a portion of the animal likely to enter the human food chain.

Prior to the 2004 U.S. Centers for Disease Control and Prevention announcement, the UK Health Minister released an announcement in March 1996 suggesting a possible link between BSE and CJD (Fisher, 1997). This news release triggered a BSE scare in the UK, disrupting meat demand and causing one of the most problematic years in recent history for the British beef industry. Fisher reports that the 1996 UK BSE scare saw consumption of vulnerable meats (beef, veal, mutton, and lamb) drop sharply: 1996 UK beef purchases were 15.9% lower than the 1995 level. Demand shifted in this period to meats that were perceived as safer by consumers, with most of the market share being gained by poultry.

Other European countries had similar experiences with falling beef demand when BSE was found on the continent in late 2000. A BSE crisis struck France at the end of October 2000. Spencer (2002) reports that in November 2000 there was a drop of 40% in French household beef purchases. The first recorded case of BSE in Germany was announced in November 2000. Over the following year, German households decreased their consumption of beef, with 2001 sales 25% below 2000 levels (Fisher, 2002). At the height of the crisis, German beef purchases were down 67% from the previous year's level. Beef was removed from the menus of many restaurants, and meat processors excluded beef ingredients from their products. The collapse in demand resulted in a dramatic and persistent drop in cattle prices, as consumers switched to poultry and, to a lesser extent, pork.

Japan has also seen an outbreak of BSE. The first Japanese case was reported on September 10, 2001, and resulted in annual per capita consumption dropping 17%, as reported by the Ministry of Agriculture, Forestry, and Fisheries (2003). The Ministry data also show that Japanese demand is sensitive to international announcements as well as domestic alerts. Specifically, in 1996, the year of the British BSE scare, Japanese per capita beef consumption dropped 8%, from 11.9 kg to 11 kg.

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<sup>1</sup> Note, however, that vCJD differs from CJD in being more prevalent in persons under age 30.

While this study highlights the experience of the UK, France, Germany, and Japan, these are not the only countries to have experienced an outbreak of BSE. For more detail on the progress of the disease internationally, interested readers are directed to Fox and Peterson (2004). For the four countries mentioned here, government responses consisting of mandatory testing and quality labeling schemes were seen as instrumental in helping beef demand to recover after several months. European testing standards are fairly strict, including mandatory testing of all cows over age 42 months, all cows over age 30 months intended for human consumption, all cows found dead over age 24 months, and all animals subject to emergency slaughtering. In addition, each European member state must test a random sample of at least 10,000 cows per year. Still, as reported by the *Japan Weekly Monitor* (2004), only Japan has mandated universal testing for cows destined for human consumption, so it is conceivable that BSE outbreaks could reoccur in any of several countries, resulting in a new series of domestic or international demand shocks.

Testing practices in the United States cover a relatively small portion of the total herd, focusing on testing within the group of 195,000 animals considered at high risk of BSE infection (Dworkin, 2004). Some consider this level of testing to be insufficient, given the magnitude of the impact of the first U.S. case of BSE on the beef market. The following sections of this study investigate whether U.S. practices to date have succeeded in restoring consumer confidence and returning retail beef sales to somewhere near their pre-BSE levels.

### **Data Sources**

Much of the data for the following sections of this study were collected from the central website of the USDA's Economic Research Service (ERS)—[www.ers.usda.gov](http://www.ers.usda.gov). According to information provided on the Livestock Marketing Information Center website, the ERS has been given the responsibility of publishing retail meat purchase prices and quantity measures for representative meat products, as mandated by The Livestock Mandatory Reporting Act of 1999 (P.L. 106-78, Title IX, Section 257, Publication of Information on Retail Purchase Prices for Representative Meat Products). This act requires the compilation and publication of retail purchase prices for "representative food products made from beef, pork, chicken, turkey, veal, or lamb."

The ERS database contains monthly average retail sales data for selected cuts of red meat and poultry, derived from electronic supermarket scanner data. The data are from supermarkets across the United States accounting for approximately 20% of U.S. supermarket sales, thus reflecting the diversity of the U.S. retail climate. This study considers the index of volume sold (2001 levels set equal to 100) for selected cuts and aggregate categories of beef, poultry, pork, and all other meats.

For purposes of this analysis, we chose to use retail scanner data (USDA/ERS, 2004c, d), rather than more commonly used "disappearance" data, as we believe the former more accurately reflect consumer trends. King, Tietyen, and Vickner (2000) explain that disappearance data proxies beef consumption as the residual of initial

beef stocks less net exports and inventories. Nevertheless, it is not always clear where the beef actually “disappears to.” Some meat may be purchased by restaurants, caterers, or other commercial or industrial outfits. These intermediate purchases presumably reach consumers eventually, though in addition to any value added provided, there may be some unrecorded leakage along the way. Because many meat products cannot be easily relegated to a producer’s inventories during periods of low market prices, it is likely some of the “disappeared” beef could be discarded by producers rather than purchased by consumers. We argue that the retail scanner data better captures the portion of beef production actually going to consumers.

Scanner data are collected at the point of sale by supermarkets using electronic scanners in the checkout lines. Supermarkets are defined as retail grocery stores with dairy, produce, fresh meat, packaged food, and non-food departments, and annual sales of \$2 million or more. ERS thus excludes butcher shops, warehouse clubs, convenience stores, and restaurants from this data set. Three variables are reported in the data set: (a) a feature-weighted average price, (b) an index of volume sold, and (c) the percentage of volume sold under feature, where “feature” indicates discounts offered to consumers through retailers’ weekly feature advertisements. Data are reported for selected cuts and aggregate categories of beef, pork, poultry, lamb, and veal.

The *Feature-Weighted Average Price* for a meat category is computed by dividing total dollar sales by the index for volume sold (where sales volume in 2001 is set to 100). This price therefore includes the effects of retailers’ weekly sales specials. As the price series is reported in nominal dollars, we convert the series to 2001 dollars using the U.S. Department of Labor’s Consumer Price Index (CPI). The ERS *Index for Volume Sold* is calculated by dividing the pounds of meat sold in a particular month by the 2001 annual average of pounds sold. This ratio is multiplied by 100 to obtain the volume index. The *Percent of Volume Sold Under Feature* is the pounds of meat sold under feature divided by the total pounds sold, multiplied by 100. (The data for U.S. retail beef sales both prior to and since the BSE announcement are defined and discussed in the next section.)

Scanner price data can produce some unexpected results depending on the marketing decisions of retail outlets. These unexpected results, described below in the section on the economic interpretation of the BSE shock, are what led us to consider an auxiliary price series, one without the effects of retailers’ weekly sales specials. The auxiliary series chosen is taken from the USDA/ERS (2004a) online price spread tables, which report data from October 2002 onward. These tables provide a measure of value for agricultural products reflecting changes in price only, as traditional price spreads can be affected by consumers switching between more- and less-processed products. Thus the beef price spread table gives a retail “value” for a pound of beef, meaning the meat itself, regardless of the value added by any processing that may be involved in the cuts chosen by consumers. We make use of this data set in an effort to isolate the effect of the December 2003 BSE announcement on demand for beef only, rather than the demand for the meat plus meat processing services. The data from this value series are used below to develop an economic interpretation of the BSE shock.

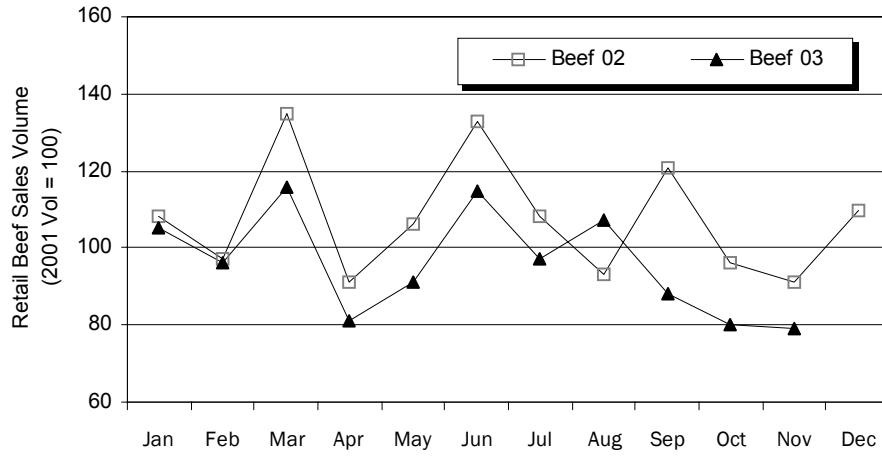
## Data Description

The USDA's *Annual Meat Report* (USDA/National Agricultural Statistics Service, 2003) defines red meat as beef, veal, pork, lamb, or mutton, and documents that U.S. red meat production totaled 46.8 billion pounds in 2003. This was only 1.2% below the record high production level of 2002. Beef production alone totaled 26.3 billion pounds in 2003, 3% below the previous record high, also set in 2002. Commercial cattle slaughter remained high as well in 2003: 35.5 million head, down only 1% from 2002. Commercial calf slaughter totaled 1 million head, down 4% from 2002. As can be seen from these figures, U.S. beef production was at a relatively high level immediately prior to the BSE announcement in December 2003. This situation presents the opportunity for a natural experiment on demand shocks: *We assume that any decline in beef purchases in the period from December 2003 on was not due to a reduction in supply, but represents a demand-side response.*

In spite of high production levels, retail purchases in 2003 were somewhat below those of 2002, as shown in figure 1. Retail sales in 2003 fell short of 2002 levels for all months except August, and average yearly beef purchases for 2003 (prior to the BSE announcement) were 11% below those of 2002. Figure 2 shows the year-to-year percentage change in monthly supermarket sales, illustrating the lower 2003 levels prior to the BSE discovery. Some of this shortfall was countered by increased exports. The U.S. Customs Service (2004) reports in its online "Foreign Agricultural Trade Commodity Aggregations" that there was an increase of 22% in U.S. beef and veal exports from 2002 to 2003.

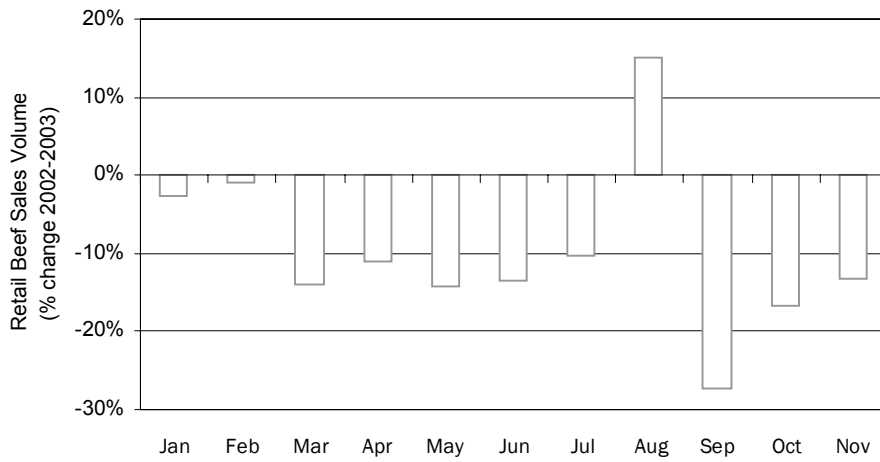
The year 2002 was one of record highs for both beef production and sales, so it should come as no surprise that sales in 2003 were consistently lower than those of the previous year. Nevertheless, these lower purchases in 2003 may be part of a longer term downward trend. Beef's consumption share (out of all meats) has been falling steadily since 1975, reflecting the socioeconomic, demographic, and lifestyle trends favoring white meats and fish over red meat. Most notably, consumers have increasingly substituted away from beef, especially in favor of chicken products in their diet. Figure 3 presents data taken from the USDA/ERS *Commodity Yearbooks* (2004), illustrating how U.S. meat producers have responded to these trends—i.e., between 1975 and 1999, beef's production share of all meats fell from 47% to 28%, while poultry's share rose from 28% to 52%.

Agriculture Secretary Ann M. Veneman's announcement on December 23, 2003 of the discovery of BSE in a cow in Washington State had an immediate negative response on retail sales, as shown in figure 4. December has historically been a high-sales month, but the BSE announcement just before the 2003 holidays apparently drove down beef sales for the entire month. The difference in sales volume between December and November 2003 (the last month before the announcement) may be even more dramatic than it appears: a USDA/Economic Research Service (2004d) data revision for the retail meat scanner data reports that sales for November 2003 would likely have been higher, had it not been for labor stoppages at some retail outlets.



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

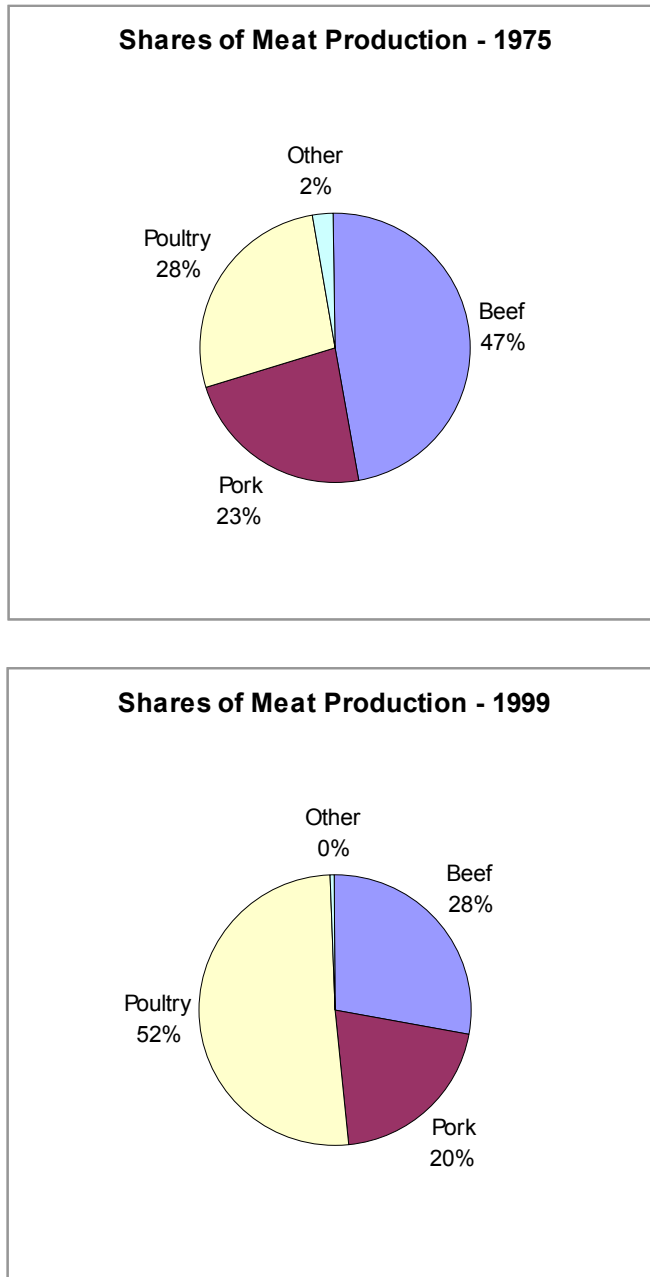
**Figure 1. Pre-BSE retail beef purchases: 2002 and 2003**



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 2. Pre-BSE year-to-year percentage changes in retail beef purchases: 2002–2003**





Source: Authors, with data derived from USDA/Economic Research Service (2004b).

**Figure 3. Changing shares in U.S. meat production, 1975 and 1999**

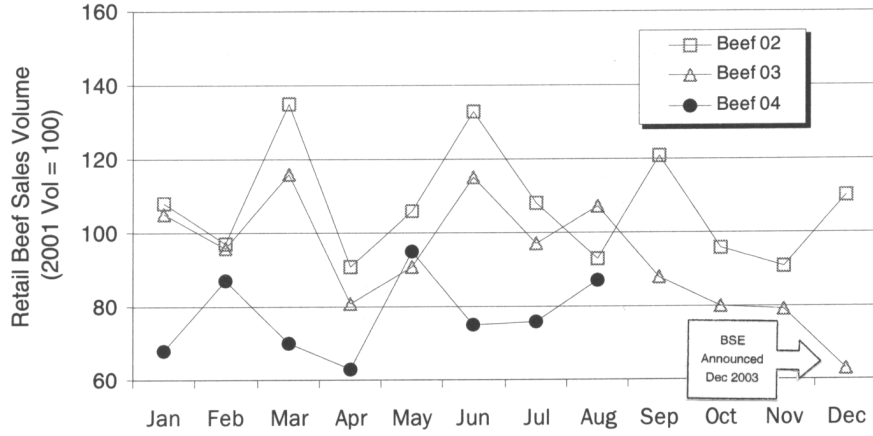
Figure 5 shows the year-to-year percentage changes in retail beef sales. Sales for December 2003, for example, were 43% below the December 2002 levels, giving the month of the BSE announcement a lower sales volume than any previous month. As observed from figure 5, retail sales remain low in the post-BSE period. Sales volume for January 2004 was down 35% from the January 2003 level, and 33% below the 35-month pre-BSE average. In fact, January 2004 shows the lowest level of sales in the data, excluding the announcement month of December 2003. By February 2004, sales appear to have recovered somewhat, down only 9% from February 2003, and 14% below the pre-BSE average. This pattern of an initial drop in sales volume followed by a recovery seems to mirror the experience of the European countries examined earlier.

March and April 2004, however, tell a different story. Beef sales dropped again, with March 2004 sales down 40% from March 2003, and 31% below the pre-BSE average. This made March the third lowest volume month since January 2001. April 2004 sales were lower still: 22% below April 2003 levels, and 38% below the pre-BSE average, falling to the same record low as December 2003, the month of the initial BSE announcement. In May 2004, there are again signs of a recovery in sales, with sales volume up 4% above May 2003, and only 6% below the pre-BSE average. Yet once again, the recovery was seen to be short-lived. June 2004 sales volume was 35% below that of June 2003, and 26% below the pre-BSE average, while July 2004 sales volume was 22% below that of July 2003, and 25% below the pre-BSE average. The most recent month available in the data set was August 2004, when sales were 19% below the August 2003 level. These figures reveal that as of eight months after the initial shock caused by the December BSE announcement, there had been no persistent recovery in beef demand.

### **Economic Interpretation of the Shock**

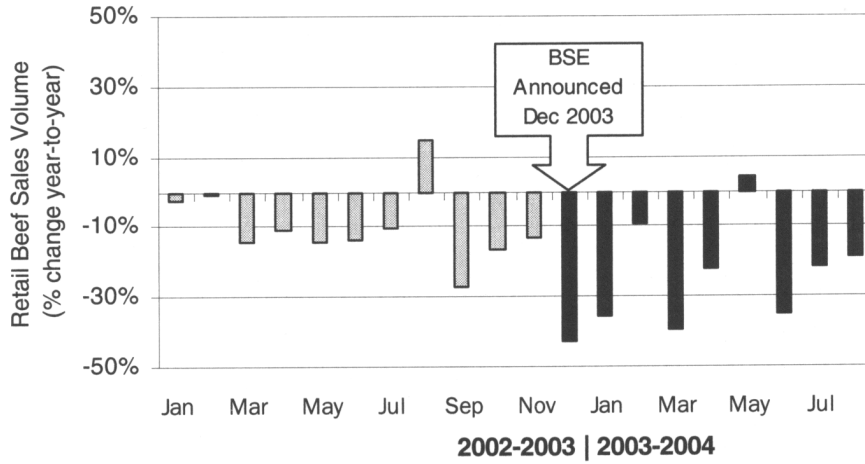
Based on this examination, December 2003 seems to be a point of structural shift. The nature of this shift is explored below. Figure 6 shows the volume series with estimated trend lines split into two portions: the first portion before the BSE announcement (periods 1 through 35), and the second portion after the BSE announcement (periods 36 through 44). Note that these trend lines were found using ordinary least squares (OLS), but neither the negative trend before the announcement nor the positive trend after the announcement is statistically significant at the 5% level. These trend lines are included here for demonstration purposes only, illustrating the immediate and persistent drop in retail beef sales caused by the BSE announcement in December 2003, which may be indicative of a beef demand shock.

It is widely accepted that agricultural supply is relatively fixed in the short run, due to the time required for raising livestock, and the perishable nature of the products, which limits storage possibilities. Given the relatively short time period under consideration in this study, and given the apparent absence of any catastrophic supply shocks such as bad weather or livestock epidemics, the drop in sales should be attributed to a shift in the demand curve.



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 4. Pre- and post-BSE retail beef purchases: 2002–2004**



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 5. Year-to-year percentage changes in monthly retail beef purchases**

Microeconomic theory states that a decrease in demand (a leftward shift of the demand curve) will lead to a decrease in equilibrium market price, *ceteris paribus*. Thus, we should be able to see this price drop in the data. Figure 7 displays a time-series graph over the full sample period for the feature-weighted average price reported in the ERS scanner data. Recall that the data have been deflated to 2001 dollars using the CPI.

Figure 7 shows a price spike for December 2003, up 27.8% from both December 2002 and December 2001, and 28% higher than the pre-BSE average price for beef. This is the opposite of what we would expect to see—i.e., an increase in price suggesting either an increase in demand or a decrease in supply. But in this case, supply is known to have remained at high levels, and the fall in purchases belies an increase in demand. The explanation for this apparent contradiction lies in the nature of the price reported by the ERS. As clarified in the Livestock Marketing Information System online website and in the data sources section of this paper, the price in the ERS scanner data is a weighted average of prices at checkout, taken across all the retailers in the sample. Consequently, this price includes the discounting effects of featuring, or weekly supermarket sales promotions. When comparing two months with similar sales volume, if one month has fewer promotions, the feature-weighted average price for that month will be higher.

Figure 8 shows how the *Percent of Volume Sold Under Feature* has varied over time. December 2003 shows the smallest percentage of volume sold under feature for the entire sample, 3.5 standard deviations below the pre-BSE sample average. Hence, it is likely that December 2003 was a month with relatively few beef promotions, which would account for both lower volume sold and a higher feature-weighted average price.

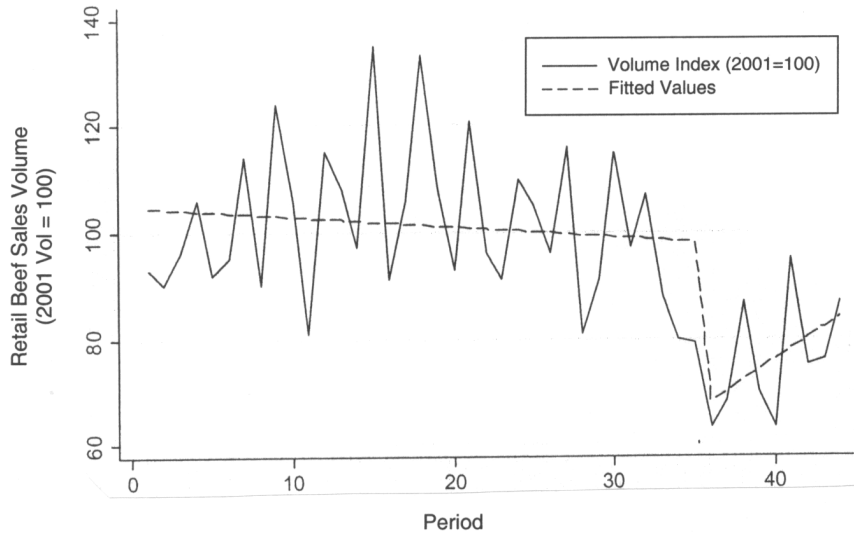
As reported by Crowley and Shimazaki (2005), other countries experiencing a BSE outbreak saw a sharp decline in beef-related advertising immediately after the outbreak. This appears to have been the case for the United States as well. To test the hypothesis that there has been less featuring for beef, we conducted a two-sample *t*-test<sup>2</sup> on the pre-BSE and post-BSE averages. The pre-BSE average percentage sold under feature was 41.1%, and the post-BSE average was 34.9%; the null hypothesis that these two means are from the same population is rejected at the 0.001 probability level.

<sup>2</sup> The two-sample *t*-test statistic is given by

$$T = \frac{(\bar{Y}_1 - \bar{Y}_2)}{\sqrt{\frac{\text{var}_1}{N_1} + \frac{\text{var}_2}{N_2}}}$$

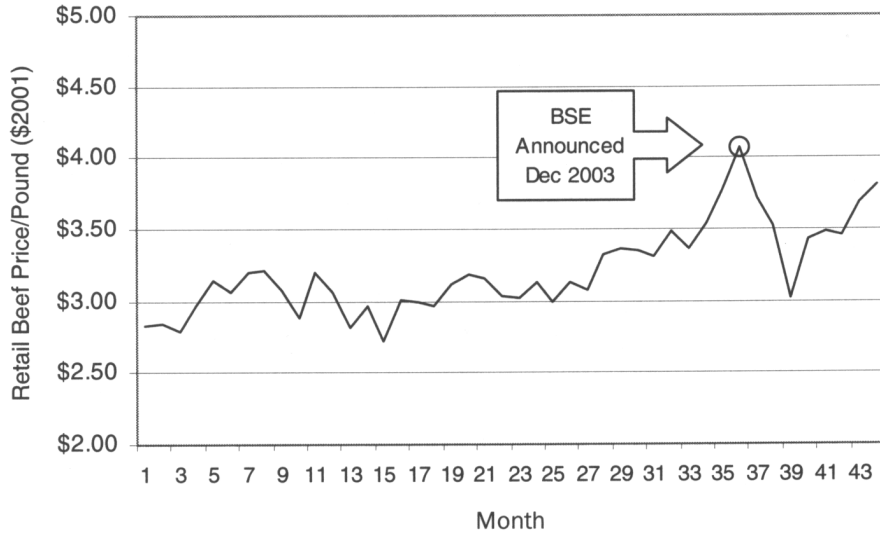
The null hypothesis of equal means is rejected at probability  $\alpha$  for  $T < -t_{(\alpha/2, v)}$  or  $T > t_{(\alpha/2, v)}$ , where degrees of freedom are given by

$$v = \left( \frac{\text{var}_1}{N_1} + \frac{\text{var}_2}{N_2} \right)^2 \cdot \left( \frac{\text{var}_1/N_1}{N_1 + 1} + \frac{\text{var}_2/N_2}{N_2 + 1} \right)$$



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 6. Trend in retail beef sales, pre- and post-BSE**



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 7. Beef feature-weighted average retail price (\$2001)**

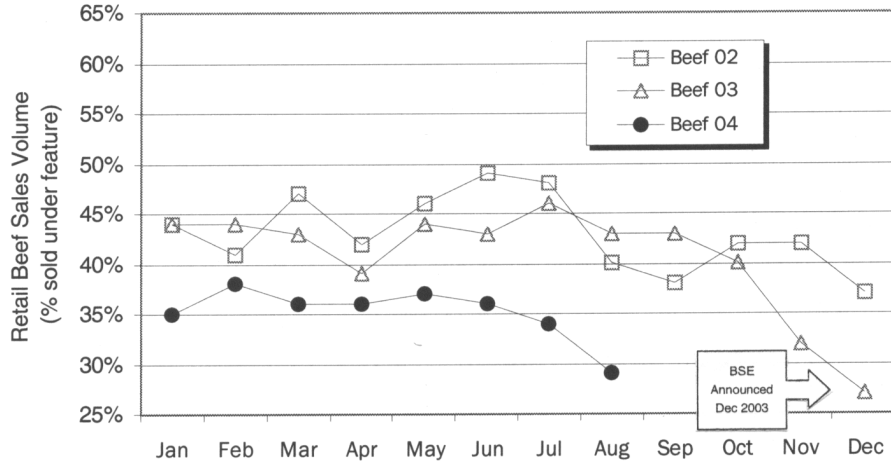
As described above in the section on data sources, ERS's price spread tables (USDA/ERS, 2004a) report the "value" of a pound of beef at retail outlets, rather than a weighted average, which includes the effects of featuring. Figure 9 presents a time-series graph for this retail value from October 2002 to August 2004. For the period shown, the retail value displays a steady increase, from \$3.34 per pound in October 2002, to a high of \$4.50 by November 2003. Once again, the data have been deflated to 2001 dollars using the CPI. The figure shows what we would expect with a drop in demand. Specifically, in December 2003, the month of the BSE announcement, the retail value reverses its climb, logging the first sizeable drop since May 2003. Then in January 2004, retail value falls again, showing the largest drop in the sample; this is the only instance of two consecutive drops in the available data. Thereafter, the value is steady at \$4.19 per pound, beginning to climb again only in April 2004, as the effects of the BSE shock finally wear off. This drop, coincident with the discovery of BSE in the United States, provides additional evidence that the BSE announcement served as a negative demand shock in U.S. retail beef sales.

### Methodology

As previously discussed in the data description section, figure 3 shows beef's loss of market share over the past few decades in the United States. The Alberta (Canada) provincial government reports in its November 1998 *Market Clippings* that U.S. per capita beef consumption has been falling steadily, from a peak in 1976 of about 127 pounds per person to about 95 pounds by 1997. Given this fact, we first considered whether any short-term negative trend could be identified in our sample, which contains retail sales data from January 2001 through August 2004. OLS regression of beef sales on *Time* and a constant, for the pre-BSE period (January 2001 through November 2003) suggests no trend: the estimated coefficient for *Time* was  $-0.191$ , with a standard error of  $0.241$  and a *t*-statistic of  $-0.79$ .

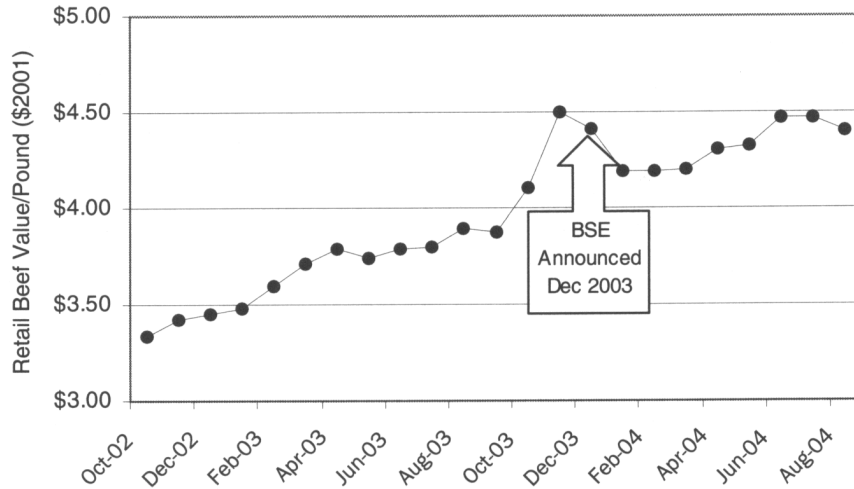
The presence of a long-term negative trend combined with no apparent trend over the short run suggests that, as with many business and economic time series, beef sales display a stochastic trend, or that the series is a random walk with drift. Diebold (1998) asserts these series are best modeled using ARIMA specifications, i.e., by differencing the series and fitting a stationary model to the differences. To model retail beef sales over the pre-BSE period (January 2001 through November 2003), we applied the time-series estimation procedure outlined by Maddala (1992). We examined the correlogram of the first differences of the retail sales series, finding damped oscillations, which indicates that the first-difference series is a stationary process. The partial autocorrelation function drops over the first two displacements, suggesting there may be an autoregressive relationship with the first and second lagged values of retail beef sales. This led us to choose the ARIMA(1, 1, 2) model, expressed as follows:

$$(1) \quad y_t' = \beta_0 y_{t-1} + \alpha_1 \Delta y_t + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2},$$



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 8. Percentage of beef sold under supermarket feature: 2002–2004**



Source: Authors, with data derived from USDA/Economic Research Service (2004a).

**Figure 9. Retail beef “value” per pound (\$2001)**

**Table 1. Estimation Results for ARIMA(1, 1, 2) Model  
(dependent variable = First Difference of Retail Sales Volume)**

Description	Coefficient	Estimate	Standard Error	<i>t</i> -Statistic	Prob $P >  t $
Autoregressive Term (AR)	$\beta_0$	0.697	0.215	3.24	0.010
Moving Average Terms (MA)	$\beta_1$	! 1.890	0.321	! 5.89	0.000
	$\beta_2$	1.000	0.327	3.06	0.002
No. of Observations	=	34			
Wald $\chi^2_{[3]}$	=	687.16			
Log Likelihood	=	! 137.71			
RMSE	=	13.20			
$\ln(AIC)$	=	5.34			
$\ln(SIC)$	=	5.47			

Notes: RMSE is root mean squared error, AIC is Akaike information criterion, and SIC is Schwartz information criterion.

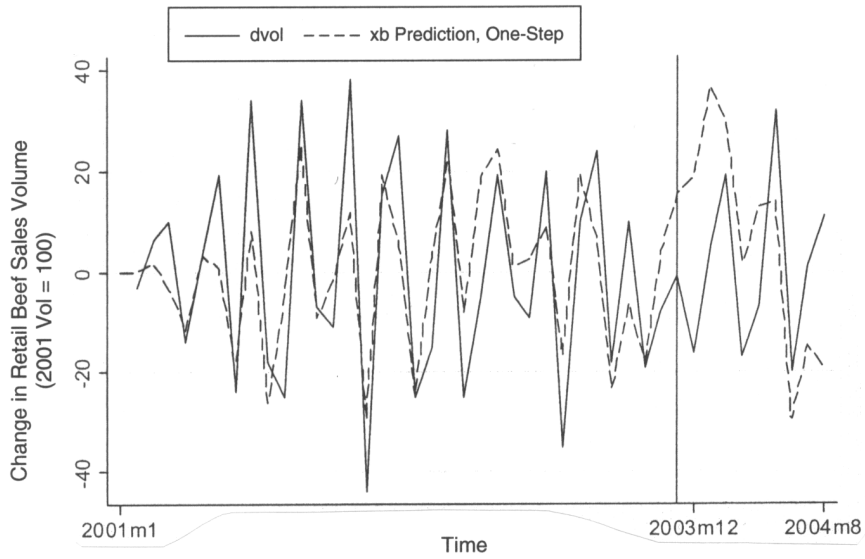
where  $y_t$  is the first difference of beef sales volume in period  $t$ . The model statistics are reported in table 1, and show that the estimated coefficients of the model are significant at less than the 1% level.

The estimated series is graphed against the historical (differenced) beef sales series in figure 10. The vertical line to the left of 2003m12 marks the end of the pre-BSE period, taken to be November 2003. Observations to the right of this line, in the post-BSE period from December 2003 onward, are the one-step-ahead forecasts for the estimated series.

Over the pre-BSE period, our model has a root mean squared error of 13.2 index points (table 1); recall that the ERS retail sales volume is reported in terms of an index based on 2001 average sales. For December 2003 and January 2004, the model overpredicts the change in sales by 34.5 index points and 31.7 index points, respectively, the two largest forecast errors in the sample. The root mean squared error in the post-BSE period error (from February 2004 on) is 18.6 index points. The outlier nature of December 2003 and January 2004 is shown graphically in figure 11, which presents a close-up view of the predicted changes in post-BSE retail sales volume, along with the 2-standard error band. This figure shows that the estimates for December 2003 and January 2004 both lie outside the 2-standard error band, but from February 2004 onward, the estimates lie within the band.

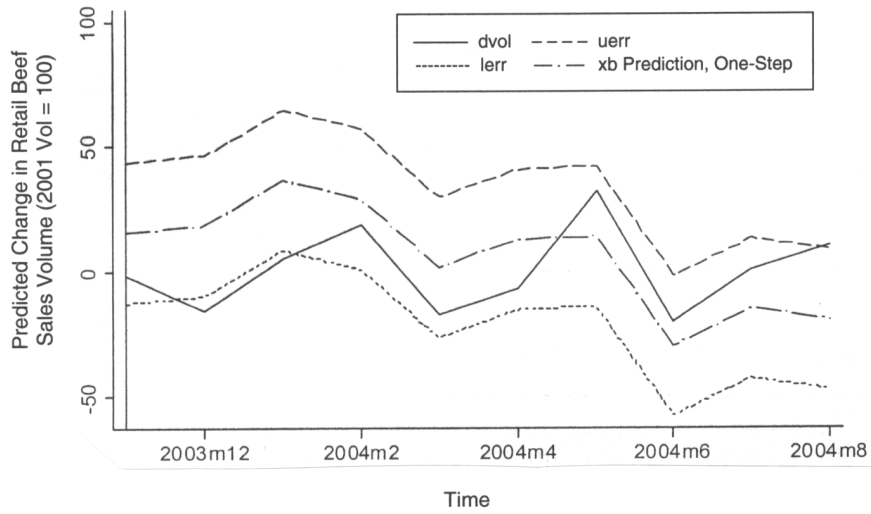
Based on the above discussion and findings, we conclude that the BSE announcement in December 2003 had an immediate short-term impact on the change in sales, resulting in reduced sales levels in the post-BSE period. In other words, there appears to have been a downward-level shift in retail sales volume, but after the initial shock, sales fluctuations seem to have returned to their pre-BSE behavior. Thus, the model that was conditioned on the pre-shock sales volume continues to represent the data well after the shock.





Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 10. Simulated versus predicted retail beef purchases (one-step-ahead)**



Source: Authors

**Figure 11. Simulated versus predicted retail beef purchases, post-BSE (one-step-ahead)**

### **An Event Study Exploration**

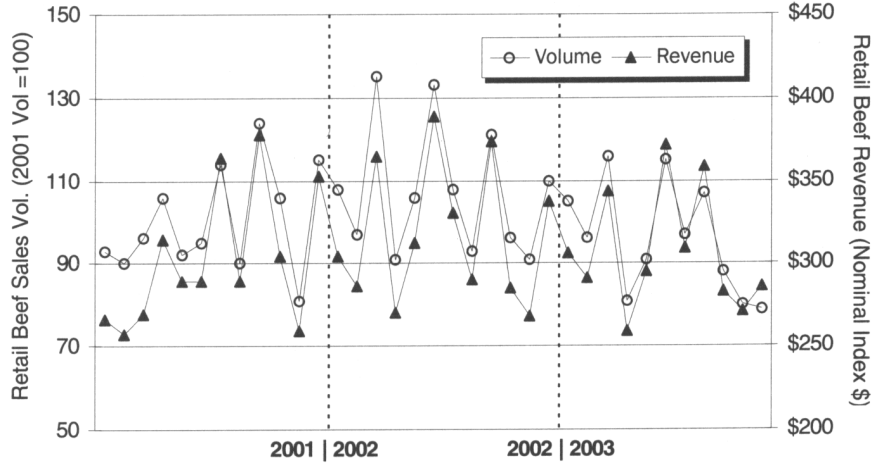
The literature on demand responses to food safety recalls makes frequent use of event studies to measure the impact of these announcements (e.g., McKenzie and Thomsen, 2001). In addition to the ARIMA methodology described above, we also carried out an exploratory event study using the entire sequence of retail beef sales. This was done with the hope of being able to measure the average effect of the BSE announcement within the time-series framework. In performing the event study, we include in the ARIMA specification a dummy variable that takes on the value of one ( $Event = 1$ ) only for the period(s) of the BSE announcement. Because the announcement came nearly at the end of December 2003, we experimented with setting the event dummy equal to one for both December 2003 and January 2004. However, better results were obtained using only December 2003 as the event month. The coefficient on the event dummy can be interpreted as the event period's change in retail beef sales volume above and beyond the expected change.

Using the ARIMA(1, 1, 2) specification developed in (1) above, the regression results show a large negative coefficient for the event dummy,  $-25.1$ , with a standard error of  $13.27$  and a  $t$ -statistic of  $-1.89$ , indicating the event dummy is significant at the 10% level. Although the event dummy was found to be significant, the remainder of the estimated variables were less significant than in the original ARIMA model, with the moving average variables faring considerably worse than the autoregressive component. We chose to adapt the original ARIMA(1, 1, 2) specification rather than specify a different ARIMA model for the event study, in order to retain some degree of comparability between the two models. Other ARIMA specifications we considered were unable to show an improvement over the ARIMA(1, 1, 2); there seems to be a tradeoff between significance of the ARIMA variables and significance of the event dummy.

Using the ARIMA(1, 1, 2), the negative coefficient on the event dummy indicates a negative shock in the differenced series of beef sales. The conclusion to be drawn from this brief event study is the same as from the original ARIMA model: the BSE announcement seems to be responsible for a downward-level shift in retail beef sales volume.

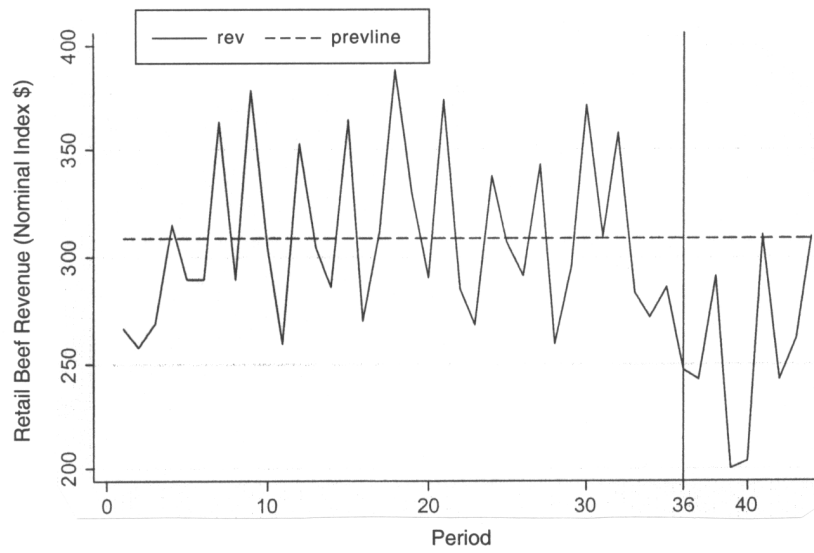
### **Estimated Revenue Loss**

Having established that retail beef sales post-December 2003 have been lower than would have been expected by a forecaster making an estimate during the pre-BSE period, we next consider what retail beef revenues may have been under the status quo, i.e., in the absence of any BSE announcement. One approach would be to derive separate forecasts of sales volume and of price, and then multiply these two variables together to obtain a forecast for retail sales revenue. However, as shown in figure 12, the revenue series has historically tracked sales volume quite closely, indicating that any forecast of the revenue series would likely be no worse than a forecast of the sales volume series. Thus, our approach was to consider the retail sales revenue series directly, and derive a simple-minded forecast over the post-BSE period.



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 12. Comparison of retail beef revenues to volume, pre-BSE**



Source: Authors, with data derived from USDA/Economic Research Service (2004c).

**Figure 13. Retail beef revenue: Projection of status quo and predicted loss**

In this simple-minded approach, the retail sales revenue series is assumed to be a random walk with drift, similar to the volume series, which it so closely tracks. To forecast sales revenue over the post-BSE period, we simply continue the trend beyond November 2003, the last month in the pre-BSE period. In fact, OLS identifies no significant trend in the pre-BSE data, so our estimate of future revenues is equal to the pre-BSE average revenue. Note that because the volume data are expressed in terms of an index, rather than in pounds, we can only make comparative statements about different revenue levels. Thus figure 12 shows the derived revenue series in terms of “nominal index dollars.”

Therefore, the pre-BSE average revenue (index) of 309 is compared to the actual post-BSE sales revenue figures for each month, from December 2003 through August 2004. The difference between these two revenue streams is our rough measure of the impact of the BSE announcement on U.S. retail revenues. Moreover, because the revenue series is calculated using the feature-weighted average price, revenue figures may be somewhat overstated for December 2003 and January 2004, months when beef features were largely absent from retailers’ circulars. Our estimate thus is a conservative guess at sales revenue loss due to the demand shift. Figure 13 illustrates the estimated revenue loss as an area, showing actual post-announcement retail sales revenues and the simple forecast assuming no BSE announcement.

The total forecasted revenue (index) for the period from December 2003 through August 2004 is 2,781. The total actual revenue (index) for this period was 2,062, which is 25.9% lower than predicted by our simple method. Again, working with revenue figures developed using a volume index rather than pounds means that comparative statements can only be made about different revenue levels; an actual dollar amount cannot be derived. To gain a general idea of the size of this difference, consider that 2001 U.S. consumer expenditures on beef totaled \$57 billion. If no BSE announcement had occurred, and the first eight months of 2004 had seen similar sales revenues to 2001, the 25.9% reduction in sales revenues estimated here would equate to \$11.1 billion, in 2001 dollars.<sup>3</sup>

## Conclusion

Concern over the safety of the U.S. food supply has been increasingly discussed since the first confirmed case of BSE in the United States in late December 2003, coupled with the finding that BSE in beef is linked with the brain-wasting Creutzfeldt-Jakob disease (CJD) in humans. This paper investigates the responsiveness of U.S. retail beef purchases to announcements such as these, and develops forecasts of retail beef sales and sales revenue to assess the impact of the 2003 BSE announcement.

In its initial response, the U.S. demand experience followed that of other countries—i.e., there was a notable drop in supermarket sales following the BSE

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<sup>3</sup> These losses represent domestic revenue only. It is likely that U.S. beef exports were also adversely affected by news of BSE in the U.S. herd.

announcement. However, in contrast to the European experience, continuing low purchases suggest that more than eight months after the initial BSE discovery, the United States has yet to achieve a complete recovery, and in fact U.S. sales have remained significantly below pre-BSE levels. The difference between these two experiences may lie in the timing and type of government response designed to restore consumer confidence, namely the testing criteria for at-risk cows.

Fitting an ARIMA model to the pre-BSE U.S. supermarket sales data results in a model that can predict changes in sales volume well over the pre-BSE period, as well as the post-BSE period from February 2004 through August 2004. The model performs poorly at predicting changes for the months most affected by the BSE announcement, December 2003 and January 2004. This indicates that although beef sales were disrupted by the announcement during these two months, the underlying process was relatively unaffected. Judging from the sales volume series, the ultimate effect was to shift retail beef sales to a lower post-BSE level.

In an attempt to gauge the magnitude of the monetary impact of this level shift, we projected pre-BSE average retail sales revenue over the post-BSE period. This is our rough estimate of what post-BSE revenues would have been in the absence of the BSE announcement. Comparing these estimates to the actual figures from December 2003 through August 2004 shows a drop of 25.9% in retail sales revenue. If the first eight months of 2004 (in the hypothetical absence of BSE) had seen sales similar to those of 2001, this would mean a loss of \$11.1 billion.

Even if U.S. retail sales manage to recover fully in the next several months, BSE will remain a cause for concern. Given the disruption created by a single case of BSE in the U.S. herd, further outbreaks of the disease could be expected to compound the problems facing beef suppliers. The high costs that would likely accompany the widespread disruption of the U.S. beef industry by additional BSE discoveries would be a serious blow to producers, consumers, and the U.S. economy as a whole. It seems prudent for the U.S. government to act now and take what precautions it can. Mandating an expanded testing regime and disseminating information on best practices for maintaining a safe U.S. food supply are the minimum first steps. As new data become available in the coming months, researchers will be better able to judge the status of a recovery in U.S. beef demand, and to quantify the effects of U.S. government actions on food safety and consumer confidence.

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