

Modeling Fresh Beef Purchases

Accounting for Trend and Seasonality Reveals That Impacts Were Short-Lived

Although weekly quantities purchased are variable, 75 percent of the variation in fresh beef purchases over the entire 7-year period can be explained by accounting for the trend and seasonality. We account for the long-term trend in purchases estimating the model

$$y_t = C + \alpha_1 t + \alpha_2 t^2 + \varepsilon_t \quad t=1, 2, \dots, 364$$

where y_t represents pounds of beef purchased in week t , C is a constant, t is a time index, and the error is assumed to have a mean of zero and a constant variance. The time-squared term allows for some bending in the trend. The model, and all others in this report, was estimated with ordinary least squares. Results are in the left-most column of numbers in table 1. By itself, this trend explains 43 percent of the variation (R^2) in quantity purchased.

Seasonality is accounted for by regressing weekly quantities purchased on 52 seasonal 0/1 (dummy) variables, as well as on the time trend. We define 52 seasonal dummy variables as follows:

$D_1 = 1$ for the first week of each year, 0 otherwise.

$D_2 = 1$ for the second week of each year, 0 otherwise...

$D_{52} = 1$ for the fifty-second week of each year, 0 otherwise.

The effects of trend and seasonality are captured by

$$y_t = \alpha_1 t + \alpha_2 t^2 + \sum_{i=1}^{52} \gamma_i D_{it} + \varepsilon_t \quad t=1, 2, \dots, 364$$

The middle numerical column of table 1 shows results of this estimation. Again, the time trend is significant, as are all 52 seasonal dummy variables. The Durbin-Watson statistic is very close to 2, indicating the absence of first-order serial correlation in error terms.

The observed patterns in weekly quantities purchased do not completely explain the variation in quantities purchased, but the explanatory power of the estimated model is large enough that the model could be used to provide evidence for the existence of a wide class of possible impacts of the BSE announcements. Impacts that are large and persistent will be most easily identified, while smaller, transitory impacts will be more difficult to detect. Finding that post-announcement quantities purchased are small, relative to quantities predicted by the trend and seasonal model, suggests that some consumers became fearful about consuming beef after hearing the BSE announcements. Of course, as the model does not fully explain the varia-

Table 1
Regression results from trend; trend and seasonal model; and trend, seasonal, and BSE announcement model

Independent variables	Dependent variable: Quantity purchased fresh beef		
	Time trend model	Time trend and seasonal model	Time trend, seasonal, and BSE announcement model
	<i>Estimated coefficient (p value)</i>		
Constant	1.14E+08 (0.0000)		
Time trend	-120543.6 (0.0000)	-117093.8 (0.0000)	-118227.2 (0.0000)
Time squared	65.29080 (0.2989)	71.71246 (0.1094)	79.84719 (0.0740)
52 seasonal dummy variables		All highly significant	All highly significant*
CAN1			8325341 (0.3582)
CAN2			-4954413 (0.5843)
CAN3			6912787 (0.4454)
CAN4			-2482467 (0.7840)
CAN5			-3609573 (0.6902)
WASH1			-23270250 (0.0108)
WASH2			-16680810 (0.0669)
WASH3			-10033931 (0.2696)
WASH4			-5419881 (0.5507)
WASH5			6280924 (0.4893)
Summary statistics			
R ²	0.427850	0.751246	0.762244
Adjusted R ²	0.424680	0.708717	0.712315
Durbin-Watson	1.312908	1.993071	2.028711

* See appendix for details.

Source: Economic Research Service/USDA.

tion in purchases, other unrelated factors could have caused deviations from trend and seasonal patterns.

Our third model is intended to identify impacts of the BSE announcements. We define five new dummy variables to indicate the weeks immediately following the Canadian announcement:

CAN1 = 1 for the week beginning May 21, 2003, 0 otherwise.

CAN2 = 1 for the week beginning May 28, 2003, 0 otherwise...

CAN5 = 1 for the week beginning June 18, 2003, 0 otherwise.

Similarly, we define five dummy variables to indicate weeks immediately following the Washington State announcement.

WASH1 = 1 for the week beginning December 24, 2003, 0 otherwise...

WASH5 = 1 for the week beginning January 21, 2004, 0 otherwise.

The model accounting for trend, seasonality, and the BSE announcements is

$$y_t = \alpha_1 t + \alpha_2 t^2 + \sum_{i=1}^{52} \gamma_i D_{it} + \sum_{j=1}^5 \delta_j CAN_{jt} + \sum_{k=1}^5 \delta_k WASH_{kt} + \varepsilon_t \quad t=1, 2, \dots, 364$$

Results are in the right-most column of table 1. Coefficients estimated for the Canadian announcement vary in sign: positive, negative, positive, negative, and negative. This pattern suggests nothing more than white noise. At conventional significance levels (0.05 or 0.10 levels), none of the five variables representing the weeks following the Canadian announcement are significantly different from zero. That is, there is no evidence to suggest the announcement led purchases away from the established trend and seasonal patterns.

The first four variables representing the Washington State announcement are negative. This pattern suggests a temporary decline in purchases. However, only the first two are significantly different from zero at conventional levels of significance (p values are below 10 percent). Thus, there is some evidence suggesting the announcements did lead to reduced purchase levels in the weeks following the announcement. The estimated decline of 23.3 million pounds in the week immediately following the announcement represents 32.6 percent of purchases predicted without the announcement. The share may look large as purchases predicted without the announcement were at a seasonal trough. The estimated decline in the second week, 16.7 million pounds, represents an 18.7-percent decline.

The estimated reductions in purchases are not precise. The 95-percent confidence interval for the reduction during the first week ranges from 5.5 million pounds to 41 million pounds. The 95-percent confidence interval for the second week ranges from an increase of 1.1 million pounds to a reduction of 34.5 million pounds.

Qualitatively, the most one can conclude is that the data suggest a short-lived reduction and some consumers temporarily decided that beef was less safe than it had been. Results from the first week are most compelling as the 95-percent confidence interval is entirely contained in negative numbers. The second week 95-percent confidence interval is less compelling as it extends into positive numbers. The third and fourth weeks show negative coefficients, but of no statistical significance. Still, the results cannot prove an announcement impact as other unrelated factors could account for the deviation from the established trend and seasonal pattern of purchases.

Accounting for Retail Prices Refines Estimates of Duration

For all consumer purchases, retail prices (relative to one another) create incentives that influence purchase decisions. Fresh beef at the meat counter is no exception. Accounting for the influence of prices as well as trend and seasonality could lead to more precise estimates of BSE announcement impacts. If the price of beef were the major determinant of quantity purchased, retailers could have muted consumers' resistance to purchasing beef by lowering price. But, we know from the trend and seasonal dummy model that habit and tradition already explain a large majority of the variation in purchases. So, the influence of price here is necessarily limited.

We estimated the weekly retail price of beef by dividing the weighted weekly total expenditures on beef by the weighted quantity purchased. As such, the price is a unit value for all types of beef. The estimated price does not hold quality constant as it allows for any mix of beef products.

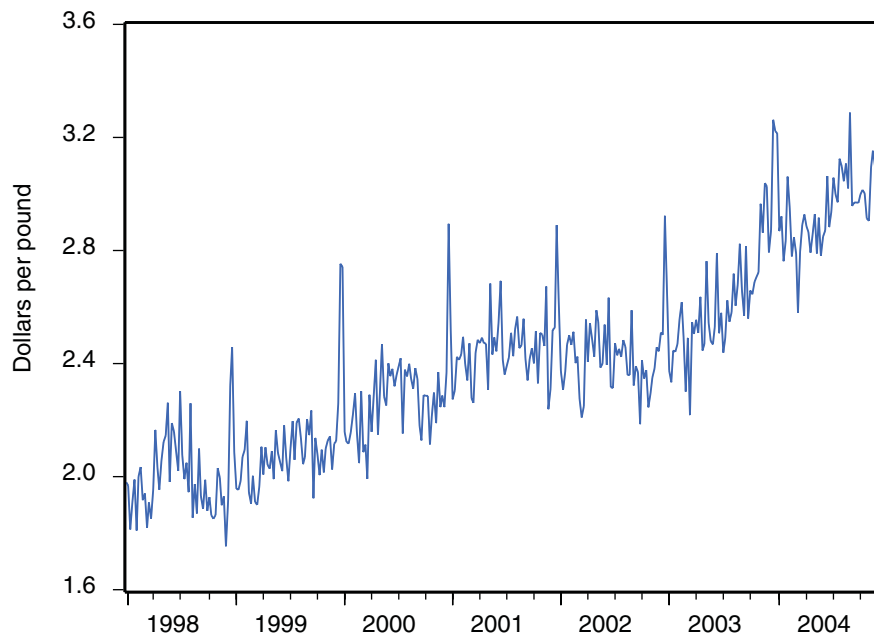
Figure 7 shows an upward trend in the retail price of beef. Over the course of 7 years, retail price has been increasing at an annual rate of 6.4 percent per year.

Before adding a price variable to a regression model, we account for the impact of inflation. Although Federal agencies have not yet developed a

Figure 7

Weekly U.S. retail price of fresh beef, 1998-2004

Prices increased an average of 6.4 percent annually between 1998 and 2004



Source: Economic Research Service/USDA, using data from the ACNielsen Homescan Panel, 1998-2004.

weekly consumer price index, one can find staple food items that are not subject to much seasonal variation in consumption. These prices could serve the same function as that of the consumer price index in making values comparable across time, albeit in a very imprecise manner. As such, we use the weekly price of bread as a price index, dividing the price of fresh beef by the price of bread. Again, the bread price is a unit value, resulting from dividing weighted weekly expenditures by weighted weekly quantities purchased.

Between 1998 and 2004, our calculated weekly bread price increased at an average annual rate of 2.7 percent. In comparison, the Bureau of Labor Statistics' Consumer Price Index monthly average bread price data increased at an average annual rate of 2.4 percent. The Consumer Price Index for food at home increased at 2.2 percent. So, our bread price index has two desirable features: it is in line with other sources for similar information and is consistent with broader price patterns.

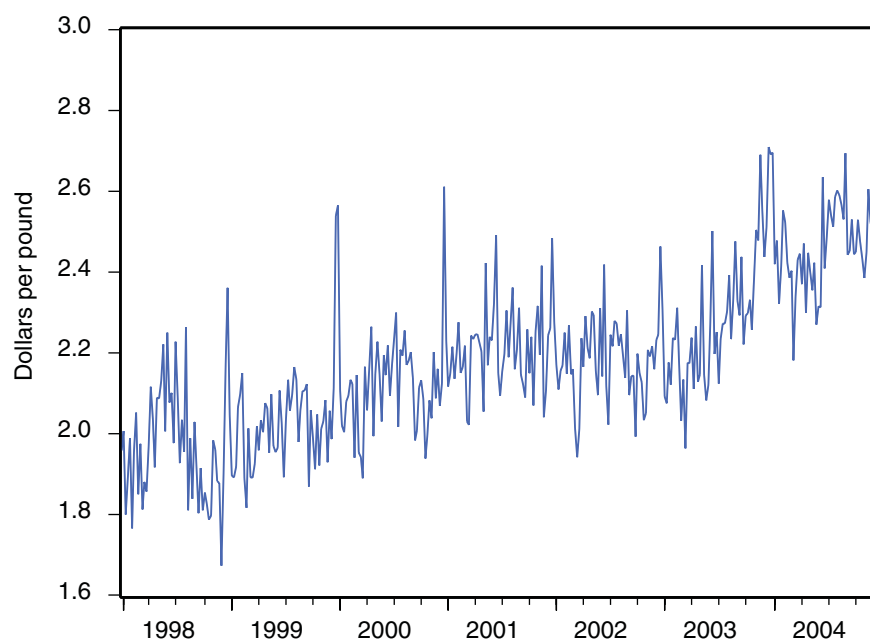
Figure 8 shows the time plot of beef prices deflated by the price of bread. Clearly, as the inflation-adjusted price still shows an upward trend, beef has increased in price more rapidly than has bread.

To show the importance of price to purchase decisions, we estimate a model accounting for trend, seasonality, and inflation-adjusted retail prices of beef and a substitute—poultry (mostly chicken and turkey). Both beef and poultry prices are deflated by the price of bread. The inflation-adjusted

Figure 8

Weekly U.S. inflation-adjusted retail price of fresh beef, 1998-2004

Beef has increased in price more rapidly than other staple foods



Source: Economic Research Service/USDA, using data from the ACNielsen Homescan Panel, 1998-2004.

price of beef is indicated in the following equation as P^B and the inflation-adjusted price of poultry is indicated by P^P .

$$y_t = \alpha_1 t + \alpha_2 t^2 + \beta_1 P_t^B + \beta_2 P_t^P + \sum_{i=1}^{52} \gamma_i D_{it} + \varepsilon_t \quad t=1, 2, \dots, 364$$

Results are in the left-most numerical column of table 2. Estimation results indicate that both retail prices are significant variables. The coefficient estimate for the beef price variable indicates that if the inflation-adjusted price increased 10 percent from the mean price, quantity purchased would be reduced by 5.1 million pounds, or 5.5 percent of the average quantity. The coefficient for the poultry price is smaller in absolute value than the beef price coefficient and opposite in sign. As expected for a substitute good, a rise in the price of poultry would induce an increase in beef purchases.

To refine our estimates of the BSE announcement impacts, we add 10 announcement impact dummy variables to the trend, seasonality, and price model

$$y_t = \alpha_1 t + \alpha_2 t^2 + \beta_1 P_t^B + \beta_2 P_t^P + \sum_{i=1}^{52} \gamma_i D_{it} + \sum_{j=1}^5 \delta_j CAN_{jt} + \sum_{k=1}^5 \delta_k WASH_{kt} + \varepsilon_t$$

$t = 1, 2, \dots, 364$

Results are in the middle numerical column of table 2. Like the corresponding model reported in table 1 (without the price variables), none of the dummy variables representing the weeks following the Canadian announcement are significant. Coefficients change from positive to negative and back several times. The first four dummy variables representing the weeks following the Washington State announcement are negative. However, here prices explain some of the variation in purchases that was formerly captured by the announcement effect dummy variables. Only the first week immediately following the Washington State announcement is significant. Results suggest a decrease of 18.8 million pounds for that one week, or about 28 percent of the quantity forecast to be purchased without the announcement.

The importance of the beef price term in this model is that it could help separate out how much demand diminished from grocers' attempts to maintain sales by lowering prices. Had grocers lowered prices below seasonal levels to reduce the sales loss caused by BSE, there would be less of an impact to explain and the weekly dummy variables would be less significant than in the model without the price term.

There are many ways one could anticipate price levels. In table 3, we report results of four methods: linear trend, trend and seasonal model, and both adjusted for inflation. When we examine price time patterns, observed prices are above prices that are predicted by extending the patterns for the Washington State announcement. Out-of-sample forecasts (weeks beginning December 24, 2003 and December 31, 2003) from the trend model and from the trend and seasonal model are uniformly smaller than observed prices. After adjusting for inflation, out-of-sample forecasts are also below

Table 2
Regression results from combined trend and seasonal models,
accounting for price effects and BSE announcements

Independent variables	Dependent variable: Quantity purchased fresh beef		
	Time trend, seasonal, and price model	Time trend, seasonal, price, and BSE announcement model	Time trend, seasonal, and price-BSE announcement interaction model
	<i>Estimated coefficient</i>		
	<i>(p value)</i>		
Time trend	-118510.8 (0.0000)	-119359.2 (0.0000)	-118482.0 (0.0000)
Time squared	162.2363 (0.0006)	162.6403 (0.0006)	160.0588 (0.0006)
52 seasonal dummy variables	All highly significant	All highly significant	All highly significant
Beef price/ bread price	-23611554 (0.0000)	-22162491 (0.0000)	-22139016 (0.0000)
Poultry price/ bread price	12136707 (0.0230)	11840466 (0.0283)	11156052 (0.0367)
(Beef price/ bread price)xCAN			-1163743 (0.6936)
(Beef price/ bread price)xWASH			-4867473 (0.0373)
CAN1		4848199 (0.5793)	
CAN2		-9527956 (0.2769)	
CAN3		6536046 (0.4523)	
CAN4		-1431062 (0.8691)	
CAN5		-5905329 (0.4977)	
WASH1		-18847852 (0.0318)	
WASH2		-7341409 (0.4085)	
WASH3		-7093669 (0.4164)	
WASH4		-2785781 (0.7496)	
WASH5		6502458 (0.4562)	
Summary statistics			
R2	0.776348	0.783010	0.779630
Adjusted R2	0.7326675	0.735680	0.738581
Durbin-Watson	2.063951	2.070999	2.077802

Source: Economic Research Service/USDA.

the observed inflation-adjusted prices. Thus, there is little evidence to indicate that retailers used price to mitigate the Washington State BSE announcement impacts. For the Canadian announcement, unadjusted prices were 4 percent lower than trend forecasts for the week beginning May 21, 2003. The following week, prices were as much as 6 percent lower than trend. These deviations could have increased purchases, but not by much, compared with impacts indicated in the announcement dummy variables. That is, none of the models reported here could detect an effect so small.

Table 3
Comparing fresh beef price forecasts with observed prices after the BSE announcements

Week beginning	Observed price		Forecast price			
	Unadjusted	Inflation adjusted	Linear trend	Trend and seasonal model	Linear trend, inflation adjusted	Trend and seasonal model, inflation adjusted
	<i>Dollars per pound</i>					
12/24/03	3.22	2.69	2.68	2.86	2.32	2.44
12/31/03	3.21	2.70	2.69	2.61	2.32	2.27
5/21/03	2.48	2.12	2.58	2.59	2.26	2.23
5/28/03	2.47	2.27	2.58	2.67	2.26	2.35

Source: Economic Research Service/USDA.

The third column in table 2 allows for the possibility that consumers changed the way they responded to inflation-adjusted retail prices just after the BSE announcements. Instead of shifting the average purchase level with BSE announcement dummy variables, we estimate the interaction between the announcements and inflation-adjusted retail prices.

None of the models so far have indicated any response that extended more than 2 weeks. Instead of having five dummy variables representing each of the 5 weeks following the Canadian announcement, we form one variable to distinguish the 2-week period immediately following the announcement. Similarly, we form one variable to distinguish the 2 weeks following the Washington State announcement. Multiplying the announcement variables by the inflation-adjusted retail price allows the price effect to vary over the announcement periods.

CAN = 1 for the weeks beginning May 21 and May 28, 2003, 0 otherwise.

WASH = 1 for the weeks beginning December 24 and December 31, 2003, 0 otherwise.

$$y_t = \alpha_1 t + \alpha_2 t^2 + \beta_1 P_t^B + \beta_2 P_t^P + \sum_{i=1}^{52} \gamma_i D_{it} + \delta_{CAN} CAN_t P_t^B + \delta_{WASH} WASH_t P_t^B + \varepsilon_t$$

t = 1, 2, ..., 364

Results are displayed in the right-most column of table 2. Again, the Canadian announcement variable is insignificant and the Washington State announcement is significant. Evaluated at observed inflation-adjusted prices, estimated impacts from the Washington State announcement are a reduction in purchases of 13.1 million pounds in each of the two post-announcement weeks (\$2.69/pound x 4,867,473 pounds).

Collectively, the estimated regressions point to the possibility (but not proof) that the Washington State announcement did reduce fresh beef purchases. There is no evidence that the Canadian announcement influenced purchases.

If the Washington State announcement did influence purchase decisions, the duration of that influence was no more than 2 weeks. Reduced sales over a 1-2 week period do not necessarily mean that grocers were much worse off. Consumers may have been temporarily unsettled by the news, but they probably continued to eat. Demands for many other protein sources likely increased.