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The BSE Crisis and the Price of Red Meat in the UK

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Abstract

This paper presents estimates of price functions for beef, lamb and pork for the UK economy which allow for the effects of the 1996 BSE crisis. Our estimates illustrate the importance of allowing for the joint endogeneity of prices in these markets. We show that the effects of this crisis had a significant negative effect on the price of beef and a positive and significant effect on the price of lamb. However, there appears to have been little effect on the price of pork.

Keywords: Demand for red meat, endogenous regressors, BSE crisis.

JEL Numbers: C32, Q11

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I. INTRODUCTION

The Bovine Spongiform Encephalopathy (BSE) crisis has proved to have wide ranging implications in the areas of public health, food safety and agricultural policy. In this paper we examine one very specific economic issue – the impact of the crisis on prices of red meat in the UK. Naturally most of the discussion to date has centred on the beef market. However, beef is just one of a range of substitutable red meats deriving from different animal species. Elementary economic theory tells us that a shock to demand or supply in one market will have implications for prices and demand in the markets for substitutes and that these effects may sometimes run counter to intuition. The purpose of this paper is to try to disentangle the effects on the markets for beef, lamb and pork of what was originally a shock to the beef market only.

The history of the BSE crisis goes back to late 1984 when the first case was identified in cattle. At first the possibility of transmission to the human population was seen as remote. However, cattle offal was banned in human food in November 1989. In May 1995 the first recorded death from variant Creutzfeldt-Jakob Disease (v-CJD) occurred. This was followed in March 1996 by official government recognition of a link between consumption of infected beef and development of the disease in humans. Although there had been a number of minor scares associated with BSE in the early 1990s, it was this official admission by the government that its previous reassurances were misleading which led to a major panic. Domestic demand for beef fell sharply as a result. In addition the EU imposed an export ban on UK beef which contributed further to the collapse of demand in this market. The effects can be seen clearly in Figure 1 which shows a fall in price of about 25% during this period.

[Insert Figures 1-3 here]

Although the effects on the beef market are well known, the effects on the markets for other red meats are less understood. Figure 2 shows the effects on the price of sheep and Figure 3 the price of pigs. There are likely to be two opposing effects on prices in these markets. First, the loss of confidence in beef is likely to have caused a demand shift towards alternative red meats and possibly an increase in price. However, the subsequent fall in beef prices will have produced an opposite effect. The net effect on lamb and pork prices is therefore uncertain. In practice prices in both these markets rose during the second half of 1996 but then fell sharply afterwards. It is at this point where an empirical model of the interactions between the markets can be illuminating.

Research on the impact of the BSE crisis has up to now tended to make us of the kind of demand systems discussed in general by Deaton and Muellbauer (1980). Examples of papers using this methodology are Burton and Young (1996); Burton, Young and Cromb (1999); Dnes (1996) and Fousekis and Revell (2002). In contrast, the approach taken in this paper is to estimate price functions which do not impose rigid restrictions on the form of the implicit demand functions but which do pay careful attention to the possibility of joint endogeneity of the price variables. It is interesting to not that Griffiths, Hill and Judge (1993) use a model with a very similar structure as a pedagogic tool to illustrate the estimation of simultaneous equations models. We treat output as exogenous in the regressions on the basis that production lags are sufficiently long that induced supply responses can be ignored.

The plan of the paper is as follows. In section II, we set out the model and discuss the econometric procedures we will adopt. Section III discusses the data and presents our estimates and interpretation of the results. Finally, section IV presents our conclusions.

II. THE MODEL

The model we use has a simple log-linear specification. The price in each market is assumed to depend on quantity available for each commodity, the price of competing products, an income variable included to capture the overall level of demand and a BSE dummy variable included to capture the effects of the loss in consumer confidence in the safety of beef following the establishing of a link between beef consumption and v-CJD in 1996. We also include a lagged endogenous variable in each equation to capture the effects of sluggish price adjustment. This variable proved to be important in eliminating serial correlation in the residuals.

The detailed specification of the model is given below in equation (1). *p* indicates a price variable with the subscripts *c*, *s*, and *p* indicating cattle, sheep and pigs respectively. All the price variables are expressed as a ratio relative to the GDP deflator. *q* indicates a quantity variable with the same subscripts applying. *y* is real personal disposable income and *BSE* is a dummy variable taking the value 1 from 1996.2 to 2000.4 but 0 elsewhere. All variables are in natural logarithms except for the dummy variable.

$$\begin{aligned} p_{c,t} &= \alpha_{11} + \alpha_{12} q_{c,t} + \alpha_{13} p_{s,t} + \alpha_{14} p_{p,t} + \alpha_{15} y_t + \alpha_{16} BSE_t + \alpha_{17} p_{c,t-1} + u_{c,t} \\ p_{s,t} &= \alpha_{21} + \alpha_{22} q_{s,t} + \alpha_{23} p_{c,t} + \alpha_{24} p_{p,t} + \alpha_{25} y_t + \alpha_{26} BSE_t + \alpha_{27} p_{s,t-1} + u_{s,t} \\ p_{p,t} &= \alpha_{31} + \alpha_{32} q_{p,t} + \alpha_{33} p_{c,t} + \alpha_{34} p_{s,t} + \alpha_{35} y_t + \alpha_{36} BSE_t + \alpha_{37} p_{p,t-1} + u_{p,t} \end{aligned} \qquad (1)$$

Our expectations are that the quantity varies should have a negative sign, hence $\alpha_{i2} < 0; i = 1,2,3$. Under the assumption that the three types of meat are substitutes and the substitution effect dominates any possible income effects, we expect the signs of the price variables in each equation to have positive sign, hence $\alpha_{ij} > 0; i = 1,2,3; j = 1,2$. We expect the income variables to be positive in each case i.e. $\alpha_{i6} > 0; i = 1,2,3$. The BSE dummy is included to capture the effects of the decline in consumer confidence in beef, therefore we would expect the sign on the variable to be negative in the beef equation but positive in the lamb and pork equations, i.e. $\alpha_{16} < 0, \alpha_{i6} > 0; i = 2,3$. Finally, the lagged price variables are included to capture sluggish adjustment and hence we would expect $\alpha_{i7} > 0; i = 1,2,3$.

The model is written with prices as the endogenous variables rather than quantities. This is equivalent to assuming that the supply of red meats is fixed in the short to medium run. It is certainly true that production is not easily shifted form one form of livestock to another. However, the effects of the BSE crisis may mean that quantity measures capture show some of the effects of cutbacks on supply in the beef industry. For example, a short-term supply glut may have depressed prices as cattle were swiftly offloaded onto the market and inventories (live animals) were reduced. In the longer term the destruction of cattle as a result of BSE will have led to a fall in the supply of beef. It is therefore plausible to expect the price of beef to overshoot its long run equilibrium value in response to the BSE crisis.

The form of the model deserves further comment. Rather than attempt the specification of a complete demand system we have chosen to adopt a relatively simple log-linear specification. We do not believe that there is a significant gain to estimating a demand system in this case because the commodities we consider comprise only a small part of total demand and therefore the restrictions implicit in a demand system (adding up, homogeneity and symmetry) may prove problematic. Moreover, the adoption of a simple specification like (1) makes it easier to deal with issues of endogeneity of regressors and correlation between the error terms of the model. In particular we wish to test the importance of allowing for the endogeneity of the price of substitutes within each equation and correlation between the disturbance terms for each equation. An example of the latter phenomenon would be a food safety scare which decreased the demand for one particular type of meat while increasing that for others.

Identification becomes an issue for this model given the simultaneous nature of the equations we wish to estimate. We have a total of three endogenous variables (p_c, p_s and p_p) and seven exogenous or predetermined variables ($q_c, q_s, q_p, y, p_{c,t-1}, p_{s,t-1}$ and $p_{p,t-1}$) plus a constant, the BSE dummy variable and three seasonal dummy variables. Each equation includes all three endogenous variables and excludes the quantity variables and the lagged prices for the other types of meat. Therefore the order condition for identification indicates that each equation is overidentified.

We present three sets of estimates for the parameters of the model. The first is Ordinary Least Squares which simply estimates each equation in turn while taking no account of possible endogeneity of the regressors or correlation between the equation errors. The second method is Two-Stage Least Squares which allows for possible endogeneity of the price of substitutes in each equation but does not allow for correlation between the equation errors and hence is not fully efficient. Finally, we estimate by Three-Stage Least Squares which allows for both endogeneity of substitute prices and correlation between the equation errors.

III. DATA AND MODEL ESTIMATES

Most of the data for our model are taken from the Department of Environment, Food and Rural Affairs (DEFRA) website. The beef price is the price of clean cattle in pence per kilogram (liveweight), the lamb price is the price of sheep p/kg (deadweight) and the pork price is the price of pigs p/kg (liveweight). These data are given on a weekly basis and were converted by averaging the observations for each month to create a monthly series and then averaging the observations for January to March for the first quarter, April to June for the second quarter, July to September for the third quarter and October to December for the fourth quarter. The quantity variables for beef, lamb and pork respectively are measured in terms of Thousands of Tonnes Dressed Carcase Weight.

Real personal disposable income is taken from the ONS website and is measured in £m at 1995 prices. The GDP price deflator was also taken from the ONS website. Finally, *BSE* is a dummy variable taking the value 1 for the period 1996.2 to 2000.4 and 0 elsewhere. All data are for the period 1985.1 to 2000.4.

Table 1 gives the regression results for our model. We present ordinary least squares (OLS), two-stage least squares (TSLS) and three stage least squares estimates (3SLS). The results given illustrate the value of allowing for the joint endogeneity of the price variables. We will consider each equation in turn.

[Insert Table 1 here]

The OLS estimates of the beef equation show a positive and significant effect of the price of lamb, the own lagged price and a negative and significant effect of the BSE dummy variable. Allowing for endogeneity of the price variables in the equation makes relatively little difference to this equation. The price of lamb remains significant in both the TSLS and 3SLS estimates as does the lagged own price and the BSE dummy. However, the pork price coefficient does increase in magnitude and become marginally significant with the wrong sign in the 3SLS estimates. Both the quantity and the disposable income variables are insignificant in all three sets of estimates. Note that the *ceteris paribus* long run effect of the BSE dummy variable amounts to a fall in the price of beef of about 34%. The insignificance of the quantity variable may reflect 'panic selling' in response to the crisis meaning leading to a confusion of demand and supply effects in this equation.

When we turn to the lamb equation, we see that OLS estimation indicates that both beef and pork prices are significant and positive. However, allowing for endogeneity of these variables means that the magnitude and the significance of the beef price falls noticeably in both the TSLS and 3SLS estimates. The quantity variable is significant and negative in all three sets of estimates although disposable income is insignificant in all cases. It is noticeable that the degree of inertia as measured by the magnitude of the lagged own price variable is lowest for this equation. Finally, we observe that the BSE dummy variable is both positive and significance in all three sets of estimates. Comparing this with the effect on the beef price, we find that the *ceteris paribus* long run effect on the price of lamb comes to about 39%.

Finally, turning to the pork equation, we find that the beef price has the correct sign but is insignificant in all three sets of estimates. It is noticeable however, that the magnitude of the beef price coefficient increases when we allow for its endogeneity. The price of lamb is insignificant in all three cases and is incorrectly signed in the TSLS and 3SLS estimates. However, the quantity variable and the lagged own price variable are both significant although the disposable income and the BSE dummy variable are insignificant.

Overall, our estimates indicate relatively strong substitution effects between beef and lamb but relatively little substitution between these two types of meat and pork. The BSE dummy variable indicates that the crisis reduced the price of beef and increased that of lamb with magnitude of the effect being roughly similar. In addition our results illustrate the importance of allowing for the joint endogeneity of the price variables in that the TSLS and 3SLS parameter estimates differ noticeably from the OLS estimates.

Finally, we need to assess our estimates for evidence of dynamic misspecification. Various test statistics are presented below each set of estimates. The statistics presented are the coefficient of determination (R^2), the standard error of the regression (SEE), the Durbin-Watson test statistic for first order autocorrelation (DW), the Ljung-Box portmanteau test statistic for fourth order serial correlation, the F-form of the Lagrange Multiplier test for a first order ARCH (autoregressive conditional heteroscedasticity) process in the residuals and the Jarque-Bera test statistic for non-normality of the residuals. Most of the test statistics we calculate do not suggest significant misspecification of the model. However, the Ljung-Box test statistic does suggest the presence of a third order serial correlation process in the residuals with a coefficient of about 0.3. Although this is statistically significant it is not large enough to seriously bias the standard errors of the coefficients and therefore we do not make any explicit adjustment for this process. None of the other diagnostic test statistics indicates misspecification at any of the normal levels of significance.

It is interesting to examine the correlations between the residuals of the equations of our model to see if these reflect our prior expectations concerning the effects of these shocks. In particular we expect that during this period there would be a negative correlation between disturbances in the beef market with those in the other two markets. Table 2 below reports the correlations between the equation residuals derived from three stage least squares estimation. Although none of the correlations are particularly strong, the largest in magnitude is the negative correlation between disturbances in the beef and lamb markets. Our belief is that this reflects the fact that these two commodities are the closest substitutes in the system.

[Insert Table 2 here]

IV. CONCLUSIONS

In this paper we have estimated price functions for three categories of red meat for the UK economy. We find important substitution effects between beef and lamb. Moreover we find that the effect of the 1996 BSE crisis affected prices in these two markets in opposite directions – depressing the price of beef while increasing that of lamb. Although we find relatively little evidence of substitution between pork and the other two types of meat, we do find a well defined inverse demand curve for pork which indicates a significant own price elasticity.

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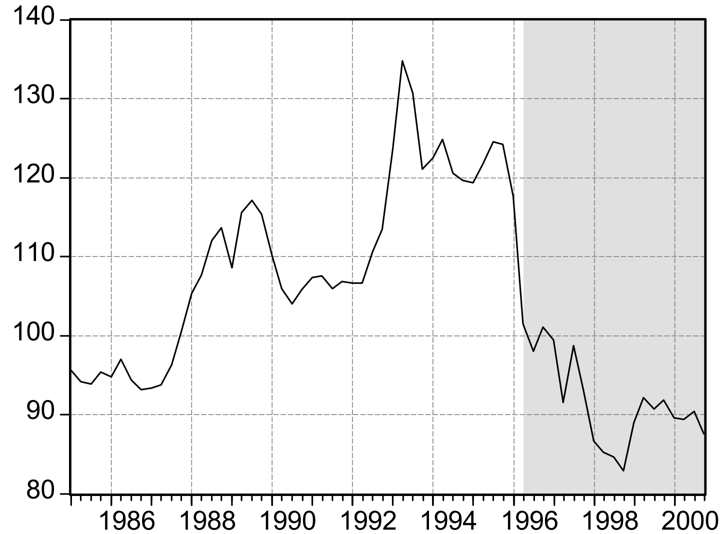

Figure 1: Seasonally Adjusted Price of Cattle

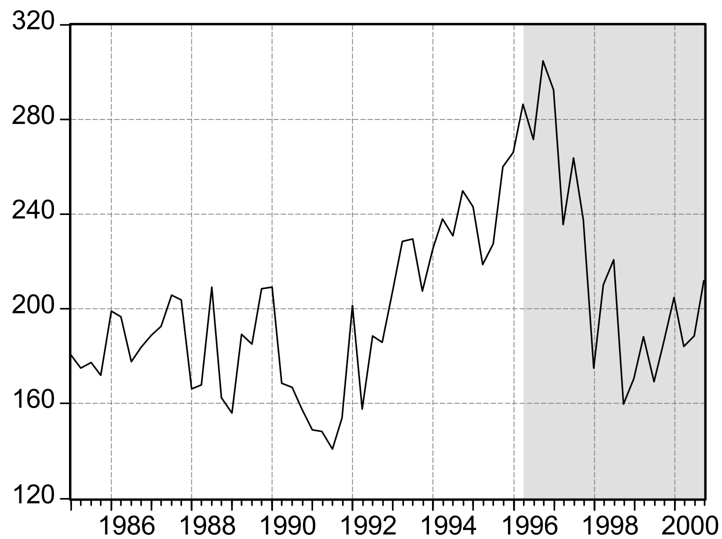

Figure 2. Seasonally Adjusted Price of Sheep

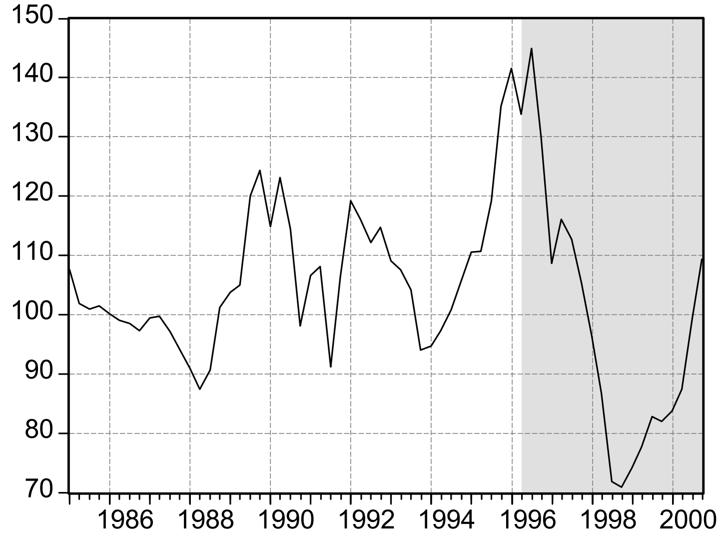

Figure 3. Seasonally Adjusted Price of Pigs

Table 1: Estimates of the Model

	OLS Estimates			*TSLS Estimates*			*3SLS Estimates*		
	Beef	*Lamb*	*Pork*	*Beef*	*Lamb*	*Pork*	*Beef*	*Lamb*	*Pork*
Beef Price		0.5950	0.2974		0.3445	0.4599		0.3992	0.4530
		(2.56)**	(1.54)		(1.14)	(1.70)*		(1.45)	(1.82)*
Lamb Price	0.1302		0.0642	0.1305		-0.0612	0.1308		-0.0558
	(3.73)***		(0.86)	(2.69)**		(-0.54)	(2.94)**		(-0.54)
Pork Price	-0.0438	0.4156		-0.0992	0.4709		-0.1015	0.4836	
	(-0.99)	(3.95)***		(-1.76)*	(3.61)***		(-1.97)*	(4.05)***	
Quantity	0.1018	-0.9100	-1.1395	0.0620	-0.9688	-1.1731	0.0555	-0.9903	-1.2009
	(1.35)	(-5.15)***	(-3.57)***	(0.76)	(-5.22)***	(-3.46)***	(0.76)	(-5.84)***	(-3.87)***
Disposable Income	-0.1143	-0.0651	0.2071	-0.1724	-0.1754	0.2671	-0.1796	-0.1605	0.2641
	(-1.10)	(-0.31)	(1.26)	(-1.55)	(-0.74)	(1.41)	(-1.77)*	(-0.74)	(1.52)
Lagged Price	0.6226	0.2498	0.6620	0.6631	0.2666	0.7103	0.6618	0.2368	0.7041
	(7.66)***	(2.61)**	(8.32)***	(7.30)***	(2.53)**	(7.97)***	(7.95)***	(2.48)**	(8.62***)
BSE Dummy	-0.1348	0.2900	0.0375	-0.1314	0.2212	0.0969	-0.1323	0.2212	0.0949
	(-4.77)***	(3.53)***	(0.54)	(-4.29)***	(2.20)**	(1.03)	(-4.71)***	(2.20)**	(1.10)
R-Squared	0.98	0.87	0.93	0.98	0.87	0.92	0.98	0.87	0.92
SEE	0.0376	0.0969	0.0734	0.0382	0.0980	0.0753	0.0382	0.0978	0.0752
DW	1.39	2.06	1.88	1.41	2.17	1.90	1.41	2.11	1.90
Ljung-Box Test	7.04 (0.13)	9.55 (0.05)	7.27 (0.12)	6.49 (0.17)	11.75 (0.02)	7.40 (0.12)	6.54 (0.16)	10.26 (0.04)	7.25 (0.12)
ARCH Statistic	0.64 (0.43)	0.81 (0.37)	0.25 (0.62)	1.07 (0.31)	0.09 (0.77)	0.18 (0.67)	1.05 (0.31)	0.16 (0.69)	0.18 (0.67)
Jarque-Bera Test	4.45 (0.11)	0.79 (0.68)	1.10 (0.58))	3.88 (0.14)	0.96 (0.62)	1.46 (0.48)	3.70 (0.16)	0.85 (0.65)	1.45 (0.48)

Estimates are based on seasonally unadjusted data. A constant and seasonal dummy variables were included but not reported. T-ratios are reported in parentheses below coefficients. * indicates a variable is significantly different from zero at the 10% level, ** at the 5% level and *** at the 1% level.

Table 2: Correlation Matrix of Residuals from 3SLS Regression NSA data

	Beef	*Lamb*	*Pork*
Beef	1.0000		
Lamb	-0.1868	1.0000	
Pork	0.0692	-0.0314	1.0000