IMPACT OF BSE AND FMD ON BEEF INDUSTRY IN UK

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ABSTRACT

This paper explores the impact of BSE and FMD on retail, wholesale and farm level prices of Beef, Lamb, Pork and Poultry in short-term as well as long term for a period of time from January 1985 to December 2002. This period covers a most difficult time in the UK meat industry as BSE and FMD diseases were at their historical peak presence. The paper studies monthly real prices in a vector error correction model (VECM) in which directed acyclic graphs are used to provide information on structural relationships among contemporaneous innovations. Results show that meat prices responded differently to the two BSE events, the early event showing much less influence on retail price. Further, price responses in a neighborhood of the FMD event are dissimilar to responses in a neighborhood of the two BSE events.

Keywords: BSE, Foot and Mouth Disease, Vector Error Correction Model, Directed Acyclical Graph, Beef, Pork, Lamb, Poultry, Retail Price, Wholesale Price, Producer's Price.

INTRODUCTION

Bovine Spongiform Encephalopathy (BSE) and Foot and Mouth Disease (FMD) have attracted considerable publicity across the world. The general perception is that these diseases resulted in decline in consumption of meats and adversely impacted the meat industry. The purpose of this paper is to explore the relationship between prices of various meats (beef, lamb, pork and poultry) in United Kingdom (UK) and how new information impacts the meat industry. Three exogenous events associated with BSE and FMD which were present in the UK meat sector are analyzed to understand the inter-relation among prices following the discovery of these pathogens for the period between 1985 and 2002.

These analyses provide us general understanding of meat prices and market response to these events in UK meat industry. There are various papers written on impact of BSE on consumption (Young, 1996) and beef sector (Irazoz, 2005) but none of these papers tried to address these events taking holistic view of meat industry. This paper tries to fill the gap and provide an analysis of the effect of BSE and FMD on the meat industry rather looking only on one meat category. The paper also analyzes price at the retail, wholesale and producer levels. This will provide us an understanding that how these events impact the different level of the marketing chain.

The paper uses new methods of modeling observational data using the artificial intelligence (directed acyclical graph). Empirical findings on the contemporaneous and short-run interdependence using a vector error correction model, causal flows based on directed acyclical graph, innovation accounting (impulse response function), and historical decomposition are presented.

The paper is divided in five sections. The first section provides general understanding of BSE and FMD disease. It includes how these diseases are transmitted and their impact on animals as well as human beings. Second section provides the description of data. Third section gives short description of the methods used in the paper. The results are discussed in the fourth section. Paper concludes with summary the results as well as future area of research.

BOVINE SPONGIFORM ENCEPHALOPATHY & FOOT AND MOUTH DISEASE

Bovine Spongiform Encephalopathy (BSE) popularly known as mad cow disease is a relatively new disease in cattle. It was first recognized and defined in UK in November 1986. BSE occurs in adult animals in both sexes, typically in animals aged five years and more. It is a neurological disease in which affected animals show signs that include; changes in mental state, abnormalities of posture and movement and of sensation. The clinical disease usually lasts for several weeks and it is invariably progressive and fatal. The exact cause of BSE is not known but it is generally accepted that the likely cause is infectious forms of a type of protein, prions, normally found in animals cause BSE. These abnormal prions initially occur in the small intestines and tonsils, and are found in central nervous tissues, such as the brain and spinal cord, and other tissues of infected animals experiencing later stages of the disease. BSE can transfer from one cattle to another consumption of contaminated feed. Chickens and pigs have been exposed to far more contaminated meat and bone meal than have cattle in the past. The infection in such animals would never be seen because they are slaughtered too young. Consumption of contaminated beef products can cause a disease similar in human beings called Creutzfeldt-Jacob Disease (CJD) and it can be fatal in nature.

Foot and mouth disease (FMD) is an infectious disease affecting cloven-hoofed animals, in particular cattle, sheep, pigs, goats and deer. The disease is serious for animal health and for the economics of the livestock industry. While FMD is not normally fatal to adult animals, it is debilitating and causes significant loss of productivity. In young animals it can be fatal on a large scale. FMD is endemic in parts of Asia, Africa, the Middle East and South America, with sporadic outbreaks in disease-free areas. Foot-and-mouth disease is extremely infectious. A very small quantity of the virus is capable of infecting an animal, and the disease could spread throughout the country if no attempt were made to control it. The interval between exposure to infection and the appearance of symptoms varies between twenty-four hours and ten days, or even longer. Virus can be destroyed by heat, sunlight, low humidity, or certain disinfectants, but it may remain active for a varying time in a suitable medium such as the frozen or chilled carcass of an infected animal or on contaminated objects. There is no cure for FMD. It usually runs its course in 2 or 3 weeks after which the great majority of animals recover naturally. Human beings rarely contact this disease. There has only been one recorded case of FMD in a human being in Great Britain and that was in 1966. The general effects of the disease in that case were similar to influenza with some blisters. It is a mild short-lived, self-limiting disease and not fatal in nature.

BSE and FMD were continuously in the headlines since 1987 due to outbreak in different parts of the world and their devastating impact on health and economies. The major events related with BSE and FMD are listed in table 1 and 2.

Three events that are analyzed in this paper are July 1988 (BSE88) when British government decided to kill all the infected animals with BSE disease. Second event is March 1996 (BSE96) when British government decided to ban ruminant protein in the form of meat and bone meals in pig and poultry rations and shortly after (August 1996) British government announced that mad cow disease can be transmitted to human beings. Third event is in January 2001 (FMD00) when FMD appeared in Britain and Continental Europe. December 2000 is used for analysis as it was starting point of all the major events related with FMD.

DATA DESCRIPTION

Data used in this study consist of eleven monthly real price series for various meat prices in United Kingdom (UK). The data is provided by the department of environmental food and rural affairs (DEFRA), United Kingdom (UK). The period for the study is from January 1985 to December, 2002. This period is one of the most difficult periods in history of UK meat industry as they had BSE and FMD during this period as evident from table 1&2. The price series which are analyzed in this study are retail price of beef (RPB), wholesale price of beef (WPB), producer's price of beef (PPB), retail price of lamb (RPL), wholesale price of lamb (WPL), producer's price of lamb (PPL), retail price of pork (RPP), wholesale price of pork (WPP), producer's price of pork (PPP), retail price of poultry (RPPo) and producer's price of poultry (PPPo).

Only real prices were available for these series and hence same are used in the analysis. The reason to choose to model prices of all major meats in this study is because of the substitution effect among meat products. Further, our interest is to study which product and marketing level is affected most in these events and are there difference in supply chain responses across meat products? The series are plotted in figure 1.

METHODS

We use modern time series methods, as categorized under the heading of vector autoregression (VAR) and error correction (ECM). These methods represent the current value of a vector of meat prices as a function of time lags of the same vector and a current period innovation (error). The error correction form of the VAR is used when the individual series are non-stationary (move away from their historical mean or covariances for long periods of time), but current period combinations of the series are stationary (Engle and Granger 1991).

Let X_t denote a vector that includes the monthly price of meat from each of the four categories, at farm-level, wholesale-level and retail-level for beef, lamb, and pork and producer-level and retail-level for poultry: $X_t' = \left[X_{1t}, X_{2t}, X_{3t}, X_{4t}, X_{5t}, X_{6t}, X_{7t}, X_{8t}, X_{9t}, X_{10t}, X_{11,t}\right]$; where the subscript "t" represents time and the integers "1" through "11" denote prices: 1–beef retail-level; 2–beef wholesale-level, 3–beef producer-level, 4–lamb retail-level, 5–lamb wholesale-level, 6–lamb producer -level, 7–pork retail-level, 8–pork wholesale-level, 9–pork producer -level, 10–poultry retail-level, and 11- poultry producer -level. If the series are non-stationary (which we expect for prices in a free market, we explore this below), the vector X_t can be modeled in an error correction model (ECM):

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + e_t, \quad (t = 1,...,T), \quad \mathrm{E}\{e_t e_t'\} = \Omega \tag{1}$$

Here Π and Γ are parameter matrices to be estimated, μ is a constant and e_t is a white noise innovation term all from a sample of T observations. Further, E is the expectation operator and Ω is a positive definite covariance matrix.

Equation (1) resembles a vector autoregression (VAR) model in first differences, except for the presence of the lagged levels of X_{t-1}. There are three cases of interest: (a) if Π is of full rank, then X_t is stationary in levels and a VAR in levels is an appropriate model; (b) if Π has zero rank, then it contains no long-run information and the appropriate model is a VAR in first differences; and (c) if the rank of Π is a positive number, *r*, which is less than *p (the number of series = 11)*, there exist matrices *α* and *β*, with dimensions *p* x *r*, such that $\Pi = \alpha\beta'$. In such a case, $\beta' X_t$ is stationary, even though X_t is not.

The dynamic response patterns summarized by an ECM or a VAR are difficult to interpret (Sims 1980; Swanson and Granger 1997). The dynamic price relationships can be best summarized through the moving average representation. Given the estimated form of equation (1) (with possible cointegrating vectors, which is applicable in this study), we can algebraically re-express equation (1) as a levels VAR. We can then solve for its moving average representation, where the vector X_t is written as a function of the infinite sum of past innovations:

$$X_t = \sum_{i=0}^{\infty} G_i e_{t-i} \tag{2}$$

where G_i is 11x11 matrix of moving average parameters, which map historical innovations at lag *i* into the current position of the vector *X*.[1] Here the matrix G_0 is generally not the identity matrix, as the elements of the vector *e* are usually not orthogonal. That is to say, there may be non-zero correlation between contemporaneous innovations.

Analysis of equation (2) without making some adjustment for non-orthogonal innovations may not reflect the dynamic historical patterns present in the data (see Sims (1980)). We prefer to work with a transformed moving average representation on orthogonalized innovations $v_t = Ae_t$, where A is such that $E\{v_t v_t'\} = D$. Here D is a diagonal matrix. Research workers employing VAR models have traditionally used a Choleski factorization of the (contemporaneous) innovation correlation matrix to provide a Wold causal chain on how an innovation in series *i* reacts to an innovation in series *j* in contemporaneous time. The Choleski factorization is recursive in its nature and may not reflect the "true" causal patterns among a set of contemporaneous innovations.

More recently, research workers have followed the structural factorization commonly referred to as the "Bernanke ordering" (Bernanke, 1986) which requires writing the innovation vector (e_t) from the estimated VAR model as: $e_t = A^{-1}v_t$, where, in our case, **A** is a 11x11 matrix and v_t is a 11x1 vector of orthogonal shocks. While the Bernanke ordering allows one to move away from the mechanically imposed constraint of recursive causal ordering embedded in the Choleski factorization, it requires research workers to actually specify a contemporaneous causal pattern among innovations. In this study we have very little information for specifying the ordering in a Choleski factorization. It is not clear if, in contemporaneous time, exogenous price signals from one meat category originate at the farm-level, wholesale level or the retail-level. Or do such signals originate in the beef, pork, lamb or poultry markets and then get passed on to other markets? Accordingly, we abandon any attempt to solve the causality in current time question with a Choleski factorization of contemporaneous covariance.

Here we apply directed graph algorithms (see the discussion given below) to place zeros on the A matrix (e.g. $v_t = Ae_t$). Directed graphs have recently been used in the literature for just this purpose in similar time-series settings (see, for example, Swanson and Granger (1997) or Bessler and Akleman (1988)). Given equation (2) (or more precisely, its estimated form) we write the vector *X* in terms of orthogonalized innovations as Equation (3):

$$X_t = \sum_{i=0}^{\infty} \Theta_i v_{t-i} \, . \tag{3}$$

Here the vector *X* is written as an infinite series of orthogonalized innovations, v_{t-i}. We use recent innovations in graph theory and algorithm search procedures (described below) to determine the

[1] While one can actually derive the first *n* terms of equation (2) analytically, we almost always allow the computer to do this following the zero-one simulation as described in Sims (1980).

causal pattern behind the correlation in contemporaneous innovations ($E\{e_t e_t^{'}\} = \Omega$) to construct orthogonal innovations ($E\{v_t v_t^{'}\} = D$).

A directed graph is a picture representing the causal flow among a set of variables. Lines with arrowheads are used to represent flows such that A→ B indicates that variable A causes variable B. A line connecting two variables, say C – D, indicates that C and D are connected by information flow, but we cannot tell if C causes D or vice versa. The fundamental idea that allows us to detect direction of causal flow to a set of (observational) variables is that of screening-off phenomena and its more formal representation as d-separation (Pearl, 2000). For three variables A, B and C, if we have variable A as a common cause of B and C so that B←A→C, then the unconditional association between B and C will be non-zero, as both have a common cause in A (this diagram is labeled a causal fork (Pearl 2000)). If we measure association (linear association) by correlation then B and C will have a non-zero correlation. However, if we condition on A, the partial correlation between B and C (given knowledge of A) will be zero. Knowledge of the common cause (A) "screens-off" association between its effects (B and C).

On the other hand, say we have variables D, E and F such that D→E←F. Here, we have E as a common effect of D and F (this diagram is labeled a causal inverted fork (Pearl 2000)). D and F will have no association (zero correlation if we constrain ourselves to linear association); however, if we condition on E, the association between D and F is non-zero (the partial correlation between D and F, given knowledge of E is non-zero). We say (in the vernacular) knowledge of the common effect does not "screen-off" association between its causes.

Finally, if we have variables G, H and I forming a causal chain, G→H→ I, the unconditional association (correlation) between G and I will be non-zero, but the conditional (partial) correlation between G and I, given knowledge of H, will be zero.

These screening-off phenomena associated with common effects and common causes have been recognized in the literature for some fifty years now; see, for example, Simon (1953). It is only recently that they have been formally introduced into the literature for assigning causal flows among three or more variables. Key to this modern re-birth is the technical work of Pearl and his associates (see Pearl 2000). Pearl and his collaborators have formalized these screening-off notions, with the idea of d-separation, which gives the connection between a causal diagram and its probability representation.

Spirtes, Glymour and Scheines (2000) and Chickering (2002) present algorithms for inference on directed acyclic graphs from observational data. The former is labeled PC algorithm, the latter GES (Greedy Equivalent Search). Both are embedded in the software TETRAD IV (see the offering at http://www.phil.cmu.edu/projects/tetrad/ and Scheines *et al*., 1996). Here we use GES.

GES (Greedy Equivalent Search) algorithm is a stepwise search over alternative DAGs using Bayesian posterior scores. The algorithm consists of two stages beginning with a DAG representation with no edges (independence among all variables). Edges are added and/or edge directions reversed in a systematic search across classes of equivalent DAGs if the Bayesian posterior score is improved. The first stage ends when a local maximum of the Bayesian score is found such that no further edge additions or reversal improves the score. From this final first stage DAG, the second stage commences to delete edges and reverse directions, if such actions result in improvement in the Bayesian posterior score. The algorithm terminates if no further deletions or reversals improves the score. Details on the algorithm, justification for selection of the sequencing of edge additions or deletions and mathematics supporting such search are given in Chickering (2002, pp. 520-524).

EMPIRICAL RESULTS

Price series generally behave as a random walk (each having unit root). Standard unit root tests, Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests are used to find whether these eleven price series are non-stationary in their levels. The null hypothesis is that the series are non-stationary in levels. Table 3 shows that most of these series are non-stationary (except lamb prices and retail poultry price) at levels as t-statistics are greater than critical value (-2.89 at a 5% significance level).

Consumers have wide choices of meats depending on price and other issues related with quality and health. Similarly other economic agents (like producers and wholesalers) can participate in one or more markets and anticipate price changes and move from one market into another in the long term. Such behavior of participants can induce cointegration in these markets. Table 4 presents a series of test of cointegration among the eleven price series. The table follows the sequential testing procedure suggested by Johansen (1992), where one begins testing for zero cointegration vectors (r=0) with the constant in the cointegrating space. If this is rejected then one tests for zero cointegration vectors (r=0) with the constant outside the cointegrating space. This process is continued (testing that $r \leq 1 \ldots$) until the null hypothesis is rejected. Following this sequential testing procedure, the first time the null hypothesis is not rejected is at $r \leq 7$. This indicates that there are seven or less cointegration vectors with constant inside the space.

Above we saw that the DF and ADF tests provide non-conclusive evidence that all price series are non-stationary. An alternative way to test the behavior of each individual series is to test the null hypothesis that each series is stationary. There are seven or less cointegration vectors (as found in table 4) and some of these may be due to one or more of the series being stationary. This possibility is tested and reported in table 5. Results reported in table 5 are on the test of hypothesis that each series is stationary in its levels. The hypothesis is rejected for each series indicating that none of these price series are stationary as expected.

Given the seven cointegrating vectors found above, it is of general interest to ask whether each meat price series is not part of the cointegration space. (i.e. it is not in at least one of the cointegration vectors). It is possible that cointegration vector is due to a linear combination of subset of eleven series. Table 6 explores this possibility where null hypothesis tested is that the given series is not part of the cointegration space. The test statistics is distributed chi-squared with seven degrees of freedom (as there are seven cointegrating vectors and exclusion of one series from all vectors implies seven zero restrictions). Null hypothesis is rejected for all series indicating that all meat prices are in at least one of the cointegrating vectors.

Table 7 explores the possibility that some meat prices do not respond to perturbation in the cointegration vector. This is a test of weak exogeneity of each series relative to long-term equilibrium. The null hypothesis is that the associated price series does not adjust to perturbations (deviations) in any of the seven long run relations. It is clear from table 7 that null hypothesis is not rejected for retail beef price. The null is rejected in all other cases. This suggests that retail beef prices do not respond, do not adjust, when the UK meat prices are not in their long run equilibrium. It is through movement in one or more of the other ten meat prices (not retail beef prices) by which equilibrium is restored.

The estimated error correction model is not reported here as the dynamic interdependence among eleven variables is difficult to interpret by focusing on individual coefficient estimates. A better approach is to summarize this dynamic relation among these prices through innovation accounting, applied to the estimated error correction model. To provide such, we need to find a structural representation (model) on contemporaneous innovations (errors). The following matrix provides the contemporaneous correlation between innovations (based on the estimated ECM) in each of the meat price series. The elements of the matrix are in order: RPB, WPB, PPB, RPL, WPL, PPL, RPP, WPP, PPP, RPPo and PPPo.

$$\begin{bmatrix}
1.0000 & & & & & & & & & & \\
0.5226 & 1.0000 & & & & & & & & & \\
0.3514 & 0.6565 & 1.000 & & & & & & & & \\
-0.0259 & 0.1850 & 0.3399 & 1.0000 & & & & & & & \\
-0.0750 & 0.2287 & 0.3212 & 0.7953 & 1.0000 & & & & & & \\
-0.0917 & 0.1732 & 0.3342 & 0.6352 & 0.8184 & 1.0000 & & & & & \\
0.2049 & 0.0131 & 0.0087 & 0.1035 & 0.0179 & -0.0699 & 1.0000 & & & & \\
0.0722 & 0.0262 & 0.1475 & 0.2698 & 0.1430 & 0.0627 & 0.3924 & 1.0000 & & & \\
0.0714 & -0.004 & 0.1298 & 0.2098 & 0.0690 & 0.0527 & 0.2552 & 0.8687 & 1.0000 & & \\
-0.0207 & -0.0659 & 0.0802 & 0.0038 & -0.0177 & 0.0467 & 0.0568 & 0.0030 & 0.0456 & 1.0000 & \\
0.0819 & 0.0455 & 0.0432 & 0.0597 & 0.0119 & -0.0381 & 0.3204 & 0.1832 & 0.1271 & 0.0846 & 1.0000
\end{bmatrix}$$

It is evident from above matrix that correlation between prices (retail, wholesale and producers) is high in case of beef, pork and lamb whereas there is not very strong relation between producer and retail prices of poultry.

Correlation is higher for wholesale and producer price than retailer and wholesale or retailer and producers. The prices are most closely related for the lamb meat and have highest correlation among retail, wholesale and producer prices followed by beef and pork. Correlation is the highest between producer and wholesale price of pork (0.8687). High correlation in lamb could be due to local supply of whereas as other meats do not have such strong relation as these could be imported. High correlation between wholesale and producer's price also provides same indications. Wholesale and producer price of beef have high correlation with lamb prices whereas retail lamb price is correlated to wholesale and producer pork prices. Pork prices are correlated to producer poultry price.

GES algorithm (briefly described above) is applied using the TETRAD IV software to above correlation matrix and generated the graph given in figure 2. Figure 2 shows that retail price of poultry (RPPo) and wholesale beef prices (WBP) are two main source of information in contemporaneous time whereas producer's price of poultry (PPPo) and producer's price of pork (PPP) are the two main recipients of price information and acts as sink in market. Wholesale prices of pork, beef and lamb play important role in price dynamic in each of these meat systems as well as exchange information with other meat systems. Producer prices are affected by retail as well as wholesale price. Pork interacts with all other meats (lamb, beef and poultry) and information flows simultaneously in retail, wholesale and producers pork price. Retail price of lamb is main communicator between beef and other meats.

In sum, DAG shows that producer prices are impacted by wholesale prices for beef, lamb and pork. Wholesale prices also play an important role in retail prices of beef and pork. Retail lamb prices connect beef, lamb and pork. Poultry market is disjoint and there is no relation between the retail and producers price.

Figure 3 indicates dynamic response of each series to a one time shock in each series under the ordering of innovations as generated by the directed graph. Retail price of beef responds positively to wholesale and producer's price of beef and negatively to retail and producers' price of lamb as well as wholesale price of pork. Wholesale price of beef responds positively to producer's price of beef and negatively to retail and producers' price of lamb as well as wholesale price of pork. Producer's price of beef responds positively to wholesale price of beef but negatively to producer's price of lamb and wholesale price of pork.

Lamb prices responds to its own system (i.e. Retail price of lamb responds to wholesale and producer's price of lamb and vice-versa). Other meats have no impact on price of lamb.

Retail price of pork responds to producer's beef price, retail lamb price and wholesale pork price. Wholesale price of pork negatively responds to retail lamb and pork price. Producers price of pork positively responds to wholesale price of pork whereas negatively responds to retail and producer's price of lamb and retail price of pork.

Retail price of poultry shows little response to shocks from other meat prices whereas producer's price of poultry responds positively to wholesale and producer's price of beef whereas negatively to all lamb prices (retail, wholesale and producer's) and retail pork prices.

Historical decomposition of each series aids in understanding the effect of a particular event. Based on the estimated form of equation (3), where innovations have been orthogonalized using the structural model given in figure 2, we can decompose each series at any date into historical shocks (innovations) in each series of the VAR (we converted the ECM into its levels VAR representation). This provides us an understanding how price behaves in a neighborhood of particular events of interest (here two BSE and one FMD events).

Our historical decomposition of each series in a neighborhood of these events begins two months before event occurred and runs out for three months following the event. This provides us the behavior of meat price before the event and after the event. Table 9, 10 and 11 contains deviation in actual prices for given series from forecasted price based on the historical data for BSE88, BSE96 and FMD00, respectively.

Table 9 analyzes the impact of BSE88 on meat prices. Beef prices were not affected by the BSE 1988 event. Retail and wholesale price of beef remained strong after event but producer's price start weakening and became negative in Oct 1988. This is expected as BSE 1988 announcement focused on killing the infected animals. Other meats did not respond to this event and were behaving in much the same way as they were before the announcement.

Table 10 provides an insight about BSE96 event. It is clear from table that beef prices (retail, wholesale and producers) were stronger (positive deviation means that actual price are higher than forecasted prices) for January and February 1996 (before the event). In month of March 96, wholesale and retail prices of beef were still strong but producers' price declined. After March, 96, prices of beef declined substantially hitting producers, wholesalers as well as retailers. Retail prices declined maximum in the month of April 1996 whereas wholesale and producer's price keep on declining till June 96. During same time April 96 to June 96, other meat prices (lamb, pork and poultry) increased. Lamb prices were the main beneficiary of this event as it gained maximum but other meats also gained. Poultry prices declined in April, 96 but gained in next month (May 96) and this reduction in April 96 could be due to ban of meat and bone meals in pig and poultry ration and this also explains why pork did not gain as much as lamb prices. Gain in other meat prices declined over next three months (April-June 96) whereas beef prices (retailers, wholesale and producer) kept declining during the same period but beef retail prices declined less compare wholesale and producers price and could be attributed to import of beef from other countries. This table also indicates the market power of wholesalers in the meat industry as they gained more than producers (sometime retailers also) when prices are high and when it is negatively they are least impacted.

Table 11 indicates the impact of the FMD00 event. FMD impacted all the animals (except poultry) but with different level of severity. Table 12 provides number of FMD infected animals slaughtered in 2003. It is clear from table 12 that sheep were most severely impacted followed by cattle and then pigs. These animals were slaughtered in February and March 2001. The price deviations were same as they were before the event with a noticeable difference in lamb where prices were less than the forecasted prices but with this event they start going up. This could be attributed to shortage of the lamb meat due to mass culling but after March 2001 the prices have fallen substantially. Since FMD does not have any impact on human health so prices mainly reacted to supply of the meat.

Figures 4, 5, 6 and 7 show the impact of each event on beef, lamb, pork, and poultry system.

SUMMARY AND CONCLUSONS

Heath concerns on the human food supply chain are of interest to everyone. Recent history of meat products in the United Kingdom provide us with evidence on how prices at various stages of the meat supply chain respond to BSE and FMD events. This study focused on the dynamic relationship between beef, pork, lamb and poultry prices using cointegration, error correction model, and directed acyclical graphs for the period January 1985 to December 2002 at retail, wholesale and producer's level.

Using historical decomposition function we explored the impact of three events: BSE88, BSE96 and FMD00. The paper shows clearly that these events did not have the same effect on meat prices. BSE88 mainly relates to slaughtering of BSE infected cattle and affected only producer's price of beef. Other meats were not impacted by this event. The BSE96 event dealt with ban of ruminant protein in meals of pigs and poultry and announcement related to transmission to humans in variant form. This severely impacted the beef sector but prices in other meats increased over this second event period. Lamb was the maximum beneficiary from this event as it was not involved in BSE; whereas pork and poultry gained but not to such a large extent. This also shows that wholesalers have some market power in case of these negative events. The FMD00 event dealt with slaughtering of animals. Sheep were the most affected animal in this FMD episode. The event did not affect the market. Prices at retail continued behaving in much the same manner as before the event; however, slaughter of sheep (evidently) caused some supply problems in lamb and wholesale and producer prices increased.

This paper provides us a unique prospective of these health related events. The events did not have the same impact on meat prices across different levels of the supply chain and across events. Replication of this study using data measured at a higher frequency data (daily prices) would be useful in providing a better understanding of these events in short as well as long term. This study can not necessarily be generalized for other countries (like USA) due to difference in preferences, production techniques.

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FIGURE 1: PLOT OF MEAT PRICES AT RETAIL, WHOLESALE AND PRODUCER'S LEVEL FOR PERIOD JANUARY 1985 TO DECEMBER 2002.

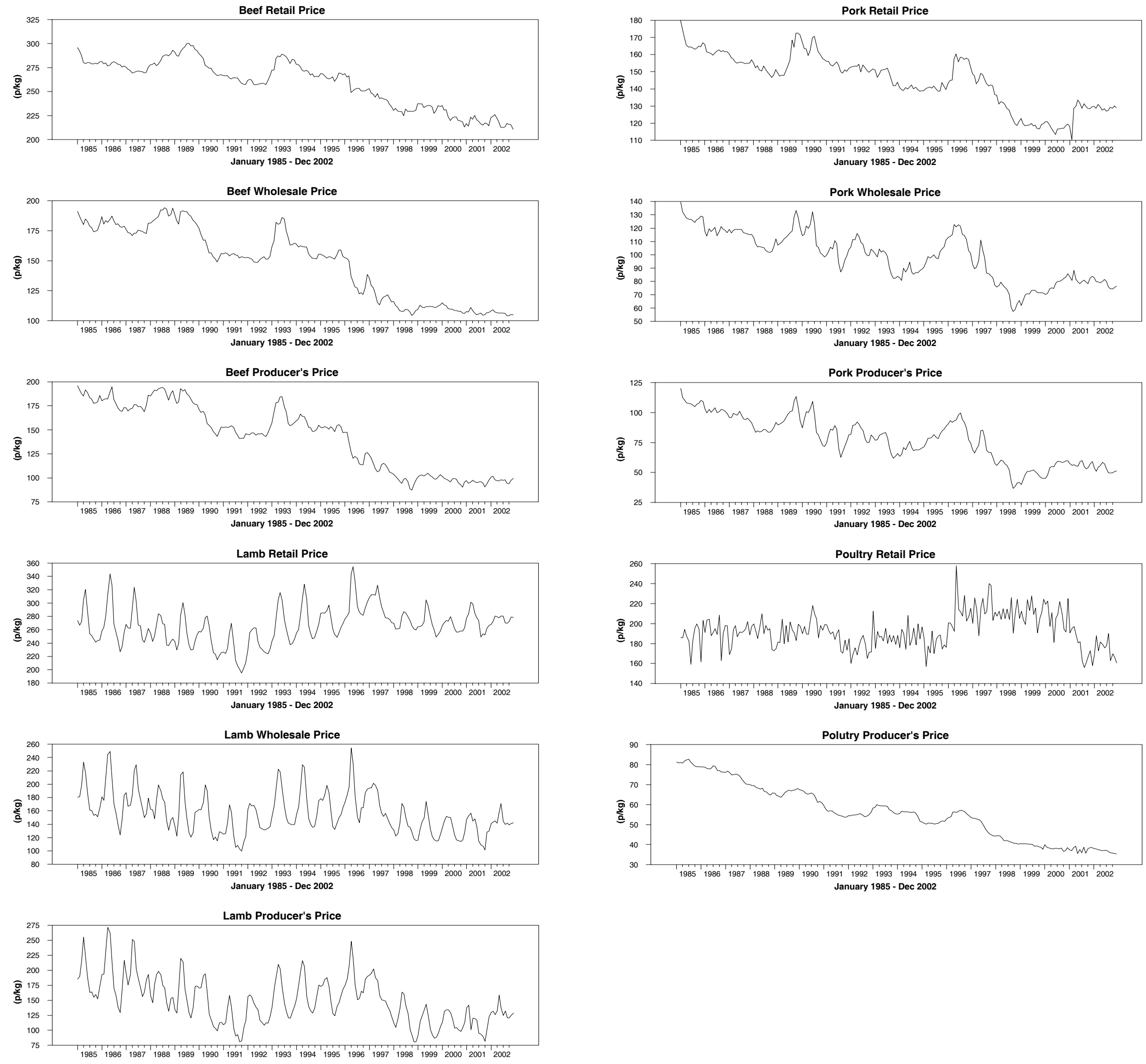


FIGURE 2: DIRECTED GRAPH ON INNOVATION FROM THE ELEVEN MEAT PRICE SERIES

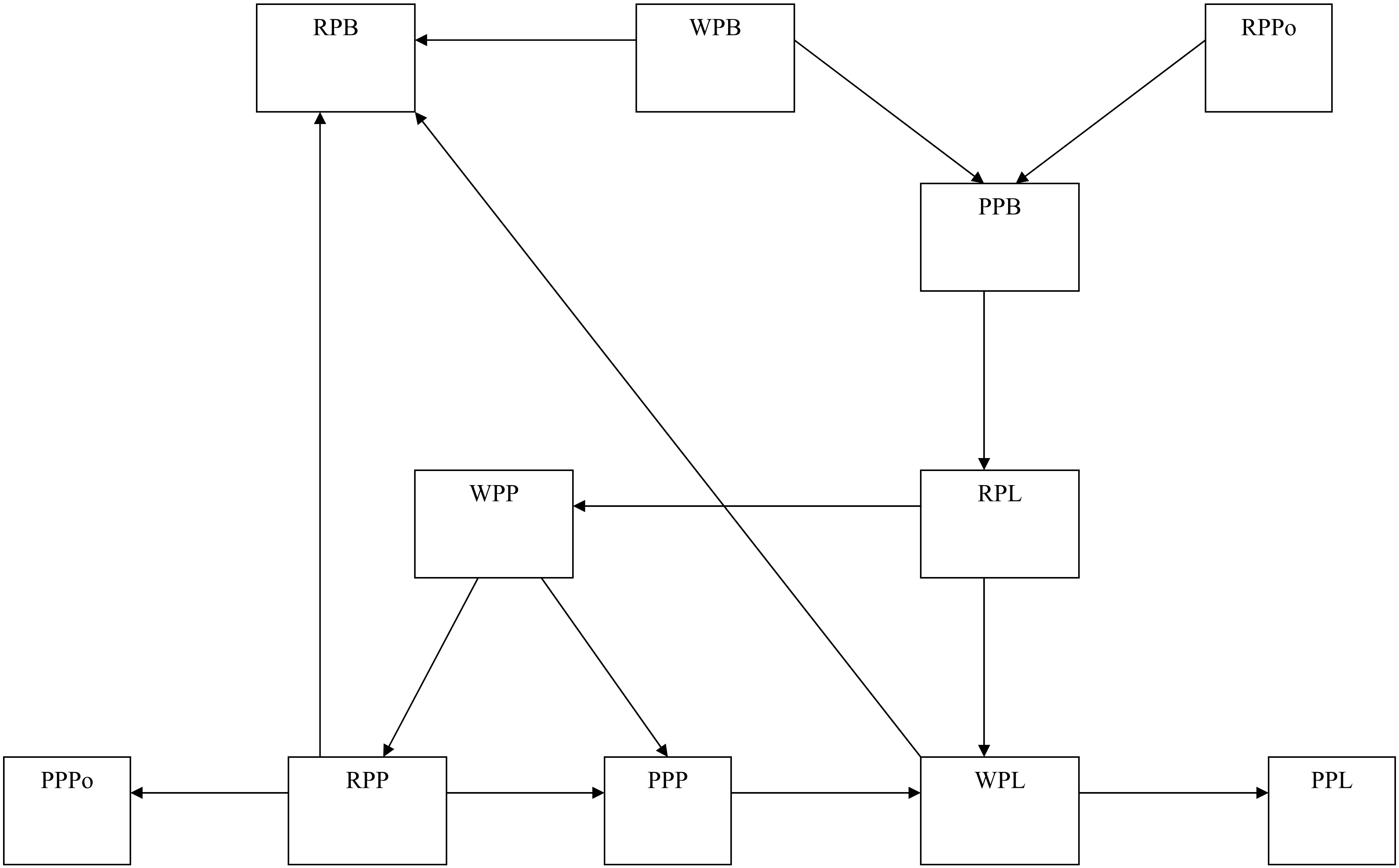


FIGURE 3: RESPONSE OF EACH PRICE SERIES TO A ONE-TIME SHOCK IN EACH SERIES

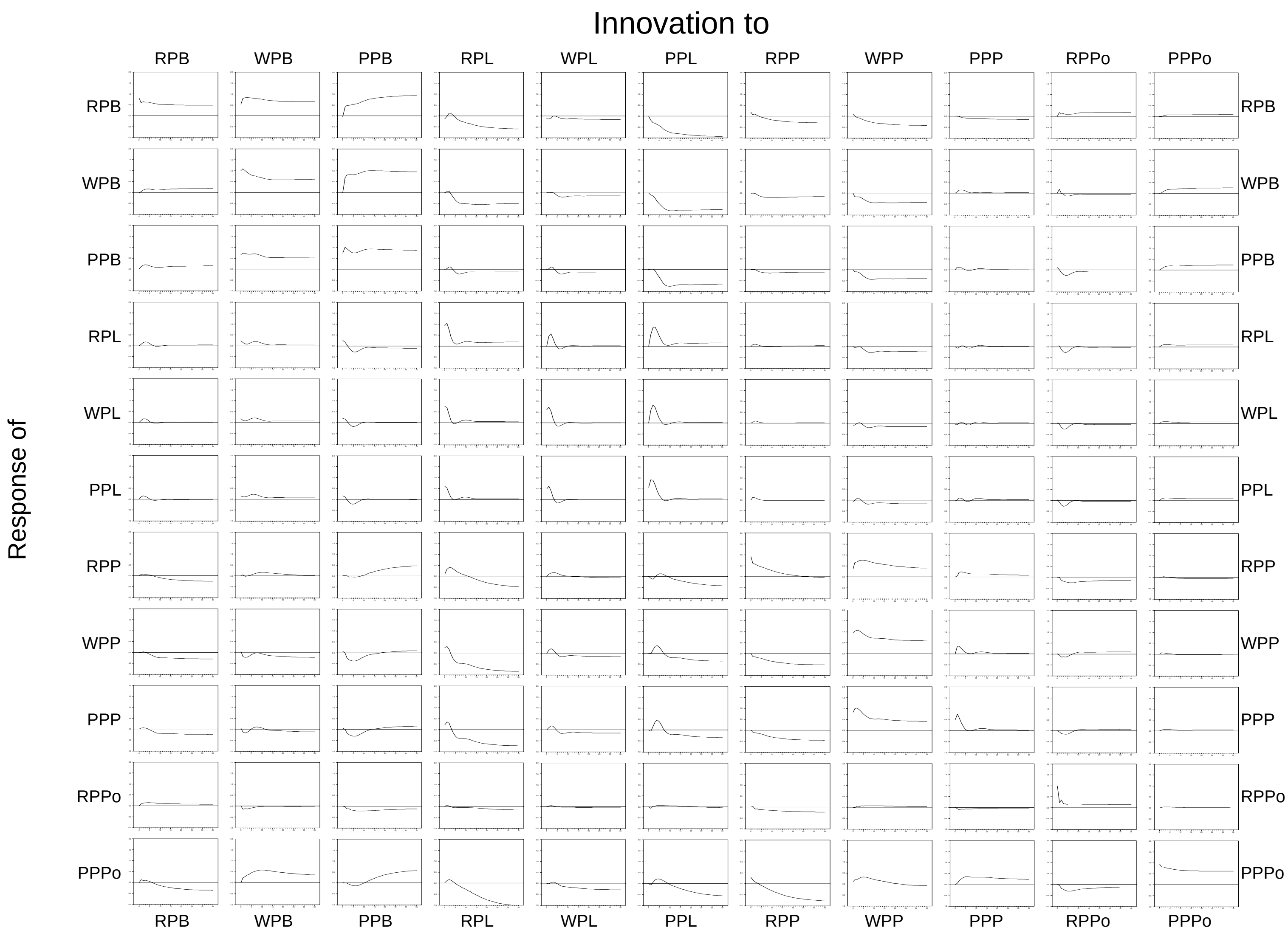
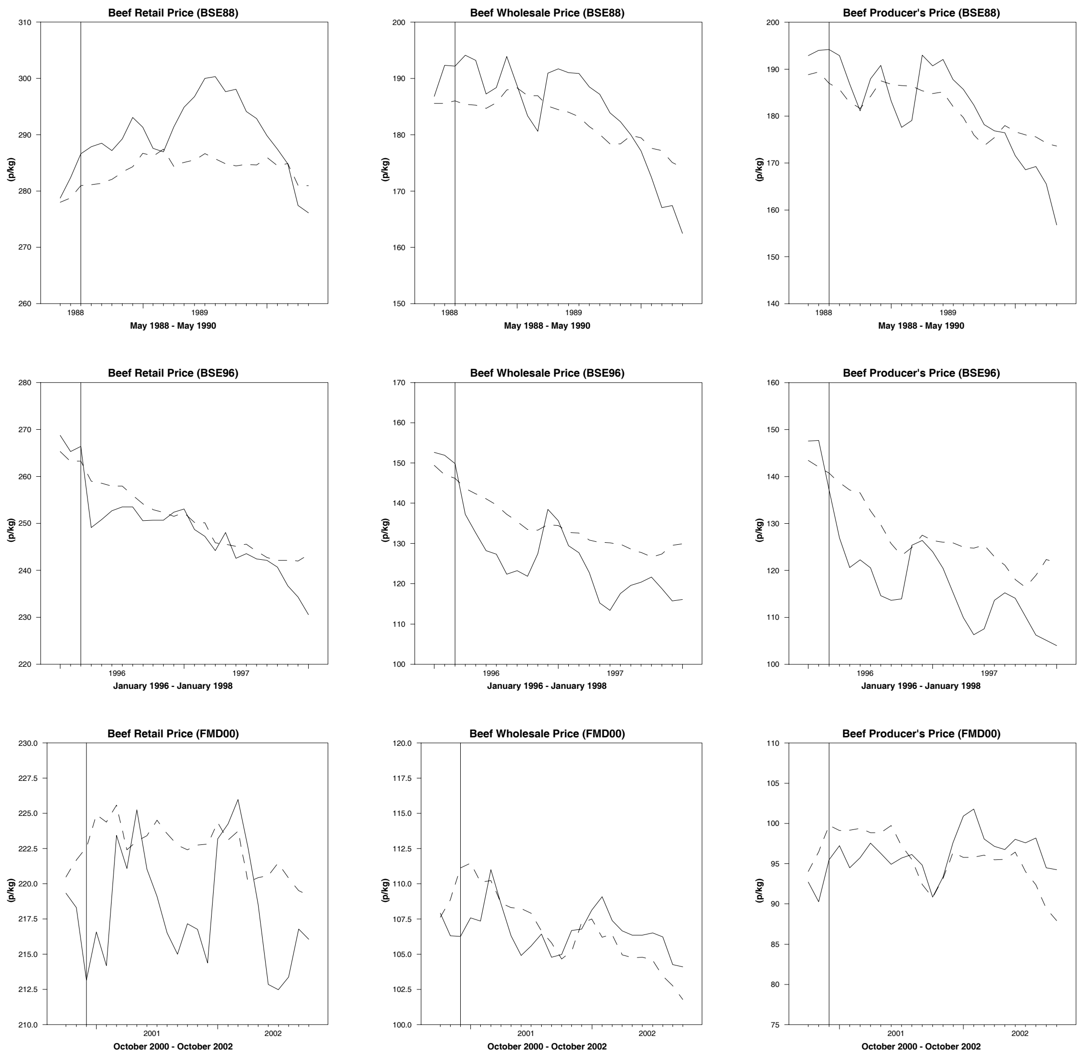


FIGURE 4: IMPACT OF BSE88, BSE96 AND FMD00 ON BEEF SECTOR

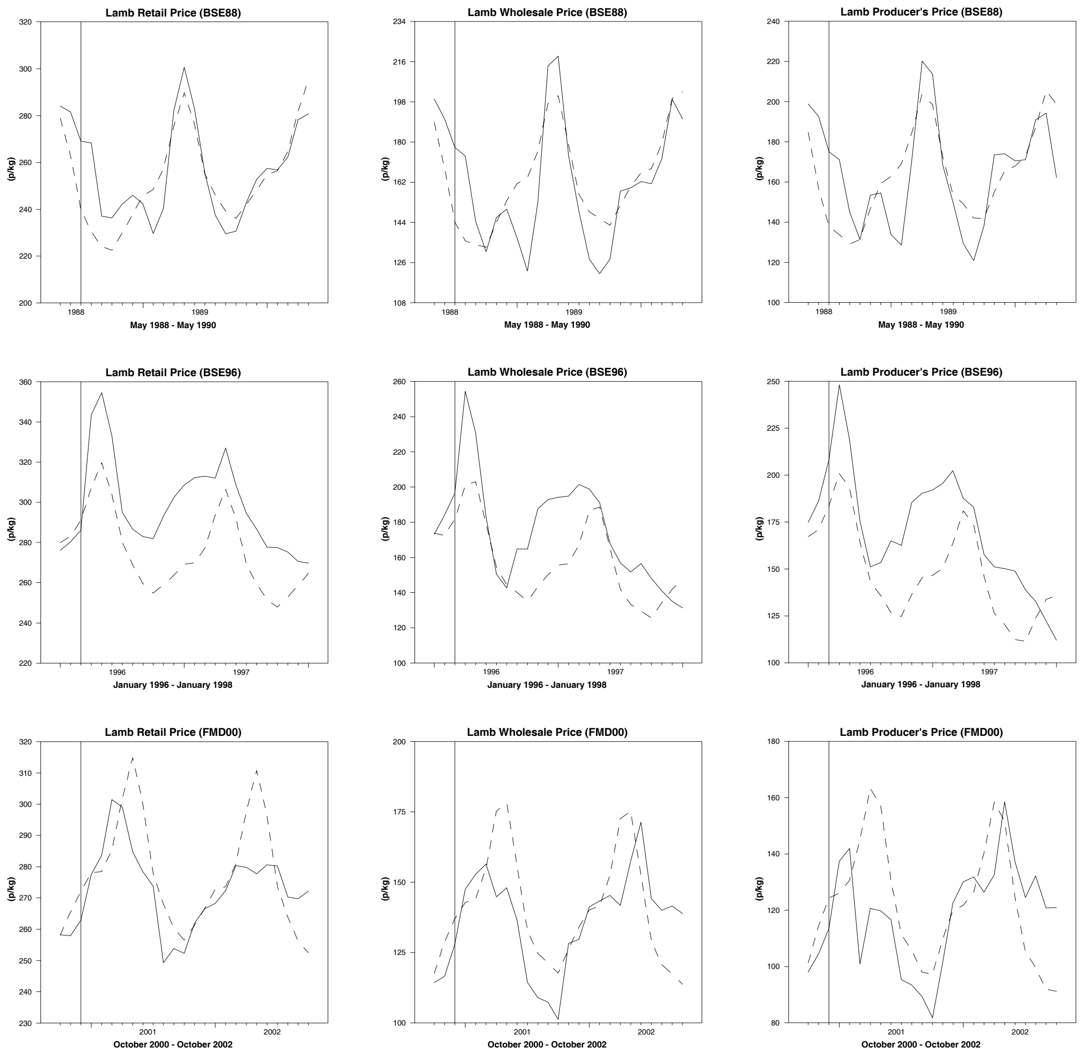


Key: Actual Price ____________

Forecasted Price Before the Event - - - - - - - - - - - -

Vertical Line is the Event of Interest |

FIGURE 5: IMPACT OF BSE88, BSE96 AND FMD00 ON LAMB SECTOR

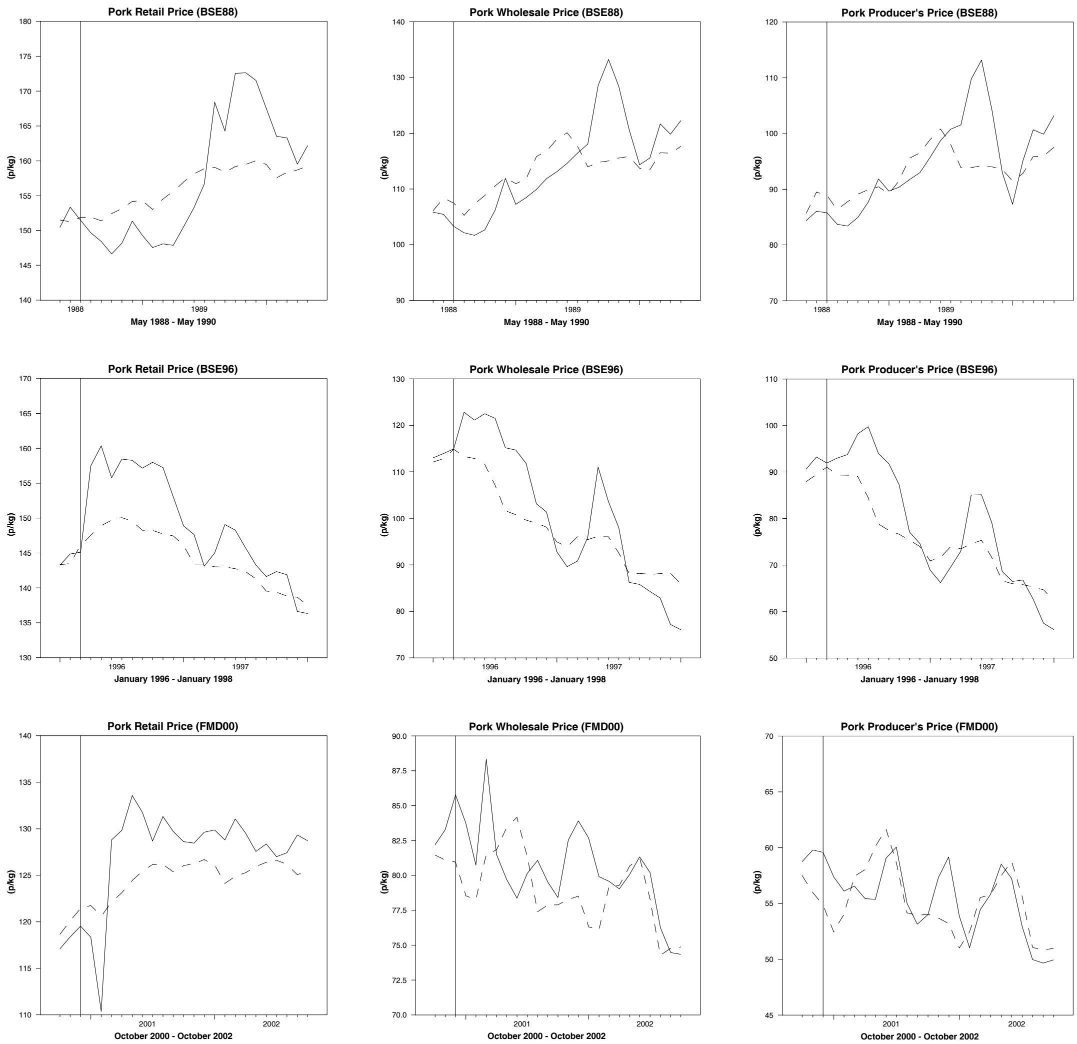


Key: Actual Price ___________

Forecasted Price Before the Event - - - - - - - - - - - -

Vertical Line is the Event of Interest |

FIGURE 6: IMPACT OF BSE88, BSE96 AND FMD00 ON PORK SECTOR

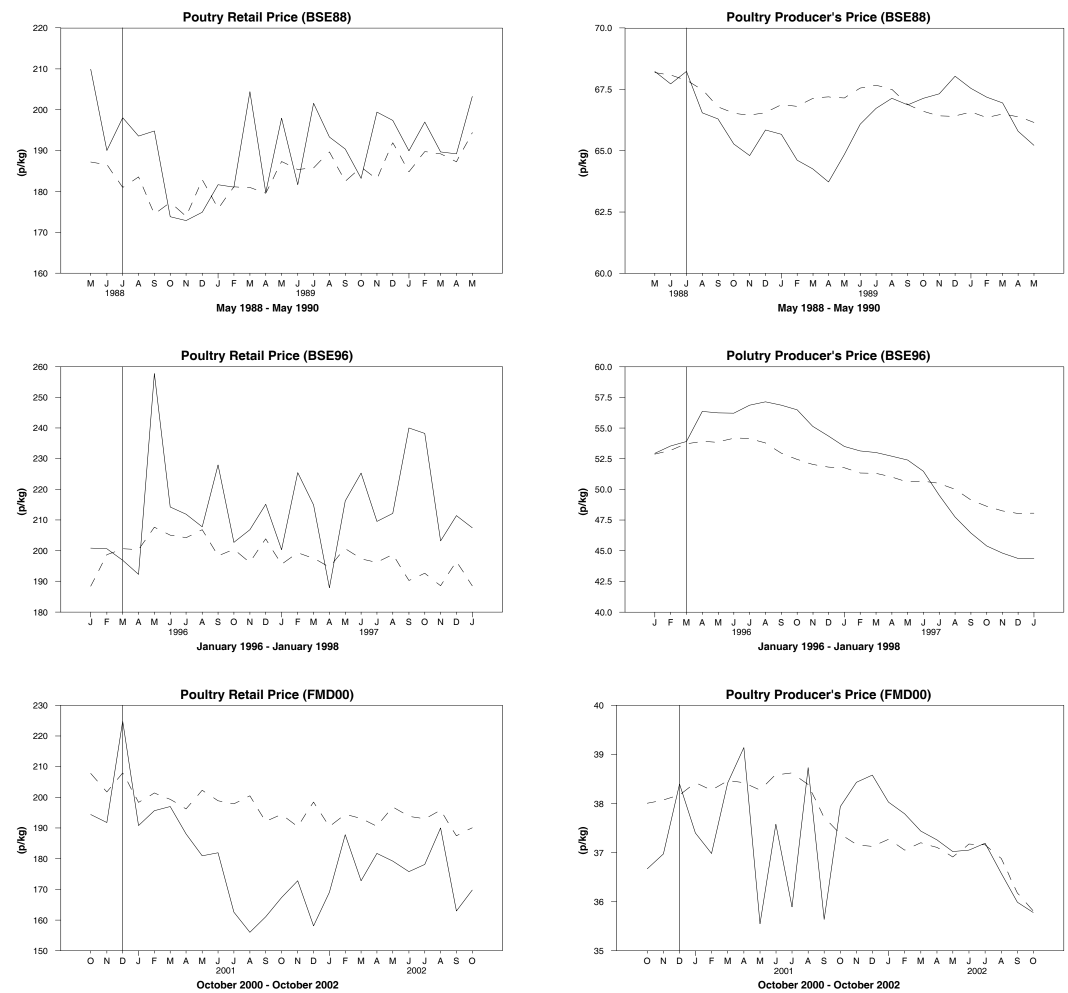


Key: Actual Price __________

Forecasted Price Before the Event ------------

Vertical Line is the Event of Interest |

FIGURE 7: IMPACT OF BSE88, BSE96 AND FMD00 ON POULTRY SECTOR



Key: Actual Price ___________

Forecasted Price Before the Event ------------

Vertical Line is the Event of Interest |

TABLE 1: MAJOR EVENTS RELATED WITH BSE

Time Line	Event
November 1986	BSE first recognized and defined in Britain
July 1988	Britain announced that all cows known to be infected with BSE will be destroyed as a precautionary measure.
November 1989	Britain banned human consumption of certain offal including brain, spinal cord, thymus, spleen and tonsils. US banned import of live ruminants including cattle, sheep, bison and goats from countries where BSE is known to exist in native cattle.
September 1990	European commission banned import from Britain of cattle over six months old. Banned meals derived from specified bovine offal.
December 1993	Beef cow in Canada diagnosed with BSE. It was imported from Britain in 1987.
July 1994	EU approved proposal to ban export of meat, containing bones, from herds that had not been free of BSE for six years instead of two.
January 1996	Western Blotting and immunocytochemistry techniques tests were carried out along with histopathology for all cases to remove any kind of uncertainty in finding BSE.
March 1996	Japan banned import of meat and bones meal from Britain and McDonald suspended the sale of beef products in its restaurants. Banned ruminant protein in the form of meat and bone meals in pig and poultry rations. EU banned British beef and beef products.
August 1996	Britain's agriculture ministry confirmed that mad cow disease can be passed from cow to calf and also admitted that BSE could be transmitted to humans in a variant form of Creutzfeldt-Jakob disease (vCJD).
July August 1997	Illegal shipment of British beef found in various EU countries.
August 1997	FDA (in USA) prohibited feeding of most mammalian protein to ruminants.
December 1997	Britain banned the sale of un-boned beef as a precautionary move to stop the risk of mad cow disease.
January 1998	Britain banned sale and import of all beef-on the bone.
August 1999	Export ban on British beef is lifted after 3.5 years.
October 1999	European commission gave British beef as a clean bill of health.
June 2000	A BSE was found in a cow which was born after the measures were introduced to eradicate mad cow disease in Britain.
December 2000	US prohibit all imports of rendered animal's protein products from Europe.
September 2001	First case of mad cow disease diagnosed in Japan, first outbreak in Asia.
April 2002	First case of ariant Creutzfeldt-Jakob disease (vCJD), the human form of mad cow disease reported in USA.
August 2002	A Canadian man died n Saskatchewan from vCJD. First death in Canada.
2003	European Union approved five tests to evaluate BSE on adult cattle

	showing clinical sign of BSE.
January 2003	WHO warned the spread of BSE in Central and Eastern Europe and Southeast Asia due to contaminated feed was exported to these countries.
May 2003	Second case of BSE found in Canada. First after 1993.
May 2003	US temporarily banned import of cattle, beef and other ruminants and ruminant products from Canada.
May 2003	Australia, Japan, South Korea, Taiwan, Mexico, Russia, Singapore, Chile, China, Brazil and Indonesia other nations banned import of Canadian beef.
November 2003	Ninth case of mad cow disease confirmed in Japan.
December 2003	At least one conformed case of BSE found in Washington State. Japan banned US beef over the fears of mad cow disease.
January 2004	FDA banned cattle blood in livestock feed and certain cow parts from dietary supplements and cosmetics.

TABLE 2: MAJOR EVENTS RELATED WITH FOOT AND MOUTH DISEASE (FMD)

Time Line	Event
June 1990	EU member states are obliged to prohibit the use of FMD vaccine
1998	EU meeting of Agriculture Ministers informed of European Commission's plans to abolish livestock farming in the UK, and convert it to an area of arable farming only.
End of 2000	FMD viruses are found 'missing' in a laboratory for biological warfare in Porton Down.
January 2001	Sheep which were shipped from Wales to France were found to have foot-and-mouth antibodies.
20 February 2001	An official announcement, named a farm in Brentwood, Essex, as the place where FMD originated.
21 February 2001	First official announcement. The export of cattle, sheep, goats and pigs is officially stopped.
24 February 2001	Official order to cull thousands of animals. Mass burning of culled animals starts.
26 February 2001	Spread of FMD in Wales. 11,000 animals are burned.
1 March 2001	2 confirmed cases of FMD in Scotland and one case in Northern Ireland. There are 31 confirmed cases in England.
4 March 2001	Number of affected farms in Great Britain rises to 53. 45,000 animals culled.
5 March 2001	Cases suspected in France. The export of cloven-hoofed animals is prohibited in France.
10 March 2001	Number of confirmed cases rises to 135. 82,000 animals culled.
13 March 2001	First confirmed FMD cases in Mayenne in the west of France.
17 March 2001	Farmers declare war on the British Government's mass culling program.
20 March 2001	The army is brought in to assist with the burning of the culled animals.
21 March 2001	First confirmed cases of FMD in the Netherlands. EU bans exports.
22 March 2001	First case of FMD in the Republic of Ireland.
25 March 2001	Mass burial pits dug at the Great Orton airfield, near Carlisle.
29 March 2001	A report by biological weapons specialist Professor Martin Hugh-Jones – which had been kept secret – suddenly appears when EU veterinary experts permit emergency vaccinations of 180,000 cattle to prevent the spread of the disease. The study supposedly proves that vaccinations do not contribute to controlling the disease.
10 April 2001	EU Agriculture Ministers reject mass vaccinations against FMD
11 April 2001	21 cases of FMD in the Netherlands.
15 April 2001	Second case of FMD in Northern Ireland.

TABLE 3: TEST STATISTICS FOR DICKEY FULLER (DF) AND AUGMENTED DICKEY FULLER (ADF) ON LEVELS FOR THE PRICE SERIES

Markets	DF	ADF	LAGS
Retail Prices Beef (RPB)	-0.8945	-1.87854	2
Wholesale Price Beef (WPB)	-0.76577	-0.6865	1
Producers Price Beef (PPB)	-1.02453	-0.86937	1
Retail Prices Lamb (RPL)	-4.01824	-3.11996	8
Wholesale Price Lamb (WPL)	-4.26324	-0.66076	10
Producers Price Lamb (PPL)	-3.6143	-0.53154	10
Retail Prices Pork (RPP)	-2.05495	-1.79141	1
Wholesale Price Pork (WPP)	-2.22366	-1.62403	1
Producers Price Pork (PPP)	-2.02572	-2.17794	1
Retail Prices Poultry (RPo)	-7.64628	-2.34604	3
Producers Price Poultry (PPo)	-1.20732	-1.17936	2

Note: The columns under the heading “DF” refers to the Dickey-Fuller test on the null hypothesis that the price data from the market class listed in the far left-hand-most column are non-stationary in levels (non-differenced data). The test for each series of price data is based on an ordinary least squares regression of the first differences of prices from each market on a constant and one lag of the levels of prices (undifferenced prices) from each class. The t-statistic is associated with the estimated coefficient on the lagged levels variable from this regression. Under the null hypothesis the statistic is distributed in a non-standard t. Critical values are given in Fuller (1976). The 5% critical value is –2.89. We reject the null for observed t values less than this critical value.

The columns listed under the heading “ADF” refer to the Augmented Dickey Fuller test associated with the null hypothesis that price data from the class listed in the far left-hand-most column are non-stationary in levels (same null as above). Here the test is of the same form as that described above, except that k lags of the dependent variable are added to the right-hand side of the DF regression. Here the value for k is determined by minimizing the Schwarz-loss metric on values of k ranging from 1 to 12. [The ADF regression was run with lags of the dependent variable ranging from one lag to twelve lags. The Schwarz loss metric was minimized at the value given in the column headed by the label “k”.] Again the critical value of the t-statistic is –2.89 and we reject for values of the calculated statistic less than this critical value.

TABLE 4: TRACE TESTS ON ORDER OF COINTEGRATING VECTORS ON MEAT MARKET IN UK

	Constant Within Cointegration Space			Constant Outside Cointegration Space		
R	**T**	**C**	**D**	**T**	**C**	**D**
0	464.327	289.705	R	449.584	276.368	R
1	372.898	244.562	R	358.308	232.600	R
2	295.008	203.340	R	280.649	192.304	R
3	231.134	165.732	R	217.364	155.748	R
4	173.883	132.004	R	160.390	123.039	R
5	117.397	101.838	R	105.484	93.918	R
6	76.072	75.737	R	64.249	68.681	R
7	45.514	53.423	F#	37.751	47.208	F
8	20.156	34.795	F	12.645	29.376	F
9	10.088	19.993	F	6.307	15.340	F
10	4.315	9.133	F	1.422	3.841	F

Note: The number of cointegrating vectors (R) is tested using trace test with constant within and outside the cointegrating vectors. The test statistic (T) is calculated trace test, associated with the number of cointegrating vectors given in the left-hand-most column. The critical values (C(5%)) are taken from Table B.2 (within) and Table B.3 (outside) in Hansen and Juselius (1995, p.80-81). The tests results presented in columns marked by an asterisk are associated with a constant within the cointegrating vectors. The un-asterisked columns are associated with tests on no constant in the cointegrating vectors, but a constant outside the vectors. The column labeled "D" gives our decision to reject (R) or fail to reject (F), at a 5 per cent level of significance, the null hypothesis of the number of cointegrating vectors ($r=0$, $r \leq 1$, $r \leq 2$,etc).
Following Johansen (1992), we stop testing at the first "F" (failure to reject) when starting at the top of the table and moving sequentially across from left to right and from top to the bottom. The symbol (#) indicates the stopping point. Here we fail to reject the hypothesis that we have 7 or less cointegrating vectors with constants in the cointegrating vectors.

TABLE 5: TEST FOR STATIONAIRTY WITH SEVEN COINTEGRATION VECTOR

Markets	Chi-squared	Sig. Value	Decision
Retail Prices Beef (RPB)	18.46	11.07	R
Wholesale Price Beef (WPB)	18.85	11.07	R
Producers Price Beef (PPB)	19.01	11.07	R
Retail Prices Lamb (RPL)	18.28	11.07	R
Wholesale Price Lamb (WPL)	17.85	11.07	R
Producers Price Lamb (PPL)	17.51	11.07	R
Retail Prices Pork (RPP)	17.96	11.07	R
Wholesale Price Pork (WPP)	17.89	11.07	R
Producers Price Pork (PPP)	18.00	11.07	R
Retail Prices Poultry (RPPo)	18.00	11.07	R
Producers Price Poultry (PPPo)	17.70	11.07	R

Note: Tests are on null hypothesis that the particular series listed in the far left hand column is stationary. The critical value indicates the chi-squared critical value at 5 percent significant level with one degree of freedom. The decision column relates to the decision to reject (R) or fail to reject (F) the null hypothesis. We reject the null hypothesis in all cases.

TABLE 6: TEST OF EXCLUSION OF EACH PRICE SERIES FROM COINTEGRATION SPACE

Markets	Chi-squared	Sig. Value	Decision
Retail Prices Beef (RPB)	23.77	14.07	R
Wholesale Price Beef (WPB)	21.36	14.07	R
Producers Price Beef (PPB)	18.45	14.07	R
Retail Prices Lamb (RPL)	45.27	14.07	R
Wholesale Price Lamb (WPL)	51.17	14.07	R
Producers Price Lamb (PPL)	54.85	14.07	R
Retail Prices Pork (RPP)	16.85	14.07	R
Wholesale Price Pork (WPP)	21.75	14.07	R
Producers Price Pork (PPP)	33.00	14.07	R
Retail Prices Poultry (RPPo)	27.00	14.07	R
Producers Price Poultry (PPPo)	24.79	14.07	R

Note: Tests are on null hypothesis that the particular series listed in the far left-hand column is not in the cointegration space. The heading "Decision" relates to the decision to reject (R) or fail to reject (F) the null hypothesis at a 5 percent level of significance. Under the null hypothesis, the test statistic is distributed chi-squared with seven degrees of freedom (exclusion from the entire cointegrating space would imply even zero restrictions, as, based on results from table 4, where there are seven cointegrating vectors).

TABLE 7: TEST OF WEAK EXOGENITY OF EACH PRICE SERIES (GIVEN SEVEN COINTEGRATION VECTORS)

Markets	Chi-squared	Sig. Value	Decision
Retail Prices Beef (RPB)	12.44	14.07	F
Wholesale Price Beef (WPB)	19.82	14.07	R
Producers Price Beef (PPB)	19.63	14.07	R
Retail Prices Lamb (RPL)	34.38	14.07	R
Wholesale Price Lamb (WPL)	45.88	14.07	R
Producers Price Lamb (PPL)	29.42	14.07	R
Retail Prices Pork (RPP)	14.44	14.07	R
Wholesale Price Pork (WPP)	16.60	14.07	R
Producers Price Pork (PPP)	19.00	14.07	R
Retail Prices Poultry (RPPo)	25.00	14.07	R
Producers Price Poultry (PPPo)	23.86	14.07	R

Note: Tests are on null hypothesis that the particular series listed in the far left column is weakly exogenous, i.e., that series does not respond to perturbations in the cointegrating space. The heading "Decision" relates to the decision to reject (R) or fail to reject (F) the null hypothesis at a 5 percent level of significance. Under the null hypothesis, the test statistic is distributed chi-squared with seven degrees of freedom.

TABLE 9: IMPACT OF BSE88 TO MEAT PRICES

Time	RPB	WPB	PPB	RPL	WPL	PPL	RPP	WPP	PPP	RPPo	PPPo
May-88	0.72	1.27	4.06	5.04	10.30	14.06	-1.01	-0.27	-1.25	22.74	0.05
Jun-88	3.68	6.75	4.58	18.69	22.40	35.89	2.05	-2.88	-3.44	3.46	-0.37
Jul-88	5.61	6.12	7.16	29.00	33.48	37.20	-0.39	-4.17	-3.08	17.12	0.36
Aug-88	6.72	8.72	7.19	37.90	37.86	37.26	-2.27	-3.13	-2.67	9.94	-0.95
Sep-88	7.11	7.94	3.83	13.01	10.33	15.99	-2.98	-5.70	-4.35	20.36	-0.50
Oct-88	5.11	2.54	-0.48	13.65	-2.04	-0.07	-5.79	-6.16	-4.16	-3.48	-1.25

TABLE 9: IMPACT OF BSE96 TO MEAT PRICES

Time	RPB	WPB	PPB	RPL	WPL	PPL	RPP	WPP	PPP	RPPo	PPPo
Jan-96	3.41	3.22	4.14	-3.73	-0.42	7.63	-0.03	0.88	2.67	12.39	0.07
Feb-96	2.08	4.85	5.69	-2.81	11.66	15.25	1.38	1.15	3.82	1.96	0.36
Mar-96	3.10	3.64	-3.57	-5.05	14.60	24.67	-0.96	0.09	0.93	-3.78	0.18
Apr-96	-9.89	-6.47	-11.72	36.18	53.29	47.31	9.95	9.51	3.59	-8.09	2.44
May-96	-7.73	-9.67	-16.48	35.00	27.79	25.64	11.50	8.28	4.44	50.11	2.39
Jun-96	-5.21	-12.86	-14.26	29.19	4.02	11.12	6.07	10.85	9.18	9.16	2.03

TABLE 11: IMPACT OF FMD00 TO MEAT PRICES

Time	RPB	WPB	PPB	RPL	WPL	PPL	RPP	WPP	PPP	RPPo	PPPo
Oct-00	-1.13	0.29	-1.32	0.16	-3.28	-3.34	-1.56	0.76	1.24	-13.47	-1.34
Nov-00	-3.36	-2.55	-6.19	-7.48	-12.25	-9.90	-1.72	2.15	3.81	-9.93	-1.10
Dec-00	-9.40	-4.87	-4.26	-9.29	-9.04	-10.86	-1.92	4.82	4.75	16.95	0.23
Jan-01	-8.34	-3.88	-1.88	-0.57	4.77	11.30	-3.41	5.21	4.91	-7.58	-1.03
Feb-01	-10.18	-2.78	-4.67	5.16	8.94	11.33	-10.21	2.46	2.04	-5.79	-1.29
Mar-01	-2.14	0.77	-3.67	15.89	1.60	-43.97	6.74	6.83	-0.89	-2.29	-0.05

Note: Above tables show deviation of price series for time mentioned on the left hand side of the column. The deviation is difference in actual price observed and forecasted price based on the historical data. The negative deviation shows that actual price is smaller than the forecasted price of that series based on the historical data.

TABLE 12: FMD INFECTED ANIMALS SLAUGHTERED IN UK IN YEAR 2001

			Animals attacked or slaughtered			
Year	**Counties**	**Outbreaks**	**Cattle**	**Sheep**	**Pigs**	**Other animals**
2001	33	2,030	594,000	3,310,000	142,000	2,000

[Source: Defra DCS database]