THE IMPACT OF FOOD SCARES ON PRICE TRANSMISSION IN INTER-RELATED MARKETS

Tim Lloyd[1], Steve McCorriston[2], Wyn Morgan[1] and Tony Rayner[1]

[1]School of Economics, University of Nottingham, Nottingham,
NG7 2RD, England, UK
[2]School of Business and Economics, University of Exeter, Exeter,
EX4 4PU, England, UK

ABSTRACT

This paper is concerned with the impact of the BSE crisis in the UK and focuses on price transmission between retail and farm prices. From a theoretical perspective we show that market power has an effect on price transmission between retail and farm prices following a demand shock. The empirical results suggest that the impact of a food scare on farm prices to be more than double that of retail prices, the direction of this effect being consistent with the impact of oligopoly dominating the effect (if any) of oligopsony. However, important in assessing the full impact of a food scare is the ability of consumers to switch into substitute products. This is also evident following the BSE crisis with the availability of substitutes contributing significantly to the overall impact on price adjustment.

Keywords: BSE crisis, price adjustment, impulse response functions

INTRODUCTION

In recent years, there has been growing concern about the health and safety of food. In some extreme cases, this has resulted in a food scare, with perhaps the most well known food scare in recent years being the BSE crisis in the UK. This lead to a dramatic fall in the consumption of beef following the link between bovine spongiform encephalopathy (BSE) and variant Creutzfeld-Jakob disease (vCJD). To date, it has been estimated that since the 1990s, 84 deaths can be linked vCJD in the UK. Not only did consumption of beef fall sharply in the UK, but British beef was banned from many countries including all Member States of the European Union.

Apart from the obvious concern with human health, an additional concern has been raised that the BSE crisis had a differential effect on UK retailers and farmers. Specifically, it was argued that while the BSE crisis reduced the consumption and price of beef, the decline in beef prices at the retail level was substantially less than that faced at the producer level resulting in a substantial increase in the retail:producer price spread. In this regard, attention was drawn to market concentration at the retail level with the 5 firm concentration ratio in UK food retailing being around 67 per cent (Dobson Consulting). The public concern with this issue was one of the primary reasons for the investigation by the UK anti-trust authorities, the Competition Commission, which noted one of their main concerns being to address:
'...[the] public perception of...an apparent disparity between farm-gate and retail prices...which is seen as evidence by some that grocer multiples were profiting from the crisis in the farming industry'. (Competition Commission, Vol. 1, p.3)

There has been little formal analysis of the potential differential impact of BSE on retail and farm-gate prices, the exception being Lloyd *et al.* who reported the result that beef prices at various stages of the food chain responded differently as a result of the BSE crisis. This paper extends that analysis in two important ways. First, we formally highlight the links between market power and price transmission following shocks to the retail demand function. In particular, the formal model deals with both oligopoly and oligopsony power. This fits with the concerns addressed by the Competition Commission in that it was not only concerned with horizontal market power but also the power exerted by food retailers vis-à-vis their suppliers.

Second, in determining the impact of BSE on retail and producer markets, we also acknowledge the potential links between beef and substitute meats at the retail level.

This is an important issue not least since both prices and consumption of substitutes rose in the wake of the BSE crisis. For example, as beef consumption fell consumption of lamb, pork and poultry all increased. Clearly, in fully evaluating the impact of a food scare on a particular marketing chain, it is important to account both for the vertical links between stages in the marketing chain of direct concern as well as the horizontal links between related markets at the retail level, since these could also have an impact on the overall assessment. Consequently, although this paper focuses on the BSE crisis in the UK, it has broader lessons for tying in the links between market power and price transmission in the presence of both oligopoly and oligopsony power. In addition, in contrast to most theoretical and empirical studies of price transmission, this paper encompasses the interaction between related markets rather than taking a specific market focus. Our results show that the impact of BSE on the beef market was substantially influenced by the substitution possibilities into other meats. Moreover, the results are consistent with the predominant role of oligopoly power at the retail level.

The paper is organised as follows. In section 1 we summarise briefly the literature on food scares and how the focus of this paper differs from this extant literature. We also present an overview of the development of the UK BSE crisis over the 1990s. The theoretical framework for identifying the varying impact on retail and farm-gate prices is developed in section 3. The econometric strategy is outlined in section 4 while in section 5 we present the empirical results. In section 6 we summarise and conclude

FOOD SCARES: RELATED LITERATURE AND UK EXPERIENCE

Related Literature

The literature dealing with food scare events is relatively thin, though early research can be dated back to the 1960s (see for example Brown)[1]. More recent is the paper by Smith *et al.* who analyse the impact of contaminated milk in Oahu, Hawaii in 1982. In their study, they focus upon the loss of sales due to contaminated milk and derive the appropriate level of compensation to producers. Focusing on the UK experience, Burton and Young investigate the impact of the BSE crisis on meat demand.

Also of relevance to the present paper is the way in which the food scare is measured and the methodology used. Smith *et al.* compile an index of press stories relating to the food scare in question. This index (separated into positive and negative news stories) is then incorporated into a regression model to evaluate the impact of the contamination event on sales. With the focus also on quantities (this time in terms of consumption), Burton and Young use an Almost Ideal Demand system to evaluate the impact of BSE where the impact of BSE is proxied by the use of a media index. Lloyd *et al.* also consider the impact of BSE in the UK meat sector, although their attention focuses upon price adjustment rather than the specification of a meat demand function[2]. In the present paper, we refine the media index used in the earlier work to take account of 'persistence' of health and safety information in the memory of consumers.

BSE in the UK

The existence of BSE in cattle was first identified in the UK in the 1980s, although at that time, it was not thought to have implications for human health. This view was challenged in the 1990s when it was discovered that that BSE could jump species following the death of a cat from BSE symptoms. However, there was continued re-assurance from the UK government and its Chief Medical Officer that British beef was safe to eat. When the first human death from vCJD occurred in 1995, official confirmation of the possible link between vCJD and BSE was announced.

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[1] There is of course a broader and related literature relating to food safety issues. Here our focus is on a well-defined and highly publicised food scare with a specific and serious outcome rather than a food safety issue that may lead to a healthier lifestyle. Examples of related papers on food safety include Brown and Schrader on cholesterol and diet due to the consumption of eggs, Chang and Kinnucan who extend the study of the cholesterol issue to the consumption of butter and Kinnucan *et al.* on the health issues and meat consumption. Ippolito and Mathios focus on advertising of health attributes and the consumption of ready-to-eat cereals.

[2] Other studies of the BSE crisis include MacDonald and Roberts who undertake a computable general equilibrium study and Henson and Mazzocchi who apply an event study to firms in the agribusiness.

Following this, consumption of beef fell immediately by 40 per cent and was accompanied by a ban on all UK beef sales in the other European Union states. To date there have been 84 deaths due to vCJD though the expectation is that this number could rise dramatically in the future particularly asvCJD has a long incubation period. Recent estimates put the total number of possible deaths to be in the thousands (New Scientist).

THE IMPACT OF FOOD SCARES ON PRICE TRANSMISSION

As noted in the introduction, one of the main concerns in the UK in the latter half of the 1990s was that the BSE crisis appeared to have a more significant impact on farmers than on food retailers. As a consequence, one of the main aspects of the Competition Commission enquiry into the food retailers was that market power at the retail level resulted in smaller declines in retail beef prices compared to those faced by farmers. In this section we outline a framework that is consistent with this argument. In addition, we also pay some attention to the role of related markets for substitute meats in determining the impact on the price transmission effect of the food scare.

To this end, we work with a variant of the equilibrium displacement model (Gardner, 1975) which accounts for both oligopoly and oligopsony power. Although we do not derive a formal test of market power, the framework used here is consistent with the public and Competition Commission concerns relating to the links between retailers and farmers in the UK. To simplify the algebra, we assume a quasi-fixed proportions technology as in Rogers and Sexton. This is not necessarily to be interpreted as a strong prior belief about the nature of the production technology in the UK beef sector but it confines our discussion to the nature of the public debate on vertical market linkages[3].

Economic Framework

The demand function for the processed product is given by:

$$Q = h(R, X) \tag{1}$$

where R is the retail price and X is the demand shifter. The supply function of the agricultural raw material is given by (in inverse form):

$$P = k(A) \tag{2}$$

where A is the quantity of the agricultural raw material.

For a representative firm, the profit function is given by:

$$\pi_i = R(Q)Q_i - P(A)A_i - C_i(Q_i) \tag{3}$$

where C_i is other costs and $Q_i = A_i / a$ where a is the input:output coefficient. The first order condition for profit maximisation is given by:

$$R + Q_i \frac{\partial R}{\partial Q} \frac{\partial Q}{\partial Q_i} = \frac{\partial C_i}{\partial Q_i} + aP + aA_i \frac{\partial P}{\partial A} \frac{\partial A}{\partial A_i} \tag{4}$$

or, in elasticity form:

$$R(1 - \frac{\theta_i}{\eta}) = M_i + aP(1 + \mu_i \varepsilon) \tag{5}$$

where η is the absolute value of the market price elasticity of demand for the processed product, θ_i is the conjectural elasticity of firm i in the processed market, $M_i (= \partial C_i / \partial Q_i)$ is the marginal cost of firm i, ε is the inverse of the price elasticity of supply of the agricultural raw material and μ_i is the conjectural elasticity of firm i in the raw material market.

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[3] This is not to deny that the inclusion of an elasticity of substitution would not play a role in determining the price transmission effect. However this does not fit with the public concerns addressed by the anti-trust authorities so for ease of modelling we employ the fixed proportions assumption here.

Using market shares as weights $(s_i = Q_i / Q)$ and summing over all firms, gives:

$$R(1-\frac{\theta}{\eta}) = M + aP(1+\mu\varepsilon) \tag{6}$$

where θ and μ are industry level (market share weighted) market power parameters and M is the industry-level marginal cost. Equation (6) can usefully be re-written as:

$$R = \lambda[M + aP(1+\mu\varepsilon)] \tag{7}$$

where $\lambda = \eta/(\eta-\theta)$.

Differentiating (7) with respect to a change an exogenous change in the demand function written in logarithmic form gives:

$$d\ln R = -\delta d\ln R + \psi\phi d\ln X + \frac{\alpha(1+\varepsilon\mu(1+\gamma))}{1+\alpha\varepsilon\mu} d\ln P \tag{8}$$

where, $\delta = \omega\theta/(\eta-\theta)$, $\omega = \partial\ln\eta/\partial\ln R$, $\psi = (-\theta/\eta-\theta)\varsigma$, $\varsigma = \partial\ln\eta/\partial\ln Q\big|R$, $\phi = \partial\ln Q/\partial\ln X$, $\gamma = \partial\ln\varepsilon/\partial\ln P$ and $\alpha = aP/(M+aP)$.

Noting from (1) and (2) that:

$$d\ln P = \varepsilon d\ln Q = -\varepsilon\eta d\ln R + \varepsilon\varphi d\ln X \tag{9}$$

equation (8) can be re-written as:

$$d\ln R = -\delta d\ln R + \psi d\ln X - \frac{\alpha\varepsilon\eta B}{D} d\ln R + \frac{\alpha\varepsilon B}{D} d\ln X \tag{10}$$

where, $B = (1+\mu\varepsilon(1+\gamma))$ and $D = 1+\alpha\varepsilon\mu$.

Using (9) and (10) we have:

$$d\ln R = \frac{\psi D + \alpha\varepsilon B}{D + \delta D + \alpha\varepsilon\eta B}\phi d\ln X \tag{11}$$

$$d\ln Q = \frac{D(1+\delta-\eta\psi)}{D + \delta D + \alpha\varepsilon\eta B}\phi d\ln X \tag{12}$$

$$d\ln P = \frac{\varepsilon D(1+\delta-\eta\psi)}{D + \delta D + \alpha\varepsilon\eta B}\phi d\ln X \tag{13}$$

where all variables are defined as above.

Proposition 1: Market power at the retail stage, either in form of oligopoly or oligopsony power, will result in a differential impact on farm level prices than on retail prices following an exogenous shift in the demand function. With oligopoly power, price transmission from retail to farm prices will increase; with oligopsony power, price transmission will decrease.

We can use (11) and (13) to show the impact of a demand shock on price transmission in the form of a 'pass-back' elasticity (ρ):

$$\rho = \frac{d\ln P/d\ln X}{d\ln R/d\ln X} = \frac{\varepsilon D(1+\delta-\eta\psi)}{\psi D + \alpha\varepsilon B} \tag{14}$$

Consider the case of no market power (i.e. $\mu = \theta = 0$). Then (14) simplifies to:

$$\rho^{c} = \frac{1}{\alpha} \qquad (14')$$

where the superscript c refers to the competitive case. In the case of oligopoly power but no oligopsony power (i.e. $\theta > 0, \mu = 0$), (14) can be re-written as:

$$\rho^{op} = \frac{\varepsilon(1+\delta-\eta\psi)}{\psi+\alpha\varepsilon} \qquad (14'')$$

where the superscript op refers to the oligopoly case. In the case of oligopsony power only (i.e. $\mu > 0, \theta = 0$), the pass-back elasticity is given by:

$$\rho^{os} = \frac{(1+\alpha\varepsilon\mu)}{\alpha(1+\varepsilon\mu(1+\gamma))} \qquad (14''')$$

where the superscript os refers to the oligopsony case.

The most straightforward way to see the impact of market power on retail and farm prices is to take representative values for the parameters in (14) and (14')-(14'''). The results are presented in Table 1. As can be seen from the table, with oligopoly in the retail sector, the price transmission elasticity increases compared to the competitive benchmark following an exogenous shift in the retail demand function. This implies that the price spread widens (narrows) when following a negative (positive) demand shock. With oligopsony power of retailers vis-à-vis farmers, price transmission will be expected to decrease relative to the competitive case, the implication here being that the spread will narrow (widen) following a negative (positive) shock that shifts the demand curve. The relevant issue for this paper is not to test formally for the presence of market power but to ascertain what we should expect from the results if one aspect of market power was to dominate the other.

Table 1. Impact of Market Structure on Price Transmission Following a Shift in the Retail Demand Function.

Market Structure	Price Transmission Elasticity
Competitive	1
Oligopoly Power only	1.6
Oligopsony Power only	0.8
Both Oligopoly and Oligopsony Power	1.4

Linear demand and supply functions were assumed which implies $\omega = 1+\eta$ and $\gamma = (1-\varepsilon)/\varepsilon$. Values for the remaining parameters were assumed to be: $M = 0$ (which implies $\alpha = 1$), $\varepsilon = 2.5$ (which implies a supply elasticity of 0.4), $\eta = 0.4$, $\theta = \mu = 0.25$

The other issue of interest in this paper is the role of inter-related markets in influencing the effect on retail and farm level prices following a shock to a specific market. As noted in the discussion above, as beef consumption fell following the BSE crisis, consumption of other meats increased. The most straightforward way to capture this multi-market effect is to follow the approach of Buse and Gardner (1987, p. 64) where the elasticity of demand for a specific product is re-interpreted as a total elasticity which in a multi-market context can be expressed as:

$$\eta_i^T = \eta_i - \sum_{\substack{i\neq j \\ j=1}}^{n} \eta_{ij}\zeta_{ij} \qquad (15)$$

where η_i^T is the total elasticity of good i, η_i is the partial elasticity, η_{ij} is the elasticity of substitution between product i and j and ζ_{ij} is the relationship between the prices of the substitute products ($= d\ln P_j / d\ln P_i$). Re-interpreting the absolute value of the elasticity of demand as the total elasticity of demand, the value of η in (14) and (14')-(14''') is reduced and leads to the following proposition.

Proposition 2: In the presence of substitute products at the retail level, the pass-back elasticity between farm and retail prices following a shock to the retail demand curve will increase.

To see the effect of reducing the elasticity of demand in the pass-back elasticity, consider once again equations (14')-(14'''). It is clear from this that changing the elasticity of demand will only matter in the presence of oligopoly power (mainly because the change in the elasticity of demand changes the elasticity of the firms' aggregate mark-up.) The role of substitutes does not matter in either the competitive or oligopsony cases (see equations (14') and (14''')). As above, the easiest way to infer the impact of the role of inter-related markets is to choose representative values for the parameters and derive the value of (14''). This result of this is reported in Table 2 where we have chosen alternative values for η keeping the value for the remaining parameters as in the previous example.

Table 2. The Effect on Price Transmission with Inter-related Markets following a Shock to the Retail Demand Function.

(Total) Elasticity of Demand	Pass-Back Elasticity with Oligopoly
$\eta = 0.3$	2
$\eta = 0.4$	1.6
$\eta = 0.5$	1.4

Values are derived using (14'') with all parameters values the same as in Table 1 except for alternative values for η. Linear functional form was also assumed.

It is clear from the above that the impact of introducing links between markets is to reduce the value of the total elasticity which in turn increases the differential effect on farm and retail prices following a shock to the retail demand curve. Intuitively this is due to the possibility that, with substitutes available, consumers will be more able to switch away from the food scare product.

To sum up, what we would expect from the empirical results is that if oligopoly power is the dominant characteristic of the UK food retailing sector, then farm level prices will fall by more than retail prices following the BSE crisis. In addition, in the presence of substitutes, the price depressing effect of the food scare should be exacerbated. We explore these issues in the remainder of the paper.

ECONOMETRIC METHODOLOGY

General

Applied to the current context, the theoretical model set out above demonstrates the differential effect on producer and retailer beef prices following the BSE crisis in the UK. Since prices are likely to be non-stationary and co-integrated it is appropriate to couch the empirical analysis in a vector autoregressive (VAR) framework. Consider a VAR(*p*) model:

$$\mathbf{x}_t = \mathbf{\Phi}_1 \mathbf{x}_{t-1} + \mathbf{\Phi}_2 \mathbf{x}_{t-2} + \ldots + \mathbf{\Phi}_p \mathbf{x}_{t-p} + \mathbf{\Psi} \mathbf{w}_t + \boldsymbol{\varepsilon}_t \qquad (16)$$

where $\mathbf{x}_t$ is a ($m \times 1$) vector ($1, 2, \ldots, i, j, \ldots, m$) of jointly determined I(1) variables, $\mathbf{w}_t$ is a ($q \times 1$) vector of deterministic and or exogenous variables and each $\mathbf{\Phi}_i$ ($i = 1, \ldots, p$) and $\mathbf{\Psi}$ are ($m \times m$) and ($m \times q$) matrices of coefficients to be estimated using a (t = 1, . . .T) sample of data. $\boldsymbol{\varepsilon}_t$ is a ($m \times 1$) vector of n.i.d. disturbances with zero mean and non-diagonal covariance matrix, $\mathbf{\Sigma}$.

The error correction representation of (16) is observationally equivalent but facilitates estimation and hypothesis testing since all terms are stationary. This re-parameterisation is given by:

$$\Delta \mathbf{x}_t = \boldsymbol{\alpha\beta}' \mathbf{x}_{t-p} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_i \Delta \mathbf{x}_{t-i} + \mathbf{\Psi} \mathbf{w}_t + \boldsymbol{\varepsilon}_t \qquad (17)$$

Attention focuses on the $(n \times r)$ matrix of co-integrating vectors, $\boldsymbol{\beta}$, that quantify the 'long-run' (or equilibrium) relationships between the variables in the system and the $(n \times r)$ matrix of error correction coefficients, $\boldsymbol{\alpha}$, elements of which load deviations from this equilibrium (*i.e.* $\boldsymbol{\beta}'\mathbf{x}_{t-k}$) into $\Delta\mathbf{x}_t$, for correction. The $\boldsymbol{\Gamma}_i$ coefficients in (17) estimate the short-run effect of shocks on $\Delta\mathbf{x}_t$, and thereby allow the short and long run responses to differ.

In the current context, $\boldsymbol{\beta}$ represents the linkages that bind the prices together in the long run. As section 2 demonstrates, these linkages occur either across substitutes at the retail level or between marketing stages for a single good. However, as Lütkephol and Riemers make clear, the coefficients of these vectors may be difficult to interpret when the variables in the system are characterised by strong knock-on and feedback effects, since they represent partial derivatives predicated on the *ceteris paribus* assumption. Where the variables are inter-related, impulse response analysis, which takes account of these interactions, provides a tractable solution since it delivers time profiles of the effect of hypothetical shocks to $\boldsymbol{\varepsilon}_t$ on the level of $\mathbf{x}_t$, thereby taking into account the knock-on and feedback effects that characterise the variables in a dynamical system such as (16). Furthermore, the *generalised impulse response function* (Pesaran and Shin) is particularly attractive for dynamic simulation since, unlike the orthogonalised impulse response function (Sims), it is invariant to the ordering of the variables in the VAR, and is thus unique. We use the generalised impulse response function to determine the impact on beef prices at both retail and farm levels and the price of substitute meats in the wake of the BSE crisis.

Decomposition Effects

We also wish to determine the impact of BSE on farm and retail beef prices in the presence of substitute markets. As such we can think about the impact of BSE being due to a direct effect (consumers reduce consumption of beef due to the food scare) and an indirect effect (consumers switch into substitute products). To decompose these effects, we rely on alternative specifications of the impulse response functions. Expressing the VAR in its moving average [MA(∞)] representation:

$$\mathbf{x}_\mathrm{t} = \boldsymbol{\varepsilon}_t + \mathbf{A}_1\boldsymbol{\varepsilon}_{t-1} + \mathbf{A}_2\boldsymbol{\varepsilon}_{t-2} + \ldots + \sum_{i=0}^{\infty} \mathbf{A}_i \boldsymbol{\Psi} \mathbf{w}_{t-i} \tag{18}$$

where the $(m \times m)$ coefficient matrices $\mathbf{A}_i$ are obtained according to:

$$\mathbf{A}_i = \boldsymbol{\Phi}_1 \mathbf{A}_{i-1} + \boldsymbol{\Phi}_2 \mathbf{A}_{i-2} + \ldots + \boldsymbol{\Phi}_p A_{i-p} \qquad i = 1,2,\ldots,$$

with $\mathbf{A}_0 = \mathbf{I}_m$ and $\mathbf{A}_i = \mathbf{0}$ for $i < 0$. In this moving average representation of the model:

$$\mathbf{A}_n = \frac{\partial \mathbf{x}_{t+n}}{\partial \boldsymbol{\varepsilon}_t'}$$

comprises coefficients that measure the effects n periods after a system-wide shock to the disturbances on each variable in the system. Specifically, the ij^{th} element of the $\mathbf{A}_n$ matrix defines the effect of a one unit increase in the j^{th} variable's disturbance at time t (ε_{jt}) on the i^{th} variable at time $t+n$, ($x_{i,t+n}$), holding all other disturbances at all dates constant. A plot of the ij^{th} element of $\mathbf{A}_n$, i.e.,

$$\frac{\partial x_{i,t+n}}{\partial \varepsilon_{jt}} \tag{19}$$

as a function of n is the *impulse response function* $\{\varphi_{i,j}(n)\}$. However, the *ceteris paribus* clause upon which (19) is predicated, denies the dynamic interaction that the VAR attempts to capture. Indeed, (19) assumes that the disturbances in (16) are un-correlated and thus that $\boldsymbol{\Sigma}$ is diagonal. Given that a shock to ε_{jt} may simultaneously perturb all other variables, and in turn $\mathbf{x}_{t+n}$, the total effect of the shock is the quantity of interest.

Focussing on $x_{i,t+n}$, the net effect of these interactions is given by:

$$\frac{dx_{i,t+n}}{d\varepsilon_{jt}} = \frac{\partial x_{i,t+n}}{\partial \varepsilon_{1t}}\delta_1 + \frac{\partial x_{i,t+n}}{\partial \varepsilon_{2t}}\delta_2 + \ldots + \frac{\partial x_{i,t+n}}{\partial \varepsilon_{mt}}\delta_m \tag{20}$$

where $(\delta_1, \delta_2, \ldots, \delta_m) = \delta$ defines the extent to which the shock to ε_{jt} contemporaneously 'impacts' on all other variables.

The *generalised impulse response function* offers a measure of (20) that, unlike the orthogonalised impulse response function of Sims is invariant to the ordering of the variables in the VAR. The impulse response function $\{\varphi_{i,j}(n)\}$ and the generalised impulse response function $\{\varphi^g_{i,j}(n)\}$ provide a basis for comparison of the relative size of the direct and indirect effects of shocks. Specifically, we can derive:

$$\iota_n = \frac{\varphi_{i,j}(n)}{\varphi^g_{i,j}(n)} \tag{21}$$

which measures the relative importance of direct to total effects on variable i, n periods following a unit shock to variable j.

Data

Monthly price data spanning January 1990 to December 2001 are supplied by the UK's Department of Environment, Food and Rural Affairs (DEFRA). Prices are measured in pence per kilogram (p/kg), have been deflated by the retail price index (December 1999 base) and are expressed in 'carcass weight equivalents' to facilitate comparison between retail and producer levels of the marketing chain.[4] To capture the importance of the food scare, we use an index of media coverage which is based upon a count of newspaper articles per month on the food and health related issues. Although this will involve a coverage of all health and safety issues related to food, given the predominance of BSE in the UK over the 1990s, it is primarily made up of BSE related issues.

Since the experience of BSE accumulates over time, we do not use the index as a simple count of media stories. Rather, to capture the effect of 'memory', we model this media index as:

$$s_t = (1-\lambda)i_t + \lambda s_{t-1} \tag{22}$$

where s_t is the log of the stock of media information and i_t is the monthly publicity count. In this model, the optimal value of λ is estimated at 0.93, implying a long but imperfect memory. The estimated habituation rate, $(1-\lambda)$, of 7% represents the rate at which media information is discounted or 'forgotten' from the stock of news and suggest that the half life of the process is around 10 months. The preferred measure of consumer awareness, called the meat scares index, is plotted in Figure 1[5].

The time path of the meat scares index can be easily separated into two parts. In the first half of the 1990s, the meat scares index was relatively low reflecting the increasing awareness of BSE in cattle but also the absence of a link between BSE and human health. However, the index jumps considerably following the announcement in early 1996 that BSE was could affect humans via vCJD with the index remaining relatively high, although declining, over the remainder of the 1990s.

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[4] The data is available on request from the authors.

[5] It should be noted that alternative specifications of (22) did not have any qualitative impact on the results. In other words, it is the accommodation of memory that seems to be important rather than its precise specification. Details of the methods and results of the grid search over λ are available on request.

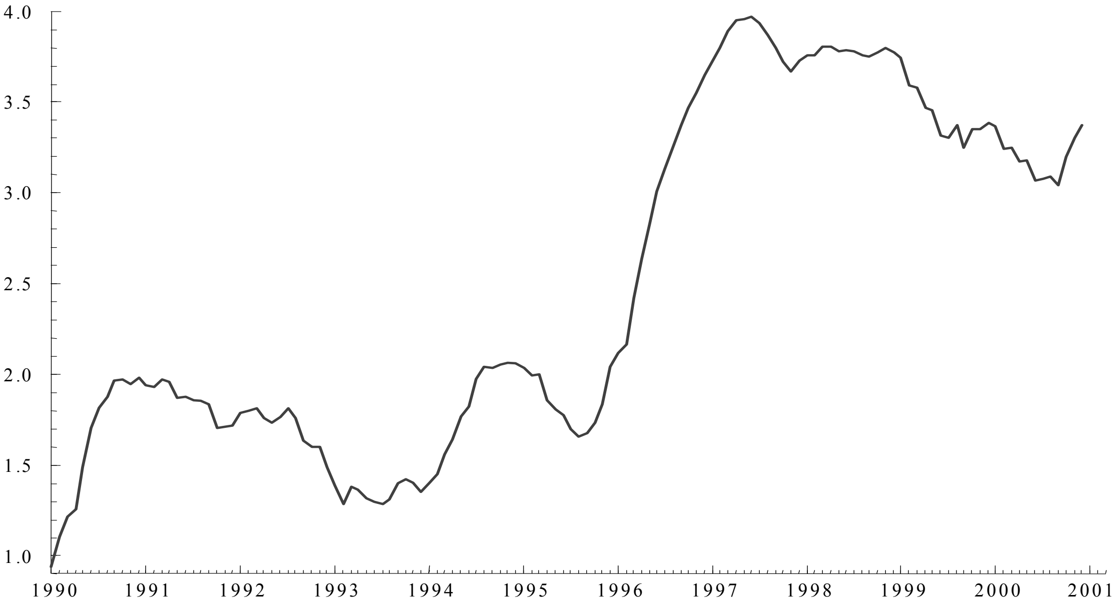

Figure 1. The Meat Scares Index 1990-2001.

EMPIRICAL RESULTS

As an initial step, the data are tested for the order of integration. The series used comprise 132 monthly observations on retail prices of beef, pork, lamb and chicken (RB_t, RP_t, RL_t and RC_t respectively), the producer price of beef (PB_t) and the Meat Scares Index (s_t). The results are reported in Table 3 and confirm that the data series are non-stationary in levels and stationary in first differences, as visual inspection of the data suggests.

Table 3. Augmented Dickey-Fuller test statistics.

Variable	Levels (lag)	Differences (lag)	Inference
RB_t	-1.73 (0)	-10.98** (0)	RB_t ~I(1)
RP_t	-1.65 (0)	-9.87** (0)	RP_t ~I(1)
RL_t	-2.23 (3)	-7.39** (2)	RL_t ~I(1)
RC_t	-2.94 (10)	-3.79** (10)	RC_t ~I(1)
PB_t	-2.47 (2)	-6.63** (0)	PB_t ~I(1)
s_t	-2.76 (7)	-5.87** (0)	s_t ~I(1)

Notes: Lag length of the ADF regression selected according to the Akaike Information Criterion and reported in parentheses adjacent to test statistic; the Augmented Dickey Fuller regression includes a constant and trend (and seasonals for lamb) for the levels and constant (and seasonals for lamb) in differences; critical values derived by MacKinnon; 5% significance denoted by *, 1% by **.

Using these data, (16) is estimated for $p = 1, \ldots, 5$ with constant, trend and seasonals. The Akaike Information Criterion selects the VAR(2) model which passes both vector (and equation) -based tests for residual auto-correlation, ARCH, and heteroscedasticity at the 5% level. The vector test for residual non-normality is strongly rejected owing to the presence of outliers in the equations for PB_t, RP_t and RC_t around March 1996, representing the Ministerial announcement linking BSE and vCJD. These are accounted for by dummy variables in the final model.

Co-integration among the variables is evaluated using Johansen's Trace test. Results are reported in Table 4 and clearly indicate the presence of two co-integrating vectors at the 5% level.[6] In the absence of additional restrictions the co-integrating relations are unidentified, and hence merely represent statistical rather than economic relationships without meaningful interpretation. However, given the discussion in the preceding section, it is possible that they represent the horizontal relationship between meat prices at the retail level and the vertical price transmission relationship between retail and producer beef prices. If so, we have a set of over-identifying restrictions, namely that producer prices are excluded from the retail relation and that the prices of substitutes are excluded from the price transmission relationship.

Table 4. Co-integration Test Statistics.

H_0	Trace Statistic	5% critical values
$r=0$	130.0 94.2	
$r=1$	70.5 68.5	
$r=2$	39.8 47.5	
$r=3$	17.0 29.7	
$r=4$	4.2 15.4	
$r=5$	0.8 3.8	

Notes: Critical values are derived by Osterwald-Lenum

Normalising on the price of beef at retail and producer levels respectively yields
:

$$RB = 0.59RP + 0.47RL + 1.10RC - 34.99s \qquad (23)$$

$$PB = 1.00RB - 8.31s \qquad (24)$$

which is not rejected at the 5% significance level (test of over-identifying restrictions: $\chi^2(3) = 7.34$).

Consequently, although the normalisation is arbitrary, these equations may be legitimately interpreted as the equilibrium relations posited in section 3 characterising the vertical links between retail and farm prices and the role of inter-related markets at the retail level. Equation (23) describes the 'horizontal' relationship and shows that as the price of substitute goods rise so does the retail price beef in a manner indicative of substitution. The estimates suggest that, *ceteris paribus*, a one p/kg rise in the retail price of chicken increases the price of retail beef by 1.1p/kg; similar increases in the price of pork and lamb are associated with 0.59 and 0.47 p/kg increases in beef prices. At mean values, these equate to price response elasticities of 1.06, 0.45 and 1.42 respectively. Equation (23) also shows that increases in the meat scares index, reflecting consumer concerns over the safety of meat, have a negative impact on the retail price of beef, which translates to an elasticity of –0.14 at mean values. The implication of this is that consumers switch consumption out of beef and into other meats following media activity.

Equation (24) represents the vertical relationship between retail and producer prices of beef and suggests that 'perfect price transmission' is consistent with the data, such that a 1p/kg fall in retail beef prices is matched by an equal change at the producer level. The *ceteris paribus* impact of the meat scares index on producer prices is also negative.

Whilst these 'long run' estimates are informative, it should be born in mind that they represent partial derivatives and thus ignore the 'knock-on' and 'feed-back' effects that characterise the inter-relationships between the meat prices in this system. The generalised impulse response function developed by Pesaran and Shin explicitly allows for these interactions and thus offers a convenient tool with which to investigate what might be more appropriately called 'long run' responses – the eventual impact that one might observe following a shock. Figure 2 shows the simulated effect of a shock of typical size (one standard error) to the meat scares index on all meat prices in the twelve months following this hypothetical shock.

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[6] Visual inspection of the co-integration residuals ($\boldsymbol{\beta}'\mathbf{x}_{t-k}$) also points to there being two stationary relations.

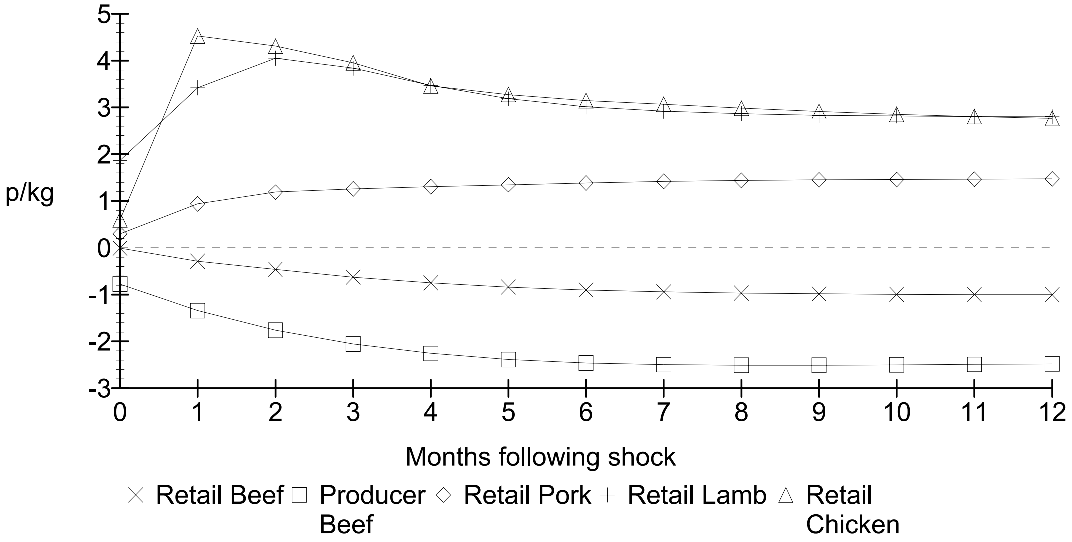

Figure 2. The Simulated Dynamic Effect of Shocks to the Meat Scares Index .

There are two obvious outcomes from the impact on prices following the food scare. First, in terms of the links with the related markets, as the price of beef at the retail stage goes down, the prices of substitute meats rise. Note that the effect on substitute meats is greater than on beef; with lamb and chicken prices rising by around 3p/kg and pork by 1p/kg, while beef prices fall by around 1p/kg.

The second result to note is the differential effect on beef prices at the retail and farm stages, a result that was also borne out by the *ceteris paribus* measures used above. Thus while the retail price of beef falls by around 1p/kg, the farm gate price of beef falls by just less than 2.5p/kg, approximately double the effect that is experienced at the retail level given a one standard error shock to the meat scares index. Taking the mean values for retail and farm level beef prices and that a one standard error shock to the index represents approximately 6 per cent of the value of the index, the elasticities of prices at both levels with respect to the index can be derived. Specifically, the elasticity of retail beef prices with respect to shock to the meat scares index is -0.063 per cent and the comparable elasticity for producer prices is -0.275 per cent. In turn, this implies a pass-back elasticity (ρ) of around 4.4 per cent, twice that implied by the *ceteris paribus* estimates above. Moreover, these figures imply that a doubling of the meat scares index would lower retail beef prices by 12.6 per cent and producer prices by 55 per cent. Taken together, the empirical results are consistent with the predominance of oligopoly at the retail level in determining the impact of food scares on the pass-back elasticities.

As noted above, the role of substitutes will affect the values of these elasticities particularly if oligopoly power is present. The use of equation (21) separates out the direct from the indirect effects on meat prices. Recall that the direct effect being the impact of the shift of the demand function and the indirect effect being the impact of consumers' ability to switch into substitute meats. The results of this decomposition are reported in Table 5. The results show that the availability of substitutes was to exacerbate the decline in beef prices at both the retail and producer levels. Specifically, while the direct effect of the meat scares index accounted for around 40 per cent of the decline in retail beef prices, around 60 per cent of the decline in beef prices was due to the switch to substitute markets. The direct effect however accounts for a greater proportion of the decline in producer prices (64 per cent), the indirect effect accounting for around 36 per cent of the decline in prices at the farm level. In terms of the direction of these effects, these results are consistent with discussion in section 2 (c.f. table 2). As for their relative magnitudes, it is likely that substitution possibilities are strongest at the retail rather than producer levels. The rationale for this can been seen by re-inspecting equations (23) and (24). While the role of substitute effects will influence producer prices insofar as they affect retail prices, producer prices are also affected directly by the food scare. Since the latter impact is in addition to the effect of the food scare on retail prices, it is to be expected that the direct effect of the food scare will be greater on producer prices than on retail prices in the presence of substitutes.

Table 5. Decomposition of Impact of a One Standard Error Shock to the Meat Scares Index (Values are change in prices p/per kilogram).

	Retail Beef Prices	Producer Beef Prices
Total Effect	-1.00	-2.45
of which,		
Direct Effect	-0.41	-1.58
Indirect Effect	-0.59	-0.87

Note: The decomposition results are derived using equation (21)

SUMMARY AND CONCLUSIONS

This paper has focussed on the impact of BSE in the UK on prices at both the retail and producer levels. Specifically, it was motivated by the public concerns raised about the differential impact on retailers and producers, the concern being that prices at the farm gate fell by more than retail prices in the wake of the BSE crisis. The principal source of that concern was market power of food retailers which lead to a subsequent investigation by the UK Competition Commission. In this paper we have shown formally how imperfect competition is likely to result in a differential effect on prices at different stages of the marketing chain following a shift in the retail demand function. We have also shown, given that the beef market is tied to other meats in terms of the availability of substitutes, how the substitute meats can also have an impact on price adjustment following a food scare.

While not a formal test of market power, the results are consistent with the concerns addressed by the Competition Commission. Following a food scare such as BSE, if oligopoly power at the retail level exists, farm level prices will be expected to fall by more than retail prices. The results show that, empirically, this effect is quite large with the price effect at the farm level following the BSE scare to be more than double that occurring at the retail level. Moreover, the availability of substitutes also has non-trivial impact particularly on price adjustment at the retail level.

Although this paper was predicated on the BSE crisis and concerns relating to market structure in the UK, the results have broader implications. First, while most studies of food scares (and food safety issues more generally) have focussed on the impact on consumers, it is also clear that food scares can cause distributional effects within the marketing chain. Second, in terms of modelling the effect of price adjustment, the links between the market of concern and substitute markets should also be taken into account.

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