Primary Demand for Red Meats in the United Kingdom

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La demande primaire de viandes rouges au Royaume-Uni

Résumé – Des systèmes de demande inverse, à différentielles flexibles, sont utilisés pour analyser le processus de formation des prix et pour tester diverses hypothèses relatives à la structure de la demande, au stade de l'exploitation, des viandes rouges (porc, boeuf et agneau) au Royaume-Uni.
Les résultats empiriques indiquent que le système de demande inverse à différentielle presque idéale (AIIDS) est plus performant que d'autres systèmes. Ils suggèrent en outre que la publicité défavorable et les révélations médiatiques sur la qualité incertaine de certaines viandes, liées en particulier à l'apparition de l'ESB et qui ont caractérisé la période 1989-1998, ont affecté le processus de formation des prix. Les paramètres estimés du modèle retenu ont permis de calculer les élasticités prix et échelle inverses, ainsi que les intensités d'interactions de Allais des trois catégories de viande considérées.

Mots-clés:
formation des prix, viandes rouges, peurs alimentaires (produits carnés), ESB, Royaume-Uni

Primary demand for red meats in the United Kingdom

Summary – Flexible differential inverse demand systems have been employed in this paper to analyse the price formation process and to test hypotheses about the structure of farm level demand for red meats (pigmeat, beef and lamb) in the UK . The empirical results suggest that the Inverse Almost Ideal Differential Demand System (AIIDS) performs better than the competing systems. They also suggest that adverse publicity and "meat scares" during 1989 to 1998, particularly relating to BSE, affected the components of the price formation. The parameter estimates of the selected model have been used to calculate scale and price flexibilities and Allais intensities of interaction for the three meat species.

Key-words:
price formation, red meats, "meat scares", BSE, United Kingdom

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EMPIRICAL studies in applied demand analysis rely on either quantity-dependent (direct) systems or on price-dependent (inverse) systems. From an empirical point of view the two types of systems are not equivalent. It is generally accepted that the application of direct systems to demand for perishable commodities which are produced subject to biological constraints, using high frequency (monthly or quarterly) market level time series data, may not be viable (Holt and Goodwin, 1997; Eales and Unnevehr, 1994).

Given a very inelastic supply in the short-run, producers of primary commodities are virtually price takers. The first hand buyers offer them prices which, when augmented with a suitable margin, are sufficiently low to induce buyers further down to the marketing chain (*e.g.* processors, exporters, caterers, retailers) to purchase the available quantities. In other words, traders set prices as a function of quantities and, as a result, the causality runs from quantity to price. Recently, a number of alternative inverse demand systems (both differential and dual) have been developed and applied to commodities such as fish, fresh fruits and vegetables, and meat (*e.g.* Holt and Goodwin, 1997; Kesavan and Buhr, 1995; Brown *et al.*, 1995; Barten and Bettendorf, 1989).

The objective of this paper is to analyze the farm level demand for red meats (beef, pigmeat, and lamb) in the UK. As Bansback (1995) points out, food demand analysis in general and meat demand analysis in particular are topics that will keep attracting the attention of researchers in the near future. This is not least because the UK meat industry will continue to experience significant changes in the aftermath of the BSE (Bovine Spongiform Encephalopathy) crisis, the price reductions under Agenda 2000, and the ongoing WTO negotiations.

There has been a number of empirical studies on meat demand in the UK (*e.g.* Burton and Young, 1996 and 1992; Burton, Young and Cromb, 1999; Tiffin and Tiffin, 1999; Fousekis and Revell, 2000). All those studies employ direct demand systems and consumer level data. The direct systems approach, although appropriate for answering questions such as how the demand for a commodity will respond to changes in prices and expenditure, are not useful in explaining the price formation process which is an integral part of commodity market analysis (Deaton and Laroque, 1992; Anderson, 1980). The consumers' willingness to pay for changes in supply is an important determinant of farmers' income. The more flexible the primary demand is, the greater the price reduction required to induce consumers to buy additional supplies (or equivalently, the greater the increase in price that will result from a reduction in the marketed quantity available). The strength of commodity interactions also plays a role since an increase in the supply of one commodity is bound to put a downward pressure on the prices of its substitutes.

Despite the importance of the topic, there are no studies on primary demand for meats in the UK (or elsewhere in the EU). The present paper besides offering empirical evidence on price formation of meat at the farm level, contributes in the relevant literature in two additional ways. First, it considers competing inverse systems and selects among them via statistical tests. Model selection has recently emerged as a very important issue in empirical demand analysis since researchers are becoming increasingly aware that different functional forms may lead to different results even on the same data set (*e.g*. Barten, 1993; Brown *et al*., 1995). Second, it modifies the inverse demand model appropriately so as to allow "meat scares" to influence price formation process of meat. From the available published data it appears that during 1989 to 1998 there has been a substantial reduction in the domestically produced supply of beef, an increase in that of pigmeat, while the supply of lamb remained almost unchanged. At the same time, the price of lamb has increased, the price of beef has decreased and the price of pork has remained relatively stable. Hence, the share of beef fell from 53 percent between 1989 to 1993 to 42 percent in the period 1994 to 1998, while the shares of lamb and pigmeat have risen from 29 percent to 35 percent, and from 17 percent to 22 percent, respectively. Burton and Young (1996) and Burton, Young and Cromb (1999) offer empirical evidence that those changes can be partly explained by the BSE crisis. This paper examines whether "meat scares" had any influence on the components of price formation, namely, the trend, the scale, and the Antonelli terms of the inverse demand system. As such, it is not only of relevance in understanding *ex post* what happened to UK primary red meat demand since 1989, but it may also serve to inform *ex ante* as to its impact through the structure of demand in other EU member states where the problem has emerged more recently.

In what follows the first part presents the theoretical framework with emphasis on model selection. The second part presents the empirical model, the modifications necessary to allow for the influence of "meat scares", and the empirical results. The last section offers conclusions.

THE THEORETICAL MODEL

Key to the development of inverse demand models is the concept of the distance function, which gives the amount by which all quantities consumed must be changed proportionally to attain a particular utility level[1].The distance function, is defined as:

[1] Primary commodities at the farm level are intermediate products or inputs rather than final products for the consumer. Therefore, a slightly different motivation (behavioral assumption) is probably necessary. As shown by Clements and Theil (1978) and Theil (1980), however, the consumer's utility maximization problem and the firm's cost minimization problem lead to demand systems which have exactly the same form and the same restrictions. Also, when the margin is proportional to price at the different market levels the demand at the farm level is the same as the demand at the retail level (Brown *et al*., 1995; Barten and Bettendorf, 1989).

$$D(u,q) = \max_{\lambda>0} \{\lambda : u(q/\lambda) = u\} \tag{1}$$

where q is a nx1 vector of quantities, $u(q)$ is the utility level and λ is a parameter (Shephard, 1970; Kim, 1997). The distance function is an alternative representation of preferences, dual to the cost function. It is linear homogeneous, concave and non-decreasing in q, and decreasing in u. Differentiation of the distance function with respect to quantities yields a system of compensated inverse demand relationships

$$\pi_i = \frac{p_i}{C} = \frac{\partial D(u,q)}{\partial q_i} = \pi_i(u,q), \quad i = 1,2,......., n \tag{2}$$

where p_i and q_i are the price and the quantity of the ith commodity, respectively, $C = \sum_i p_i q_i$ is the total expenditure, and π_i is the normalized price which gives the fraction of total expenditure paid for one unit of good i.

Differential inverse demand systems have been developed from (2) by Barten and Bettendorf (1989). These systems are flexible, implying that they provide first order Taylor approximations to unknown demand functions, and are parsimonious in parameters (Mountain, 1988). They have also been employed in a number of empirical works (*e.g.* Brown *et al.*, 1995; Fousekis and Karagiannis, 2001). The differential inverse systems can be written as

$$w_i\, d \ln \pi_i = h_i\, d \ln Q + \sum_j h_{ij}\, d \ln q_j \tag{3}$$

where w_i are cost shares, $d \ln Q = \sum_i w_i\, d \ln q_i$ is the change Divisia volume index and $h_i = w_i \dfrac{d \ln \pi_i}{d \ln Q}$ and $h_{ij} = w_i \dfrac{d \ln \pi_i}{d \ln q_j}$ represent the scale and the Antonelli (compensated) substitution terms, respectively.

Brown *et al.* (1995) show that a Synthetic model can be developed from (3) which nests the inverse Rotterdam (RIDS), the inverse CBS (CBSIDS), the Inverse Differential AIDS (AIIDS), and the inverse Neves' system (NBRIDS). The synthetic model is

$$w_i\, d\ln\pi_i = (h_i - e_1 w_i)\, d\ln Q + \sum_j (h_{ij} + e_2\, w_i\, (\delta_{ij} - w_j))\, d\ln q_j \tag{4}$$

where δ_{ij} is the Kronecker delta and e_1 and e_2 are two additional parameters. Adding up requires $\sum_i h_i = -1 + e_1$ and $\sum_i h_{ij} = 0$, while homogeneity and symmetry require $\sum_j h_{ij} = 0$ and $h_{ij} = h_{ji}$, respectively.

The scale flexibility, that is, the response of the normalized price to a proportionate increase in all commodities in the bundle is

$$n_i = \frac{SC_i}{w_i} \qquad (5)$$

where $SC_i = h_1 - e_1 w_i$ is the scale term of the synthetic model. The scale flexibility is the analog of the expenditure elasticity in direct demand systems. The compensated price flexibility, that is, the response of the normalized price of commodity *i* to a change in the quantity of commodity *j* (holding scale constant) and the uncompensated price flexibility are

$$n_{ij} = \frac{A_{ij}}{w_i} \qquad (6)$$

$$\text{and } m_{ij} = n_{ij} - n_i w_j \qquad (7)$$

respectively, where $A_{ij} = (h_{ij} + e_2 w_i (\delta_{ij} - w_j))$ is the Antonelli effect of the synthetic model. The compensated and the uncompensated price flexibilities are the analogs of the compensated and the uncompensated price elasticities in direct demand systems.

The RIDS, the CBSIDS, the AIIDS and the NBRIDS can be obtained from (4) by restricting e_1 and e_2, appropriately. When $e_1 = e_2 = 0$, the synthetic reduces to the RIDS; when $e_1 = 1$ and $e_2 = 0$, it reduces to the CBSIDS; when $e_1 = 1$ *and* $e_2 = 1$, it reduces to the AIIDS; and when $e_1 = 0$ *and* $e_2 = 1$, it reduces to the NBRIDS. The Likelihood Ratio Test (*LRT*) for model selection is $LRT = -2(ln\, L^R - lnL^U)$, where L^U and L^R are the log values of the likelihood function for the unrestricted (Synthetic) and the restricted model (*i.e.*, RIDS, CBSIDS, AIIDS, and NBRIDS), respectively (Amemiya, 1985). Under the null hypothesis that a restricted model best describes the data generation process, the *LRT* statistic has an asymptotic χ^2 distribution with 2 degrees of freedom.

THE EMPIRICAL MODEL AND THE RESULTS

The empirical model

The empirical model sets out to estimate the primary demand for finished livestock as expressed at the first point of sale. The study used average monthly producer prices for cattle, sheep and pigs over the period January 1989-December 1998 and domestically produced supplies as published by the Meat and Livestock Commission as base data. For cattle and sheep, prices were auction prices (*i.e.* first hand sale prices) for all prime cattle and for standard quality lambs quoted on a pence per kg liveweight basis. These were subsequently converted to their carcass weight or deadweight equivalents. For pigs, the price was the Average All Pigs Price (now GB specification) quoted in p/kg deadweight. In order to ensure all prices were on a comparable basis, they were expressed in carcass weight equivalent terms in £ per kg. The prices thus represent the fob purchase cost to slaughters/wholesalers *i.e.* the prices paid for their raw materials. Meat supplies were the monthly estimated volumes of beef, pork and lamb produced domestically available for consumption [2]. Table 1 presents a summary of the descriptive statistics on the estimated industry cost shares and prices.

Table 1.
Descriptive Statistics[a]

Variable	Sample Average	Standard Deviation	Min	Max
Pork Cost Share	0.32	0.055	0.25	0.46
Beef Cost Share	0.48	0.084	0.30	0.60
Lamb Cost Share	0.20	0.036	0.14	0.28
Pig Price	1.10	0.17	0.61	1.51
Beef Price	2.11	0.25	1.42	2.73
Lamb Price	2.22	0.57	1.05	3.96

[a] Prices are expressed in £/kg.

The empirical model excludes poultry meat, although it is acknowledged that poultry is a major substitute for red meats at the retail level. This approach is justified by the very characteristics of the UK meat slaughtering/processing sector where pigs, cattle, and sheep can be slaughtered in multi-species abattoirs, while poultry production and processing takes place at specialized plants which are closely integrated with poultry production. In other words, pigs, cattle, and sheep are inputs to a sub-sector of primary meat processing which is distinct from that of poultry. Moreover, the prices of red meats are generally deter-

[2] An anonymous reviewer pointed out that the exogeneity of prices or quantities is an empirical issue. Eales, Durham and Wessels (1997) use a modified Davidson and MacKinnon (1983) p-test to discriminate between inverse and direct systems for fish demand in Japan. The empirical results rejected the direct systems. They were, however, found to be quite fragile to the choice of instruments. Given the inherent problems in any test procedure involving instrumental variables, it seems that the safest course (for the time being) is rather to rely on *a priori* reasoning. The lower the frequency of the data, the more unlikely is the exogeneity of quantities (time eases biological constraints). Furthermore, at the retail level, the demand for primary commodities may be satisfied by imports and prices at that level are likely to be exogenous. This paper uses very high frequency data (monthly) and at the same time focuses on the primary level (where the demand is exclusively for domestically produced meat). Therefore, the answer to the question “inverse or direct?” is straightforward under these circumstances.

mined by direct competition in the market place, while poultry prices are less subject to such a transparent competitive price determination process at the primary level.

The exclusion of poultry meat from the analysis is equivalent to assuming weak separability between red meats and poultry at the slaughtering/processing level. Weak separability, which is a very common assumption in demand analysis (*e.g.* Nayga and Capps, 1994; Deaton and Muellbauer, 1980) implies that the marginal rates of substitution between inputs in the sub-sector of red meats (and the within-group expenditure shares) are independent of the volume of poultry processed. It allows, however, for interactions between aggregate red meats and poultry. One, thus, may think of a two-stage process for expenditure allocation in the meat slaughtering/processing sector. In the first stage, expenditure is allocated between the group of red meats and poultry; in the second stage, expenditure is further allocated among the red meats, given the decisions at the first stage. The scale and price flexibilities for red meats in this context are conditional upon the first-stage allocation.

Two modifications are required for the empirical implementation of the synthetic inverse demand system. The first is a consequence of the monthly data used. Here, as in the work of Kesavan and Buhr (1995), seasonality has been accounted for by a harmonic variable representation to conserve valuable degrees of freedom. Second order harmonic variables, after some initial experimentation (involving *LR* tests on higher orders), were found adequate for the analysis. The harmonic variables have been incorporated into the demand system by including intercepts, α_i, in each of the equations (4) in the form

$$\alpha_i = sd_{i0} + \sum_{g=1}^{2} sd_{ig} \sin(\frac{2\pi gt}{K}) + \sum_{g=1}^{2} sd_{ig+2} \cos(\frac{2\pi gt}{K}) \quad (i = 1,2,3) \qquad (8)$$

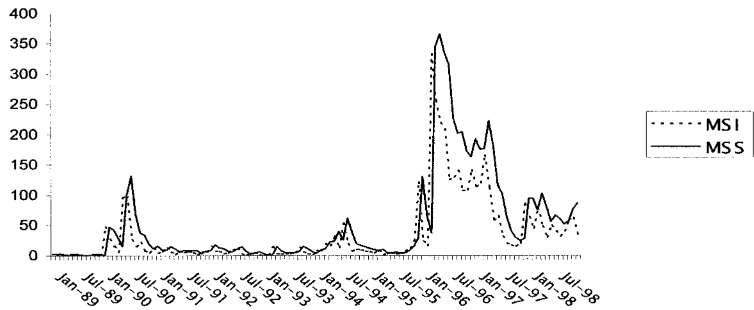
where *sd* are parameters to be estimated, *g* is the order of the harmonic variables, *t* is the time trend and $K = 12$ for monthly data.

The second modification relates to our objective to determine whether "meat scares" had any influence on the components of price formation. To this end, a "Meat Press Reports" index (denoted as MSI) consisting of the number of articles in the major UK daily newspapers (*The Times*, *Sunday Times*, *Guardian*, and *Observer*) was employed. Prior to November 1996 the articles were mainly BSE related [3]. Afterwards, the

[3] The authors wish to acknowledge the co-operation and assistance of the MAFF in making the series available, which is constructed for MAFF by Euro-PA and Associates.

index includes also articles relating to e-coli, abattoir hygiene, etc. As in the recent study of Burton, Young and Cromb (1999), the index was converted into a stock measure (denoted as MSS) using a 68 percent depreciation rate per month [4]. Burton and Young (1992 and 1996) and Burton, Young and Cromb (1999) discuss in detail the advantages of using publicity data in evaluating the effects of "meat scares". Figure 1 presents the MSI and the MSS.

Figure 1. Meat Scares Index (MSI) and Scares Stock (MSS)



To allow MSS to influence trends in the depended variables we redefine the intercept in (8) as

$$sd_{i0} = \phi_{i0} + \phi_i MSS \tag{9}$$

where ϕ_{i0} and ϕ_i are new parameters [5].

To allow MSS to influence the scale terms we redefine SC_i as

$$SC_i^{MSS} = h_i - e_1 w_i + \theta_i MSS \tag{10}$$

where θ_i are new scale parameters, while to allow MSS to influence the Antonelli terms we redefine A_{ij} as

$$A_{ij}^{MSS} = (h_{ij} + e_2 w_i(\delta_{ij} - w_j) + \theta_{ij} MSS) \tag{11}$$

where θ_{ij} are new Antonelli parameters. Note that the treatment of MSS here is similar to the treatment of structural change in the work of Moschini and Meilke (1989) [6].

[4] To assess the sensitivity of the empirical results to the choice of the depreciation rate, model selection tests and flexibility estimates for a much lower rate (34 percent) were also conducted. No significant change was observed and these results are available from the authors upon request.

[5] The constants ϕ_{i0} in differential systems are trend parameters (*e.g.* Alston and Chalfant, 1993; Fousekis and Pantzios, 1999). In particular, the inclusion of intercepts ϕ_{i0} allows for time rates of change in normalized prices equal to ϕ_{i0}/w_i, *ceteris paribus*.

[6] For the inclusion of intervention variables, like the MSS, in differential demand systems, see Alston and Chalfant (1993) and Gao and Spreen (1994).

The introduction of the new parameters requires further restrictions on the synthetic system.

These are $\sum_i \phi_{i0} = 0$, $\sum_i \phi_i = 0$, $\sum \theta_i = 0$, $\sum \theta_{ij} = 0$ (adding-up), $\theta_{ij} = \theta_{ji}$ (symmetry), and $\sum_j \theta_{ij} = 0$ (homogeneity). The "meat scares" have no influence whatsoever on the price formation process for red meats at the farm level when all ϕ_i, θ_i, θ_{ij}, $(i,j = 1, 2, 3)$ are zero. Hypothesis testing about individual components is also possible. For example, adverse meat publicity has no influence on scale elasticities when all θ_i are equal zero. The impact of meat press reports on a particular component of price formation depends on the signs of the relevant parameters. For example, a positive sign in the scale term implies that the MSS works, *ceteris paribus*, towards a smaller (in absolute value terms) scale elasticity for the commodity in question (keep in mind that scale elasticities are negative since a proportional increase in all commodities reduces the willingness to pay for each individual commodity). In the same way, a positive θ_{ij} works towards lower (in absolute value terms) flexibility of the price of the *i*th commodity to the available quantity.

Model estimation, testing, and selection

Since differential inverse demand systems are singular, only two equations have been estimated for the three-commodity model (the lamb equation left out) [7]. The approach by Berndt and Savin (1975) has been used to test for autocorrelation [8]. In all estimated systems, the above approach indicated that correction for first order autocorrelation was necessary. The systems, with the theoretical restrictions of symmetry and homogeneity imposed, have been estimated by the SURE method (Judge *et al*., 1988) in the TSP 4.4 program.

Table 2 presents the parameter estimates along with the corresponding standard errors for the Full model, that is, the synthetic incorporating the MSS related terms. Table 3 presents the model selection tests. The strategy adopted here involves two steps. In the first step we test whether "meat scares" influence price formation. In the second step, we search for the model which best describes the data generation process, given the results in the first step. The null hypothesis that MSS has no effect whatsoever on the components of price formation requires the following restrictions to hold simultaneously $\phi_1 = \phi_2 = 0$, $\theta_1 = \theta_2 = 0$, and

[7] The results were robust to the choice of the equation to be dropped.

[8] Under the Berndt and Savin approach, a system's autocorrelation matrix is specified as diagonal with a common scalar autocorrelation parameter. For alternative ways to deal with autocorrelation in systems, see Moschini and Moro (1994).

$\theta_{11} = \theta_{12} = \theta_{22} = 0$ [9]. With an empirical value of the *LRT* statistic 27.21, the null hypothesis is rejected at any reasonable level of significance. We conclude therefore that "meat scares" have exerted an influence on primary demand for red meats in the UK. A closer examination of Table 2, however, reveals that all trend terms associated with MSS (ϕ_1,ϕ_2,ϕ_3) are completely insignificant. Indeed, the empirical value of the *LRT* statistic for $\phi_1 = \phi_2 = 0$ is 0.276 suggesting that the trend impacts of "meat scares" are zero and the influence of "meat scares" on price formation works through the scale and the Antonelli terms, only. This result is also perfectly consistent with the fact that the dependent variables in the model fluctuate around zero without exhibiting trends or abrupt changes with time. To avoid over-parameterization, the restriction $\phi_1 = \phi_2 = 0$ has been imposed in the system.

Table 2. Parameter Estimates from the Full Model [a]

Parameter	Estimate	Standard Error	Parameter	Estimate	Standard Error
ϕ_{10}	-0.0002	0.002	θ_{22}	-0.0002	0.0002
ϕ_1	-0.00004	0.00002	sd_{21}	-0.01*	0.002
h_1	-0.034	0.05	sd_{22}	-0.007*	0.002
θ_1	-0.0005*	0.0002	sd_{23}	0.005*	0.001
h_{11}	-0.25*	0.12	sd_{24}	0.006*	0.001
h_{12}	0.16 (**)	0.095	ϕ_{30}	0.0005	0.002
θ_{11}	-0.0015*	0.0004	ϕ_3	0.0001	0.0003
θ_{12}	0.0065*	0.0002	θ_3	-0.00016	-0.0002
sd_{11}	0.006*	0.002	h_3	-0.02	0.036
sd_{12}	0.0008	0.0022	h_{13}	0.09*	0.04
sd_{13}	-0.004*	0.002	h_{23}	0.13*	0.06
sd_{14}	-0.002	0.002	h_{33}	-0.22*	0.09
ϕ_{20}	-0.0003	0.001	θ_{13}	0.0009*	0.0002
ϕ_2	-0.000001	0.00002	θ_{23}	-0.0005*	0.0001
h_2	-0.13	0.1	θ_{33}	-0.0004*	0.0002
θ_2	0.0007*	0.0002	e_1	0.82*	0.18
h_{22}	-0.28 (**)	0.15	e_2	1.16(**)	0.6
			ρ	0.31*	0.07

[a] 1 is pigmeat, 2 is beef, 3 is lamb. The coefficients of the lamb equation have been recovered from the theoretical restrictions. The standard errors of these coefficients have been calculated by the ANALYZ procedure in the TSP4.4 program.

*(**) Denote statistically significant coefficients at the 5 (10) percent level. Rho is the scalar autocorrelation coefficient resulting from Berndt and Savin (1975) approach. The coefficients of determination are 0.81 for the pigmeat equation and 0.96 for the beef equation.

[9] Notice that when $\phi_1 = \phi_2 = 0$ then $\phi_3 = 0$ from the adding up conditions; when $\theta_1 = \theta_2 = 0$ then $\theta_3 = 0$ from the adding up conditions; and when $\theta_{11} = \theta_{12} = \theta_{22} = 0$, then $\theta_{13} = \theta_{23} = \theta_{33} = 0$ from the symmetry, the homogeneity and the adding up conditions.

Table 3. Model Testing and Selection

Model	Log-likelihood	Df	Empirical Value
Full (Synthetic with the MSS Variable)	743.993	-	-
"Meat Scares" have no Influence on Price Formation	730.388	7	27.21*
"Meat Scares" have no Influence on the Trend Component	743.885	2	0.276**
Synthetic+	743.885	-	-
RIDS	732.889	2	21.99**
CBSIDS	741.524	2	4.72**
AIIDS	743.338	2	0.89**
NBRIDS	733.878	2	20.01**

* The theoretical values are 11.99, 14.03, and 24.31 at the 10, 5, and 1- percent level of significance, respectively.

** The theoretical values are 4.6, 5.99, and 9.21 at the 10, 5, and 1- percent level of significance, respectively.

\+ The Synthetic is the full system with $\phi_1 = \phi_2 = 0$ imposed.

From the parameters capturing the influence of MSS on the scale terms, two (out of three) are statistically significant at the 5 percent level or less. Their signs suggest that, *ceteris paribus*, the MSS works towards higher (in absolute value terms) scale flexibilities for pigmeat and lamb and towards lower scale flexibility for beef. On average, the presence of the MSS variable increases the scale flexibilities of pigmeat and lamb by 8 and 4 percentage points, respectively, while reduces the scale flexibility beef by 7 percentage points. From the parameters capturing the influence of MSS on the Antonelli terms five (out of six) are statistically significant at the five percent level or less. It appears that the MSS works towards higher (in absolute value terms) own-quantity Antonelli effects. On average, the presence of the MSS variable increases the compensated price flexibilities by 21, 2, and 13 percentage points, for pigmeat, beef, and lamb, respectively [10]. From the parameters capturing the influence of MSS on the cross-quantity Antonelli terms two are positive and one is negative.

Turning now to the model choice, the Synthetic system rejects the RIDS and the NBRIDS at any reasonable level of significance, it rejects the CBSIDS at the 10 percent level but it fails to reject the AIIDS sug-

[10] The calculations of the average impacts of the MSS on the scale and the price flexibilities are based on $\theta_i \frac{\overline{MSS}}{\overline{w}_i}$ and $\theta_{ii} \frac{\overline{MSS}}{\overline{w}_i}$, respectively, where the "bar" denotes sample averages.

gesting that the latter model provides a better description of the data generation process. Thus, only results from the AIIDS are discussed further in this section [11].

Separability, price flexibilities and Allais intensities of interaction

An interesting property of demand systems is that of separability. A distance function is said to be separable in the partition of the bundle of goods $\hat{I} = \{I^1, I^2, ...I^r, ..., I^m\}$ when the price ratio of any pair of goods in a subset does not depend on the quantity of a good not in this subset. Formally,

$$\frac{\partial\left(\pi_i / \pi_j\right)}{\partial q_k} = 0, \; i, j \in I^r \text{ and } k \notin I^r \quad (12)$$

Kim (1997) shows that a necessary and sufficient condition for separability is that the Antonelli effects between *i* and *k* and *j* and *k* are proportional to the cost shares of *i* and *j*. On the basis of the notation introduced previously separability requires

$$\frac{A_{ik}^{MSS}}{A_{jk}^{MSS}} = \frac{w_i}{w_j}, \; i, j \in I^r \text{ and } k \notin I^r \quad (13)$$

Here, there are three possible cases: a) lamb is separable from pigmeat and beef; b) pigmeat is separable from beef and lamb; and c) beef is separable from pigmeat and lamb. Wald tests have been used for separability and the results are presented in Table 4. At the 5 percent level, the null hypothesis of separability has been rejected for the pairs beef and pigmeat and pork and lamb. It has not been rejected, however, for the pair beef and lamb. We conclude, therefore, that the underlying distance function is separable in the partition ((beef, lamb), pigmeat).

Table 4.
Separability Analysis[a]

Null Hypothesis	Empirical Value[b]
Lamb is Separable from Pigmeat and Beef	16.62
Beef is Separable from Pigmeat and Lamb	3.81
Pigmeat is Separable from Beef and Lamb	2.5

[a] Carried out at the sample averages.
[b] The theoretical values (χ^2 distribution with one degree of freedom) are 2.7, 3.84, and 6.65 at the 10, 5, and 1 percent level of significance, respectively.

[11] Parameter estimates from the AIIDS are available upon request. From the very small empirical value of the *LRT* statistic, however, it is evident that the parameters of the AIIDS are almost identical to those of the Synthetic. The discussion, therefore, about the signs and the significance and the impacts of the MSS parameters remains valid for the selected model (AIIDS).

All own-quantity compensated effects for the AIIDS model are negative. This implies that an increase in the quantity of the ith commodity reduces, *ceteris paribus*, its normalized price, that is, reduces the buyers' willingness to pay for this commodity. One may also say that a commodity is its own-substitute. The eigenvalues of the Antonelli substitution matrix, $A = \left[A_{ij}^{MSS}\right]$, are – 0.123, – 0.0018 and – 0.00002, suggesting that this matrix is negative semi-definite, as stipulated by the economic theory. Two out of three, however, cross-quantity compensated effects are positive. Extending the notion of substitution to all negative cross-quantity compensated effects, it is natural to consider the positive ones an indication of complementarity. Barten and Bettendorf (1989) and Holt and Goodwin (1997), however, argue that the cross-quantity compensated effects in inverse demand systems are imperfect measures of the interrelations among commodities. This is because the homogeneity conditions along with the negative semi-definiteness of the Antonelli matrix entail a dominance of positive cross-quantity compensated effects. Red meats belong, however, to the same market and *a priori* are expected to be substitutes (Asche *et al*., 1997; Eales and Unnevehr, 1994; Chalfant *et al*., 1991). To avoid drawing incorrect inferences about the input interrelationships from the compensated cross-quantity effects in the following we present the uncompensated price flexibilities along with Allais intensities of interaction (Barten and Bettendorf, 1989; Allais, 1943). The Allais intensities of interaction are computed with constant total input volume and, in addition, they allow utilization of *a priori* beliefs (in this case, the belief that red meats are substitutes).

Table 4 presents the scale and the uncompensated price flexibilities. The scale flexibilities are statistically significant and very close to minus one suggesting that an increase in the aggregate quantity of meats available (holding the composition constant) leads to a decrease in the normalized prices by the same proportion. Unitary scale flexibilities of primary demand have been also reported by Barten and Bettendorf (1989) and Fousekis and Karagiannis (2001) for fish species, and by Brown *et al*. (1995) for fresh vegetables. Holt and Goodwin (1997) report scale flexibilities which are very close to minus one for the two out of four meats considered in their study. Kesavan and Buhr (1995) find that prices are flexible with respect to scale for most of the meat species in the USA. The results of the last two studies, however, are not strictly comparable with ours since they rely on retail level data.

All own-quantity uncompensated flexibilities are negative and statistically significant. All cross-quantity uncompensated flexibilities are also negative, four out of six are statistically significant at the 5 percent level and one is significant at the 10 percent level. The negative signs of cross flexibilities suggest that red meats in the UK are gross q-substitutes

(Eales and Unnevehr, 1994). The own-flexibilities are smaller than unity (in absolute value) implying that an increase in the supply of the ith red meat by one percent reduces the buyers' valuation for this meat by less than one percent (or equivalently, a decrease in the supply by one percent increases the value by less than one percent). The inflexibility of farm level prices to changes in the own-quantities suggests that the reduction in the supply of the domestically produced beef during 1989 to 1998 resulted in producer losses. Pigmeat producers, however, have probably gained because the reduction in pigmeat prices required to absorb additional domestic supplies were proportionately smaller. Inflexible own-price response will also reflect the impact of imported meat supplies into the UK which can dampen the effects of domestic supply changes on prices. This is particularly the case for beef, where introduction of the Over Thirty Month Slaughter Scheme for mature animals removed them from the food chain, and declining domestic supplies were partially offset through imported beef. There have been, furthermore, increase imports of pigmeat during the sample period, and for lamb, there has been a regular, albeit very seasonal import trade.

The magnitudes of price flexibilities obtained in this study are similar to those reported in earlier studies. According to Holt and Goodwin (1997) the uncompensated own-quantity price flexibilities for meat species in the USA range from – 0.31 for turkey to – 0.75 for pork, while according to Kesavan and Buhr (1995) they range from – 0.35 for chicken to – 0.89 for ground beef. Inelastic responses of price to quantities have been also reported in the studies of Barten and Bettendoff (1989), Fousekis and Karagiannis (2001) and Brown *et al*. (1995).

The Allais intensities of interaction are calculated as

$$\psi_{ij} = \frac{\gamma_{ij}}{\sqrt{\gamma_{ii}\gamma_{jj}}} \tag{14}$$

where

$$\gamma_{ij} = \frac{A_{ij}^{MSS}}{w_i w_j} - \frac{A_{ls}^{MSS}}{w_l w_s} + \left(\frac{SC_i^{MSS}}{w_i} - \frac{SC_l^{MSS}}{w_l}\right) + \left(\frac{SC_j^{MSS}}{w_j} - \frac{SC_s^{MSS}}{w_s}\right) \tag{15}$$

and *ls* is the standard pair against which the intensities of interaction of the remaining pairs are evaluated. The Allais coefficient for the standard pair, γ_{ls}, equals to zero and so does the corresponding Allais intensity of interaction. For the other pairs, the Allais intensities of interaction range from – 1 (perfect substitution) to + 1 (perfect complementarity). The own-intensities of interaction are – 1, since every commodity (meat species) is a perfect own-substitute.

Table 5.
Allais Intensities of Interaction from the AIIDS [a]

	Pigmeat	Beef	Lamb
Pigmeat	-1	-0.69	0
Beef	Symmetry	-1	-0.64
Lamb			-1

[a] Calculated at sample averages.

The pair pigmeat-lamb was selected in this paper as the standard one for the simple reason it ensures all that other intensities of interaction are negative. This expresses our *a priori* belief that the red meats are substitutes. Table 5 presents the Allais intensities of interaction. The intensity of interaction between beef and pigmeat is slightly higher than that between beef and lamb, which is consistent with the respective price flexibilities (Table 6).

Table 6.
Scale and Uncompensated Price Flexibilities from the AIIDS [a]

	Scale	Quantity of		
Price of		Pork	Beef	Lamb
Pork	-1.02*	-0.55*	-0.46*	-0.07**
	(0.043)	(0.064)	(0.03)	(0.04)
Beef	-1.005*	-0.30*	-0.49*	-0.22*
	(0.02)	(0.024)	(0.017)	(0.016)
Lamb	-0.96*	-0.027*	-0.498*	-0.295*
	(0.067)	(0.09)	(0.047)	(0.067)

[a] Calculated at sample averages.
* (**) Statistically significant at the 5 (10) percent or less.

CONCLUSIONS

The process of price formation at the farm level is an integral part of commodity market analysis. There have been, however, few empirical studies on this important topic. The objective of this paper has been to analyze farm level demand for red meats in the UK. To this end, inverse demand systems and monthly observations on the supply and prices of three meat species have been utilized. The systems in this study have been appropriately modified to empirically assess whether “meat scares” had any influence on price formation at the farm level. The parameter estimates have been used to test hypotheses about the structure of demand and to calculate scale and price flexibilities along with Allais intensities of interaction.

The empirical results of the paper suggest that the AIIDS provides a better description of the data generation process among the alternative inverse demand models considered. The Meat Press Reports index of "meat scares", measured here as the stock of publicity, has exerted a statistically significant influence on price formation at the farm level. However, BSE and other such health concerns have had no trend impact on producer prices but have been reflected through the scale and the Antonelli species substitution flexibilities. The scale flexibilities are close to unity in absolute values, while the uncompensated price flexibilities are substantially smaller. The latter suggests that domestic supply reductions, particularly for meats such as beef, have contributed to lower producer revenues. Finally, at the level of primary demand pigmeat and beef are slightly closer substitutes than beef and lamb.

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