Development of German Beef Prices During the BSE Crisis

Some Empirical and Theoretical Results

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Abstract: This paper analyzes the market failure on the beef market caused by information about a severe BSE risk, and shows the recovery of the market due to the introduction of the BSE test. In the empirical part we use break robust cointegration tests to find that producer and consumer prices of beef in Germany are cointegrated with a joint co-break in the BSE crisis.

Key words: BSE, market failure, price transmission, cointegration, structural break
JEL classification: Q11, I18, C22, C32

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1. Introduction

The information about the first BSE case in Germany caused a collapse of the beef market. A recovery was observed only when a BSE test became available. In this paper we analyze the price reactions to BSE information from a theoretical and empirical point of view.

The BSE epidemic caused huge economic costs and a pronounced human mortality risk. These and other facts shall first be recalled in a brief history of BSE in Europe. We subsequently draw a simple model to explain the developments on the consumer market for beef. We start by describing the situation before the first BSE case was detected, using partial analysis of a competitive equilibrium. To explain the BSE crisis, we develop the demand shortfall within the framework of the expected utility hypothesis and quality dependent valuation. Whether we find a complete market collapse or equilibrium at a low level depends on the position of the new demand and supply curves. Market recovery is modeled by gain of reputation due to the existence of a BSE test.

In the empirical part of the paper we analyze price reactions before and during the BSE crisis. Using weekly data about producer and consumer prices we show the following results: Time series are integrated of order one with a structural break in the level. A cointegration relation can be shown clearly until the day before the first BSE case was detected in Germany. Estimations with data during the crisis indicate that the stationary relationship between producer and consumer prices disappears. Producer prices decrease as expected but consumer prices rise. This could be explained by additional costs due to the test and conditions on waste disposal and, last but not least, by the consumer's preference for good quality beef. Having eliminated the level breaks, we find that the adjusted consumer and producer prices reveal a cointegration relationship for the whole period of examination.

2. History of BSE: United Kingdom, Europe and Germany

The first indicators of bovine spongiform encephalopathy (BSE) were found in the nineteen seventies. The first BSE case was diagnosed in 1986. BSE is a disease of the brain characterized by the presence of an abnormal form of a protein called a prion. The origins are not clear but it is probably acquired by eating feed containing contaminated meat and bonemeal, and by maternal transmission.

In 1996, the causal relationship between BSE and the new variant Creutzfeldt-Jakob Disease (vCJD), a fatal degenerative disease in the human brain, was considered as highly probable.

At that time it was already impossible to contain the disease by selective slaughtering. Instead, it only remained to slaughter all 13 million bovines or to hope the disease would pass by without severe consequences for human beings. The Thatcherian policy of leaving the way free for businesses and, at the same time, rigorously cutting public expenses favored the later alternative.

In 1998, the Ministry of Agriculture, Fisheries and Food (MAFF) was given an information monopoly about the new epidemic. Critical researchers were no longer allocated funding. The role of the MAFF is analyzed critically by Dressel (2000). She points out:

1. "...that scientists weren't free to report to other scientists or to publish until all writings and so on had been exhaustively reviewed by all sorts of administrators..."
2. "Instead, when the new cattle disease, BSE, loomed, MAFF did not inform the Department of Health about the outbreak of the disease, or about any crucial scientific research that might have a bearing on its potential transmission to humans."
3. "And it was only with a delay of about six months after MAFF's awareness that BSE might have implications for public health, that the DoH [Department of Health] was informed about BSE."

The European Union banned the feeding of ruminant derived meat and bonemeal in the United Kingdom in July 1988 but not the export of this risk material. Exports increased significantly. Ten months later, Germany stopped the import of meat and bonemeal. The European Union only stopped the export of BSE contaminated meat and bonemeal from United Kingdom in 1996; 14 months later feeding was forbidden in the European Union.

Estimations suggest that there were about 1.9 million infected animals, about 1.6 of which were slaughtered and consumed before showing any clinical sign of the disease (Donnelly et. al., 2002). The insufficient control of the feeding ban caused 36,000 additional BSE infections (Court of Auditors, 1998). In 2002, there were still more than one thousand new reported BSE cases in the United Kingdom.

The Court of Auditors (2001) reports that the costs of the BSE crisis borne by the EU were 4.7 billion euro. The largest recipient was the United Kingdom with 2,058 million euro followed by France and Germany with 741 and 720 million euro, respectively. The main expenditures were direct income support payments, public interventions and the so-called "over thirty months scheme (UK)". The latter was introduced in 1996 to eliminate cattle aged over 30 months from the human food and animal feed chains.

The exact mechanism of transmission of the BSE agent to the human population has not yet been identified, but dietary exposure to BSE contaminated beef products remains the most likely hypothesis.

As a result of the BSE epidemic, there have been a total of 143 victims in Great Britain, 101 neuropathological confirmed deaths from the vCJD and an additional 36 deaths due to vCJD. The number of definite or probable vCJD victims still alive is 6 (The UK Creutzfeldt-Jakob Disease Surveillance Unit, 2003). Estimations from Andrews (2003) suggest that the epidemic is no longer increasing exponentially but has reached a peak or a plateau. Ferguson et. al. (2002) estimate the 95% confidence interval for future vCJD mortality to be 50 to 50,000 human deaths, considering exposure to bovine BSE alone. If they include exposure from the worst-case scenario, i.e., BSE entering the sheep population as well, the upper bound lies at 150,000 human deaths.

On November 24, 2000, Germany had its first own diagnosed case of BSE. 12 days later, chancellor Schröder proclaimed a reform of the agriculture sector. BSE tests for all bovines over 30 months were introduced on December 6. Some days later, BSE risk material was found in sausages. On January 31, 2001, the slaughter of 400,000 bovines for price intervention was announced. The price offered for one animal was 1,000 DM. From March to June the slaughter was carried out.

In Germany, there is a high probability that cases of BSE have gone undetected because the monitoring and testing programs were inadequate. The Court of Auditors (2001) criticized that the feed ban had not been applied effectively in Germany and that some meat and bonemeal material had been processed at a substandard level.

There are substantial regional differences in the occurrence of the German BSE cases. In table 1, we compare the number of BSE cases with the livestock. Due to an incubation period of 3 to 7 years, BSE is especially pronounced in dairy cows. We therefore also compare the BSE cases with milk production.

Table 1: Regional differences in BSE occurrences 2001

Länder	BSE cases	Bovine livestock in thousands	milk production in thousand t	BSE cases in percent of the livestock	BSE cases in percent of milk production
Germany	125	14227	4475	0.09	0.28
Bavaria	59	3987	1376	0.15	0.43
Lower Saxony	17	2765	767	0.06	0.22
Baden-Württemberg	12	1193	416	0.10	0.29
Schleswig-Holstein	12	1291	373	0.09	0.32
Rhineland-Palatinate	4	432	128	0.09	0.31
Saxony	4	535	208	0.07	0.19
Saxony-Anhalt	4	383	145	0.10	0.28
Brandenburg	3	631	182	0.05	0.16
Hesse	3	520	160	0.06	0.19
Mecklenburg-West-Pomerania	2	577	182	0.03	0.11
North Rhine Westphalia	2	1450	388	0.01	0.05
Thuringia	2	384	129	0.05	0.16
Saarland	1	58	15	0.17	0.67
Berlin	0	1	0	0.00	0.00
Bremen	0	12	3	0.00	0.00
Hamburg	0	8	1	0.00	0.00

Source: Own calculation with data from the Ministry of Consumer Protection, Food and Agriculture and Federal Statistical Office Germany.

In Bavaria, the highest number of BSE cases occurred. In comparison with the livestock, Bavaria reached second place and Baden-Württemberg and Schleswig-Holstein were both placed third. The first place in this category, the Saarland, has only one case and is therefore a too small number to be a reliable result. In the category of BSE cases in comparison to milk production, Bavaria again holds the top position. It must be concluded from these figures that some Länder have severe problems in effectively controlling quality standards.

3. A Model Describing the Development of Prices on the Beef Market

In this section of the paper we look at the consumer market for beef. Our weekly data show that prices on the consumer market increase though the producer price of the cows declines. We are able to explain this fact without using markets of substitution goods like markets for pork, lamb, or chicken. We therefore prefer the method of partial analysis. Throughout the following sections we assume many consumers with identical preferences described by quasi-linear utility functions and many sellers behaving as price-takers due to increasing marginal costs. Thus we can illustrate equilibria, if they exist, as intersections of a demand and supply curve.

3.1 The Situation before Detection of the First BSE Cow

There exists only one "good" quality of meat on the market. Consumers in particular have no reason to question the quality of the meat they bought. The BSE problem is not yet known. We therefore work within a world of complete markets.

Demand

We start assuming a representative consumer with a given yield y measured in units of money. He spends x amounts of his income on buying beef and a x_0 amount of composite good. Denoting p as the price of one unit of meat and assuming a price-level of 1 per unit of the composite good, we work with the following budget restriction:

$$y = p \cdot x + x_0 \, . \qquad (3.1)$$

In this paper we are not interested in relations with one or more goods within the composite good. Thus we assume that a change of p does not influence the relative prices of the goods combined to the composite good.

The representative consumer measures his utility U in terms of the composite good, and the utility obtained from consuming beef is described by a non-linear, increasing concave function V(x). We work with the following quasi-linear utility function:

$$U = V(x) + x_0 \quad \text{with} \quad V'>0 \text{ and } V''<0 \, , \qquad (3.2)$$

which implies there are no income effects. Maximizing (3.2) subject to the budget constraint (3.1), leads to the equivalent unconstraint problem:

$$\max V(x) + y - p \cdot x \quad \text{with respect to x.} \qquad (3.3)$$

The solution of (3.3) gives the consumer's demand function, which is decreasing in p and independent of his income. As all consumers have identical preferences, aggregate demand for beef is given by

$$X_1^D = D_1(p) \quad \text{with } D_1' < 0. \qquad (3.4)$$

Supply

On the supply side we assume many identical profit maximizing firms, behaving as price takers on markets for beef and factors. They offer one product, beef, though in reality they are multi-product firms with a joint production process resulting in an indeterminate price system. The firm can solve this simultaneous equation system by choosing sufficient linear independent restrictions (for a detailed description see Frisch, 1965, chapter 14 and 15). Regarding the market from outside you can only take into account the producer price of the cattle and a number of strictly determined relative quantities of the joint product. This means, it is impossible to get more than one linear independent vector, describing the relations between producer price of the cattle and the prices for the different beef products.

Ignoring those problems of joint production, the different kinds of meat may be represented by one product. In this case it is possible to use the theory of a single product firm (see Krelle, 1969, p. 5). Each firm only sells one product, beef, which is offered using a linear increasing marginal cost curve:

$$x = (p - b) / a_1 \qquad \text{with } p > b > 0 , a_1 > 0. \tag{3.5}$$

If there are N_1 identical firms on the market, the aggregate supply function is described by

$$X_1^S = S_1(p) = N_1 \cdot (p - b) / a_1 . \tag{3.6}$$

The supply curve gets flatter in a X-p-diagram if the number of firms grows.

Equilibrium

We assume that consumers are willing to pay more than b units of money for one unit of beef. Then there exists a unique supply-demand equilibrium on the beef market, illustrated by point A in figure 3.1, with (X_1*, p_1*) being the equilibrium quantity and price, respectively.

3.2 The Market Failure after Detection of the First BSE Cow

We now have to explain how consumers and firms behave after being informed about the possibility to buy or sell beef originating from cattle infected by BSE.

Demand

Our representative consumer can no longer be sure that he is buying a good quality, since there is no test available for him until now. He evaluates good qualities by $V_G(x)$ and bad qualities by $V_B(x)$. The measure for good qualities is the same as that used in the preceding section, i.e. $V(x) = V_G(x)$. The consumer's willingness to pay for one unit of good quality is always higher than for bad quality. We therefore assume $V_G' > V_B' > 0$ and $V_B'' < 0$. Let π denote the probability of obtaining a good quality. In the situation of uncertainty the consumer regards his expected utility EU. In contrast to (3.3), our representative consumer has to solve the following problem

$$\max EU = \pi \cdot V_G(x) + (1-\pi) \cdot V_B(x) + y - p \cdot x \quad \text{with respect to } x. \tag{3.7}$$

The solution of this problem results in the new demand function

$$X_2^D = D_2(p) \quad \text{with } D_2' < 0. \tag{3.8}$$

Proposition: Decreasing demand after BSE information

Assume $V_G' > V_B' > 0$ *and* $0 < \pi < 1$. *Then the demand after detecting the first BSE case is lower than in the competitive situation before BSE was known, i.e.* $D_2(p) < D_1(p)$.

Proof. p_1 and p_2 are denoted as the prices resulting from the first-order conditions belonging to problem (3.3) and (3.7). Thus we have

$$EU' = \pi \cdot V_G'(x) + (1-\pi) \cdot V_B'(x) = p_2 \quad \text{and} \quad U' = V'(x) = V_G'(x) = p_1. \tag{3.9}$$

Since $V_G' > V_B'$ and $0 < \pi < 1$, we can conclude

$$p_2 = \pi \cdot V_G'(x) + (1-\pi) \cdot V_B'(x) < \pi \cdot V_G'(x) + (1-\pi) \cdot V_G'(x) = V_G'(x) = V'(x) = p_1. \text{ QED.}$$

Thus we have shown that the demand curve turns to the left when the BSE problem is relevant on the beef market.

Supply

Firms observe the new demand function $D_2(p)$ and reduce their offer. Many butchers were no longer able to sell beef any more. We therefore assume a decreasing number of the firms down to N_2. Another reason for the reduction of the supply stems from the fact that some parts of the cows like the brain are no longer allowed to be sold. This raises marginal costs. The supply curve becomes steeper, denoted by

$$X_2^S = S_2(p) = N_2 \cdot (p - b) / a_2 . \tag{3.10}$$

For ease of discussion, we assume that b remains constant although it could increase or decrease, depending on the change in the production function and lower input prices for cattle.

Equilibrium

Here we consider two possible results. At first it could occur that consumers are not willing to pay more than b units of money for one unit of beef. In this case, the market completely breaks down. As this did not happen on the German beef market, we come to the observable case with reduction of demand and supply, denoted by point B in figure 3.1, with corresponding quantity and price, (X_2^*,p_2^*). The fact that consumer prices rose during the crisis is explained in our context by the decline of supply. The reduction of demand on its own would result in lower prices than in the situation before the BSE crisis.

3.3 The Market Recovery Due to a BSE Test

Two weeks after having detected the first BSE case in Germany, a quick-test was available to detect infected animals. We now extend our model to include this fact.

Demand

The existence of a test leads to a situation in which consumers can distinguish between tested and untested supplies of beef, at least in principle. The development of the demand depends on the reliability of the test. If we assume that any cattle could be tested with certainty as being free from BSE and no fraudulent supplies are on the market, the demand function $D_3(p)$ should fall together with that from section 3.1. Thus we have

$$X_3^D = D_3(p) = D_1(p) \quad \text{with } D_3' < 0. \tag{3.11}$$

Supply

Firms must decide whether they offer tested or untested meat. The latter raises the costs of the firms. Here we assume that the government only allows tested beef or that the firms prefer tested beef in order to build up credibility in the eyes of the consumers. Thus, in a first step the supply function will turn even further left. It is also possible that new firms enter the market later on. These two cases are described by the supply functions

$$X_{31}^S = S_{31}(p) = N_2 \cdot (p - b) / a_3 \tag{3.12}$$

and

$$X_{32}^S = S_{32}(p) = N_3 \cdot (p - b) / a_3 , \tag{3.13}$$

with b assumed constant.

Equilibrium

We now combine the demand function (3.11) with the two supply functions (3.12) and (3.13). Their intersections describe two possible market solutions in the case of consumer confidence due to a BSE test, denoted by points C and D, with (X_{31}*,p_{31}*) and (X_{32}*,p_{32}*), respectively.

Figure 3.1:

Equilibria on the beef market before and during the crisis

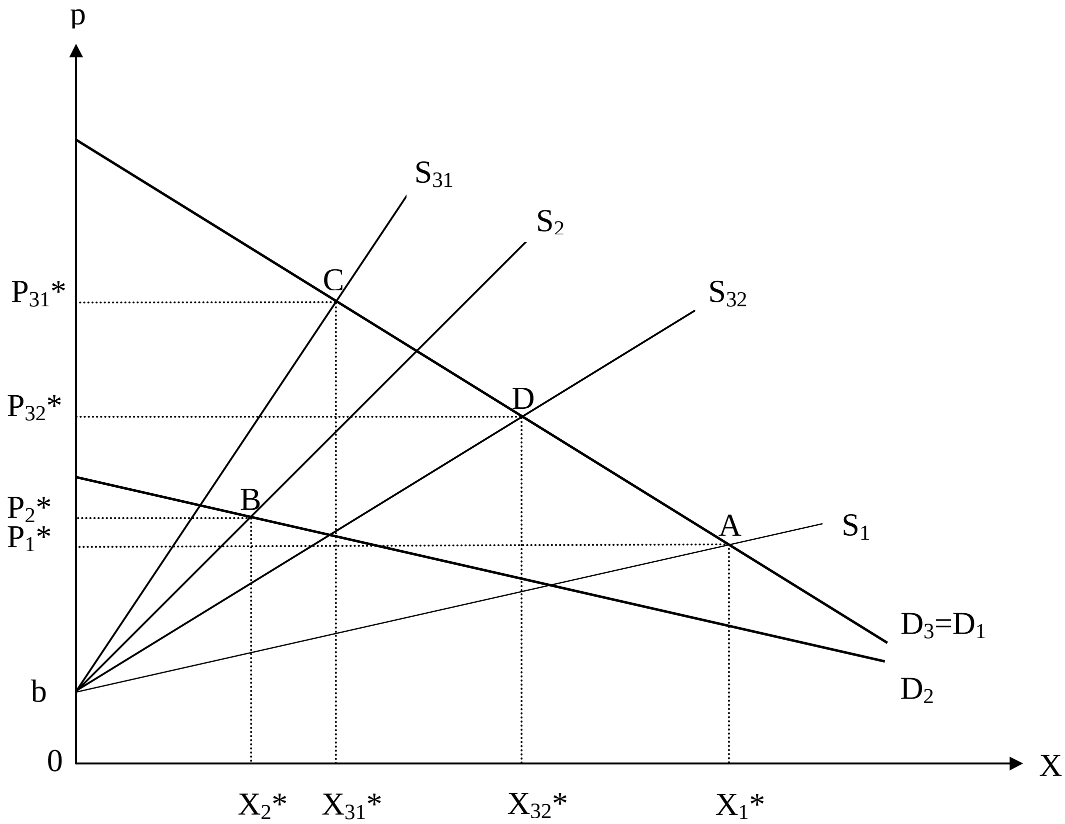


Figure 3.1 summarizes the three steps of our analysis. Point A describes the equilibrium before the outbreak of BSE whereas point B represents the situation after detection of the BSE risk in the market. Points C and D are two possible equilibria after the introduction of a BSE test by the government.

4. Empirical Results

Most empirical work so far has been done with data from the United Kingdom. Mainland/Ashworth (1992) analyze the effect of BSE on the revenue from beef fatstock with ARIMA forecast techniques. They estimate a revenue loss of 216.6 million pounds for the period from October 1989 to September 1990. Burton/Young (1996) and

Burton/Young/Cromb (1999) estimate the impact of BSE on the demand for beef and other meats in Great Britain within a dynamic almost ideal demand system. They find significant effects of BSE on the allocation of consumer expenditure among meats. A regional input-output model is used by Caskie/Davis/Moss (1999) to quantify the effects in final demand for beef in Northern Ireland. They find a regional income loss of 0.5% of the regional GDP and 0.6% job losses caused by BSE.

Pennings/Wansink/Muelenberg (2002) show that in comparison with Dutch and US consumers, Germans are extremely risk averse. At the beginning of 2001, German consumers were willing to reduce their beef consumption by 73.2% to 91.1%, depending on the supposed vCJD infection probability.

In the empirical part of our paper, we analyze the influence of BSE on the relationship between consumer and producer prices in a cointegration framework. In the next section, we start to describe the basics of our examination.

4.1 The Data

In November 2000, the month of the outbreak of the German BSE crisis, there were 14.48 million cattle in Germany, 4.54 million of which were dairy cows (Federal Statistical Office Germany, 2000). Two years later, there were 13.70 million cattle, including 4.37 million dairy cows (Federal Statistical Office Germany (2003).

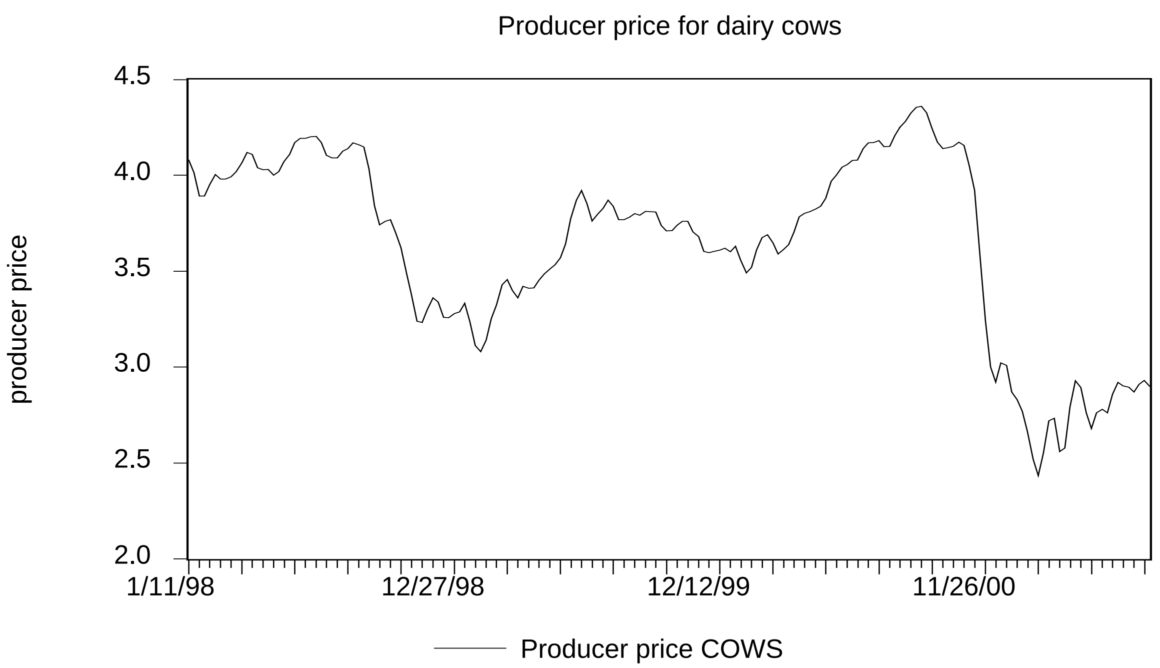
Using data from the German Ministry of Consumer Protection, Food and Agriculture (2003) from November 20, 2003 there have been a total of 283 BSE cases, 7 of which were in 2000, 125 in 2001, 106 in 2002 and 45 in 2003. The average age of a BSE bovine is 5 years and 11 months. The youngest was 2 years and 5 months and the oldest was 15 years and five months old. The birth cohorts range from September 1987 to December 1999. On average, the infected BSE bovines were born in August 1995. The average animal population of one farm with infected cattle was 200 bovines, with a minimum of 4 and a maximum of 2,946 animals. In two cases, the BSE bovine come from the same cohort/farm. This implies that there is on average a higher probability of finding an infected bovine on farms with one confirmed BSE case. This probability is 0.0036% in comparison with 0.0020% in the whole cattle population. More clearly: if a person daily consumes small quantities of non-tested beef, and assuming the beef stems from a different cow each time, the probability of eating infected meat throughout the year would be 0.73%! For this reason BSE risk constitutes a serious risk that should not be neglected.

The BSE risk played an important role in public discussions in Germany after the first BSE cases were found and the ignored risk suddenly became obvious. Beef consumption decreased sharply, e.g., 58.5% in the first week after detection of the first German case. We therefore have reason to expect the fear of eating infected beef to be reflected in the price level.

Because of their long life, dairy cows have a very high BSE risk and also a lower quality of meat. Meat cows are not tested because the incubation time of BSE is rather long (3 to 7 years) and BSE tests only detect BSE half a year before the outbreak of the disease. Meat cows, however, normally get slaughtered before they reach the age when BSE may be detected. We therefore use producer prices of dairy cows (COWS) and compare them with different beef prices for low and middle quality.[1)] In detail, we use prices for boiling meat (BBOILING), ground meat (BGROUND) and beef joints (BJOINT). We expect pronounced price reactions due to the BSE information.

In figure 4.1 the producer prices of slaughtered dairy cows are presented. We see, as expected, that the producer prices fall sharply with the occurrence of the first German BSE case on November 24, 2000. Before the BSE case the price was around 3.60 DM/kg; two weeks later it had reached 3.00 DM/kg. Market interventions were announced at the end of January 2001. Interestingly, the price reached a trough at 2.55 DM/kg in the next two weeks. Afterwards, the price began to rise again. - It should be noted that producer prices of younger cows behave similarly to those of dairy cows, but with less intensity.

Figure 4.1:



The price development of consumer prices presented in figure 4.2 is markedly different. Consumer prices, especially that of boiling meat, increase against the expected development.

Figure 4.2:

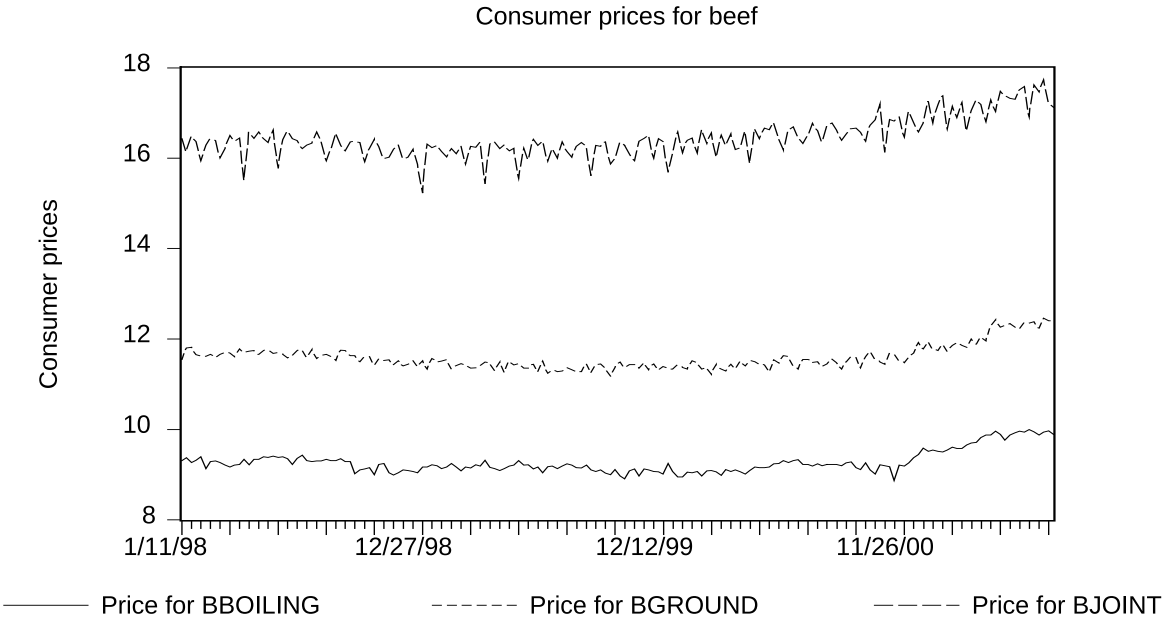
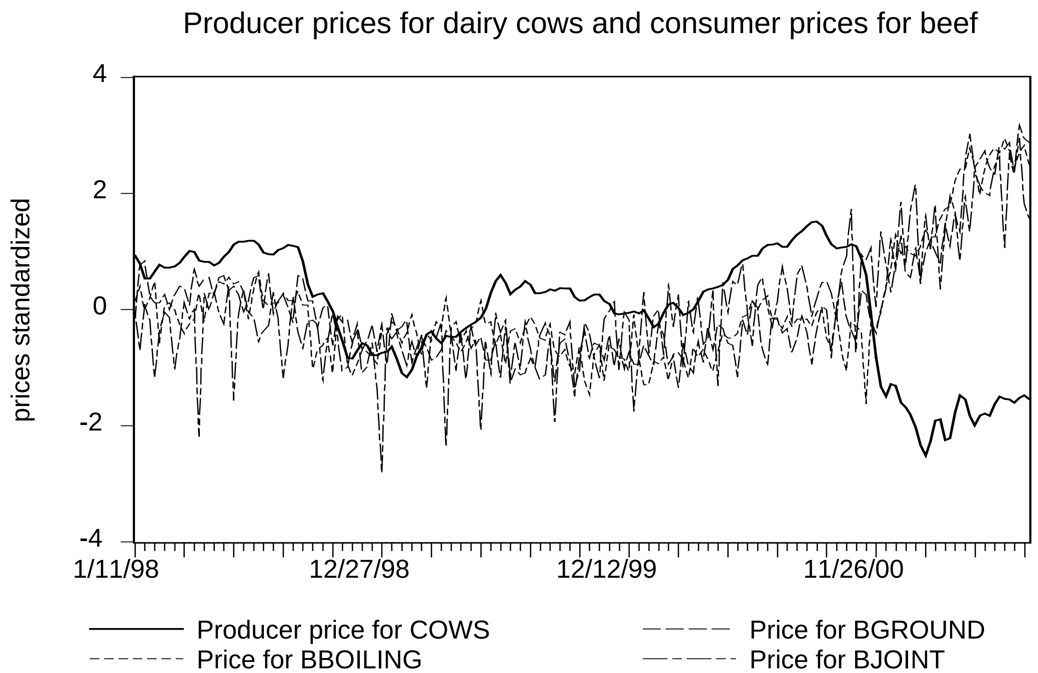


Figure 4.3:



[1] The data is from ZMP, Bonn.

In figure 4.3, we standardize all prices. We can see the joint band of shortly volatile consumer prices and, as a bold line, the development of producer price for dairy cows. The gap between producer and consumer prices after the first German BSE case is very clear.

In the next section, we analyze the time series properties of the consumer and producer prices and estimate the relationship between them. In particular, we investigate the question of a possible break due to the new BSE information.

4.2 Unit Root Tests under Known Break Points

We test the hypothesis of a unit root for the four price series assuming a known breakpoint that influences the mean of the time series using a modified augmented Dickey-Fuller test by Perron (1990) and Perron/Vogelsang (1992). In the first step, therefore, we regress the prices against a constant and the breakpoint dummy:

$$y_t = \mu_0 + \delta_1 \mathrm{D}U_t + u_t \tag{4.1}$$

with $\mathrm{D}U_t=0$ for $t \leq T_B$ and $\mathrm{D}U_t=1$ for $t>T_B$, where T_B is a breakpoint that shifts the level of the time series. The breakpoint we use is the first confirmed BSE case on November 24, 2000.

In the next step, we apply the augmented Dickey-Fuller (ADF) test to the adjusted time series $y_{adj,t} := y_t - \mu_0 - \delta_1 \mathrm{D}U_t$,

$$\Delta y_{adj,t} = \alpha y_{adj,t-1} + \delta_1 \Delta y_{adj,t-1} + \ldots + \delta_p \Delta y_{adj,t-p} + \beta_1 \mathrm{D}U_{t-1} + \ldots + \beta_p \mathrm{D}U_{t-p} + \mathrm{e}_t. \tag{4.2}$$

The optimal lag length p is chosen by the Schwarz criterion. The null hypothesis that the break adjusted y_{adj} time series are integrated of order one is H_0: $\alpha = 0$. We use the critical values from Perron (1990, p. 158) for the t-type test statistic. The results of this modified

Table 2:

Unit Root tests for the price series in the presence of a break

Time series	Modified ADF[(a)]	ADF for $t<T_B$[(b)]
COWS	-1.476	-1.72
BBOILING	-2.970*	2.53*
BGROUND	-2.295	-1.46
BJOINT	-2.573	-1.72

Note: '*' shows that the hypothesis of a unit root can be rejected at the 10% level.

(a) The estimation period is 1/11/1998 – 7/01/2001. T_B is 11/24/2000, the number of observations is T=182, and the fraction of observations after T_B is λ=0.82. We use the critical values for T=200 and λ=0.8 indicated by Perron (1990).

(b) ADF test with constant and 4 lags. The estimation period is 1/11/1998 – 11/19/2000.

ADF test are presented in table 2. Additionally, a standard ADF test (with a constant and 4 lags) is presented for the time before the outbreak of the German BSE crisis. The results show that we have no clear evidence to reject the unit root hypothesis for the data. Only the boiling meat reaches the 10%-significance level. We therefore assume that the adjusted time series are integrated of order one.

4.3 Robust Cointegration Test under Structural Breaks

We explain the producer price of dairy cow meat by a bundle of the three consumer prices. The results of the unit root test indicate that the price series are integrated of order one. We expect that these consumer and producer prices are cointegrated (i.e. they share a long-run stationary linear combination) with a co-break caused by BSE information and additional costs of slaughtering and BSE testing.

Arranz/Escribano (2000) show that dynamic conditional error correction models based on economic variables that have simultaneous co-breaks do not require the use of dummy variables. In simulation experiments, they find for sample sizes with more than 100 observations that one should use the N(0,1) critical values. This is valid for any value of the short term adjustment parameter, any jump size and for any type of segmented trend. In detail, they analyze different timings of the break, breaks only in one series, simultaneous breaks in the two series, breaks in the level of the series, breaks in the first differences of the series and also the possibility of two breaks. In Monte Carlo experiments they show a very good power of their cointegration test. In many situations the size adjusted power is 100% or near 100%. We therefore employ this model for our data set.

The starting point is the error correction model

$$\Delta y_t = c_t + a\Delta x_t + b(y_{t-1} - \alpha x_{t-1}) + u_{1t}, \qquad (4.3a)$$

$$\Delta x_t = \Delta\mu_x + u_{2t}, \qquad (4.3b)$$

and

$$c_t := \Delta\mu_y - a\Delta\mu_x - \mathrm{b}(\mu_{y,t-1} - \alpha\mu_{x,t-1}) \qquad (4.3c)$$

where y_t and x_t are two cointegrated time series and μ_y, μ_x are unconditional means of y and x. They include all possible deterministic elements like constant terms, trends, segmented trends, and dummy variables. Δ is the difference operator and a, b, α are parameters. The intercept c_t describes breaks in the differences $\Delta\mu$ as well as in the levels μ of the time series y_t and x_t. The time series have co-breaks in differences if $\Delta\mu_{y,t} - a\Delta\mu_{x,t}$ is a finite constant parameter, and in levels if $\mu_{y,t-1} - \alpha\mu_{x,t-1}$ is a finite constant parameter. In the case of a full co-break, meaning a simultaneous co-break in difference and in levels $c_t = c$, we get the standard error correction model. The interesting hypothesis of no-cointegration is H_0: b=0.

Using the idea of Toda/Yamamoto (1995) and Dolado/Lütkepohl (1996) of robust granger-causality testing with integrated and possibly cointegrated variables, Arranz/Escribano (2000) suggest overparametrizing the model by adding an extra lag to the error correction term in order to get standard inference results,

$$\Delta y_t = c + a\Delta x_t + b(y_{t-1} - \alpha x_{t-1}) + d(y_{t-2} - \alpha x_{t-2}) + u_t. \qquad (4.4)$$

The t-ratio of parameter b in equation (4.4) converges to the standard Normal distribution (Arranz/Escribano, 2000, p. 42). Hence we can test the hypothesis of no-cointegration using the standard normal distribution for t_b.

When there are extra dynamic regressors, the model becomes

$$\Delta y_t = c+ \delta_1\Delta y_{t-1}+...+\delta_p\Delta y_{t-p} + a\Delta x_t+ a_1\Delta x_{t-1}+...+ a_q\Delta x_{t-q}+b(y_{t-1}-\alpha x_{t-1})+ d(y_{t-k-2}-\alpha x_{t-k-2})+u_t, \quad (4.5)$$

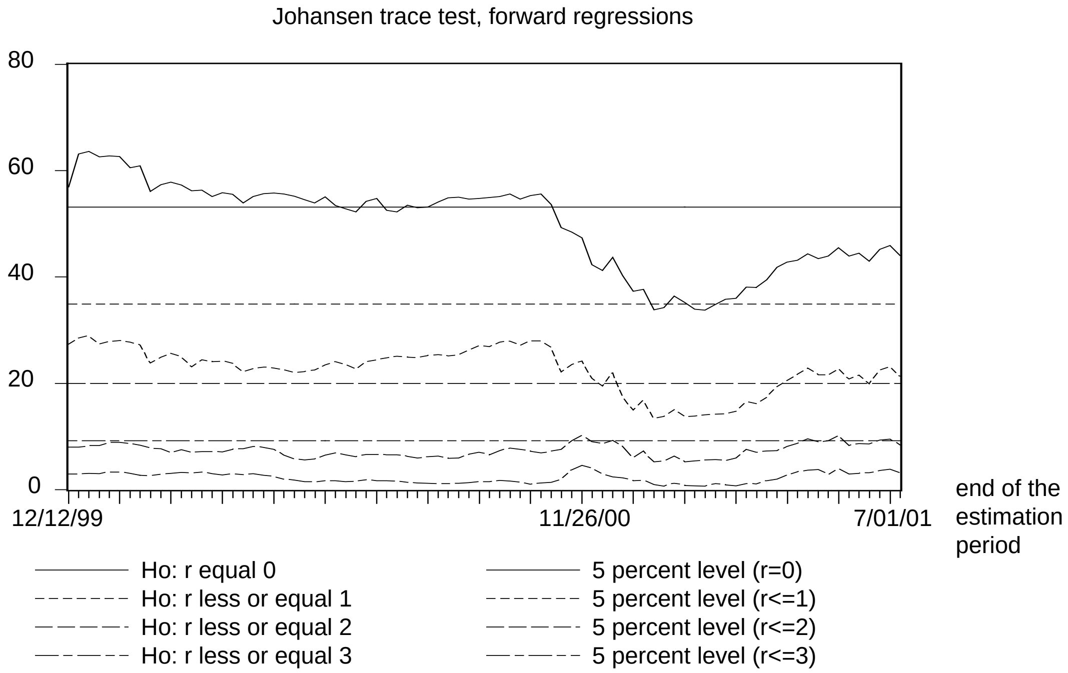
where k=max{p,q} is selected by using a consistent model selection criterion, in our case the Schwarz criterion. Alternative specifications of equation (4.5) are described by Arranz/Escribano (2000, p. 48).

4.4 Results of Cointegration Tests

We first employ recursive cointegration tests with the Johansen trace test (see Johansen/Juselius, 1990) in a four-dimensional vector autoregressive model of the price series with 4 lags and a constant term in the cointegration vector to analyze the dependence of the cointegration behavior on structural breaks. The lag length is suggested by the AIC criterion for the whole estimation period and also for the estimation period before the first German BSE case. We use forward regressions with the estimation period beginning on 1/11/1998 and at least 100 observations.

The results are presented in figure 4.4. For the pre-BSE period the null hypothesis of a cointegration rank equal to zero can be rejected at the 5%-significance level (critical values are taken from Osterwald-Lenum (1992, table 1*, p. 47), but not the hypothesis of higher cointegration ranks. Thus, we have one cointegration vector, meaning that the price decisions cannot be separated one from an other. With the first German BSE case the level of the test statistics begins to fall and we can no longer find any significant cointegration relationships.

Figure 4.4:



The next cointegration tests are carried out in the break robust dynamic model suggested by Arranz/Escribano (2000) according to equations (4.4) and (4.5). The maximum lag length *p*,*q* is set equal to 3. We use non-linear least squares estimation techniques to estimate these equations directly. The convergence rate is sometimes very slow, but all estimations converge. The outcome of the cointegration test strongly depends on the lag structure used. The optimal lag length chosen by the Schwarz criterion is $p = 2$ and $q = 0$. If we only select models under the restriction of equal lag length, the optimal lag length will be $p=q=1$. The test results of these estimations are presented in table 3.

Table 3:

Cointegration tests in a robust extended error correction model

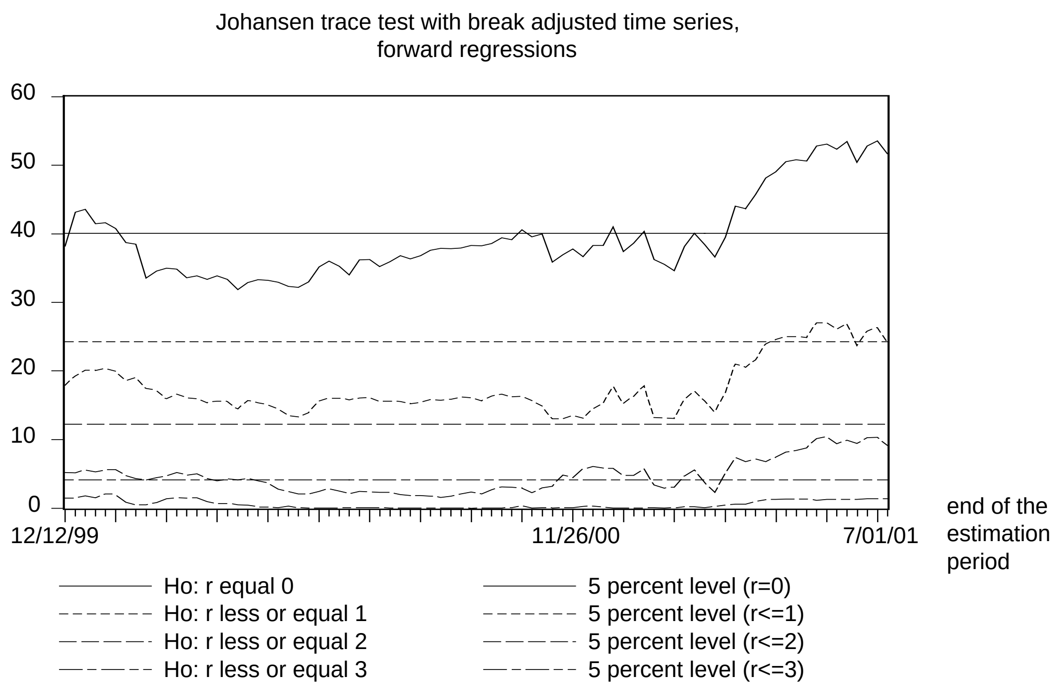
Model	equation (4.4)	equation (4.5)	
Lags (*p*,*q*)	(0,0)	(1,1)	(2,0)
Coefficient *b*	-0.006	-0.427***	0.199
t_b-statistics	-0.862	-6.147	2.672
R^2	0.101	0.476	0.510
Schwarz criterion	-2.203	-2.721	-2.751

Note: '***' shows that the hypothesis of no-cointegration can be rejected at the 1% level.
The estimation period is 1/11/1998 – 7/01/2001.

The message of the test results is not really clear. In the case of equation (4.4), the null hypothesis of no-cointegration cannot be rejected. If we allow additional dynamics according to equation (4.5), we find clear evidence against the null hypothesis of no-cointegration with $p=q=1$. But with $p=2$ and $q=0$, the no-cointegration hypothesis again cannot be rejected. In the last case, the error correction coefficient b is greater than zero and violates the cointegration condition of $-2<b<0$.

Additional recursive system cointegration tests with a simplified version of the Saikkonen/Lütkepohl (2000) trace test for time series with a level shift indicate that there might be at least one cointegration vector for consumer and producer prices. The Saikkonen/Lütkepohl (2000) system cointegration test is a two-step procedure. In the first step, the time series are mean and break adjusted and in the second step a cointegration trace test is performed. To adjust the time series, we use estimates of a vector autoregressive model in levels with $p=5$ lags, a constant term, and contemporaneous and lagged BSE dummies for the full sample period. The simplification is that we ignore the cointegration structure in this step. This might affect the small sample properties of the test, but not the asymptotic behavior, as remarked by Saikkonen/Lütkepohl (2000). In the next step, we perform the Johansen trace test with p-1 lags in the vector error correction model and no constant term in

Figure 4.5:



the cointegration equation for the mean and break adjusted series. We perform this step in forward regressions, starting with 100-*p* observations. We use the critical values from Trenkler (2003, p. 7, table 3), assuming a constant term with a level shift in the cointegration vector. The results are presented in figure 4.5.

A comparison with figure 4.4 reveals a similar outcome of the test up to the first German BSE case, but a lower significance level. The result might be explained by the loss of the first *p* observations in the first step of the procedure and by the small sample properties of the test. With the level break adjusted time series, the trace test lies below the 5%-significance level for some period before and after the outbreak of the BSE crisis. Nevertheless, for the full estimation period we find at least one highly significant cointegration vector. This cointegration result can only be explained by regarding the joint production process of the meat (see section 3.1 for a more detailed discussion).

5. Conclusions

Though the first BSE case in Germany was detected three years ago, the story has not yet come to an end. Thuringia had its fifth case of BSE on November, 19 2003. In our overview we started with the first case detected in Great Britain in 1986. Ten years later, the causal relationship between BSE and the new variant Creutzfeldt-Jakob Disease (vCJD) was considered highly probable and is no longer doubted at all today. By now, there have been 143 victims in Great Britain. Future vCJD victims are to be expected. In Germany, there is a high probability that cases of BSE have gone and will still go undetected, because monitoring and testing programs were inadequate.

In the second part of the paper, we present a simple model to describe the development of prices on the consumer market for beef. We work with a quasilinear utility function neglecting any substitution or income effects and develop the demand and supply functions based on one good production. With these instruments, we show the collapse of the market under the new occurrence of BSE risk, compared with a competitive situation under certainty. Due to a BSE test which works with certainty we explain the recovery of the market.

In the empirical analysis, we use weekly data of producer and consumer prices of beef in Germany for the period from January, 1998 to July, 2001. A graphical inspection of the data shows a strong structural break caused by the first BSE case. The producer price falls as expected, but the consumer prices rise. The price series reveals a long-run cointegration relationship between consumer and producer prices, which is affected by the outbreak of the

BSE crisis. But we have some indication of a joint co-break between the series. Having eliminated the breaks in the consumer and producer price series, we now find a cointegration relationship for the whole period. This means there is evidence of a new price mechanism between producer and consumer prices after the BSE outbreak, reflecting a change in behavior and additional costs.

The empirical facts suggest that our model should be extended. In future research, questions about the uncertainty of the BSE test, substitution effects, product differentiation and fraudulent behavior on the supply side should be answered. On the demand side, the behavior of consumers after having become used to BSE news is worth analyzing.

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