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# Food scare crises and price volatility: The case of the BSE in Spain

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ABSTRACT

Recent incidents of contaminated food products coupled with the widespread diffusion of news by mass media and the growing social concerns about food safety, have resulted in significant food market crises. One of the most highly publicized recent food scares involved Bovine Spongiform Encephalopathy (BSE). In our analysis, we evaluate the impacts from a BSE outbreak on the price volatility transmission along the Spanish food marketing chain by using a smooth transition conditional correlation (STCC) GARCH model. Our work is the first to assess price volatility responses to food scares. Results suggest that two distinct regimes involving different price volatility behavior can be distinguished, one characterized by turbulent markets and another where markets are calming down.



## Introduction

The structure of dependence for prices along the food marketing chain has received considerable attention in the price transmission literature, which has mainly focused on characterizing price level relationships (Goodwin and Holt, 1999; Miller and Hayenga, 2001; Serra and Goodwin, 2003). In an efficient market, where information is fully reflected in prices and assuming a given processed food supply, consumer demand determines retail food prices (Buguk et al., 2003). Making the necessary caveats for specific market conditions, it is generally true that prices at lower levels of the marketing chain can be determined by subtracting processing, transportation and other marketing costs from retail prices. Given the vertical linkages along the food marketing chain, it is reasonable to expect that not only price levels, but also price volatilities will be vertically transmitted (Natcher and Weaver, 1999). However, volatility interactions have generated much less interest than price level relationships, with some notable exceptions being the papers by Arpegis and Rezitis (2003), Buguk et al. (2003), or the unpublished work by Natcher and Weaver (1999).

Buguk et al. (2003) examine price volatility transmission along the US catfish supply chain by means of an exponential GARCH model. They find evidence of unidirectional spillover effects down the supply chain. Using aggregate agricultural input and output prices and retail food prices in Greece, Arpegis and Rezitis (2003) study volatility links in Greek food markets. Using a multivariate GARCH model, they find evidence of volatility links flowing up and down the marketing chain. Natcher and Weaver (1999) assess volatility transmission along the US beef marketing chain, by estimating individual conditional volatilities using a GARCH model. Predicted conditional variances are then introduced in a multivariate VAR model to explore volatility links between markets. Their results suggest volatility transmission among different market levels.

Market shocks may result in price level and volatility changes and may render traditional risk management tools ineffective. Since price volatility may bring losses to both consumers and producers (Newberry, 1989), it is important to assess volatility links in food markets. In contrast to the Food Economics literature, the Financial Economics literature has thoroughly assessed volatility links between financial assets, by modeling conditional covariances for the assets integrating a portfolio. Correlation has been commonly used as a measure for the linear dependence between individual financial asset standard deviations, and as an instrument that allows for conditional covariance measurement. Constant conditional correlation (CCC) GARCH models (Bollerslev, 1990) and their extensions such as the Dynamic Conditional Correlation (DCC) GARCH models (Engle, 2002) have been traditionally employed to estimate conditional variance and correlation matrices. Within this literature, there seems to be general agreement that major market events elicit dramatic changes in volatility correlations (Lin et al., 1994; Bookstaber, 1997; Longin and Solnik, 2001). While the impacts of shocks on financial markets have been deeply analyzed, the economics literature has paid little attention to the effects of markets shocks on price volatility along the food marketing chain.

If price volatility was fully and instantly transmitted through an efficient food marketing chain, one would expect a perfect (unity) correlation between volatility of prices at different market levels. A less than full pass-through of volatility along the food marketing chain (i.e. less than unity correlation) may occur under different

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circumstances (Arpegis and Rezitis, 2003): when farm output is substantially more perishable and less storable than the final processed food product; when demand elasticities differ at different levels of the marketing chain; or when market power at a certain market level prevents smooth price links. Negative correlations may also occur if volatility increases at one market level coincide with decreases in volatility at other levels. For example, during a food scare crisis, retail and producer prices may not react at the same time and to the same extent. After suffering from an initial price decline, retailers may choose to adopt strategies for ensuring food quality. They may carry out strict and costly quality controls which allow price recovery and stability. Coinciding with a decline in retail price volatility, one may observe a progressive increase in producer price instability. During this period, the observed volatility correlation is expected to be negative. It is also important to note that volatility interactions are not likely to remain constant over time due to changes in market structure and market shocks in the form of food scares or policy changes.

Recent incidents of contaminated food products along with the widespread diffusion of news by mass media and the growing social concerns about food safety issues have resulted in significant food market crises. The objective of this research is to assess the impacts of food scares on price instability in the marketing chain. More specifically, we discuss the impacts of one of the most highly publicized food scares over the last recent years, the Bovine Spongiform Encephalopathy (BSE), on beef markets in Spain.

Our empirical application is based upon the recently developed smooth transition conditional correlation (STCC) GARCH model by Silvennoinen and Teräsvirta (2005, 2009a). The use of STCC-GARCH models has been scarce and mainly confined to the Financial Economics literature. Our work makes two main contributions. First, this research is the first to assess food scare impacts on price volatility along the food marketing chain. Second, we apply a recently developed methodology that has not yet been used to assess price behavior in agrofood markets.

STCC models allow for an assessment regarding the existence of linear dependence between beef price volatility at different levels of the marketing chain. This method also allows us to evaluate the response from a market shock of the dependence relationship between prices. More specifically, our analysis focuses on how market signals elicited by food scares are assimilated by market price volatility, thus shedding light on market risk behavior during times of economic distress and helping market participants in designing appropriate hedging strategies.

For example, if we assume that the correlation between the standard deviation of producer and consumer prices is positive and strong then the risks faced by producers and consumers have common paths. This might also illuminate that an increase in risk at one level of the marketing chain is likely to involve an increase in the risk at another level. During an economic crisis, the correlation between volatilities may change. This is especially plausible if price levels during the crisis are not subject to the same adjustment processes in all marketing stages.

Previous research has shown that during past BSE crises beef consumer prices remained more or less constant while producer prices experienced significant adjustments (Lloyd et al., 2006). This was the case in Spain, where retailers mostly adopted a quality ensuring strategy, i.e., they assured that eating beef meat was safe. Since cutting retailer prices would be contradictory to the quality image they want to present, they maintained prices relatively constant. Conversely, producer prices suffered important declines. Hassouneh et al. (2010) further suggested that producer price adjustments were proportional to the time-changing magnitude of the crisis. This implies that the crisis may have caused different volatility impacts on different prices, causing changes in volatility links between producer and consumer prices. More specifically, we anticipate that conditional correlations are time varying and changed according to the magnitude of the BSE food scare crisis. Given the differences in price adjustments across different market levels, we hypothesize that conditional correlations may have experienced a decline (or even a sign switch from positive to negative) during the crisis. We measure the degree of the crisis by means of a media coverage index that proxies society concerns over beef contamination.

## The BSE and food safety concerns in Spain

In 2007, Spain produced 9% of EU-15 beef, being the fifth most relevant producer behind France, Italy, Germany, and the UK (Eurostat, 2009). Further, Spanish beef production represents around 16% of the gross animal production (Ministerio de Medio Ambiente y Medio Rural y Marino – MARM, 2008a). In contrast to the buoyant beef production activity in Spain, this country has the second lowest per capita consumption of beef within the EU (FAO, 2009).

BSE was first identified in 1986 by the UK's Government Central Veterinary Laboratory at Weybridge. Eruption of the crisis, however, did not occur until breakthrough news regarding the evolution of the disease were publicized in 1996, when the UK Government announced a possible link between consuming BSE-infected meat and the contraction of the variant Creutzfeldt-Jacob disease (vCJD), a lethal pathology that has claimed several human lives. Even though several measures were implemented, both at the national and EU levels, to prevent the infected animals from entering the food marketing chain and the spread of the disease, BSE expanded surpassing UK boundaries and infecting cattle in other EU and non-EU countries, and infecting food as well.

Since November 2000, when the first two BSE incidences in Spain were announced, the number of confirmed cases in Spain has grown reaching a maximum in 2003 with 167 reports. From 2000 to the end of 2009, the total number of reported cases was 763 (Administración General del Estado, 2009), which positions Spain in fourth place in the EU ranking of registered BSE incidents since 2001, after the UK, Ireland and France (Directorate General for Health and Consumers, 2010).

The evolution of beef production, trade and consumption in Spain has been significantly affected by BSE. While production grew from 565 thousand tons in 1996 to 678 thousand tons in 1999, it declined by 7% in 2000, coinciding with identification of the first BSE infection in Spain. Production recovered from this decline during the first half of the 2000s (Eurostat, 2009). The most visible impacts of BSE were on foreign trade and consumption. Spanish beef exports (imports) experienced a decline on the order of 19% (32%) in 2001 (MARM, 2008b). Beef consumption, around 10 kg per capita and year, went down in 2001 to 7.9 kg. Foreign trade and consumption recovered during the first half of the 2000s (MARM, 2006).

Previous literature has shown the relevance of non-price and non-income determinants in explaining consumer behavior. Among these determinants, consumer information on food contamination has been found to significantly influence purchase decisions (Piggott and Marsh, 2004). Studies on the economic impacts of food contamination have mainly focused on assessing the link between the magnitude of the crisis and consumer response (Mazzocchi, 2006; Piggott and Marsh, 2004; Burton and Young, 1996). Food safety indices based on a count of articles published in the popular press, have traditionally served as proxies for the public awareness of food scares.

The literature has proposed different alternative methods to build food safety indices. Mazzocchi (2006) or Burton and Young

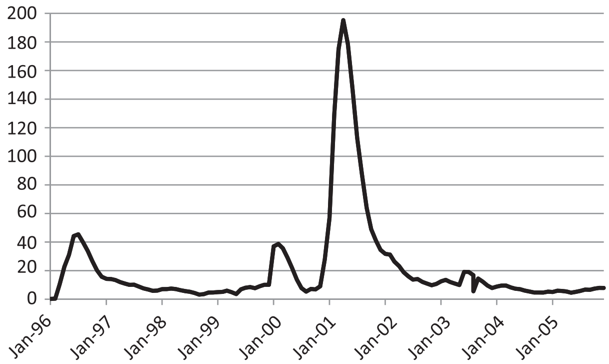


**Fig. 1.** Food scare information index derived by Hassouneh et al. (2010).

(1996) suggest that a food safety index should allow the effects of the news to dissipate over time. The index proposed by Chern and Zuo (1997) is based upon the assumption that news articles have a finite duration as an information source. Hassouneh et al. (2010) recently developed a food safety index based on Chern and Zuo (1997) to measure the degree of BSE food scare in Spain (Fig. 1). This index shows that two main events have increased consumer concerns in Spain: (1) the reported link between BSE and vCJD issued in 1996, and (2) the first detected BSE infection in the Spanish bovine herd in 2000.

## Methodology

Our analysis aims to assess temporal dependence in second-order moments between beef prices at different levels of the Spanish beef marketing chain. Multivariate GARCH models are especially well-suited to assess price volatility when prices are interrelated. The accurate estimation of time-varying covariances between these prices requires generalizing univariate models to a multivariate context (Silvennoinen and Teräsvirta, 2009b).

A widely used method in multivariate GARCH modeling has been to model conditional covariances through conditional correlations between individual standard deviations. One of the most well known models within this group is the CCC-GARCH model. However, the restrictive assumption of constant linear correlation has motivated a series of extensions that relax the constant correlation hypothesis. Silvennoinen and Teräsvirta (2005) propose a STCC-GARCH model that is based upon the assumption that conditional correlations change depending on the economic regime that prevails at each point in time. Following previous research results that demonstrate that major market events induce changes in volatility correlations (Lin et al., 1994), it is reasonable to assume that different price behavior regimes are also associated with different degrees of market turbulences.

The hypothesis that there exists a link between price volatility and market news is due to the seminal work by Engle and Ng (1993), who show how new price information is incorporated into price volatility by means of a news impact curve. Zheng et al. (2008) provide evidence that this link holds for US food markets. We model this link in the Spanish beef marketing chain by means of a STCC-GARCH model that allows conditional correlations between price standard deviations to change smoothly over time. The dynamic structure of time-varying correlations is allowed to be a function of an exogenous BSE media coverage index.

Consider the following stochastic 2-dimensional vector process containing producer ($y_p$) and consumer ($y_c$) beef prices:

$$\mathbf{y}_t = E[\mathbf{y}_t|\mathscr{F}_{t-1}] + \boldsymbol{\varepsilon}_t, \quad t = 1, \cdots, T, \tag{1}$$

where $F_{t-1}$ is the σ-field that has been generated by the information available up to time $t-1$. Each of the univariate errors in (1) can be expressed as $\varepsilon_{it} = h_{it}^{1/2} z_{it}$, where $i = 1, 2$, $z_{it}$ form a sequence of independent random errors with mean zero and unit variance, and $h_{it}$ is a conditional variance following a univariate GARCH structure:

$$h_{it} = \alpha_{i0} + \sum_{j=1}^{q} \alpha_{ij}\varepsilon_{i,t-j}^2 + \sum_{j=1}^{p} \beta_{ij} h_{i,t-j}. \tag{2}$$

The conditional covariance elements of vector $\mathbf{z}_t$ are given by $E[\mathbf{z}_t\mathbf{z}_t'|\mathscr{F}_{t-1}] = \mathbf{P}_t$. Since, as noted, the individual elements in $\mathbf{z}_t$ have unit variance, matrix $\mathbf{P}_t = [\rho_{ij,t}]_{i,j=1,2}$ is the conditional correlation matrix for $\boldsymbol{\varepsilon}_t$. The conditional covariance matrix for $\boldsymbol{\varepsilon}_t$ can be expressed as a function of conditional correlations as follows:

$$E\left[\boldsymbol{\varepsilon}_t\boldsymbol{\varepsilon}_t'\middle|\mathscr{F}_{t-1}\right] = \mathbf{S}_t\mathbf{P}_t\mathbf{S}_t, \tag{3}$$

where $\mathbf{S}_t = \mathrm{diag}\left(h_{1t}^{1/2}, h_{2t}^{1/2}\right)$. In the STCC-GARCH model the correlations $\rho_{ij,t}$ are allowed to vary over time. If $\rho_{ij,t} > 0$ ($\rho_{ij,t} < 0$), an increase in price volatility at one market level entails more (less) volatility at the other level. Full (less than full) volatility transmission involves $\rho_{ij,t} = 1$ ($\rho_{ij,t} < 1$).

Silvennoinen and Teräsvirta (2005) specify the dynamic structure of the conditional correlation as follows:

$$\mathbf{P}_t = (1 - G_t)\mathbf{P}_1 + G_t\mathbf{P}_2, \tag{4}$$

where $\mathbf{P}_1$ and $\mathbf{P}_2$ are positive definite correlation matrices that ensure positive definiteness of $\mathbf{P}_t$. $G_t$ is a continuous transition function bounded between zero and one, that depends on the transition variable $\Delta I_t$, defined as the food scare information index in first differences,[1] and the associated parameters $c$ and $\gamma$ that reflect the location of the transition between regimes and the speed of transition from one regime to another, respectively. A value of $c$ close to zero implies that price behavior can be characterized by two extreme regimes, one occurring during periods in which news on the food scare are growing ($\Delta I_t > 0$) and another during periods characterized by a decline in the number of news ($\Delta I_t < 0$). Further, a value of $\gamma$ close to zero should be interpreted as evidence against time-changing correlation, while big values of $\gamma$ represent a price system where volatility correlations vary quickly over time depending on the food scare index changes ($\Delta I_t$). The transition function is specified as a logistic function as follows:

$$G_t(\Delta I_t; \gamma, c) = \left(1 + e^{-\gamma(\Delta I_t - c)}\right)^{-1}, \quad \gamma > 0. \tag{5}$$

Under this specification, $G_t$ changes monotonically from 0 to 1 as the transition variable increases. For values of $\Delta I_t - c$ close to $+\infty$, $G_t = 1$, while for values of $\Delta I_t - c$ close to $-\infty$, $G_t = 0$. Actual conditional correlations $\mathbf{P}_t$ can move within the range defined by the two extreme correlation regimes, $\mathbf{P}_1$ and $\mathbf{P}_2$, and a whole range of middle regimes is also allowed as follows. When $\Delta I_t < c$, i.e., when the number of news is declining, actual correlations will be closer to $\mathbf{P}_1$, conversely, $\Delta I_t > c$ (i.e., an increase in the number of news) will lead to correlations closer to $\mathbf{P}_2$. As explained in the introduction section, we expect a decline in volatility correlation between the two prices studied as a response to rising levels of the food scare index.

The STCC-GARCH model can be estimated by maximum likelihood procedures under the assumption that the errors are jointly conditional normal $\mathbf{z}_t|\mathscr{F}_{t-1} \sim N(0, \mathbf{P}_t)$ (Silvennoinen and Teräsvirta, 2005). Before model estimation, one should test for constant

[1] Important convergence difficulties in the estimation process were encountered when using $I_t$ as opposed to $\Delta I_t > 0$. Convergence difficulties are usual in the estimation of STCC-GARCH models (Silvennoinen and Teräsvirta, 2005). Further, as will be seen below, the fact that the dependent variables ($\boldsymbol{y}_t$) in our model represent producer and consumer prices in first differences may make $\Delta I_t > 0$ more suitable to explain their volatility.

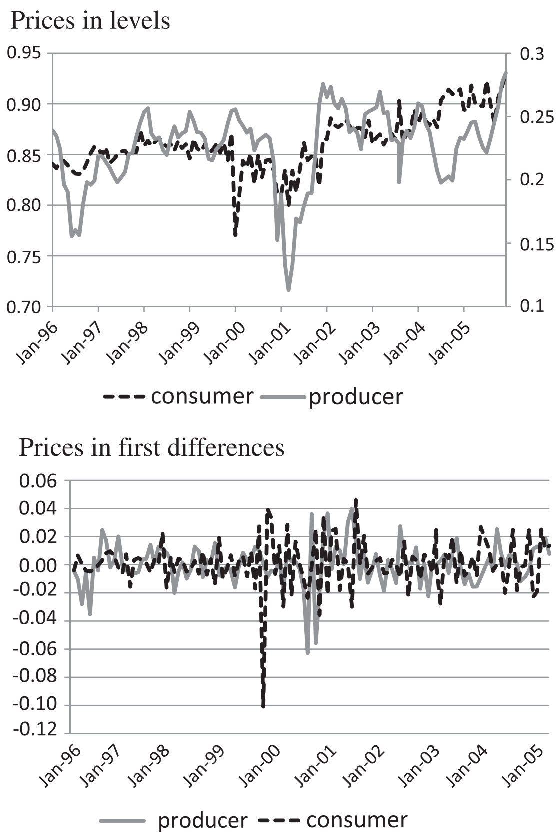


**Fig. 2.** Logged producer and consumer prices in levels and in first differences. Note: in the first graph, producer (consumer) prices are plotted on the right (left)-hand side of the axis.

against time-varying conditional correlation. Silvennoinen and Teräsvirta (2005) propose a LM-type test of the null hypothesis of constant conditional correlation, $H_0: \gamma = 0$, against the alternative of a STCC-GARCH model. For details on how to estimate the model and derive the statistic, see Silvennoinen and Teräsvirta (2005).

## Empirical application

The objective of this article is to assess the linkages between price volatility at different levels of the Spanish beef marketing chain resulting from the Spanish BSE crisis. We focus on farm-gate and consumer beef prices. Monthly farm-gate prime beef (1–2 years old cattle) prices expressed in euros per kilo (live weight) and consumer prices, defined as average fresh retail beef prices (in euros per kg) are collected by the Spanish Ministry for Agriculture (MARM). While farm-gate prices are publicly available from the monthly publication "Boletín Mensual de Estadística," consumer prices are available from the Ministry upon request. Although the two prices are comparable, retail prices include marketing services not included in producer prices. Stability in marketing services' prices may contribute to more stability in consumer prices relative to producer prices. This may lead to a less than full pass-through of price volatilities along the food marketing chain.

As noted, the impact of BSE on beef markets is likely to be proportional to the changing magnitude of the scare, which we approximate by means of a news index. We use the index recently built by Hassouneh et al. (2010) that, together with the price series mentioned above, are freely available from the Wiley Interscience Website.[2] The index is presented in Fig. 1. Logged and

[2] http://www3.interscience.wiley.com/journal/123234978/abstract.

**Table 1**
Johansen $\lambda_{trace}$ test for cointegration.

| Ho | Ha | $\lambda_{trace}$ | *P*-value |
|---|---|---|---|
| $r = 0$ | $r > 0$ | 21.187 | 0.035 |
| $r \leqslant 1$ | $r > 1$ | 2.202 | 0.737 |

first-differenced price levels are graphically presented over time in Fig. 2. A comparison of these figures suggests that major price adjustments coincide with major increases in the food scare index, which may indicate that the index is a good indicator of the economic impacts from the crisis.

From Fig. 2, it is also evident that major adjustments in producer and consumer prices do not match. While both prices are found to decline as a response to the crisis, consumer prices responded early in 2000, coinciding with an increase in the number of news and the progressive infection of neighboring countries such as France. However, they recover afterwards and do not fall back to previous levels once the first BSE cases are detected in Spain. This is compatible with the position adopted by retailers during the crisis, who assured that eating beef meat was safe, which would result in a recovery of consumer demand and higher prices. Conversely, producer prices fall significantly once the BSE enters Spain.

Logarithmic transformations of the series are taken to carry out the price analysis. Previous to the estimation of the model, the time-series properties of the logged price series were studied. Unit root tests confirmed that the price series are integrated of order 1.[3] The results from cointegration tests based on Johansen (1988) are found in Table 1 and provide evidence that producer and consumer prices are linked through the following long-run relationship: $y_p = 0.560 - 0.548y_c$ .

In light of the difficulties involved in the estimation of the STCC-GARCH model, the mean equations in (1), $E[\mathbf{y}_t|\mathscr{F}_{t-1}]$, were estimated in a first stage.[4] The errors from this first stage were then used to model conditional error covariances. Mean equations were expressed as follows:[5]

$$\begin{cases} \Delta y_{p,t} = \delta_{11} ect_{t-1} + \delta_{12}\Delta y_{p,t-1} + \delta_{13}\Delta y_{p,t-3} \\ \qquad\quad +\delta_{14}\Delta y_{c,t-1} + \delta_{15}\Delta y_{c,t-3} + \delta_{16}\Delta I_t \\ \Delta y_{c,t} = \delta_{21} ect_{t-1} + \delta_{22}\Delta y_{p,t-1} + \delta_{23}\Delta y_{p,t-3} \\ \qquad\quad +\delta_{24}\Delta y_{c,t-1} + \delta_{25}\Delta y_{c,t-3} + \delta_{26}\Delta I_t \end{cases} \tag{6}$$

where $ect_{t-1}$ measures the distance of the price system to the long-run relationship at $t-1$. Results derived from the estimation of (9) using the SUR technique are presented in Table 2. Compatible with previous research (Hassouneh et al., 2010), parameter estimates suggest that while producer prices react to deviations of the price system from the equilibrium relationship and move to re-equilibrate it, consumer prices do not respond to system disequilibriums. Short-run price dynamics suggest that producer and consumer prices respond to their own lags. Further, both prices are found to react to changes in the food scare index: increases (reductions) in the index are found to reduce (increase) producer and consumer prices.

Parameter estimates for the STCC-GARCH model were derived by ML procedures (Silvennoinen and Teräsvirta, 2005). As is common practice, parameters $p$ and $q$ in (2) were set to one. The transition variable, $\Delta I_t$, is presented in Fig. 3. Parameter estimates are presented in Table 3. The test for the null of a CCC against the

[3] Results are available from authors upon request.
[4] Joint estimation was not possible since the optimization algorithm did not converge.
[5] Different specifications of the model were considered and yielded similar results. The final selection of lags was based upon parsimony and statistical significance.

**Table 2**
Mean equations parameter estimates.

| | Producer equation ($\Delta y_{p,t}$) parameter (std) | Consumer equation ($\Delta y_{c,t}$) parameter (std) |
|---|---|---|
| $ect_{t-1}$ | −0.194 (0.047)** | 0.004 (0.053) |
| $\Delta y_{p,t-1}$ | 0.096 (0.086) | 0.094 (0.097) |
| $\Delta y_{p,t-3}$ | 0.179 (0.086)** | 0.153 (0.097) |
| $\Delta y_{c,t-1}$ | −0.045 (0.069) | −0.471 (0.078)** |
| $\Delta y_{c,t-3}$ | −0.008 (0.068) | −0.032 (0.077) |
| $\Delta I_t$ | −0.037 (0.011) ** | −0.046 (0.012)** |

* Statistical significance at the 10% significance level.
** Statistical significance at the 5% significance level.

alternative of a STCC-GARCH (Silvennoinen and Teräsvirta, 2005) allows us to comfortably reject the null and provides evidence that conditional correlations change depending on the food scare information index. The transition parameter, that takes the value of 0.35 is not statistically different from zero. This allows us to distinguish between two price behavior regimes: one corresponding to increases and the other to declines of the food scare index. As noted above, a transition parameter ($\gamma$) that is equal to zero suggests a constant conditional correlation between producer and consumer price volatilities. Conversely, a value of infinity implies an immediate adjustment in this correlation to changes in market conditions. Compatible with the CCC versus STCC-GARCH test results, our $\gamma$ parameter estimate is statistically significant thus supporting the hypothesis of time-changing correlation. However, it's

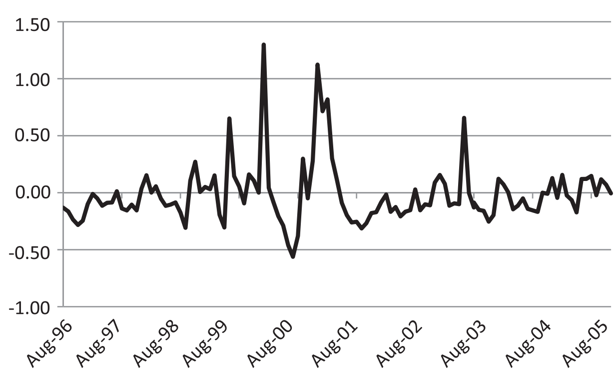


**Fig. 3.** Transition variable.

**Table 3**
STCC-GARCH model parameter estimates.

| | Univariate GARCH processes | |
|---|---|---|
| | Producer equation ($\Delta y_{p,t}$) parameter (std) | Consumer equation ($\Delta y_{c,t}$) parameter (std) |
| $\alpha_{i0}$ | 6.843e-4 (5.440e-7)** | 1.205e-4 (2.442e-5)** |
| $\alpha_{i1}$ | −0.269 (0.013)** | 0.694 (0.026)** |
| $\beta_{i1}$ | 0.363 (0.086)** | 0.240 (0.034)** |
| *Correlation parameters. Parameter (std)* | | |
| $\rho_1(G_t = 0)$ | | 0.389 (0.158)** |
| $\rho_2(G_t = 1)$ | | −0.635 (0.155)** |
| *Transition function. Parameter (std)* | | |
| $\gamma$ | | 1.030 (0.602)* |
| $c$ | | 0.352 (0.340) |
| *Test of a CCC-GARCH against a STCC-GARCH* | | |
| $LM_{CCC}$ | | 5.207** |

* Denotes statistical significance at the 10% significance level.
** Denotes statistical significance at the 5% significance level.

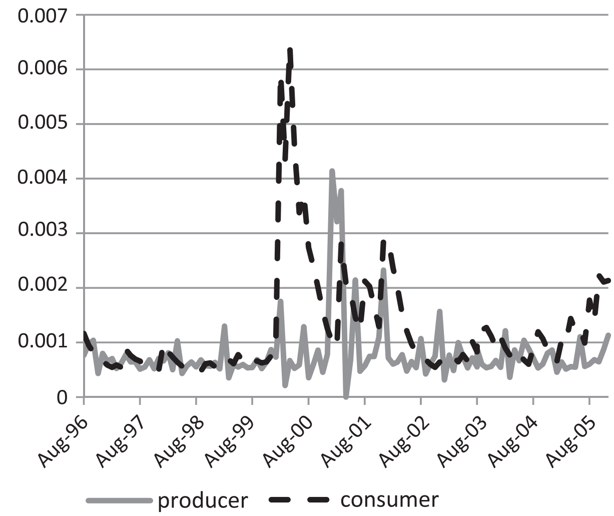


**Fig. 4.** Predicted price variances.

small value of 1.03 is still far from denoting an immediate adjustment.

The first price regime corresponds to negative values of the transition variable, i.e., to a situation where the number of BSE news is declining. Within this regime, the correlation between producer and consumer price volatility is positive. This implies that in periods when the food scare index levels are falling, an increase in the volatility at one market level will be related to more volatility at another level. Given the relatively low value of the correlation coefficient (0.38), the transmission of volatility, however, is not perfect. As noted above, relatively stable marketing prices included in consumer prices partially contribute to explain this less than full pass-through of price volatilities.

The second regime is related to an increase in the number of news coverage. The correlation within this regime is negative thus confirming our initial hypothesis. This correlation, equal to −0.63, implies that an increase in the volatility at one market level, is related to less volatility at the other level. This is compatible with the BSE crisis affecting differently consumer and producer prices: during the early 2000 consumer prices change considerably and producer prices remain stable. By the end of the year and during 2001, it is the producer price that declines, while consumer markets are quieter. Predicted volatilities are presented in Fig. 4 and confirm this hypothesis: during the early 2000s, consumer prices are highly volatile, while producer markets are relatively peaceful. By the end of the year and during 2001, coinciding with the first BSE cases, strong turbulences affect producer markets while consumer markets start to relax.

The change in the sign of the correlation coefficient from positive to negative when the food scare index levels change from falling to rising, suggests the presence of several rigidities in the Spanish beef marketing chain that prevent transmission of price volatility during times of economic distress. While the market power exerted by retail chains allowed them to follow a quality ensuring strategy that quickly stabilized prices after an initial decline, producers were unable to do so and suffered strong price declines and instability during the peak of the crisis.[6]

[6] It is important to note however that the econometric model applied in our analysis is not based upon a theoretical framework capable of incorporating all aspects of price formation. Since competing hypotheses may underlie a certain form of revealed price behavior, our interpretation of our results based on market power should be taken with care.

Previous research on the impacts of BSE on price behavior has ignored price volatility, being thus difficult to assess whether our results can be extended to other countries. Lloyd et al. (2006) have shown that UK producer prices experienced stronger adjustments relative to consumer prices, which coincides with the Spanish case (Hassouneh et al., 2010). Price declines were however of different magnitude and required different time periods to materialize. The producer price index for cattle in the UK declined from 1995 to 1998 by 31%. Conversely, the same price index in Spain suffered a decline from 2000 to 2001 on the order of 12% (Eurostat, 2009). Since volatility issues are related not only with the magnitude of price adjustment, but also with the time it takes a price to adjust, we should not extend our conclusions to other countries.

Structural differences across countries and sectors may also call for caution when extrapolating results to other countries or food scares. A recent analysis shows the important differences in the elasticity of price transmission along the food marketing chain across different EU countries (Bukeviciute et al., 2009) that are attributed to differences in macro-economic factors, cost structures in EU member states, the fragmented EU single market, or the differences in the food marketing chain in terms of competition and regulation.

## Discussion and concluding remarks

Dealing with abrupt market shocks requires not only an assessment of how price levels respond, but also of how their volatility is affected. Changes in volatility may render traditional risk management tools ineffective. They may also have important structural implications. Bénabou and Gertner (1993) argue that volatility in retail prices may increase search costs, reducing the incentive for consumer search and increasing retailer market power. Volatility may also foster the abandonment of small agricultural producers unable to cope with lower and much more volatile prices. This may require public intervention in the market. Assessing volatility along the food marketing chain is thus relevant for both market participants and policy makers.

One of the most relevant shocks that food markets can experience is a food scare. BSE has been one of the most highly publicized food scares in recent memory. We assess the impacts of BSE on price volatility in the Spanish beef marketing chain. In the presence of a food scare, public intervention in the form of inventory management tends to be relevant. While this can be a powerful risk management tool, results suggest that the BSE crisis has substantially affected both beef price levels and volatility at the different levels of the marketing chain. While price levels have declined, volatility has increased.

Abrupt changes in volatility during the crisis results in two different price behavior regimes. In a first regime, representing a situation where the number of news on the food scare is falling, an increase in the price volatility at one market level implies an increase in the volatility at the other levels. In the second regime, corresponding to rising levels of the food scare index, and due to the strategy that retailers adopted to face the BSE crisis, there is a negative correlation between the volatilities at the different levels of the beef marketing chain. Hence, public intervention during the crisis was unable to prevent an important increase in volatilities and, further, was not capable of stabilizing both consumer and producer prices at the same time due to the negative sign associated with volatility spillovers along the food marketing chain.

Hence, mitigating the impacts of relevant food scares may require different types of intervention at different levels of the market chain: our results show that during turbulent times, price volatilities can be negatively correlated and one cannot expect that stabilizing one market will lead to stability in other related markets. This result is compatible with previous research results that suggest that retailers' market power may prevent price shocks from flowing up and down the food marketing chain.

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