Food scares and price volatility: the case of German and Spanish pig chains

Tsion Taye Assefa, Miranda P.M. Meuwissen and Alfons G.J.M. Oude Lansink

Business Economics Group, Department of Social Sciences, Wageningen University

Abstract

With the liberalization of EU agricultural markets, EU farmers are increasingly exposed to global and local market shocks. A major source of market shocks in the livestock sector is animal food scare. By applying the recently developed methodology of volatility response functions of Hafner and Herwartz (2006), we investigated how news of selected food scares affected price volatilities in the German and Spanish pig chains. Overall, the results suggest that the size of the shock matters for price volatility to increase in response to news of a food scare. Our results confirm that if the shock is large enough, news of food scares do increase price volatility. The results highlight the importance of price risk insurance for non-infected farms given the current opportunity to benefit from EU premium subsidies for such type of insurance.

Keywords: Price volatility, food scares, pig chain, Germany, Spain, volatility impulse response functions.

JEL codes: C5, Q11

1. Introduction

With the increased liberalization of EU agricultural markets, EU farmers are increasingly exposed to price volatility stemming from both global and local markets shocks (Tangermann, 2011). Factors causing imbalance of demand and supply such as weather shocks and trade restricting policy measures are often attributed to the rise in price volatility (FAO et al., 2011). In the livestock sector, a largely ignored source of price shocks is animal food scare. News of food scares results in consumer panic and loss of confidence in the safety of consuming meat products (Feindt and kleinschmit, 2011; Kupferschmidt, 2011; Serra, 2011; Thomson et al., 2012), and therefore in lower producer prices. Although the link between producer price levels and news on food scares is fairly explored (Hassouneh et al., 2010), the link between producer price volatility and news of food scares remains unexplored. This is with the exception of the studies by Serra (2011) and Van Asseldonk et al. (2000) who showed that periods of outbreaks are associated with higher producer price volatility.

Price volatility implies risk in particular to non-infected farms which, in addition to facing lower prices for their livestock have to face price uncertainty. In the EU, private insurance indemnifications are in general available for infected farms covering direct and consequential losses (Melyukhina, 2011). Insurance coverage of market losses of non-infected farms is perceived as difficult to insure due to the size of the risk and the uncertainty surrounding the scope of the insurance (whether it should apply to the whole country or to only non-infected farms in restriction zones) (Meuwissen and Van Asseldonk, 2013). However, there is still scope for insuring price risk of non-infected farms given the availability of EU premium subsidies for mutual and commercial insurance schemes as indicated in Article 68 of EC 73/2009 (Meuwissen and Van Asseldonk, 2013). It is therefore of interest to investigate the effects that news of food scare has on the volatility in livestock prices.

In this study, we investigate the effect of shocks arising from news of selected food scares on price volatility in the German and Spanish pig sectors. Germany and Spain are two of the leading pig producers in the EU (Eurostat, 2010) who have seen their share of food scares in the last decade. The effects of four food scares are investigated in this study. These are the January 2011 detection of dioxin in pig feed in Germany (European Commission a), the June 2001 detection of Classical Swine Fever in Spain (USDA), the February 1997 detection of Classical Swine Fever in the Netherlands (Mangen and Burrell, 2003) and the November 2000 detection of the BSE (Bovine Spongiform Encephalopathy) in Germany and Spain (Feindt and Kleinschmit, 2011; Serra, 2011). We include the last two food scares to see any cross-country (Netherlands versus Germany and

Spain) and cross-product (pig versus cattle) effects in food scares and price volatility. A comparison between volatility responses in Germany and Spain will further reveal implicit differences in consumer responses to food scare news in these two countries.

We employ the recently developed method of volatility impulse responses (VIRF) computations of Hafner and Herwartz (2006) to analyse the volatility effect of shocks arising from news of the selected food scares. In traditional impulse response analysis within a multivariate framework, it is assumed that errors are not contemporaneously correlated. This implies that a shock in one market occurs without contemporaneous shocks in the other market. Hafner and Herwartz (2006) argue to the contrary and develop a method to measure independent shocks that occur simultaneously and affect different markets at the same time. The VIRF computations are based on the coefficients estimates of a BEKK (Baba-Engle-Kraft-Kroner) model, which we estimate using monthly wheat, piglet and pig prices in the two countries. We incorporate wheat prices in the model as wheat is a major ingredient in pig feed (42% of cereals used in pig compound feed in the EU (Brookes, 2001), and can give a more complete picture of price volatility linkages along each of the two pig chains.

Our contribution to the current literature is twofold. First, to our knowledge, no study in the field of agricultural economics has employed the recent VIRF methodology of Hafner and Herwartz (2006). Their method has been applied though in the finance and energy literature with the studies by papers by Panopoulou and Pantelidis (2009), Le Pen and Sevi (2010), Jin et al. (2012) being notable ones. Its application in this study demonstrates the method's potential to investigate any other major market shocks with effects on food and agricultural price volatilities. The method is particularly suitable to investigate the immediate effects of market shocks on price volatility. Second, we also show through the BEKK coefficient estimates the effect of wheat price volatility on piglet and pig price volatility, and vice versa. Although it is generally acknowledged that feed price volatility plays an important role in pig price volatility, such impact has not been quantified so far (with the exception of Khan and Helmers (1997) on corn-pig volatility transmissions in the US). Investigations of feed-pig price volatility transmissions have been limited to date to the catfish and poultry sectors (Assefa et al., 2014).

The remainder of the paper is organized as follows. Section 2 provides literature on food scares and prices. Section 3 presents the BEKK model, explains the computations of VIRF, and Section 4 describes the data used. Section 5 presents the results of the BEKK model and VIRF and discusses the results. Section 6 concludes the study.

2. Food scares and prices

Studies on the effect of food scares on the transmission of meat prices along the chain have dominated the current literature on the relationship between food scares and prices. The papers by Lloyd et al. (2001), Lloyd et al. (2004), Sanjuan and Dawson (2003) for the UK beef market, Livanis et al. (2005) for the US beef market, Lloyd et al. (2006) for the UK beef market, and Hassouneh et al. (2010) for the Spanish beef market are examples of such studies. These papers share a commonality in that they focus on the detection of the BSE in the period from the early 90's to early 2000's. A media index on the BSE is generally used to measure the BSE crisis. Although slight variations exist across these studies, the computation of the media index generally involves the generation of a time series of monthly or weekly counts of newspaper articles that published on the BSE crisis. This indicates the important role that the media plays in the realization of food scare related market shocks. A common finding of the studies is that farm prices dropped much more than the retail prices as a result of the BSE crisis, thereby causing a widening of retail-farm marketing margin.

Although with less number of studies, another category of studies are those focusing solely on livestock prices levels and food scares. The papers by Saghaian et al. (2007) for the Japanese beef market and that of Leeming and Turner (2004) for the UK beef, lamb and pork markets fall in this category. Both papers study the BSE crisis of the early 90's and early 2000's. The studies take different approaches to measure the crisis. Saghaian et al. (2007) compare actual producer beef price series with forecasts of beef prices using price data before the crisis, with the forecasted price series serving as proxy of beef prices if the crisis had not occurred. Leeming and Turner (2004) on the other hand, use dummy variables taking a value of 1 during the outbreak period and 0 elsewhere. Both studies find a negative effect of the crisis on beef prices. Leeming and Turner (2004) additionally find a positive effect of the crisis on lamb prices, with no effects on pork prices. This finding highlights substitution effects across lamb and beef.

The third category of studies, also with few numbers of studies, focuses on the relationship between price volatility and food scares. The papers by Serra (2011) on the Spanish beef market and Van Asseldonk et al. (2000) on the Dutch, German, Danish, Belgium and French pig market are, to our knowledge, the only studies focusing on this relationship. While Van Asseldonk et al. (2000) study the effect of the 1997 Dutch CSF, Serra (2011) studies the effect of BSE crisis that occurred between the early 90s and early 2000s in Spain. Dummy variables that take a value of 1 during outbreak periods and 0 otherwise, as well as dummies taking a value of 1 after the outbreak and 0 other wise are used to measure the CSF crisis in Asseldonk et al. (2000). Serra (2011) on the other hand uses the media index developed by Hassouneh et al. (2011) to measure the BSE crisis. It should be noted that the paper by Serra (2011) does not focus on the effect of the crisis on price volatility per se, but rather the effect of the crisis on the correlations between producer and retail price volatilities. Van Asseldonk et al. (2000) find that the CSF had a positive effect on pig price volatilities not only in The Netherlands, but also in the other countries as well. The latter point highlights the cross-country effects of food scares. Serra (2011) finds a negative effect of the BSE crisis on the correlations of producer and retail price volatilities.

In sum, the above literature confirms the negative relationship between price levels and food scares, as well as the positive relationship between food scares and price volatility. Three limitations emerge however from the review. The first and most obvious one is the limited coverage of the pig sector. Second, studies on the effect of food scares on price volatility are very scarce. Third, although the paper by Asseldonk et al. (2000) addresses the effect of food scare crisis on price volatility, the immediate effects of the crisis on volatility were not assessed. This is because their paper looks at the average effect of the crisis over several months of the outbreak. The methodology of Hafner and Herwartz (2006) employed in our paper can address this literature gap.

3. Methods

3.1. Model

We employ a multivariate generalized autoregressive conditional heteroskedasticity model (MGARCH) with BEKK (Baba-Engle-Kraft-Kroner) specification to analyse volatility transmissions in the German and Spanish pig chains. The volatility impulse response functions will be computed using the BEKK coefficients. The BEKK specification is suitable for the analysis of volatility transmissions across markets compared to alternative MGARCH specifications such as the Constant Conditional Correlation and the Dynamic Conditional Correlation models. Cross and own market shock and volatility transmissions and persistence can easily be identified using BEKK coefficients (Gardebroek and Hernandez, 2013). The full BEKK model is specified as follows:

$$Y_t = C + \sum_{j=1}^{k} \Gamma_j Y_{t-j} + u_t \tag{1}$$

$$H_t = WW' + A' u_{t-1} u_{t-1}' A + B' H_{t-1} B \tag{2}$$

Equation (1) is the first moment part of the BEKK model, and is specified as a vector autoregressive model (VAR), where Y_t is an 3×1 vector of wheat, piglet and pig prices and C is a 3×1 vector of constants. Mean spillover effects are given by the 3×3 matrix of coefficients Γ_j. The forecast error of the best linear predictor of Y_t, based on past information I_{t-1} , is given by the 3×1 matrix u_t. In Equation (2), H_t is a 3×3 variance-covariance matrix, W is an upper triangular matrix of constants, A is a 3×3 matrix of ARCH term coefficients, and B is a 3×3 matrix of GARCH term coefficients. The A matrix is a coefficient matrix for own and cross *recent shock* transmission effects across markets, while the B matrix contains coefficients for own and cross *past volatility* transmission effects across markets.

3.2.Volatility impulse response functions

Hafner and Herwartz (2006) argue that error terms from a multivariate framework are contemporaneously correlated and therefore that it is difficult to identify the shock in one of the errors terms without taking into account the effect of the other components. They argue that independent news or shocks can be identified through a Jordan decomposition of the covariance matrix H_t. The Jordan decomposition of the covariance matrix eliminates the orthogonalization and ordering problems that characterizes the commonly used Cholesky decomposition (Hafner and Herwartz, 2006; Panaoulou and Pantelidis,2009). The standardized residuals are given by:

$$z_t = H_t^{-1/2} u_t \tag{3}$$

where $H_t^{1/2} = \Gamma_t \Lambda_t^{1/2} \Gamma_t'$ is the Jordan decomposition of the covariance matrix H_t , $\Lambda_t = diag(\lambda_{1t}, \lambda_{2t}, \lambda_{3t})$ is a 3×3 diagonal matrix whose components are the eigen values and $\Gamma_t = (\gamma_{1t}, \gamma_{2t}, \gamma_{3t})$ is a 3×3 corresponding matrix of eigen vectors of H_t. An independent shock hitting the system at time $t = 0$ can be defined by the 3×1 vector z_0 and is computed from the residuals and covariance matrix estimated using equation (2).

Hafner and Herwartz (2006) define the volatility impulse response function as the expectation of volatility conditional on an initial shock and history, subtracted by the baseline expectation that only conditions on history, i.e.

$$V_t(z_0) = E[vech(H_t)|z_0, I_{t-1}] - E[vech(H_t)|I_{t-1}] \tag{4}$$

where the first, third and sixth element of the 6×1 vector $V_t(z_0)$ are the responses of the conditional variances of the first (wheat), second (piglet) and third (pig) variables to the shock that occured at $t = 0$. An analytical expression of the volatility impulse response functions at time $t = 1$ and beyond is given below:

$$V_1 = A^*\{vech\big(H_0^{1/2} z_0 z_0' H_0^{1/2}\big) - vechH_0\} \tag{5}$$
$$= A^* D_N^+ (H_0^{\frac{1}{2}} \otimes H_0^{\frac{1}{2}}) D_N vech(z_0 z_0' - I_N)$$

and for $n > 1$, $V_t = (A^* + B^*) V_{t-1}$ (6)

In Equation (5) and (6), $A^* = D_N^+(A \otimes A) D_N$ and $B^* = D_N^+(B \otimes B) D_N$ where A and B are the ARCH and GARCH coefficients of the BEKK model specified in Equation (2). Both A^* and B^* are $N(N+1)/2$ dimensional matrix of coefficients (with $N = 3$ in our case). The duplication matrix D_N , an $N^2 \times N(N+1)/2$ matrix (with $N = 3$), transforms $vec\, A$ into $vech\, A$ and its Moore-Penrose inverse D_N^+ transforms $vech\, A$ into $vec\, A$ (i.e, $D_N vech\, A = vec\, A$ and $D_N^+ vec\, A = vech\, A$). It should be noted that the impact of a shock on volatility will depend on the size of the shock z_0 as well as on the level of the volatility H_t at the time the shock occrus (Le Pen and Sevi, 2010; Jin et al., 2012). This implies that a given shock will not always increase expected volatility.

In this paper, we consider five historical shocks, i.e. the detection of dioxin in feed in Germany in January 2011, the detection of Classical Swine Fever in Spain in June 2001, the February 1997 detection of Classical Swine Fever in the Netherlands and the November 2000 detection of the BSE in Germany and Spain. The effects of these five shocks on both German and Spanish wheat, piglet and pig price volatilities will be evaluated. The procedure of volatility impulse responses computations is as follows. We first estimate Equation (1) and (2) for both chains and save the values of the residuals u_t and covariance H_t at $t =$ January 2011, June 2001, February 1997 and November 2000. We then compute the standardized residuals z_t at those dates using equation (3). Next, we apply equation (5) and (6) to recursively compute volatility responses for $t + 1$ and beyond. We scale the volatility responses with respect to the volatilities at the time the shocks occurred (i.e. H_t where t is the date the shock occured) to measure the responses in percentages.

4. Data

German and Spanish wheat, piglet and pig monthly price data, from January 1991 to October 2013 were obtained from the European food price monitoring tool page of the European Commission’s website (European Comission b). Since no feed wheat prices were available for the Spanish chain, common bread making wheat prices were used instead for both German and Spanish chains. This allowed comparability of results among the two chains. We tested for the correlation between feed and bread making wheat prices using German prices, and find a correlation of nearly 1. Using bread making wheat prices instead of feed wheat prices is therefore expected not to affect the results. Piglet prices for both chains refer to 20 kilogram piglets and are expressed per 100 kilogram of carcasses. Pig prices for both chains refer to pigs of class E and are also expressed per 100 kilogram of carcasses. Descriptive statistics of the price series are reported in Table 1.

[Insert Table 1 about here]

5. Results and Discussions

5.1.Model estimation

Prior to estimating the BEKK model, we tested for stationarity in the monthly log prices using the Augmented-Dickey-Fuller (ADF) and Kwiatkowski-Philips-Schmidt-Shin (KPSS) tests by incorporating an intercept and a trend in the tests. The results of these tests are reported in Panel B of Table 1. The KPSS test and the ADF test show conflicting results for the log German wheat, log Spanish wheat and log Spanish piglet prices. The tests indicate that the log price series are not integrated of the same order and therefore that a vector error correction model cannot be estimated. We estimate instead a VAR in log differences. Based on the automatic lag selection of the Akaike information criterion and the Final prediction error, we first estimated a VAR with 10 lags for the German chain. We then restricted insignificant coefficients based on the Schwarz criterion. For the Spanish chain, the Akaike information criterion, the Final prediction error and Hannan-Quinn criterion suggested a lag length of 9. Similar to the German chain, we restricted insignificant coefficients based on the Schwarz criterion. The final coefficient estimates of the VAR models for the German and Spanish chains are reported in Panel A of Table 2 and 3 respectively.

[Insert Table 2 about here]

[Insert Table 3 about here]

The results in Table 2 clearly indicate that wheat prices do not affect piglet and pig prices in the German pork chain. On the other hand, transmissions between piglet and pig prices are rather strong. On the other hand, Table 3 shows that wheat prices have a significant effect on both piglet and pig prices in Spain. Similar to the German chain, the interactions between pig and piglet prices are strong. Wheat prices seem to be relatively immune from pig and piglet prices in Spain than in Germany.

Before proceeding to the estimation of the BEKK model, we checked VAR residuals for normality and ARCH effects using the Jarque-Bera and ARCH LM (Auto regressive conditional heteroskedasticity Lagrange Multiplier) tests, respectively. The results for the German and Spanish chains are reported in Panel B of Table 2 and 3 respectively. The ARCH LM test shows that there are significant ARCH effects in the VAR residuals. This is with the exception of $\Delta \text{log\_pig}_t$ residuals for the German chain. Since the results of the ARCH LM test suggest that the estimation of a GARCH model is appropriate, we proceed with the estimation of the BEKK model for both chains. The Jarque-Bera test shows that the residuals are not normally distributed. A student-t distribution for the errors is thus assumed in the estimation of the BEKK models. Coefficient estimates of the BEKK models are reported in Panel A of Table 4.

[Insert Table 4 about here]

To test the adequacy of the BEKK model, we tested for any remaining ARCH effects in the BEKK standardized residuals. Except for ARCH effects at 1 lag, the test shows that ARCH effects present in the VAR residuals have been eliminated in the BEKK model. The results of the BEKK model suggest that volatility transmissions are much lower in the Spanish pig chain than in the German pig chain. This is reflected by the number of statistically significant off-diagonal elements of the a_{ji} and b_{ji} coefficients. In the BEKK model, interpretation of individual coefficients can be misleading as each coefficient enters each of the variance and covariance equations through interaction terms with other coefficients. We therefore conducted likelihood ratio tests to jointly check if price volatility transmits from each of the three markets to the other remaining two markets. The result of this test is reported in Panel B of Table 4. The test shows that wheat price volatility affects neither piglet nor pig price volatilities in both German and Spanish chains. Pig price volatilities, on the other hand, affect both wheat and piglet price volatilities in both chains. While piglet price volatilities transmit to wheat and piglet price volatilities in the German chain, they do not do so in the Spanish chain. Figure 1 shows the volatility predictions for both chains. The Figure clearly indicates that wheat price volatilities do not move together with piglet and pig price volatilities, while the latter two do move with each other.

In Germany, the absence of significant transmissions of wheat price volatilities to the pig sector can be attributed to the fact that a majority of German pig farmers produce their own wheat which they feed to their pigs (Vroleijk et al., 2009). The German finding suggests that other ingredients of compound feed such as barley and soya might be responsible for increased pig price volatility. In Spain, many pig farms are owned by feed producers who depend on the imports of major ingredients (Soldevila et al., 2009). The same feed producers also buy the finished pigs from the farmers (Soldevila et al., 2009). The results for Spain indicate that, although feed producers transmit predictable wheat price changes (as shown in Table 3), they absorb the volatility in feed ingredient prices leading pig price volatilities to be irresponsive to wheat price volatilities.

[Insert Figure 1 about here]

5.2.Volatility impulse response functions

The responses of price volatilities to the detection of dioxin in feed in Germany in January 2011, the detection of Classical Swine Fever in Spain in June 2001, the February 1997 detection of Classical Swine Fever in the Netherlands and the November 2000 detection of the BSE in Germany and Spain are shown in Figure 2, 3, 4 and 5 respectively. A finding worth noting is the higher volatility responses in the German chain than in the Spanish chain. German piglet and pig price volatilities increased in response to almost each of the news on food scares both inside and outside of Germany. All responses were also immediate. The highest volatility responses were in response to the detection of dioxin in feed in Germany. This is a reasonable finding given that the detection was in Germany itself. On January 2011, the estimated residuals were (0.073 -0.146 -0.110) for wheat, piglet and pigs, respectively. The signs of the residuals show that the news increased wheat prices while it reduced piglet and pig prices. The media attention was voluminous leading German consumers to demand angrily information on what led to the excess dioxin found in pig feed (Kupferschmidt, 2011). Although German authorities to reduce public fear, this had done little to reassure consumers about the safety of consuming pig products (Kupferschmidt, 2011). The rise in the volatility of wheat prices can be attributed to a temporary ban in the slaughter of pigs. This in turn might have increased the demand and thus the price of wheat which is a major ingredient of compound feed.

When it comes to cross country effects, the higher response of German piglet price volatility in response to the CSF in Spain than to the CSF in the Netherlands is rather unexpected. This is because of the geographical closeness of Germany and the Netherlands and the stronger ties one might expect in the trade of piglets between these two countries. Cross-product effects of food scares are clearly reflected in the German results. The residuals estimated for November 2000- the month the BSE was first detected in Germany-were (0.011 0.152 0.075) for wheat, piglet and pigs respectively. The signs of the residuals suggest that the news has led to an increase in both piglet and pig prices. Although the sign for wheat price residuals is also positive, the wheat price volatility did not increase in response to the shock as the size of the shock in wheat prices was not large enough. Piglet and pig price volatilities, on the other hand, have increased in response to the news on the BSE detection. The positive signs of piglet and pig price residuals suggest that consumers might have substituted beef meat for pork in response to the BSE news. According to Banati (2011), the detection of the BSE led to consumers developing a certain level of fear of beef.

Food scares that originated in the pig sector seem to have no volatility increasing effect in the Spanish pig chain. One exception is the detection of dioxin in feed in Germany when the volatility in wheat prices increased by more than 50% (and estimated residual for wheat in January 2011 was 0.049). This result highlights positive correlations between wheat prices in Germany and Spain. The absence of a positive response of pig and piglet price volatilities to pig related food scares could be a reflection of the high importance of pork consumption among Spanish consumers. That is, Spanish consumers do not reduce their pork consumption even in the event of news about pork related food scares. Another implication of the lack of positive response could be that the pig related food scares were not publicised by the media as much as it was in Germany. The detection of BSE, on the other hand, resulted in the increase in piglet and pig price volatility by up to 10% and 20%, respectively. The residuals estimated for November 2000 were (0.004 0.134 0.078) for wheat, piglet and pig prices, respectively. Similar to the German case, the positive signs of the residuals for both piglet and pig prices reflect a substitution effect between pork and beef meat. According to Serra (2011), the BSE crisis was one of the highly publicised food scares in recent memory. The positive shock in piglet and pig prices could be attributed to this media frenzy.

[Insert Figure 2 about here]

[Insert Figure 3 about here]

[Insert Figure 4 about here]

[Insert Figure 5 about here]

6. Conclusions

EU farmers are increasingly exposed to price volatility as a result of shocks that arise in both local and international markets. A major source of price shock in the livestock sector is one that arises from food scares. By using the recently developed methodology of volatility impulse response functions by Hafner and Herwartz (2006), we investigated the effects of news about five food scares on price volatilities in the German and Spanish pig chains. The news were on the detection of dioxin in feed in Germany in January 2011, the detection of Classical Swine Fever in Spain in June

2001, the February 1997 detection of Classical Swine Fever in the Netherlands and the November 2000 detection of the BSE in Germany and Spain. The volatility impulse response functions were based on coefficient estimates of the multivariate GARCH model BEKK. Using the BEKK coefficients, we additionally investigated possible volatility transmission between wheat - a major compound feed ingredient - and pig and piglet prices.

Overall, the results from the volatility impulse responses suggest that the size of the shock matters for price volatility to increase in response to a food scare. This feature of volatility impulse responses is typical to the methodology of Hafner and Herwartz (2006). Our results confirm that if the shock is large enough, news of food scares do increase price volatility. Our results further confirm that news of food scares have a price depressing effect (and a price increasing effect for substitute products). We further showed that news of food scares have far reaching effects that go beyond the country in which the food scares first originated. Our results highlight the importance of price risk insurance for non-infected farms given the current opportunity to benefit from EU premium subsidies for such type of insurance. Contrary to expectations, we do not find any significant effect of wheat price volatility on piglet and pig price volatilities in both German and Spanish chains. Future research could investigate if the volatilities in the price of other major ingredients of compound feed (such as barley and soya) could have an effect on the volatilities in piglet and pig prices.

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Table 1- Descriptive statistics of prices and stationarity tests

	Monthly prices - Germany			Monthly prices - Spain		
	Wheat (∈/100 kg)	**Piglet (∈/100 kg)**	**Pig (∈/100kg)**	**Wheat (∈/100 kg)**	**Piglet (∈/100 kg)**	**Pig (∈/100 kg)**
Panel A						
Mean	15.243	46.162	144.951	17.156	35.820	145.002
Median	13.788	47.890	146.505	15.755	35.650	144.340
Maximum	27.187	79.420	219.180	27.433	135.680	214.030
Minimum	9.298	17.800	85.760	13.124	10.780	75.330
Std. Dev.	4.191	10.867	24.068	3.458	11.85	25.473
Observations	274	274	274	274	274	274
Panel B						
Stationarity test on log price levels						
ADF	-3.218	-4.798**	-4.944**	-3.544**	-2.740	-4.882**
KPSS	0.280**	0.036	0.040	0.271**	0.069	0.065
Stationarity test on log price differences						
ADF	-11.362**	-9.915**	-14.359**	-10.153**	-11.820**	-4.143**
KPSS	0.029	0.030	0.027	0.030	0.034	0.037

**Significant at 5% level of significance. The stationarity tests include a trend and intercept.

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Table 2 - VAR model for German pig chain

	Δlog_wheat_t		Δlog_piglet_t		Δlog_pig_t	
	Coefficients	**SE**	**Coefficients**	**SE**	**Coefficients**	**SE**
Panel A: Estimation results						
Δlog_wheat_{t-1}	0.331**	0.055				
Δlog_wheat_{t-4}	0.141**	0.055				
Δlog_wheat_{t-9}	-0.185**	0.056				
Δlog_piglet_{t-1}			0.274**	0.041		
Δlog_piglet_{t-4}			0.174**	0.068	0.275**	0.047
Δlog_piglet_{t-5}	-0.123**	0.035	-0.353**	0.062		
Δlog_piglet_{t-6}			-0.186**	0.058		
$\Delta logpig_{t-4}$			-0.282**	0.094	-0.328**	0.068
$\Delta logpig_{t-5}$			0.282**	0.078		
$\Delta logpig_{t-6}$	0.127**	0.051	0.270**	0.073		
$\Delta logpig_{t-8}$					-0.157**	0.041
$\Delta logpig_{t-10}$			0.154**	0.053		
Panel B: Diagnosis tests on VAR residuals						
Jarque-Bera test	118.935**		53.727**		13.529**	
ARCH LM test:						
1 lag	17.6432**		5.8373**		1.0226	
5 lags	18.3226**		10.6422		4.6281	
6 lags	18.2630**		10.4928		11.4719	
12 lags	27.6514**		11.9225		14.0380	

** and * significant at 5% and 10% levels, respectively. SE denotes standard errors.

Table 3 – VAR model for Spanish pig chain

	Δlog_wheat_t		Δlog_piglet_t		Δlog_pig_t	
	Coefficients	**SE**	**Coefficients**	**SE**	**Coefficients**	**SE**
Panel A: Estimation results						
Δlog_wheat_{t-1}	0.515**	0.060				
Δlog_wheat_{t-2}	-0.215**	0.067			0.282**	0.073
Δlog_wheat_{t-3}	0.207**	0.062	0.751**	0.163		
Δlog_wheat_{t-4}			-0.710**	0.161		
Δlog_wheat_{t-8}			-0.405**	0.149		
Δlog_wheat_{t-9}					0.304**	0.077
Δlog_piglet_{t-1}			-0.218**	0.043		
Δlog_piglet_{t-4}					0.171**	0.023
Δlog_piglet_{t-5}					0.159**	0.023
Δlog_piglet_{t-7}			-0.359**	0.046		
Δlog_piglet_{t-8}			-0.216**	0.046		
Δlog_pig_{t-1}	-0.091**	0.030				
Δlog_pig_{t-2}			-0.109**	0.085		
Δlog_pig_{t-4}					-0.332**	0.046
Δlog_pig_{t-5}					-0.314**	0.048
Δlog_pig_{t-6}					0.141**	0.043
Δlog_pig_{t-7}			0.781**	0.095		
Δlog_pig_{t-8}			0.487**	0.095		
Δlog_pig_{t-9}			0.415**	0.084		
Panel B: Diagnosis tests on VAR residuals						
Jarque-Bera test	269.257**		145.340**		17.598**	
ARCH LM test:						
1 lag	5.8106**		16.1910**		9.6227**	
5 lags	6.6294		17.8410**		13.6578**	
6 lags	6.6439		28.4853**		28.6602**	
12 lags	17.2292		28.9012**		32.4895**	

** and * significant at 5% and 10% levels, respectively. SE denotes standard errors.

Table 4 – BEKK estimation results

	German pig chain			Spanish pig chain		
	Wheat $(\boldsymbol{i=1})$	**Piglet** $(\boldsymbol{i=2})$	**Pig** $(\boldsymbol{i=3})$	**Wheat** $(\boldsymbol{i=1})$	**Piglet** $(\boldsymbol{i=2})$	**Pig** $(\boldsymbol{i=3})$
Panel A: Estimation results						
	0.0296**			0.0203**		
c_{1i}	(0.0000)			(0.0001)		
	0.0030**	0.0477**		0.0020	0.0886**	
c_{2i}	(0.0004)	(0.0001)		(0.1835)	(0.0043)	
	0.0051**	0.0276**	-0.0002**	-0.0030	0.0406**	-0.0000
c_{3i}	(0.0001)	(0.0003)	(0.0000)	(0.0282)	(0.0001)	(0.0029)
	0.6367**	0.0293**	0.0032	0.7244**	0.0231	-0.1048
a_{1i}	(0.0145)	(0.0053)	(0.0120)	(0.1458)	(0.0309)	(0.1510)
	-0.1173**	-0.0782**	-0.4344**	-0.0787	0.4050*	-0.0833
a_{2i}	(0.0276)	(0.0236)	(0.0825)	(2.6116)	(0.1922)	(0.8879)
	0.0272**	-0.2714**	0.1514**	0.0257	0.1906*	0.1189**
a_{3i}	(0.0078)	(0.0069)	(0.0241)	(15.9193)	(0.0957)	(0.0442)
	0.5127**	0.0021	-0.0064	0.4155**	0.0066	0.0288**
b_{1i}	(0.0254)	(0.0408)	(0.0263)	(0.1468)	(0.6871)	(0.0022)
	0.0347	0.6841**	-0.1303	-0.0454	-0.2640	-0.6672
b_{2i}	(0.1486)	(0.0643)	(0.1402)	(37.4136)	(2.4502)	(22.2172)
	-0.1323**	0.0086	0.8120**	-0.0380	-0.4024	0.7039
b_{3i}	(0.0281)	(0.0105)	(0.0428)	(32.4579)	(0.4144)	(4.2692)
Panel B: Diagnosis tests						
ARCH LM test on BEKK residuals						
1 lag	1.6292	0.1355	1.5616	0.3139	0.6110	5.2395**
5 lags	3.1763	8.9028	4.4443	0.9055	2.8255	6.6711
6 lags	3.7682	8.7789	4.3408	1.0798	10.1538	8.2045
12 lags	14.9211	12.2677	9.4193	3.2498	12.8669	11.9996
Likelihood ratio test on non-causality in variances						
$a_{1i}=b_{1i}=0$	-0.2			1.2		
$a_{2i}=b_{2i}=0$	17.4**			1.2		
$a_{3i}=b_{3i}=0$	7**			32.6**		
Degree of freedom	10.681			5.676		
Log likelihood :	1261.7			1213.8		

*and ** significant at 10% and 5% levels, respectively. Standard errors are in parenthesis.

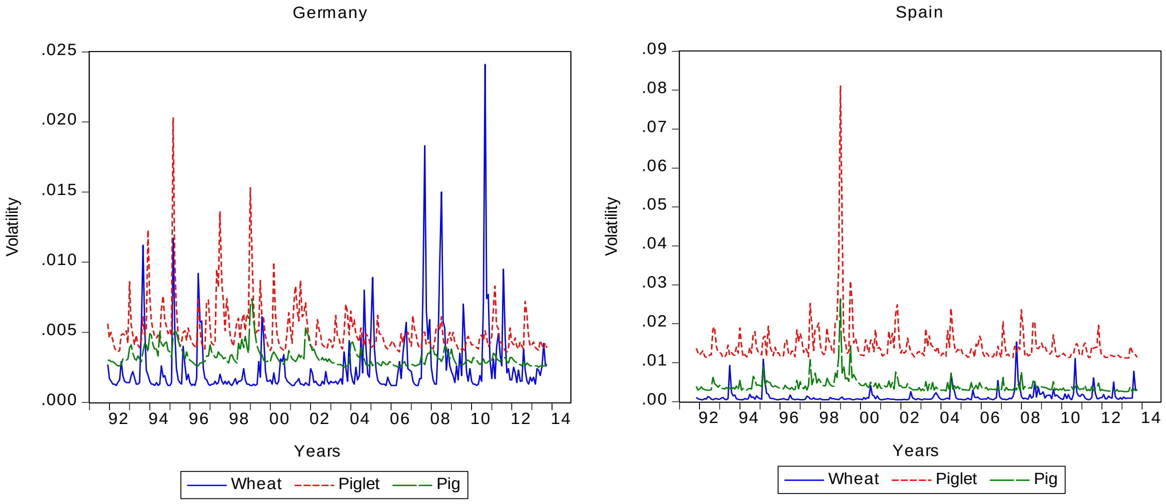

Figure 1 – Conditional volatilities

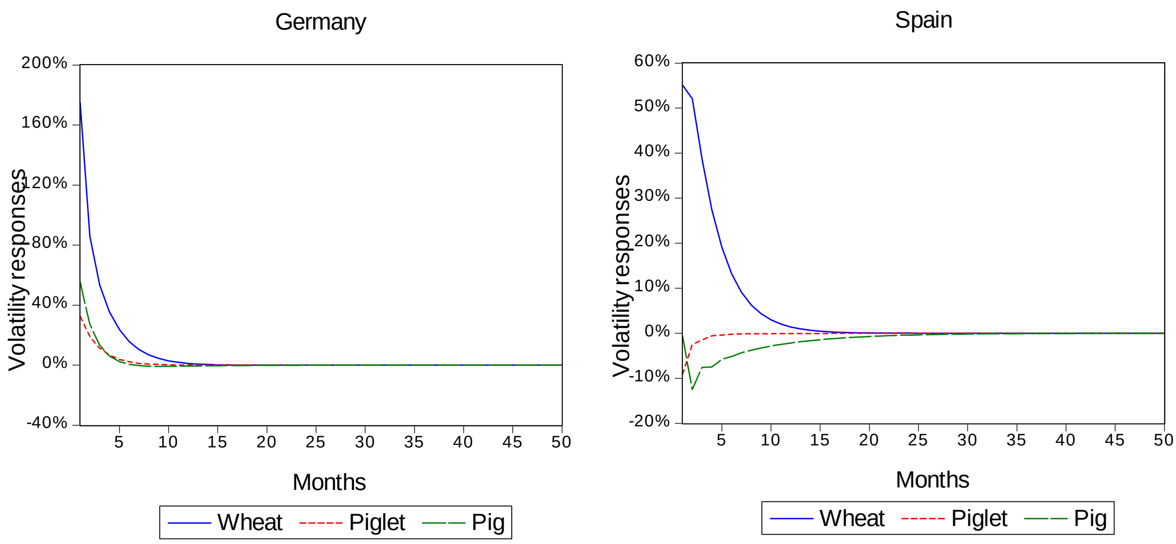

Figure 2 – Effects of the detection of dioxin in feed in Germany in January 2011

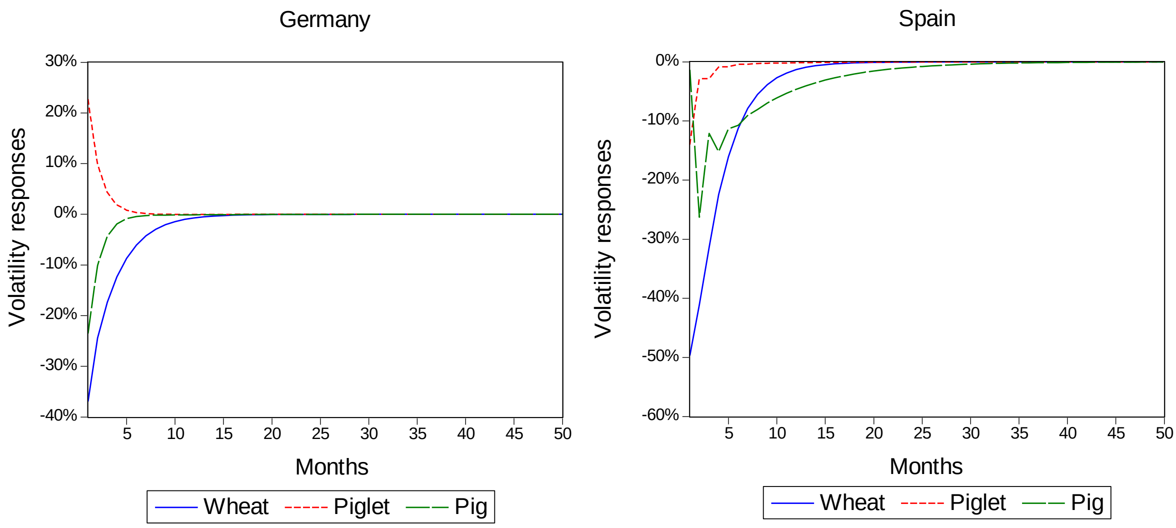

Figure 3 – Effects of the detection of Classical Swine Fever in Spain in June 2001

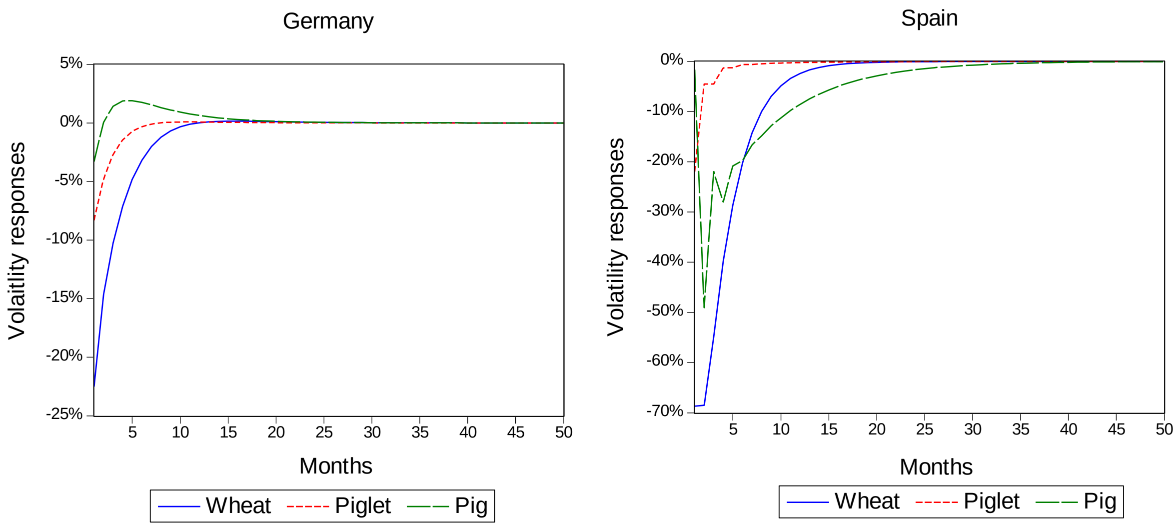

Figure 4 - Effects of the detection of Classical Swine Fever in the Netherlands in February 1997

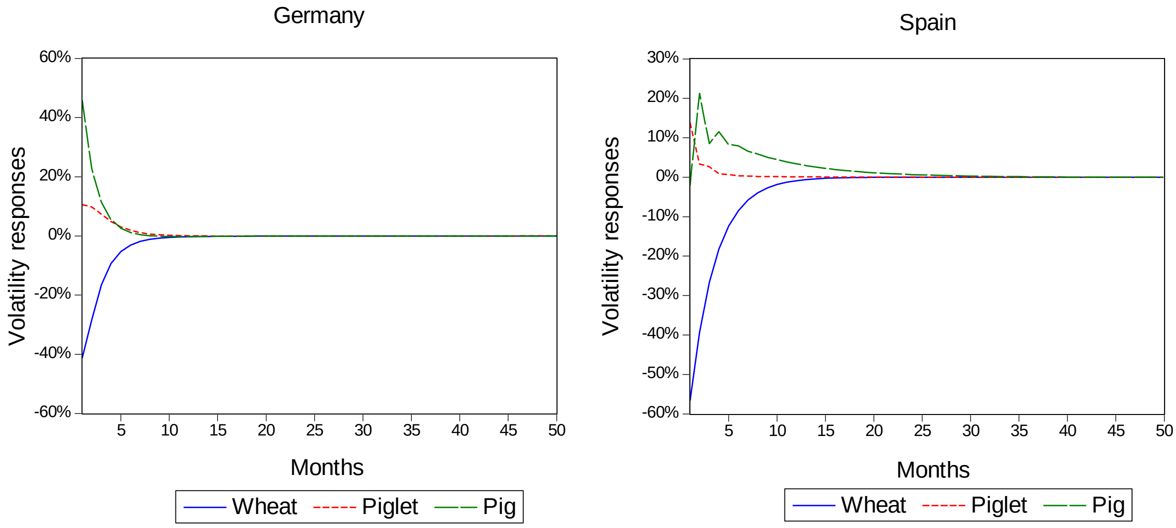

Figure 5 - Effects of the detection of BSE in Germany and Spain in November 2000