sustainability

MDPI

Article

Geographical Indications and Price Volatility Dynamics of Lamb Prices in Spain

Hugo Ferrer-Pérez [1,2], Fadi Abdelradi [3] and José M. Gil [4,*]

1 Centro de Investigación y Tecnología Agroalimentaria (CITA), Unidad de Economía Agraria y de los Recursos Naturales, 50059 Zaragoza, Spain; hferrer@cita-aragon.es
2 Instituto Agroalimentario de Aragón, Universidad de Zaragoza, 50013 Zaragoza, Spain
3 Department of Agricultural Economics, Faculty of Agriculture, Cairo University, Giza 12613, Egypt; fadi.abdelradi@agr.cu.edu.eg
4 Centre de Recerca en Economia i Desenvolupament Agroalimentari (CREDA)-UPC-IRTA, 08860 Castelldefels, Spain
* Correspondence: chema.gil@upc.edu; Tel.: +34-935-521-210

Received: 11 March 2020; Accepted: 8 April 2020; Published: 10 April 2020

Abstract: For decades, food quality standards have attracted the interest of governance institutions and regulation authorities, who have responded to the increasing and demanding societal challenges. In addition, the open debate on significant variability and unusually high levels of agrifood prices recorded in 2007 and later in 2011 affect the behavior of the chain actors involved. As an attempt to bring together these wide concerns within a quantitative framework, a comparative analysis of the performance of the price volatility dynamics allowing for asymmetric behavior along the supply chain of a protected geographical indication (PGI)-certified lamb and its corresponding non-PGI counterpart, both located in the same region of Spain, was undertaken using weekly farm-retail prices for the period 2011–2018. The results indicate the existence of significant volatilities and an asymmetric transmission mechanism along the non-PGI-certified lamb supply chain, whereas the PGI-certified supply chain is impacted by volatility effects, yet characterized by symmetric behavior, which may suggest a high degree of relative market efficiency.

Keywords: food quality schemes; geographical indication; price volatility; cointegration; multivariate GARCH; asymmetry; lamb; supply chain

1. Introduction

The 1992 reform of the Common Agricultural Policy (CAP) has contributed to the support of rural development as well as the promotion of food quality, which has led to the development of four food quality schemes (regulated by [1,2]). First, the Protected Designation of Origin (PDO) label designates agricultural products and foodstuffs for which all of the stages of production, processing, and preparation are entirely carried out in a specific geographical area. Second, the Protected Geographical Indication (PGI) label also indicates territory links, but also that one of the stages of production, processing, or preparation of the products takes place outside the area. Third, the Traditional Specialty Guaranteed (TSG) label indicates food that recognizes the tradition, but it is not linked to the territory. Lastly, the Organic designation certifies organic production of agricultural products.

Moreover, since the start of the World Trade Organization agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) in the mid-1990s, geographical indications as an integral part of food quality schemes have been demonstrated as powerful tools to deliver important benefits for sustainable rural development at socioeconomic and environmental levels [3]. As a consequence, the number of protected food products has greatly increased. For instance, Spain had 42 products registered in 1996 and 196 in 2018 [4].

Recently, the CAP became more market- and consumer-driven [5]. As a consequence, food quality standards have increasingly attracted the interest of governance institutions and regulation authorities worldwide as a relevant tool to respond to the demanding societal challenges around the increasing demand for local food quality production, food security, and supply chain quality control mechanisms like traceability and food system sustainability. In this regard, efforts have been directed towards improving the effectiveness of the food quality schemes because of the potential they have in the domestic and international markets to achieve competitiveness and social and territorial cohesion. Specifically, these measures aim at helping producers communicate to consumers the specific characteristics of food products and farming attributes, guaranteeing more transparency so that the producers' credibility and consumers' welfare may be benefited at the same time in a context characterized with a high degree of market liberalization.

The dynamic nature of current agrifood prices worldwide has stimulated the study of price level behavior and volatility patterns along the food supply chain, especially after the 2007 global crisis, which took place after a period of relative stability [6]. Since then, prices have been unusually high, with a significant increase in volatility, which has strengthened the debate among experts on whether current price volatility is higher than in the past or will continue increasing in the future, among others [7–12].

Prices of agricultural and food products commonly fluctuate due to market fundamentals and other factors (i.e., fuel prices, levels of pollution, or changing market conditions due to supply and demand shocks). However, when these price fluctuations are large and unexpected, all of the actors involved in the food marketing chain are challenged because the adoption of decisions in the long term may become riskier, and this may generate a negative impact on food-price stabilization [10–13].

In this regard, the analysis of price volatility transmission along the food supply chain has become a key research area. Depending on the degree of efficiency of the market chain, stabilizing measures could be adopted at different levels of the chain. For instance, if markets are efficient, they could transmit market information instantaneously through the chain and hence may dissipate any shocks with no degree of persistence on volatility. Hence, knowing the extent to which price volatility is transmitted and factors affecting it along the supply chain may assist policy makers in developing more appropriate policies to reduce and manage risks associated with food price stabilization, with the fewest market distortions [10,12,14].

After a detailed review of the related literature, one may observe that the interest in examining price linkages through the food supply chain has increased and revealed several facts. First, the body of literature on food commodities designated with a quality label has grown over the years using different approaches: Consumers' perceptions [15–18], marketing strategies [19,20], power relations between participants [21,22], and implications on the producers' and consumers' wellbeing [23,24]. Second, previous research dealing with price transmission dynamics in a protected supply chain is scarce, and only the authors of [25,26] investigated the vertical transmission of prices in levels along the supply chain for organic milk and PDO Parmigiano Reggiano, respectively, for a recent period after the longstanding global crisis. Both studies provided a comparative analysis of the behavior of price dynamics in levels of the quality-differentiated product and its conventional counterpart. Third, despite the growing importance of the analysis of price volatility through the supply chain, this issue has been limited to non-protected food products, with scarce country and product coverage ([27,28] in the agrifood sector and [29,30] in the seafood sector), but has not covered food-quality-labeled products so far.

In view of this, further research is needed to examine price volatility transmission through the food supply chain and, hence, to assess the similarities and differences in the efficiency of the price system between quality-differentiated (premium) and conventional products, as demanded by [13,31,32].

Therefore, this study brings together these two key research concerns in the international policy agenda. In particular, this research focuses on the fresh lamb meat sector in Spain because of the relevant role that Spain plays in both domestic and international lamb markets. Moreover, the Spanish lamb market is characterized by changing market conditions, retailers' market power, and the presence of asymmetric information, which may make the pricing negotiation process slightly unstable [33].

The main objective is hence to examine price volatility dynamics of the Spanish lamb meat sector. In particular, the study focuses on a lamb protected with a European Geographical Indication (GI) label in Spain and also compares the results with those of its conventional counterpart. Both lamb markets are located in the same demarcated area, which represents an important added value for comparing both competing lamb markets. Data used include farm-retail weekly prices pairwise for the two products covering 2011 to 2018 extracted from the Observatory of Agricultural Prices of the Government of Navarra.

The structure of the rest of this paper is as follows. Section 2 describes the lamb sector along with an overview of the European Food Quality Schemes in Spain. Section 3 describes the methodological approach employed. Section 4 describes the data and presents the results. Section 5 contains a brief discussion of the results. Section 6 concludes the paper.

2. The Lamb Sector and the European Food Quality Schemes in Spain

A visual inspection of the 2018 official Eurostat statistics leads one to see that Spain ranks second in EU lamb production, with 17% of the total production behind the United Kingdom and before countries like France, Greece, Ireland, and Italy. Moreover, its overall breeding flock size is the second largest in the EU, with almost 16 million ewes (after the United Kingdom and before Romania, Greece, Italy, and France) according to a 2018 agricultural census, which has remained steady during recent years [34]. This rank in lamb production has been maintained despite its declining trend of almost 15% that has been occurring over the last fifteen years. This negative tendency is also found in household lamb meat consumption, which has registered lower levels of consumption and a significant fall of almost 48% between 2007 and 2018. However, in 2018, Spain witnessed a slight growth in household lamb meat consumption (1% year-on-year) and in lamb meat production (3% year-on-year) and showed a fairly robust demand over the past year. However, the fact that consumption has declined at a faster rate than production levels has led to pressure on farm prices and, at the same time, opened the door for new international expansion strategies, which seems to indicate potential for promising progress for the lamb meat sector. As an example, Spain is still the third largest EU exporter, behind the United Kingdom and Ireland, and the sixth largest worldwide [35].

Spain has witnessed an impressive increase in the production of agricultural commodities and foodstuffs designated with quality labels. Thus, in 1988, Spain had 15 registered products, whereas there were 196 registered products in 2018. The structure of the Spanish product quality portfolio has followed a progressive development, especially between 2000 and 2005, coinciding with the period of the highest prosperity in the economy, in both the number of certifications and total turnover. Thus, it can be seen that, in 2018, 20 out of these 196 certifications corresponded to fresh meat products with a total turnover of €234.85 million and, in particular, six certifications of commercialized fresh lamb meat with a total turnover of €42 million, showing a trending pattern over the last few years [4].

Against this background, lamb production has undoubtedly contributed especially to the development of less-favored rural areas in Spain. The fact that more than two thirds of the lamb farms use traditional production systems with high production costs has led to the design of a financial assistance regime, complementary to the CAP. Its objective is to ensure the profitability of lamb producers especially in this market characterized by seasonality, changes in supply/demand, the existence of retail power and asymmetries [33], and perishability (among others), which may generate instability in lamb prices.

This paper focuses on the PGI Cordero de Navarra (lamb from Navarra) and on its reference counterpart. Both products are located in the same market area with similar production systems according to traditional methods linked to territory, which may provide additional value to this study, as potential differences due to different managerial systems could be somehow controlled. Moreover, the availability of solid official datasets at the two extremes of the marketing chain allows us to conduct reliable pricing analysis given that the availability of official price statistics lags behind the increasing demand of these protected quality commodities.

The mark Cordero de Navarra was created in 1998 as a quality label and, in 2002, was recognized as a PGI with the objective of protecting and promoting an unknown and underestimated foodstuff produced traditionally so that the consumer may perceive this as a reliable system that ensures the superior quality of Navarra and Lacha pure-breed lamb meat. Only male or female lambs born, raised, and sacrificed locally in Navarra based on the sustainable exploitation of natural resources can be certified as "PGI Cordero de Navarra".

In particular, this quality designation distinguishes two types of lambs: The suckling lamb, fed with milk only from the suckler lamb, and the light lamb, fed with milk until at least 45 days after birth in the case of the Navarra breed and between 25 and 30 days for the Lacha breed, and fattened with white cereal straw and a concentrate mainly from cereals, vitamins, legumes, and minerals. Both types of animals are raised based on extensive or semi-extensive systems following a diet of grass, fodder, and cereals according to the guidelines imposed by the Regulatory Council of the PGI Cordero de Navarra. Once the animal gets to the slaughterhouse, this center records all of its data, such as farm numbering, date of slaughter, ear-tag, date of birth, sex, category, weight of slaughter, carcass weight, final ratio, shape, and degree of fatness, which are checked by the Regulatory Council. For example, the live weight and the degree of fat should be carefully supervised so as not to exceed the maximum carcass weight and the maximum degree of fat set by the standards of the PGI Cordero de Navarra. After that, carcasses can be distributed directly to butchers or can be transported to cutting rooms for different preparations according to the different orders of clients. Cutting rooms record every entry and exit each day and store the PGI lamb carcasses separately from those of the non-PGI lambs. The distribution of carcasses and half-carcasses is registered. Finally, the Regulatory Council collects meat samples in the slaughterhouse and also conducts inspection visits to retailers to collect meat samples again and compare them with former samples to check whether the traceability principle has been respected along the whole supply chain.

PGI lamb meat is characterized by a low level of fat, pale pink (or pearl white) color, tenderness, and very succulent and smooth flavor, and ternasco lamb or lamb meat is characterized by a low level of fat, high nutrition content, pale pink color, and more intense flavor because it is a larger and older animal. In terms of the carcass, for the suckling lamb, its weight ranges between 5 to 8 kg for lacha and 6 to 8 kg for navarra, and for the lamb, this ranges between 9 to 12 kg.

The Regulatory Council (RC) of the PGI Cordero de Navarra is the official institution that guarantees that the specifications included in the official bidding document of PGI Cordero de Navarra are addressed, defends and promotes PGI lamb, and monitors and supervises the performance of the official body that provides the certification for the PGI Cordero de Navarra (INTIA, Instituto Navarro de Tecnologías e Infraestructuras Agroalimentarias S.A., registered at ENAC, Entidad Nacional de Acreditación, is the official body that controls the PGI Cordero de Navarra). In this regard, the RC conducts specific controls at farms by identifying each lamb after birth and monitoring it from upstream levels to downstream levels, including processor level (slaughterhouses), with the objective of guaranteeing credibility and quality of the PGI product to the final consumer, contributing to the management and organization of the sector as well as to standardization of the product at retail level [36]. In 2018, more than 120 farms were registered, producing more than 30,000 heads of certified lambs commercialized only by authorized retail stores such as traditional butchers, mainly at domestic markets [4].

3. Methodology

The methodology applied is based on the joint estimation procedure of two models: The vector error correction and the multivariate generalized autoregressive conditional heteroscedasticity (MGARCH) [37,38]. In this analysis, the Babba, Engle, Kraft, and Kroner (BEKK) extended parameterization developed by [39] is followed to allow for the possible presence of asymmetries in the price volatility transmission process to test whether the magnitude and sign of any shocks in prices at a certain stage have the same impact on the other price stages.

The set of analyses performed in this study is based on time-series econometrics, as agricultural commodities usually show significant and clustered time-varying volatility along with a common trend over time, which lead us to the analysis of the stochastic properties of the price time series of each level of the supply chain.

To examine whether price time series share a common trend, we started by applying univariate stochastic analysis of the price series to see whether the series were nonstationary.

Detailed research on recent empirical studies dealing with price analysis of agricultural commodities shows that standard unit root tests like the (augmented) Dickey and Fuller test (DF) of [40] and the PP tests of [41] are greatly favored, despite those unit root tests that have been proposed more recently with improved properties, such as the influential contributions of [42] and [43]. See [44–46] for excellent reviews on the topic.

That being so, in this study, the tests proposed by [47], henceforth PQ, were used, as these authors suggested a useful modification of the Ng and Perron tests of [43] that ensure a correct identification of the integration order of the series, as these modified tests lead to substantial improvements in terms of size and power. For confirmatory purposes, the popular stationarity KPSS test of [48] was also applied, as by reverting the unit root null hypothesis, it is possible to reduce the asymmetry that appears in the traditional procedure of hypothesis testing that tends to favor the null.

After having conducted the preliminary analysis of the univariate stochastic properties of the series, the next step was to determine whether each farm-retail pair of nonstationary series share a long-run stationary relation in each market. To do so, Johansen's maximum likelihood approach developed by [49] and the cointegration rank using the Bartlett corrected trace test as in [50] were used to perform cointegration rank analysis after having correctly determined the deterministic components and the optimal lag choice order to be included in the model, as indicated by [51].

Based on this, price level and price volatility dynamics were captured using a multivariate generalized autoregressive conditional heteroscedasticity (GARCH) approach that entails two models: i) A conditional mean model that is based on the cointegration relationship that captures price level dynamics in the short- and long-term by means of a vector error correction model, and ii) the conditional variance model. In this paper, both the conditional mean and variance models are jointly estimated to ensure more efficient estimates than those obtained with the usual two-step procedure, as a detailed review of recent empirical contributions reveals that the two-step procedure has been usually implemented when there is no convergence when the joint estimation approach is followed [9,28].

The mean equation model is defined as follows:

$$\Delta P_t = \mu + \alpha\varepsilon_{t-1} + \sum\nolimits_{i=1}^{k} \Gamma_i \Delta P_{t-i} + e_t \quad (1)$$

where Δ denotes the first differences operator, farm and retail prices in levels for each market are represented by $P_t = (P_{1t}, P_{2t})'$, the disturbance term is $e_t \big| \Omega_{t-1} \sim iidN(0, H_t)$, and H_t is the variance–covariance matrix. Note as well that $\alpha\varepsilon_{t-1}$ reflects the long-run relation between commodity prices, and Γ_i reflects the short-run effects. The optimal lag-length, k, is determined using information criteria, as usually implemented for model selection.

Note that the conventional assumption of H_t being constant over time cannot be ensured in (1), as agricultural commodity prices may show time-varying variability [52]. Accordingly, a multivariate generalized autoregressive conditional heteroscedastic model by [38] was adopted to permit the variance–covariance matrix to depend on lagged residuals and on its own lags. For our purposes, the BEKK parameterization was used:

$$H_t = CC' + A' u_{t-1} u'_{t-1} A + B' H_{t-1} B \quad (2)$$

with C, A, and B $(m \times n)$ being matrices of intercept terms, ARCH term coefficients (own and cross recent shock transmission effects), and GARCH term coefficients (own and cross past volatility transmission effects), respectively. This specification assumes symmetric volatility patterns, which suggests that any shocks have the same impact regardless of their sign and magnitude. However, to allow for a more realistic assumption of asymmetric effects, the extended BEKK as in [39] was applied:

$$H_t = CC' + A'u_{t-1}u'_{t-1}A + B'H_{t-1}B + D'v_{t-1}v'_{t-1}D \quad (3)$$

where C, A, and B are defined as in (2), and D is a $(m \times n)$ matrix of asymmetric effects, where $v_t = u_t$ if u_t is negative and $v_t = 0$ if otherwise. This parameterization may permit the identification of whether a negative shock (unexpected decrease) in prices may lead to a higher posterior volatility than an unexpected rise in prices of similar magnitude.

4. Data and Results

Data were collected from the Government of Navarra's Observatory of Agricultural Prices and contain information for PGI lamb and its conventional counterpart. Data are available at farm (price received by the farmer) and retail (price paid by the consumer) levels, which is a natural selection for our purposes and is commonly employed in the literature [53]. Data frequency is weekly with a total of 373 observations over the period 2011 to 2018. For the PGI market, farm and retail prices are denoted as FPI and RPI, respectively, whereas for the conventional market, FP and RP are used, respectively.

Figures 1 and 2 show the farm–retail prices (in levels) for the PGI lamb chain and for the non-PGI lamb market, respectively. A visual inspection of each figure may one lead to suspect that farm–retail prices seem to obey a long-term relationship in each market with more significant volatile episodes at retail than at farm prices.

The empirical specification of the MGARCH model was conducted for each product following four stages: First, determining the nonstationarity of the price series; second, determining whether there is a cointegration relationship in the farm–retail pair of prices; third, performing the joint estimation of the conditional mean and variance models; and fourth, predicting the conditional variances.

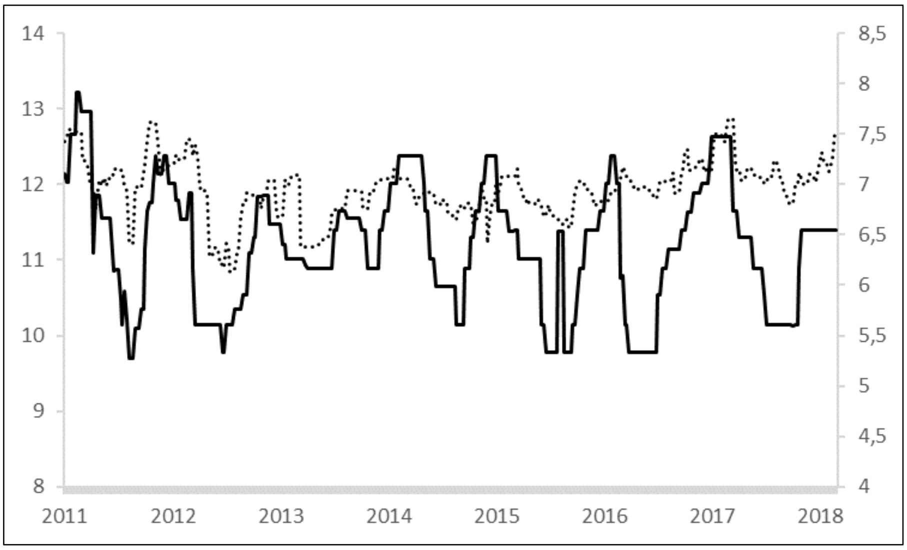


Figure 1. RPI: Retail prices of Protected Geographical Indication (PGI) lamb (main axis); FPI: Farm prices of the PGI lamb (secondary axis). Prices are expressed in €, and vertical axes are measured in €/kg carcass.

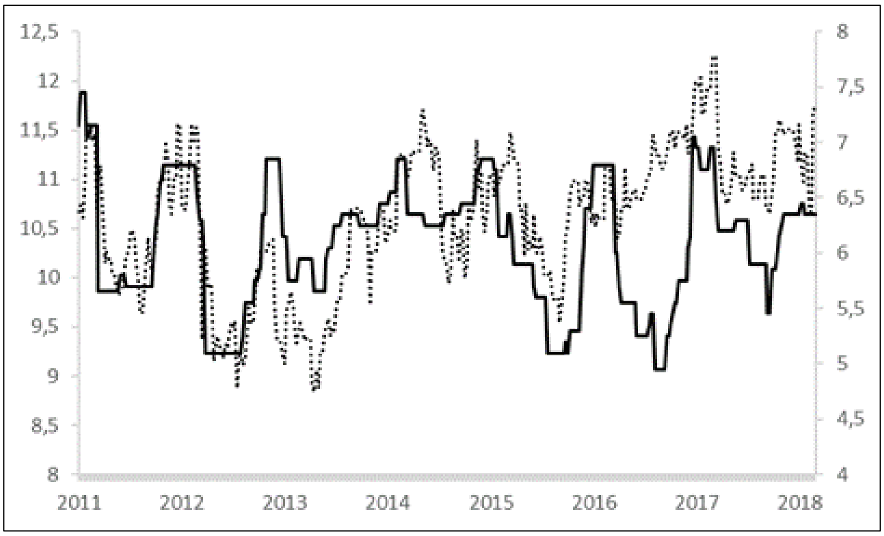


Figure 2. RP: Retail prices of the non-PGI lamb (main axis); FP: Farm prices of the non-PGI lamb (secondary axis). Prices are expressed in € and vertical axes are measured in €/kg carcass.

4.1. *PGI Cordero de Navarra*

Table 1 reports a summary of basic descriptive statistics together with univariate tests for the order of integration of the price series.

Table 1. Summary of descriptive statistics and univariate nonstationarity tests for PGI lamb.

	FPI	**RPI**
Number of observations	373	373
Mean	6.398	11.945
Minimum	5.280	10.840
Maximum	7.91	12.870
Standard deviation	0.617	0.385
Test for ARCH effects	331.812 ***	317.817 ***
Linear time trend	-6.7×10^{-4} **	4.99×10^{-4} ***
PQ (2007)	−16.684	−14.414
KPSS (1992)	0.423 ***	2.284 ***

Notes: FPI: Farm prices of PGI lamb; RPI: Retail prices of PGI lamb. Prices are transformed into logs. Test for the presence of autoregressive conditional heteroscedasticity (ARCH) effects (lags = 2). ** (***) indicates statistical significance at 5% (1%).

The results of the PQ and KPSS tests confirm that the two price series are nonstationary of the first order. Hence, according to theory, cointegration may exist when nonstationary variables show a tendency to move together in the long run, and deviations from this equilibrium due to unexpected shocks tend to revert eventually. So, the aforementioned Johansen's multivariate approach is applied for testing for the existence of a cointegration relationship between both prices of the PGI chain. The results, reported in Table 2, confirm the presence of a single cointegration relationship at least at the 5% significance level.

Table 2. Cointegration rank test for PGI lamb.

Rank	**Eigenvalue**	λ^{*}_{trace}
0	0.053	29.947 ***
1	0.026	9.606 **

Notes: Following [50], the Bartlett corrected trace test was used based on the optimal lag order (1) selected using standard information criteria. * [**] (***) indicates statistical significance at the 10% [5%] (1%) level.

Moreover, as prices are expressed in logs, the statistically significant cointegration relationship between farm and retail prices suggests that they are moving together in the long term (the parameters of the cointegration relationships are explained as elasticities), in the sense that an increase in farm prices may lead to an increase in retail prices. This can be seen in the first row of Table 3. This positive relationship of both prices may be expected a priori, as an increase in farm prices for any reason may lead to an increase in prices at a downstream level, reflecting a low price elasticity (16%), suggesting that the information is transmitted with fewer distortions.

Table 3. Estimated results for VECM–Babba, Engle, Kraft, and Kroner (BEKK)– multivariate generalized autoregressive conditional heteroscedasticity (MGARCH) model for the PGI lamb.

Cointegration Relationship: $RPI_t = 2.184^{***} + 0.160^{***} FPI_t$		
Conditional Mean Equation (VECM):		
$\begin{pmatrix} \Delta RPI_t \\ \Delta FPI_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \varepsilon_{t-1} + \begin{pmatrix} \delta_{11} & \delta_{12} \\ \delta_{21} & \delta_{22} \end{pmatrix} \begin{pmatrix} \Delta RPI_{t-1} \\ \Delta FPI_{t-1} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$		
	$\Delta RPPGI_t$	$\Delta FPPGI_t$
ΔRPI_{t-1}	0.091 **	0.080
ΔFPI_{t-1}	0.007	0.057
ε_{t-1}	−0.103 ***	0.040
Multivariate ARCH LM test:		18.49 **
Multivariate Q test:		45.234
Conditional variance equation (symmetric BEKK–MGARCH):		
$\begin{pmatrix} h_{11} \\ h_{22} \end{pmatrix} = \begin{pmatrix} c_{11} & 0 \\ c_{12} & c_{22} \end{pmatrix} \begin{pmatrix} c_{11} & c_{21} \\ 0 & c_{22} \end{pmatrix} + \begin{pmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \end{pmatrix} \begin{pmatrix} u^2_{1t-1} \\ u^2_{2t-1} \end{pmatrix} \begin{pmatrix} u^2_{1t-1} & u^2_{2t-1} \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} + \begin{pmatrix} b_{11} & b_{21} \\ b_{12} & b_{22} \end{pmatrix} \begin{pmatrix} h_{11t-1} & h_{12t-1} \\ h_{21t-1} & h_{22t-1} \end{pmatrix} \begin{pmatrix} b_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$		
c_{11}	0.011 ***	
c_{21}	0.006	
c_{22}	0.012 *	
a_{11}	0.039	
a_{12}	−0.028	
a_{21}	−0.105	
a_{22}	0.107	
b_{11}	0.271	
b_{12}	−1.795 ***	
b_{21}	0.090	
b_{22}	0.670 **	
Joint stability test:		4.372 *
LR test for the null that a_{ii}, b_{ii} for $i = 1, 2$ are zero:		179.416 ***
LR test for the null that $a_{12}, a_{21}, b_{12}, b_{21}$ are zero (BEKK cross effects):		31.831 ***

Note: * [**] (***) indicates statistical significance at the 10% [5%] (1%) level.

Once the cointegration relationship was established, the short-term dynamics were modeled using a vector error correction type model and were estimated together with the conditional variance model using a BEKK–MGARCH model that allows for the presence of asymmetric effects. However, it should be noted that the estimation procedure allowing for asymmetric effects in the conditional variance model was not satisfactory, as the LR test for testing the null of joint significance of asymmetric coefficients was 1.716 with a p-value of 0.143. This evidences that, in this case, there are no relevant asymmetries in the price volatility transmission through the quality-differenced market channel. Based on this, the system is estimated assuming symmetric effects. Estimated results are reported in Table 3, along with residual-based tests of the VECM and BEKK–MGARCH. In particular, the residuals from the VECM were tested using the multivariate Q statistic developed by [54] for testing the null of no autocorrelation and the multivariate ARCH LM for testing the null of no ARCH effects. The results support the absence of autocorrelation and the presence of ARCH effects in the residuals, which supports the use of a MGARCH model.

As for the results of the estimated VECM with one lag, it can be seen that the estimated α_i represents the speed at which prices correct any deviations from the equilibrium relationship in the long run. In this case, adjustments to deviations from the long-run equilibrium relationship are only significant at retail level, while the contrary cannot be supported by the data, indicating that farmers cannot benefit from retailers when prices increase. Moreover, in relation to short-run dynamics, only significant lagged prices can be found in the retail prices equation, suggesting the important role played by this level of the chain.

The results of the conditional variance (BEKK–MGARCH) are also displayed in Table 3 (lower panel). Thus, the residual-based tests ensure joint stability using Nyblom's test developed by [55] and time-varying volatility (parameters of matrices A and B are jointly statistically significant) at least at the 5% significance level.

Conditional variance equations are reported in Table 4, as the direct interpretation of individual estimated coefficients from the MGARCH model cannot be addressed. Looking at the results, only volatility spillovers from retail to farm price volatility (h_{22}) are statistically significant through the covariance term (h_{12t-1}). This suggests that price fluctuations can be mitigated if both actors collaborate to reduce volatility of farm prices. Own past volatility effects and past market shocks have no impact through the market channel. Retail price volatility remains unaffected by farms and its own past volatility and market shocks.

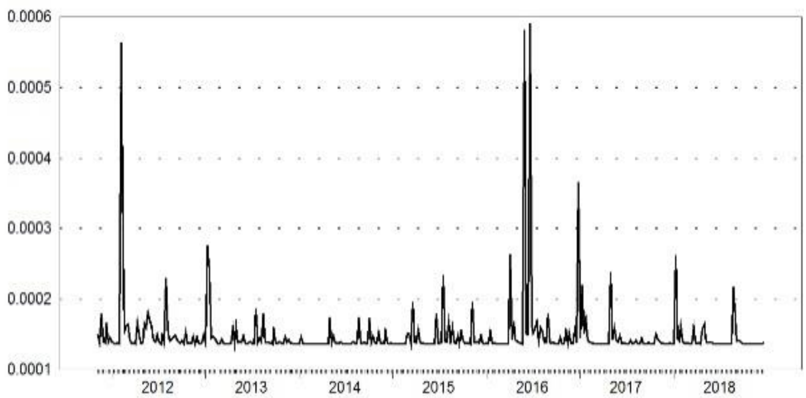
Table 4. Predicted conditional variance equations for PGI lamb.

$$h_{11} = 1.54 \times 10^{-4} \quad +0.074h_{11t-1} + 0.008h_{22t-1} + 0.049h_{12t-1} +0.002\, u^2_{1t-1} + 0.011\, u^2_{2t-1} - 0.008\, u_{1t-1}u_{2t-1}$$

$$h_{22} = 1.45 \times 10^{-4} \quad +3.221^{*}h_{11t-1} + 0.449\, h_{22t-1} -2.404^{***}\, h_{12t-1} + 0.001u^2_{1t-1} + 0.011u^2_{2t-1} -0.006u_{1t-1}u_{2t-1}$$

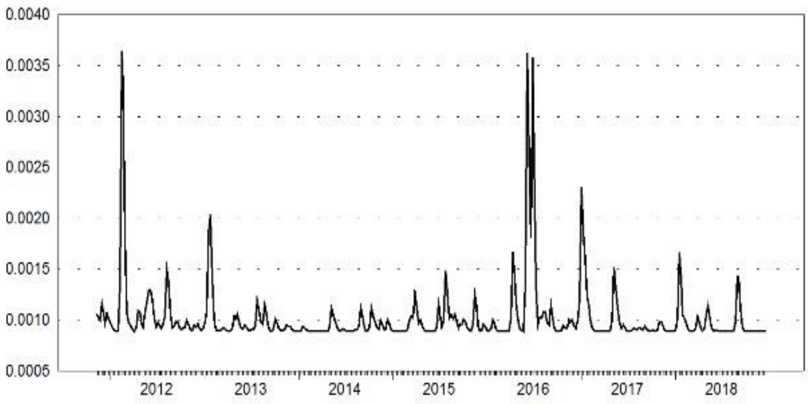
Notes: h_{11} denotes retail price variance, and h_{22} denotes farm price variance. * (***) indicates statistical significance at the 10% (1%) level.

Finally, the predicted volatility of retail and farm prices are graphically represented in Figure 3. In both graphs, one can see higher predicted volatility at the beginning of 2012 and 2016, which mirrors the significant increment of prices in levels shown in Figure 1. As expected, predicted volatility in retail prices is almost neglected, whereas it is quite weak in farm prices.



(**a**)

Figure 3. *Cont.*



(**b**)

Figure 3. (**a**) Predicted conditional variances at retail price level; (**b**) predicted conditional variances at farm price level.

4.2. Non-PGI Cordero de Navarra

Basic descriptive statistics and test statistics for testing the order of integration of the price series are reported in Table 5.

Table 5. Summary of descriptive statistics and univariate nonstationarity tests for the non-PGI lamb.

	FP	RP
Number of observations	373	373
Mean	6.086	10.607
Minimum	4.950	8.840
Maximum	7.450	12.250
Standard deviation	0.570	0.725
ARCH effect test	338.299 ***	324.403 ***
Linear time trend	-2.60×10^{-4}	0.003 ***
Perron and Qu (2007)	−5.521	−17.118
KPSS (1992)	0.695 ***	2.259 ***

Notes: FP: Farm prices; RP: Retail prices. Prices are transformed into logs. Test for the presence of ARCH effects (lags = 2). *** indicates statistical significance at the 1% level.

The results of the analysis of the univariate stochastic properties of all of the series confirm the existence of a unit root in the two price series, so, the next step was to test for the presence of a cointegration relationship between farm–retail prices following Johansen's multivariate test [49] using the Bartlett corrected trace test, as in [50]. The results reported in Table 6 suggest the presence of a single cointegration relationship at least at the 5% significance level.

Table 6. Cointegration rank test for the non-PGI lamb.

Rank	Eigenvalue	λ^*_{trace}
0	0.044	25.212 ***
1	0.024	8.897 *

Notes: Following [50], the Bartlett corrected trace test was used based on the optimal lag order (3) selected using standard information criteria. * (***) indicates statistical significance at the 10% (1%) level.

As with the PGI system, prices are considered in logs, and the cointegration parameters can be interpreted as price elasticities according to economic theory. Thus, we can observe in the first row of Table 7 a direct relationship in both markets, which is roughly double that obtained in the PGI system (30.4%), implying that an increase in farm prices leads to a rise in retail prices and that information is transmitted with some distortions.

Table 7. Estimated results for the VECM–BEKK–MGARCH model for the non-PGI lamb.

Cointegration Relationship: $RP_t = 1.811^{***} + 0.304^{***}FP_t$

Conditional Mean Equation (VECM):

$$\begin{pmatrix} \Delta RPPGI_t \\ \Delta FPPGI_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} \varepsilon_{t-1} + \begin{pmatrix} \delta_{111} & \delta_{112} \\ \delta_{121} & \delta_{122} \end{pmatrix} \begin{pmatrix} \Delta RPPGI_{t-1} \\ \Delta FPPGI_{t-1} \end{pmatrix} + \begin{pmatrix} \delta_{211} & \delta_{212} \\ \delta_{221} & \delta_{222} \end{pmatrix} \begin{pmatrix} \Delta RPPGI_{t-2} \\ \Delta FPPGI_{t-2} \end{pmatrix} + \begin{pmatrix} \delta_{311} & \delta_{312} \\ \delta_{321} & \delta_{322} \end{pmatrix} \begin{pmatrix} \Delta RPPGI_{t-3} \\ \Delta FPPGI_{t-3} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$$

	ΔRP_t	ΔFP_t
ΔRP_{t-1}	−0.049	0.014
ΔRP_{t-2}	−0.081 *	0.016
ΔRP_{t-3}	−0.042	0.062
ΔFP_{t-1}	0.134 ***	0.130 *
ΔFP_{t-2}	0.094 *	0.077 **
ΔFP_{t-3}	0.009	0.002
ε_{t-1}	−0.036 **	0.005
Multivariate ARCH LM test:		30.96 ***
Multivariate Q test:		0.703

Conditional variance equation (asymmetric BEKK–MGARCH):

$$\begin{pmatrix} h_{11} \\ h_{22} \end{pmatrix} = \begin{pmatrix} c_{11} & 0 \\ c_{12} & c_{22} \end{pmatrix} \begin{pmatrix} c_{11} & c_{21} \\ 0 & c_{22} \end{pmatrix} + \begin{pmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \end{pmatrix} \begin{pmatrix} u^2_{1t-1} \\ u^2_{2t-1} \end{pmatrix} \begin{pmatrix} u^2_{1t-1} & u^2_{2t-1} \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} + \begin{pmatrix} b_{11} & b_{21} \\ b_{12} & b_{22} \end{pmatrix} \begin{pmatrix} h_{11t-1} & h_{12t-1} \\ h_{21t-1} & h_{22t-1} \end{pmatrix} \begin{pmatrix} b_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} + \begin{pmatrix} d_{11} & d_{21} \\ d_{12} & d_{22} \end{pmatrix} \begin{pmatrix} v^2_{1t-1} \\ v^2_{2t-1} \end{pmatrix} \begin{pmatrix} v^2_{1t-1} & v^2_{2t-1} \end{pmatrix} \begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix}$$

c_{11}	0.0125 ***	
c_{21}	0.004 ***	
c_{22}	0.015 ***	
a_{11}	−0.125 ***	
a_{12}	−0.461 ***	
a_{21}	0.013	
a_{22}	0.165 ***	
b_{11}	0.757 ***	
b_{12}	−0.176 ***	
b_{21}	0.180 ***	
b_{22}	0.545 ***	
d_{11}	0.288 ***	
d_{12}	−0.655 ***	
d_{21}	0.122 **	
d_{22}	0.107	
Joint stability test:		6.528 *
LR test for the null of asymmetric effects		57.897 ***
LR test for the null that a_{ij}, b_{ij}, d_{ij} for $i, j = 1, 2$ are zero:		1828.121 ***
LR test for the null that a_{ij}, b_{ij} for $i, j = 1, 2$ are zero:		1800.093 ***
LR test for the null that a_{ij}, b_{ij} for $i \neq j,\ i, j = 1, 2$ are zero (BEKK cross effects):		47.822 ***

Note: * [**] (***) indicates statistical significance at the 10% [5%] (1%) level.

Having detected the presence of a long-run equilibrium relationship between farm–retail prices, the next step was to jointly estimate the VECM model (conditional mean) and the multivariate BEKK–GARCH model (conditional variance). The results are presented in Table 7 along with the usual residual-based tests. In particular, the residuals from the VECM were tested using the multivariate Q statistic for testing the null of no autocorrelation and the multivariate ARCH LM test for the null of no ARCH effects. Results support the absence of autocorrelation and the presence of ARCH effects in the residuals, which supports the use of a MGARCH model.

Regarding price dynamics, the estimated α_i suggests that only in the retail price equation are adjustments to any deviations from the long-run equilibrium relationship significant at retail price level (elasticity of 3%). This implies slower adjustments compared to those obtained previously in the PGI market, suggesting that there is certain degree of market power at the retail level in the Spanish lamb market, which is in line with [33]. Moreover, short-run price dynamics are characterized by significant lagged prices.

The estimation of the conditional variance model is also reported in Table 7 (lower panel). The results of the residual-based tests from the BEKK–MGARCH model indicate that joint stability of the model is ensured using Nyblom's test [55] as well as the presence of time-varying volatility (parameters of matrices A and B and parameters of A, B, and D are jointly statistically significant) at least at the 5% significance level. Furthermore, data support the presence of asymmetries in the price volatility transmission process, as the null of parameters of matrix D being zero is rejected at the 1% significance level. In this case, the conventional lamb market is characterized by significant asymmetries, contrarily to what was found in the PGI lamb chain.

As previously indicated, the direct interpretation of the estimated coefficients of the asymmetric BEKK–MGARCH model of Table 7 cannot be addressed. In its place, the predicted conditional variance equations are obtained in Table 8. Conversely to the results obtained from the quality-differenced system, direct and indirect past volatility effects are found in retail (h_{11}) and farm (h_{22}) price volatility equations. In particular, retail price volatility (h_{11}) is affected by its own past volatility (h_{11t-1}) and by past price volatility at farm price level (h_{22t-1}). Price volatility spillovers from the farm level (h_{12t-1}) are found to be statistically significant, becoming a tool to increase price instability if both prices move in the same direction. Past shocks have no significant impact. The results also indicate that past shocks to retail (v^2_{1t-1}) seem to have an asymmetric effect on retail price volatility, which suggests that price instability increases with negative shock in its variance over time, since h_{11t-1} was found to be statistically significant.

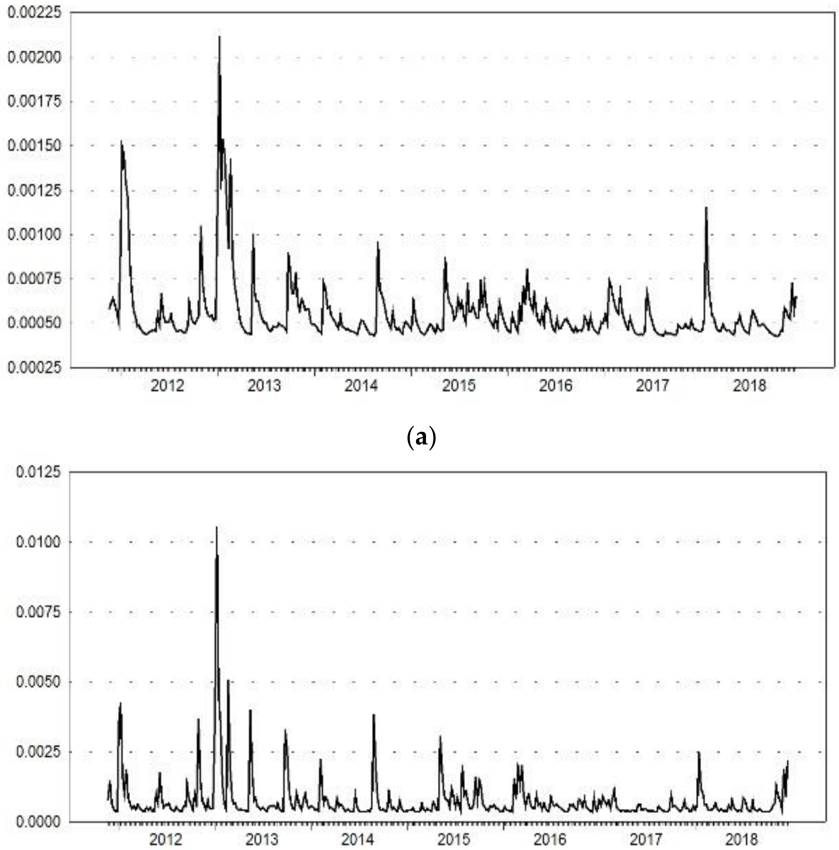
Table 8. Predicted conditional variance equations for the non-PGI lamb.

$h_{11} = 1.74 \times 10^{-4***}$	$+0.573^{***}h_{11t-1} + 0.032^{***}h_{22t-1} + 0.272^{***}h_{12t-1}$
	$+0.016u^2_{1t-1} + 1.66 \times 10^{-4}u^2_{2t-1} - 0.003\ u_{1t-1}u_{2t-1}$
	$+0.083^{***}v^2_{1t-1} + 0.015v^2_{2t-1} + 0.104^{***}v_{1t-1}v_{2t-1}$
$h_{22} = 2.30 \times 10^{-4***}$	$+0.031^{***}h_{11t-1} + 0.299^{***}\ h_{22t-1} - 0.192^{***}h_{12t-1}$
	$+0.213^{***}u^2_{1t-1} + 0.027^{*}u^2_{2t-1} - 0.152^{***}u_{1t-1}u_{2t-1}$
	$+0.429^{***}v^2_{1t-1} + 0.012v^2_{2t-1} - 0.715^{***}v_{1t-1}v_{2t-1}$

Notes: h_{11} denotes retail price variance, h_{22} denotes farm price variance. * (***) indicates statistical significance at the 10% (1%) level.

Regarding farm price volatility (h_{22}), the results indicate that own past volatility (h_{22t-1}) has a larger effect than that of retail past volatility (h_{11t-1}). In this case, price instability tends to be mitigated if both prices move together, since the estimated coefficient of the covariance term (h_{12t-1}) is statistically significant. Retail past shocks (u^2_{1t-1}) tend to raise farm price volatility with a higher incidence than that of own past shocks (u^2_{2t-1}) over time. Moreover, negative shocks to retail prices are found to affect farm price volatility. The asymmetric effect on the covariance term seems to indicate that cross volatility spillovers are favored due to the effects of lagged price changes at retail level. This suggests that the farm price response tends to be more affected by retail price decreases than by increases, so a price decrease could foster competitiveness in the long-term.

Finally, Figure 4 illustrates the predicted volatility across the two price levels of the conventional lamb chain. As can be seen in both chain levels, higher predicted volatility is found at the beginning of 2013, mirroring an important rise in price levels reported in Figure 2. However, farm levels exhibit more price volatility compared to retail prices, which may suggest that price volatility in the upstream barely is transmitted to the downstream level.



(**a**)

(**b**)

Figure 4. (**a**) Predicted conditional variances at retail price level; (**b**) predicted conditional variances at farm price level.

5. Discussion

The results obtained in the previous section show the differences and similarities in the price volatility dynamics along the lamb supply chain for a quality-differentiated product and its conventional counterpart.

In both the PGI and conventional systems, farm–retail pairwise prices are characterized as nonstationary and seem to share a long-term relationship. In other words, farm and retail prices in each system are cointegrated, implying that if farm prices increase, retail prices may increase, showing a slightly superior response in the non-PGI system to a change in farm prices, as the price elasticity (30%) is greater than that obtained in the quality system (16%). The error correction term is found statistically significant in the retail price equations of the two systems, implying that farm prices tend to correct any deviations from the long-term equilibrium in the retail equations of both systems. Specifically, the speed of this adjustment in the PGI system seems to be slightly superior (−0.103) to that obtained in the conventional system (−0.036).

Interestingly, the results obtained for the conditional volatility model reveal that the volatility estimated in the PGI system seems to be much weaker than that obtained in the conventional system. Thus, in the PGI system, whereas retail price volatility is not influenced either by own past volatility or past farm price volatility, farm price volatility is impacted by significant cross volatility spillovers from the farm and retail markets. This suggests that, through the PGI system, fluctuations contribute to smoothening the price variations but still need to be improved to protect farmers through minimum prices and price premiums. In this system, the results also do not support the presence of asymmetric effects, meaning that price changes, regardless of the sign and intensity, have a similar impact on the conditional price volatility in the market and cannot support the presence of significant retail market power. Conversely, in the conventional system, short- and long-term persistent volatility can be identified for both prices. Thus, retail and farm conditional volatilities are explained by their own respective past volatilities on their own chain stage as well as by lagged volatility spillovers from the other stage. Farm price volatility shows statistically significant own volatility spillovers and cross-market spillovers, the former being more intense. The presence of asymmetric effects between farm and retail levels is also confirmed. Unidirectional retail to farm volatility spillover is found statistically significant in both levels, suggesting that demand shocks seem to play a significant role in defining price volatility. This may imply that past shocks to retail price markets have an impact on both retail and farm price volatility that may have a limited persistence in the long-run and can be more vulnerable to price shocks. The results also point to the presence of certain retail market power, as in [33]. Evidence of asymmetric price volatility transmission was also found in [30] when investigating the wild fresh hake supply chain in Spain, and in [9] when examining the relationships between food and energy prices. The presence of information asymmetry may suggest that the responses of retail and farm prices seem to be slightly more affected by price decreases than by increases.

6. Conclusions

For the first time in the literature, price volatility dynamics along the food supply chain under a European geographical indication label have been investigated together. This paper addresses two current trending topics in the current international policy agenda: Price volatility dynamics, which received increased interest after the rise in prices for the first time in 2007 and later in 2011, and food quality schemes, which are considered a cornerstone of the European food quality policy and have attracted the growing interest of chain actors, experts, and governance authorities for their potential to increase competitiveness and social and territorial cohesion in both domestic and international markets.

The study investigated price volatility dynamics along the supply chain, distinguishing between the supply chain of the Protected Geographical Indication lamb from Navarra and the supply chain of its reference counterpart, both located in the same demarcated area in Spain. The obtained results may be useful to better understand the differences and similarities of the price volatility dynamics between a premium product and its conventional counterpart so as to improve their operation and governance. In that sense, promoting PGI lamb as an efficient tool to protect the farmer from fluctuating prices could positively affect their wellbeing so that guaranteeing remunerative prices may assure the fulfillment of positive externalities, such as the preservation of cultural heritage, local identity, and rural lifestyles. In terms of social cohesion, farmer-to-farmer collaboration could help to develop larger lamb producer groups and to design common marketing strategies. This could lead to increased competitiveness not only in domestic markets through direct sales or traditional distribution channels, for instance, but also to increased access to international markets. Finally, it could also protect the consumer by offering more transparency and increasing trust in the added value product.

In this work, an official dataset with weekly price time series at farm and retail levels of the food supply chain for the period 2011 to 2018 was used. A vector error correction model and a multivariate BEKK–GARCH model were jointly estimated following the approach, which also allows for the possible presence of asymmetries in the variance–covariance matrix. The results show some differences worthy of mention between PGI lamb and the reference lamb systems. First, although time-varying volatility is corroborated by both products, the reference system evidences higher levels. Second, prices in both systems seem to exhibit a positive relationship and share a tendency to move together in the long-term, but the adjustment to any deviation from the equilibrium is slightly superior in the PGI system. Third, the presence of asymmetries is only found in the reference system, whereas the volatility dynamics in the PGI system are characterized by symmetric behavior. This may suggest that a similar response of (own and cross) price volatility spillovers in the PGI lamb chain could be expected against positive and negative price changes. This means that the PGI farmers are less impacted by volatility transmission compared with the conventional markets, as well as the lack of retail market power as with the non-PGI chain, suggesting a higher degree of market efficiency in the sense that information can be transmitted faster to eliminate shocks with no persistent effects on price volatility.

Finally, extending the product coverage to other premium or quality-differentiated products as well as incorporating an intermediate chain level would be useful to provide a better understanding of the price dynamics transmission between these two groups of products, which, subsequently, could be used to support future stabilizing policies included in the international policy agenda to face current demanding challenges, such as reducing risks associated with food price stabilization with the fewest market distortions. It is an especially important point to make moderate volatility in prices compatible with policies enhancing sustainability of food production systems to further positively affect rural development, assuming that the benefit of chain agents can change between different supply chains, which may differ not only in production, but also in processing methods.

Author Contributions: Conceptualization, H.F.-P. and J.M.G.; formal analysis, H.F.-P., F.A., and J.M.G.; funding acquisition, J.M.G.; writing—original draft preparation, H.F.-P., F.A., and J.M.G.; writing—review and editing, H.F.-P., F.A., and J.M.G. All authors have read and agreed to the published version of the manuscript.

Funding: The authors, H.F.-P. and J.M.G., thank the funding received from the European Union's Horizon 2020 research and innovation program Strength2Food under grant agreement No 678024.

Acknowledgments: Authors gratefully thank technical support from the technicians of the Observatory of Agricultural Prices of the Government of Navarra (Spain).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Regulation (EU) No 1151/2012 of the European Parliament and of the Council of 21 November 2012 on Quality Schemes for Agricultural Products and Foodstuffs. Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:343:0001:0029:en:PDF (accessed on 30 March 2020).
2. Council Regulation (EC) No 834/2007 of 28 June 2007 on Organic Production and Labelling of Organic Products and Repealing Regulation (EEC) No 2092/91. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0834&from=EN (accessed on 30 March 2020).
3. Arfini, F.; Antonioli, F.; Donati, M.; Gorton, M.; Mancini, M.C.; Tocco, B.; Veneziani, M. Conceptual Framework. In *Sustainability of European Food Quality Schemes*, 1st ed.; Arfini, F., Bellasen, V., Eds.; Springer International Publishing: Cham, Switzerland, 2019.
4. MAPA. Datos de las Denominaciones de Origen Protegidas (D.O.P), Indicaciones Geográficas Protegidas (I.G.P) y Especialidades Tradicionales Garantizadas (E.T.G.) de Productos Agroalimentarios. 2018. Available online: https://www.mapa.gob.es/es/alimentacion/temas/calidad-agroalimentaria/informedop_igp_2018_ver6_tcm30-513985.pdf (accessed on 10 December 2019).
5. Arfini, F. EU Food Quality Policy: Geographical Indications. In *EU Bioeconomy Economics and Policies: Volume II*, 1st ed.; Dries, L., Jongeneel, R., Purnhagen, K., Wesseler, J., Eds.; Palgrave Macmillan: Cham, Switzerland, 2019; pp. 27–46.
6. Sanjuán-López, A.I.; Dawson, P.J. Volatility Effects of Index Trading and Spillovers on US Agricultural Futures Markets: A Multivariate GARCH Approach. *J. Agric. Econ.* **2017**, *68*, 822–838. [CrossRef]
7. Balcombe, K. The nature and determinants of volatility in agricultural prices: An empirical study from 1962–2008. In *The Evolving Structure of World Agricultural Trade*; Sarris, A., Morrison, J., Eds.; FAO: Rome, Italy, 2009; pp. 109–136.
8. Hassouneh, I.; Serra, T.; Bojnec, Š.; Gil, J.M. Modelling price transmission and volatility spillover in the Slovenian wheat market. *Appl. Econ.* **2017**, *49*, 4116–4126. [CrossRef]
9. Abdelradi, F.; Serra, T. Asymmetric price volatility transmission between food and energy markets: The case of Spain. *Agric. Econ.* **2015**, *46*, 503–513. [CrossRef]
10. FAO; IFAD; OECD; UNCTAD; WFP; World Bank; WTO; IFPRI; UNHLTF. *Price Volatility and Agricultural Markets: Policy Responses*; OECD-FAO Report; OECD Publishing: Paris, France, 2011.

11. Gilbert, C.L.; Morgan, C.W. Food price volatility. *Philos. Trans. R. Soc. B* **2010**, *365*, 3023–3034. [CrossRef] [PubMed]
12. Huchet-Bourdon, M. *Agricultural Commodity Price Volatility: An Overview*; OECD Food, Agriculture and Fisheries Working Papers No. 52. OECD Publishing: Paris, France, 2011.
13. Brümmer, B.; Korn, O.; Schlüssler, K.; Jaghdani, T.J.; Saucedo, A. Volatility in the after crisis period: A literature review of recent empirical research. In *Agricultural Markets Instability: Revisiting the Recent Food Crises*; Garrido, A., Brümmer, B., M'Barek, R., Meuwissen, M.P.M., Morales-Opaz, C., Eds.; Routledge: New York, NY, USA, 2016.
14. Gilbert, C.L.; Morgan, C.W. Food price volatility. In *Methods to Analyse Agricultural Commodity Price Volatility*; Piot-Lepetit, I., M'Barek, R., Eds.; Springer: New York, NY, USA, 2011; pp. 45–61.
15. Loureiro, M.L.; McCluskey, J.J. Assessing Consumer Response to Protected Geographical Identification Labeling. *Agribusiness* **2000**, *16*, 309–320. [CrossRef]
16. Bonnet, C.; Simioni, M. Assessing Consumer Response to Protected Designation of Origin Labelling: A Mixed Multinomial Logit Approach. *Eur. Rev. Agric. Econ.* **2001**, *28*, 433–449. [CrossRef]
17. Angulo, A.M.; Gil, J.M. Risk perception and consumer willingness to pay for certified beef in Spain. *Food Qual. Prefer.* **2007**, *18*, 1106–1117. [CrossRef]
18. Dias, C.; Mendes, L. Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Speciality Guaranteed (TSG): A bibiliometric analysis. *Food Res. Int.* **2018**, *103*, 492–508. [CrossRef]
19. Belletti, G.; Burgassi, T.; Manco, E.; Marescotti, A.; Pacciani, A.; Scaramuzzi, S. The roles of geographical indications in the internationalisation process of agri-food products. In *International Marketing and Trade of Quality Food Products*; Canavari, M., Cantore, N., Castellini, A., Pignatti, E., Spadoni, R., Eds.; Wageningen Academic Publishers: Wageningen, The Netherlands, 2009.
20. Mora, C.; Menozzi, D. Vertical contractual relations in the Italian beef supply chain. *Agribusiness* **2005**, *21*, 213–235. [CrossRef]
21. Rangnekar, D. Remaking place: The social construction of a Geographical Indication for *Feni*. *Environ. Plan. A* **2011**, *43*, 2043–2059. [CrossRef]
22. Mancini, M.C. Geographical Indications in Latin America Value Chains: A "branding from below" strategy or a mechanism excluding the poorest? *J. Rural Stud.* **2013**, *32*, 295–306. [CrossRef]
23. Lence, S.H.; Marette, S.; Hayes, D.; Foster, W. Collective Marketing Arrangements for Geographically Differentiated Agricultural Products: Welfare Impacts and Policy Implications. *Am. J. Agric. Econ.* **2007**, *89*, 947–963. [CrossRef]
24. Menapace, L.; Moschini, G. Quality Certification by Geographical Indications, Trademarks and Firm Reputation. *Eur. Rev. Agric. Econ.* **2012**, *39*, 539–566. [CrossRef]
25. Antonioli, F.; Ben Kaabia, M.; Arfini, F.; Gil, J.M. Price transmission dynamics for quality-certified food products: A comparison between conventional and organic fluid milk in Italy. *Agribusiness* **2019**, *35*, 374–393. [CrossRef]
26. Ferrer-Pérez, H.; Arfini, F.; Gil, J.M. Modelling Price Transmission within the Supply Chain under a European Protected Designation of Origin Framework: The Case of Parmigiano Reggiano. *Soc. Sci.* **2019**, *8*, 87. [CrossRef]
27. Assefa, T.T.; Meuwissen, M.P.; Gardebroek, C.; Oude Lansink, A.G. Price and Volatility Transmission and Market Power in the German Fresh Pork Supply Chain. *J. Agric. Econ.* **2017**, *68*, 861–880. [CrossRef]
28. Ait Sidhoum, A.; Serra, T. Volatility Spillovers in the Spanish Food Marketing Chain: The Case of Tomato. *Agribusiness* **2016**, *32*, 45–63. [CrossRef]
29. Buguk, C.; Hudson, D.; Hanson, D. Price volatility in agricultural markets: An examination of U.S. catfish markets. *J. Agric. Resour. Econ.* **2003**, *28*, 86–99.
30. Ferrer-Pérez, H.; Gracia-de-Rentería, P. Asymmetric price volatility transmission in the Spanish fresh wild fish supply chain. *Mar. Resour. Econ.* **2020**, *35*. in press.
31. Piot-Lepetit, I.; M'Barek, R. *Methods to Analyse Agricultural Commodity Price Volatility*; Springer: New York, NY, USA, 2011.
32. Assefa, T.T.; Meuwissen, M.P.M.; Oude Lansink, A.G.J.M. Price Volatility Transmission in Food Supply Chains: A Literature Review. *Agribusiness* **2015**, *31*, 3–13. [CrossRef]
33. Ben Kaabia, M.; Gil, J.M. Asymmetric price transmission in the Spanish lamb sector. *Eur. Rev. Agric. Econ.* **2007**, *34*, 53–80. [CrossRef]

34. MAPA. Estadísticas y Encuestas ganaderas año 2018. Ministerio de Agricultura, Pesca y Alimentación. Available online: https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/resultados_nov2018_ovino-caprino_tcm30-502924.pdf (accessed on 30 March 2020).
35. MAPA. El sector ovino y caprino de carne en cifras. Principales Indicadores Económicos. Available online: https://www.mapa.gob.es/es/ganaderia/estadisticas/indicadoreseconomicosdelsectorovinoycaprino_carne_2018_tcm30-511496.pdf (accessed on 30 March 2020).
36. Cordero de Navarra. La IGP Cordero de Navarra. Available online: http://www.corderodenavarra.com/ (accessed on 20 September 2019).
37. Engle, R.F. Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation. *Econometrica* **1982**, *50*, 987–1007. [CrossRef]
38. Bollerslev, T. Generalized autoregressive conditional heteroskedasticity. *J. Econom.* **1986**, *31*, 307–327. [CrossRef]
39. Kroner, K.F.; Ng, V.K. Modeling asymmetric comovements of asset returns. *Rev. Financ. Stud.* **1998**, *11*, 817–844. [CrossRef]
40. Dickey, D.A.; Fuller, W.A. Distribution of the estimators for autoregressive time series with a unit root. *J. Am. Stat. Assoc.* **1979**, *74*, 427–431.
41. Phillips, P.C.B.; Perron, P. Testing for a unit root in time series regression. *Biometrika* **1988**, *75*, 535–547. [CrossRef]
42. Elliott, G.; Rothenberg, T.J.; Stock, J.H. Efficient tests for an autoregressive unit root. *Econometrica* **1996**, *64*, 813–836. [CrossRef]
43. Ng, S.; Perron, P. Lag length selection and the construction of unit root tests with good size and power. *Econometrica* **2001**, *69*, 1519–1554. [CrossRef]
44. Hayashi, F. *Econometrics*; Princeton University Press: Princeton, NJ, USA, 2000.
45. Patterson, K. Unit Root Tests in Time Series, Volume 1: Key Concepts and Problems. In *Palgrave Texts in Econometrics*; Palgrave Macmillan: Hampshire, UK, 2011.
46. Choi, I. *Almost All about Unit Roots*; Cambridge University Press: Cambridge, UK, 2015.
47. Perron, P.; Qu, Z. A simple modification to improve the finite sample properties of Ng and Perron's unit root tests. *Econ. Lett.* **2007**, *94*, 12–17. [CrossRef]
48. Kwiatkowski, D.; Phillips, P.C.B.; Schmidt, P.; Shin, Y. Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *J. Econom.* **1992**, *54*, 159–178. [CrossRef]
49. Johansen, S. Statistical analysis of cointegration vectors. *J. Econ. Dyn. Control.* **1998**, *12*, 231–254. [CrossRef]
50. Johansen, S. A small sample correction of the test for cointegrating rank in the vector autoregressive model. *J. Time Ser. Anal.* **2002**, *24*, 663–678. [CrossRef]
51. Juselius, K. *The Cointegrated VAR Model: Methodology and Applications*; Oxford University Press: New York, NY, USA, 2006.
52. Myers, R.J. Time Series Econometrics and Commodity Price Analysis: A Review. *Rev. Mark. Agric. Econ.* **1994**, *62*, 167–181.
53. Goodwin, B.K.; Piggott, N.E. Spatial market integration in the presence of threshold effects. *Am. J. Agric. Econ.* **2001**, *83*, 302–317. [CrossRef]
54. Hosking, J.R.M. Equivalent forms of the Multivariate Portmanteau Statistic. *J. R. Stat. Soc. B* **1981**, *43*, 261–262. [CrossRef]
55. Nyblom, J. Testing for the constancy of parameters over time. *J. Am. Stat. Assoc.* **1989**, *84*, 223–230. [CrossRef]