



## Research Paper

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# Horizontal price transmission in major EU broiler markets: A non-linear asymmetric co-integration approach

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## ABSTRACT

The present study attempts to assess price transmission relationships between the four major EU broiler markets, namely Germany, France, Spain and the United Kingdom. Data consist of monthly wholesale prices spanning from the period 1991:01 to 2016:01 and were obtained from the European Commission database. A non-linear framework was employed taking into account structural breaks and asymmetric adjustment. Results support a partial degree of integration between the markets and asymmetric price dependence; therefore rejecting the Law of One Price. Results further indicate a faster response of the three market prices to shocks from UK prices that squeeze profit margin than to stretch them, in order to retain their market share.

**Keywords:** Spatial price transmission, market integration, broiler sector, momentum threshold autoregressive approach.

O. Tremma<sup>1,2</sup> and A. Semos<sup>1</sup>

<sup>1</sup>Department of Agricultural Economics, School of Agriculture, Faculty of Agriculture, Forestry and Natural Environment, Aristotle University of Thessaloniki, Greece.

<sup>2</sup>Department of Land, Farm and Agribusiness Management, Harper Adams University, Edgmond, Newport – Shropshire, United Kingdom.

\*Corresponding author. E-mail: otrema@harper-adams.ac.uk

## INTRODUCTION

The European Union has made great efforts throughout the years to integrate markets and remove barriers that impede free trade of products amongst its members. The stabilization of prices and the pattern of spatial price relationships illustrate the degree of integration among the geographically separated markets. Over the years, several attempts were made on behalf of the European Commission. The milestones were the adoption of the Single Market Strategy, in 1993 and the Single Market Review, in 2006, mainly through the strategy of market monitoring, which focused on understanding the obstacles that prevent the well-functioning of markets.

On spatially integrated markets, a price shock in one market evokes responses to the other. In this case, arbitrage activities ensure that price differentials of a homogeneous commodity between the two separated markets, equal, at most, the transportation costs from one market to the other. As noted by Fackler and Goodwin (2001), this constitutes the weak version of the Law of One Price (LOP). The strong version of the LOP is characterized by equality of the prices in the two separated markets

(Rapsomanikis et al., 2003). The LOP is valid under the assumption that goods and information flow freely among the separated markets. In the case of market segmentation, however, markets are not well integrated resulting in efficiency losses (Meyer and von Cramon-Taubadel, 2004; Serra et al., 2006; Emmanouilides and Fousekis, 2012; Fousekis, 2015).

The analysis of spatial price transmission in terms of speed and symmetry has enabled policy makers to evaluate the degree of dependence in geographically separated markets. Higher speed of price transmission implies higher degree of market integration, since the long-run price differential is corrected in a faster pace. Moreover, symmetry indicates that positive and negative shocks occurring in one market are transmitted with the same intensity to the other market. Therefore, benefits are distributed equally to trading partners.

Previous literature on spatial price transmission provides a small number of studies regarding EU meat markets. Researchers have mainly focused on meat market integration through co-integration techniques (Zanias,

**Table 1.** Descriptive statistics of natural logarithms of broiler prices in DE, FR, UK and ES.

Descriptive statistics	DE	FR	UK	ES
Mean	5.164895	5.072395	4.976974	4.865095
Maximum	5.594351	5.459586	5.245957	5.307697
Minimum	4.783696	4.391244	4.723835	4.125653
Std. Dev.	0.277327	0.309731	0.131433	0.285193

1993; Sanjuán and Gil, 2001) assuming symmetric price responses. Serra et al. (2006) looked for asymmetries in EU pork markets using both parametric and non-parametric models, thus, taking into account the non-linear nature of spatial price relationships due to transaction costs. Fousekis (2015) extended this work and employed the non-parametric local linear regression. Also, Grigoriadis et al. (2016) assessed the degree of integration along EU pig meat markets using mixed R-vine copulas.

Others researchers emphasized on spatial price relations in EU meat markets, in terms of the Law of One Price (LOP) using parametric and non-parametric regressions (Fousekis, 2007; Emmanouilides and Fousekis, 2012; 2015). To the best of knowledge, no earlier work has examined the pattern of price transmission allowing for structural breaks, non-linearities and asymmetric adjustments within the EU broiler markets. Thus, a contribution to literature is provided.

In this study, the markets under consideration are Germany, France, Spain and the United Kingdom. These markets are among the EU leading countries in broiler meat production. In 2015, they produced half of the EU-28 broiler meat along with Poland and their production shares range from 13% for the United Kingdom to 10.2% for Spain. Per capita consumption of poultry meat, in 2015, for the United Kingdom is recorded to be 22.9 kg/head, for Spain almost 29 kg/head, 17.5 kg/head for France while Germany reaches almost 12 kg/head (AVEC, 2016). The key exporters to EU-15 are hierarchically, Spain, United Kingdom, France and Germany. At the same time, these countries represent the four major importers in the EU-27 intra trade. In this case, the United Kingdom holds the reins followed by Germany, France and Spain (Eurostat, 2016).

Broiler production is one of the most important meat sectors across the EU agro-food supply chain. Analyzing and understanding the price relationships within the EU broiler market is significant for many reasons. Since 2008, the EU-28 meat industry suffers the impacts of the economic downturn; however, broiler meat consumption is less affected (AHDB, 2015). Moreover, the EU poultry market has not experienced much intervention by policy makers compared to other markets such as beef, milk and wheat through CAP reforms (El-Agraa, 2013). Hence, limited intervention is expected to enhance full price transmission across the EU markets (Gotzet al., 2012).

Also, the EU broiler industry demonstrates a high degree

of concentration with a small number of multinational companies to predominate in the EU broiler market. Indeed, in UK, four of the key industry players process over 70% of British broilers (Sheppard, 2004; Ford, 2015). The concentration of market power derived mainly through consolidation may lead to incomplete price transmission (Azzam, 1999).

In addition, the EU broiler sector during the examined period experienced a great number of outbreaks such as campylobacteriosis and *Avian Influenza*. These zoonoses in conjunction with fluctuations in feed prices have caused a notable effect on the supply and demand for meat commodities (European Commission, 2008; 2011).

## MATERIALS AND METHODS

### Data

The utilized data consist of monthly wholesale prices of whole broilers from Germany (DE), France (FR), Spain (ES) and the United Kingdom (UK) over the period 1991:01 to 2016:01. The prices were obtained from the European Commission (EC, 2017) and expressed in euro/kg and for the analysis they were converted into natural logarithms.

Moreover, pair wise analysis was applied since it constitutes a common type of analysis when dealing with price transmission. When using pair prices, the central market is assumed to be the largest in volume market (Serra et al., 2006). In our case, the United Kingdom is considered as the leader market and therefore the central market. Several characteristics of this market prompt us to consider the United Kingdom as the market, which determines prices. First, the United Kingdom holds by far, the highest per capita consumption of chicken meat. In addition, in terms of EU-27 intra trade, among the examined markets, the United Kingdom is the largest importer and a significant exporter of chicken meat. According to AHDB (2016), the poultry meat produced in UK in 2015 was 1.4 million tonnes out of 930 million slaughtered broilers.

Since four markets made up the examined sample and UK is the price leader, three price pairs were formed. Table 1 shows the descriptive statistics of the four countries. It appears that Germany has, on average the highest prices while Spain has the lowest price. Figure 1 illustrates the natural logarithms of broiler prices for the four markets.

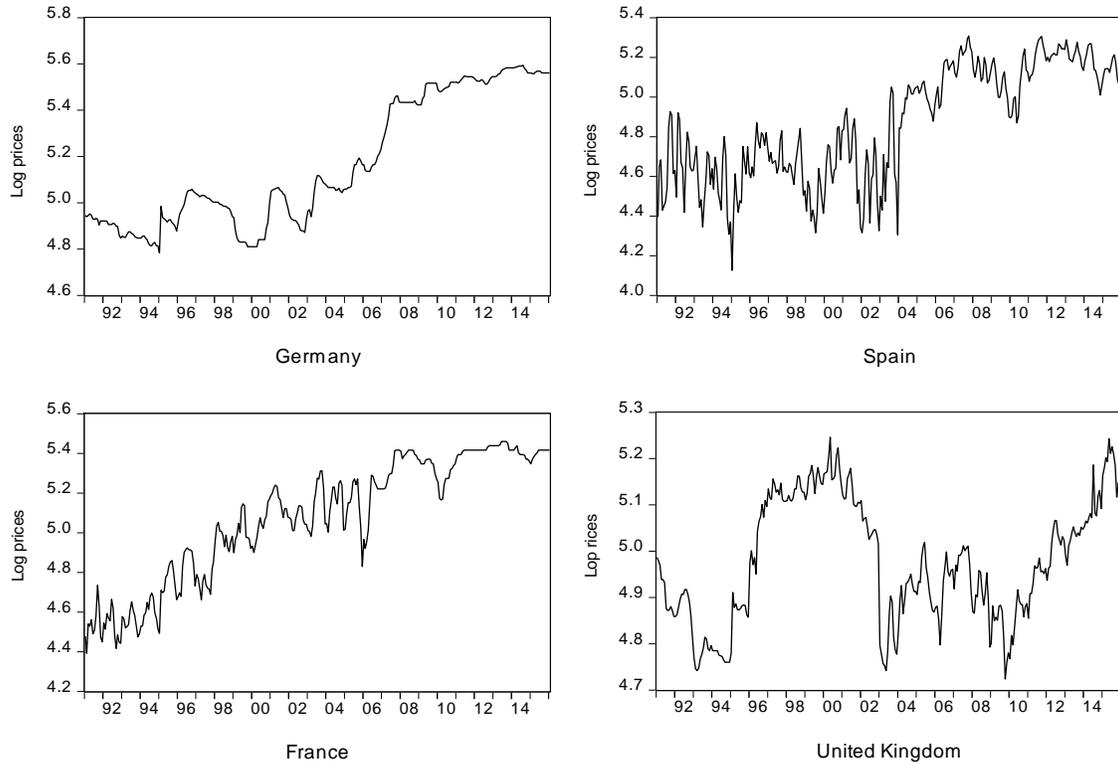


Figure 1: Natural logarithms of the four EU broiler markets.

On overall, the four markets appear to follow an upward pattern implying that spatial market integration exists. Likewise, abrupt shifts suggest the presence of possible breaks that have to be taken into consideration throughout the analysis.

**Methodology**

**Engle – Granger and Phillip – Ouliaris residual based tests**

Under the assumption that the examined variables are integrated of order one, known as I (1), cointegration tests can be applied to investigate whether variables co-move in the long run. The single equation residual based tests of Engle – Granger (1987) and Phillips – Ouliaris (1990) were therefore employed to identify the existence of a long-run equilibrium relationship between the examined variables.

These tests are unit root tests applied to the residuals obtained from the equation:

$$Y_t = a + bX_t + u_t \tag{1}$$

Where,  $Y_t$  is the dependent variable (Germany, France and Spain),  $X_t$  is the independent variable (the United

Kingdom) and  $u_t$  the obtained residuals. The tests differ in the method of considering serial correlation in residuals. The Engle – Granger test is based on the parametric Dickey-Fuller methodology whilst the Phillips – Ouliaris test employs the non-parametric Phillips-Perron approach.

**Bai and Perron (1998, 2003a)**

In order to examine the existence of possible structural breaks in the co-integrating relationships, the Bai and Perron (1998, 2003) methodology was used. The approach includes a number of  $SupF(l+1 | l)$  tests which allows us to endogenously determine multiple break points. The sequential  $SupF(l+1 | l)$  tests firstly examined the null hypothesis of 1 structural breaks against the alternative hypothesis of  $l+1$  breaks. In case the alternative hypothesis is accepted, the procedure is repeated in order to identify the appropriate number of structural changes. The tests follow the model in Equation 2, with  $m$  breaks and  $m + 1$  regimes:

$$Y_t = X'_t\beta + Z'_t\delta_j + u_t \tag{2}$$

with  $j = 1, \dots, m + 1$ , where,  $Y_t$  is the dependent variable,  $m$  corresponds to the number of breaks,  $X_t$  is

Table 2. Unit root tests.

Markets	KPSS	
	Levels	
DE	1.865(a)***	0.329(b)***
FR	1.960(a)***	0.336(b)***
UK	0.572(a)**	0.514(b)***
ES	1.726 (a)***	0.1703 (b)**
First differences		
DE	0.120(a)	0.069(b)
FR	0.115(a)	0.036(b)
UK	0.058(a)	0.053(b)
ES	0.126 (a)	0.097 (b)

(a) Model only with a constant, without deterministic trend, (b) Model with constant and deterministic trend, \*\*\* Denotes significance at the 1% level and \*\* Denotes significance at the 5% level.

the independent variable,  $Z_t$  is the constant term along with the coefficients  $\beta$  and  $\delta_j$  respectively while  $u_t$  represents the disturbance term.

**Enders and Siklos (2001) cointegration**

The non-linear cointegration model - Momentum Threshold Autoregressive (MTAR) -developed by Enders and Siklos (2001) was applied in our analysis. This method is an extension to the proposed test of Engle and Granger (1998), allowing for asymmetries. The MTAR model is described in Equation 3 as:

$$\Delta\mu_t = I_t\rho_1\Delta\mu_{t-1} + (1 - I_t)\rho_2\Delta\mu_{t-1} + \sum_{i=1}^{p-1} \gamma_i\Delta\mu_{t-i} + \varepsilon_t \tag{3}$$

Where  $\mu_t$  represents the residuals obtained from the Engle-Granger co-integration technique,  $I_t$  is the Heaviside indicator and equals 1 when  $\Delta\mu_{t-1} \geq \tau$  or zero when  $\Delta\mu_{t-1} < \tau$ , where  $\tau$  is the threshold value calculated endogenously through Chan's (1993) method. The coefficients  $\rho_1$  and  $\rho_2$  express the different adjustment speeds to positive and negative changes. Initially, the null hypothesis of no co-integration, which is represented by  $\rho_1 = \rho_2 = 0$  is tested through an F-test using asymptotic critical values developed by Enders and Siklos (2001).

Once, the null hypothesis of no co-integration is rejected, the null hypothesis of symmetrical adjustment can be tested, where  $\rho_1 = \rho_2$ , against the alternative hypothesis of asymmetrical adjustment using an F-test.

Should co-integration with adjustment asymmetry be confirmed, the asymmetric error correction model displayed in Equation 4 can be performed.

$$\Delta Y_t = a_0 + \sum_{i=1}^p a_1\Delta Y_{t-i} + \sum_{i=1}^p a_2\Delta X_{t-i} + \delta_1 I_t \Delta\mu_{t-1} + \delta_2 (1 - I_t)\Delta\mu_{t-1} + \varepsilon_t \tag{4}$$

**RESULTS AND DISCUSSION**

At first, the Kwiatkowski-Phillips-Schmidt-Shin (1992) test for stationarity was applied to determine the order of integration of the examined variables. The test results, reported in Table 2 suggest that all the involved variables are non-stationary processes in levels, while they become stationary when converted into first differences. Thus, they can be described as integrated processes of order one, I (1). The co-integration residual-based test proposed by Phillips - Ouliaris (1990) can therefore, be applied to each possible model combination.

Results presented in Table 3 suggest that the null hypothesis of no co-integration between the series is accepted for all pairs. Given that the broiler sector has faced external shocks caused by diseases outbreaks and other structural changes, the co-movements between price pairs are expected to be unstable. The Quandt (1960) likelihood ratio (QLR) was applied in order to examine the stability of the parameters. Moreover, the test detects potential structural breaks in the long run relationship between the considered variables. Table 4 presents the results of the QLR test, which confirm the existence of instability in each price pair. Specifically, in every case the value of F-stat (2.297) exceeds the critical value at the 1% level of significance.

Regarding the aforementioned results, we take our analysis one-step further and perform the Bai - Perron test

**Table 3.** Residual based test of Phillips – Ouiliaris.

Phillips – Ouiliaris test		
Dep.-Indep. Variable	t-stat	p-value
DE-UK	-0.459	0.9655
FR-UK	-2.070	0.4922
ES-UK	-2.925	0.1322

MacKinnon (1991) p-values.  $H_0$ : series are not cointegrated; \*\* Denotes significance at the 5% level; \* Denotes significance at the 10% level.

**Table 4.** Quandt likelihood ratio (QLR).

Dep. - Indep. Variable	F- statistic	Break dates estimates
DE – UK	1182.3 ***	2007:01
FR – UK	612.92 ***	2003:01
ES – UK	498.637***	2004:01

Qlr test with 15% trimming, critical values (Stock and Watson, 2003). \*\*\* indicates significance at the 1% level.

**Table 5.** Bai – Perron test and break dates estimates.

Variables (Dep.-Indep.)	SupF ( $\ell + 1 \ell$ )	F-stat	Scaled F-stat	Break dates estimates
DE-UK	SupF (4/3)	47.29***	94.59***	1998M11, 2003M04, 2007M01, 2010M10
FR-UK	SupF (5/4)	44.86***	89.73***	1995M02, 1999M03, 2003M12, 2007M09, 2012M04
ES-UK	SupF (3/2)	49.72***	99.44***	2003M03, 2006M012, 2011M05

**Table 6.** Engle – granger co-integration analysis.

Dependent variable	Variable				
DE	UK	Constant	2003M04	2007M01	$U_t$
	0.226***(3.386)	3.794*** (11.71)	0.207***(10.33)	0.381***(16.25)	-4.047 ***
FR	UK	Constant	1999M02	2007M07	$U_t$
	0.329*** (6.099)	3.063*** (11.60)	0.406***(20.14)	0.273***(19.89)	-5.927***
ES	UK	Constant	2003M03	2006M12	$U_t$
	0.324***(5.098)	3.000***(9.426)	0.362***(14.671)	0.175***(6.931)	-4.820***

The optimal lag structure is based on the Schwarz criterion; T-statistics are in parenthesis; \*\*\* indicates rejection of the null hypothesis at the 1% significance level and  $U_t$  represent the residuals of the co-integration.

(1998, 2003) to endogenously detect multiple structural changes in the long run relationships. The test result presented in Table 5 indicated that four structural breaks were detected in the long run relationship of the pair DE-UK. Concerning the pair FR-UK, five potential breaks were estimated while for the price pair ES-UK, the test identifies three breaks.

Subsequently, the Engle – Granger (1987) co-integration approach was applied including the estimated structural breaks. Table 6 shows results of the two-step procedure of

co-integration analysis illustrated. Noteworthy is the fact that only the statistically significant breaks were presented along with the ADF unit root tests on the residuals. The analysis validates the hypothesis of a stable co-integration relationship between all the examined variables, when break dates are taken into account.

The long run elasticities show that all the variables have a positive and significant relationship. Thus, broiler price changes possibly occur due to demand side shocks. Regarding the pair DE-UK, a 1% increase in the wholesale

prices of the United Kingdom induces a 0.22% increase in the German broiler prices. Concerning the pair FR-UK, the coefficient suggests that if the UK broiler prices increase by 1%, the French prices will also increase by 0.33%. With respect to the price pair ES-UK, a 1% increase in the UK broiler prices will increase the Spanish wholesale prices by 0.32%.

As pointed by literature, broiler production and broiler prices are mainly influenced by disease outbreaks and fluctuations in input costs, especially feed costs. The detected breaks involved in the long run relations (Table 6) are likely to be attributed to such reasons.

The significant break estimated in the early 1999's is probably related to the *Bovine Spongiform Encephalopathy* crisis, which was recorded in France; switching consumers' demand mainly to poultry meat (European Commission, 2010). Moreover, the detected breaks in 2003 might be related to the severe drought that occurred at that period, leading to the increase in feeding stuff prices in many Member States (European Commission, 2004). Concerning the estimated breaks in the early and mid-2007, they possibly reflect the recorded increase in feed costs. Therefore, high feed prices spurred producers to ramp out broiler prices. The major determinants of this hike seem to have been the biofuel development policies and the decrease in cereal stocks (European Commission, 2008, 2011).

In the next step of our analysis, the possibility of asymmetric linkages between each price pair in the long-run time horizon was investigated. The methodology of consistent - momentum threshold autoregressive model (MTAR) proposed by Enders and Siklos (2001) was employed. At first, we decomposed the residuals obtained from the Engle - Granger procedure and tested whether co-integration and asymmetry exist. Alongside, the Chan's method (1993) was used to determine the consistent estimate of the threshold for each price pair. Based on Goodwin and Piggott (2001), our analysis takes into account the influence of the unobservable transaction costs on the spatial price relationships. As pointed by Ankamah-Yeboah (2013), this threshold depicts a proxy for transaction costs where actors react to any deviation from the long run equilibrium above or below the estimated threshold.

Table 7 represents the results of the MTAR model. The null hypothesis of no co-integration  $H_0: \rho_1 = \rho_2 = 0$ , is rejected for all price pairs as the F-stats are 12.81, 20.90 and 16.15 respectively. Since co-integration exists, we therefore test for asymmetry. Results indicate that the null hypothesis of symmetry,  $H_0: \rho_1 = \rho_2$ , is rejected in all price pairs as the F-stats are 12.73, 10.79 and 15.37 respectively.

Regarding the price pair DE-UK,  $\rho_1$  and  $\rho_2$  indicate convergence such that the speed of adjustment is faster for negative ( $\rho_2$ ) ( $\approx 4.5$  months) than for positive ( $\rho_1$ ) ( $\approx 26$  months) deviations from the equilibrium at  $\tau = -0.009479$ . Results suggest that discrepancies from the long run

equilibrium arise from decreases in the German prices or increases in the UK prices while other changes persist. This means that broiler producers in Germany are more likely to lose from negative-type price shocks in the UK than to gain from positive ones (in UK). On the other hand, consumers in Germany are expected to benefit from price decreases in the UK than to suffer from price increases in the same country.

Results concerning the price pair of FR-UK confirmed a faster convergence for negative ( $\rho_2$ ) ( $\approx 3.2$  months) than for positive ( $\rho_1$ ) ( $\approx 9.7$  months) discrepancies from the threshold equal to  $-0.015969$ . A decrease in the French prices or an increase in the UK prices may lead to discrepancies from the long run equilibrium which are quickly overcome. Therefore, broiler producers in France are more likely to lose from price decreases in the UK than to gain from positive-type price shocks (in UK). On the other hand, consumers in France are expected to benefit from negative-type price shocks in the UK than to suffer from price increases in the same country.

As regards the price pair ES-UK, the  $\rho_1$  and  $\rho_2$  display convergence as well. Specifically, the speed of adjustment is faster for negative ( $\rho_2$ ) ( $\approx 2$  months) than for positive ( $\rho_1$ ) ( $\approx 6.7$  months) deviations from the equilibrium, at  $\tau = -0.075763$ . Hence, a decrease in the Spanish wholesale broiler prices or an increase in the UK prices may lead to a temporary divergence from the long run equilibrium, while other changes persist. Thereafter, producers in Spain are expected to lose from price decreases in UK than to gain from price increases in the same country. On the contrary, consumers in Spain are more likely to gain from price decreases in UK than to be hurt by positive-type price shocks (in UK).

In general, stable long run relationships between the examined pairs are confirmed implying that the major EU broiler markets are indeed co-integrated. However, price transmission - in the long run - appears to be asymmetric since negative shocks from UK to DE, FR and ES are transmitted with higher intensity than positive-type shocks. Thus, the validity of the LOP is rejected by definition and the examined markets cannot be characterized as efficient (Emmanouilides et al., 2014; Fousekis and Trachanas, 2016). This is against the results obtained from the study of Emmanouilides and Fousekis (2015) which confirmed the validity of the LOP- in its weak version though, regarding broiler prices in EU markets.

Given that co-integration and asymmetry between the examined variables are supported, therefore, an asymmetric error correction model can be estimated for each price pair. The Wald tests reported in Table 8, suggest that the null hypothesis of no co-integration and symmetry can be both soundly rejected for all pairs. Furthermore, the asymmetric error correction model outcomes are in accordance with the MTAR results presented in Table 7.

In particular, DE prices react faster to UK price changes

**Table 7:** Consistent Momentum Threshold Autoregressive Model (MTAR).

Dep./ Indep. variable	$\tau$	$\rho_1$	$\rho_2$	$\rho_1 = \rho_2 = 0$	$\rho_1 = \rho_2$	K
DE/UK	-0.009479	-0.037959* (0.021344)	-0.220877*** (0.046593)	12.817530***	12.739320***	1
FR/UK	-0.015969	-0.103037*** (0.034373)	-0.308169*** (0.053052)	20.909220***	10.796630**	1
ES/UK	-0.075763	-0.147339*** (0.059819)	-0.494149*** (0.087514)	16.157300***	15.378890***	1

$\tau$  represents the threshold value; k represents the lag length selected using the SBC criterion; SE are in parenthesis;  $\rho_1 = \rho_2 = 0$  is the null hypothesis of no co-integration, the critical values are obtained from Enders and Siklos (2001) p.172;  $\rho_1 = \rho_2$  is the null hypothesis of symmetry, critical values for 5% and 1% level of significance are de/uk: 8.25 and 11.62, fr/uk: 8.36 and 11.77, es/uk: 8.31 and 12.01. Simulated 5% and 1% critical values (10,000 replications); \*\*\* indicates rejection of the null hypothesis at the 1% significance level; \*\* indicates rejection of the null hypothesis at the 5% significance level.

**Table 8.** Asymmetric error correction model estimations.

Variable	$\tau$ value (-0.009479)	Coefficient	t-stat	Wald Tests	Cointegration ( $H_0: \beta_1 = \beta_2 = 0$ )	Asymmetry ( $H_0: \beta_1 = \beta_2$ )	Short-run causality ( $H_0: \delta_j = 0$ )
DE-UK	Constant	0.001406	1.282872	F-stat	10.01211***	5.384784**	0.037000
	b <sub>1</sub>	-0.045345**	-2.426872	p-value	0.0001	0.0210	0.8476
	b <sub>2</sub>	-0.145543***	-3.747640				
FR-UK	Constant	0.001224	0.408373	F-stat	16.44934***	5.617090**	0.685091
	b <sub>1</sub>	-0.090320***	-2.711584	p-value	0.0000	0.0184	0.4085
	b <sub>2</sub>	-0.220893***	-5.045716				
ES-UK	Constant	-0.005423	-0.904848	F-stat	37.44703***	15.29936***	0.710968
	b <sub>1</sub>	-0.242724***	-4.660221	p-value	0.0000	0.0001	0.3998
	b <sub>2</sub>	-0.617561***	-7.476645				

\*\*\* indicates rejection of the null hypothesis at the 1% significance level and \*\* indicates rejection of the null hypothesis at the 5% significance level.

in deviations below the threshold value. This response is greater in absolute terms when UK prices are worsening (b<sub>2</sub>) ( $\approx 14.5\%$ /month) than improving (b<sub>1</sub>) ( $\approx 4.5\%$ /month). In other words, DE price decreases take place at a faster rate when UK prices are falling while German price increases occur at a slower rate compared to UK increases.

Regarding the FR prices, they seem to respond faster to UK price changes to deviations from the equilibrium below the threshold value and when UK prices are worsening (b<sub>2</sub>) ( $\approx 29\%$ /month) than improving (b<sub>1</sub>) ( $\approx 9\%$ /month). That is to say, France reduces its price at a faster rate compared to UK, although UK price increases take place faster than in FR.

Similarly, ES price reaction is more intense to UK price changes to deviations from the long run equilibrium below the threshold. Results suggest that the ES prices react faster when the UK prices are worsening (b<sub>2</sub>) ( $\approx 62\%$ /month) than improving (b<sub>1</sub>) ( $\approx 24.3\%$ /month). Otherwise speaking, ES price increases occur at a slower

rate relative to UK (price increases) but ES prices decrease at a faster pace when UK prices fall.

Taking into consideration the aforementioned results, it may be noted that DE, FR and ES reduce their prices at a faster rate compared to UK in order to retain their market share. This is also supported by Abdulai (2000), noting that if middlemen have market power, they may react faster to price shocks that decrease their margin than to shocks that increase the margin. Due to transaction costs, the price pairs DE-UK, FR-UK and ES-UK trigger adjustment to the equilibrium when (absolute) price deviations exceed about 1, 1.5 and 7.5% respectively. The speed of adjustment to the equilibrium appears to be higher for the pair ES-UK, followed by FR-UK and then DE-UK. This is an indication that the ES and UK markets are strongly interconnected, especially when compared to the other country pairs due to trade intensification. This is supported by the fact that ES is a leading exporter and UK is a major importer in the broiler market (Goodwin and Piggott, 2001).

Additionally, it is implied that ES is the least expensive country, followed by FR and then DE, which is in line with real world data. Considering the short run dynamics, results do not confirm any Granger-causality effect between the examined price pairs. Given that the broiler meat constitutes a homogeneous commodity and EU policy makers have intervened less in this product, higher speeds of price transmission were expected. Certain characteristics may cause broiler prices to differ between the examined markets. The broiler sector has faced several outbreaks (for example, *Avian Influenza*) which have triggered policy interventions like the removal of animals from the market. Consequently, this might have affected the price transmission procedure (Thompson et al., 2002; Meyer and von Cramon-Taubadel, 2004; Serra et al., 2006).

Moreover, market power; which is obtained mainly through consolidation, is probably a reason to explain the differences in the speed of price transmission (Sexton, 1991; Azzam, 1999; Abdulai, 2000; Emmanouilides and Fousekis, 2012). A small number of multinational companies dominate the poultry industry. These firms have the ability to adjust prices in order to retain their margins in case shocks arise (Fousekis, 2015). The increased concentration among these firms may facilitate non-linear and asymmetric price adjustments (Serra et al., 2006).

Transaction costs and uncertainty are also likely to be blamed for the non-linear nature of price relationships as they lead to lack of perfect arbitrage (Goodwin and Piggot, 2001; Meyer and von Cramon-Taubadel, 2004; Brooks and Melyukhina, 2005; Ghoshray, 2009). Another reason that may cause prices to differ is the fact that UK has not adopted euro as its currency. In this case, it is difficult to distinguish shifts in supply or demand to changes in the nominal exchange rates between euro and GBP (Knetter, 1993). Additionally, product differentiation may yield market segmentation thus, resulting in non-linearities in the spatial price transmission (Grigoriadis et al., 2016). This is due to the relevant differences which exist in consumer preferences across EU; which enable dominant firms to add premium on their products (Fousekis, 2007). Lastly, inventory management strategies and stocks policies may impede full price transmission among the broiler markets, as well as enhancing asymmetric adjustments (Moghaddasi, 2008).

## Conclusions

The objective of the present article is to examine the price transmission relationships within four major EU broiler markets; namely Germany, France, Spain and United Kingdom. A non-linear framework (consistent-MTAR) which takes into consideration structural breaks is applied. Results show that all price pairs are co-integrated and the adjustment mechanism is asymmetric. Hence,

trading partners appear to enjoy an advantage over another. What has to be highlighted is the fact that if one ignored the presence of the structural breaks, the existence of co-integration would be rejected for the majority of the pairs.

The findings in this paper further support that in the long run, negative price shocks from the United Kingdom are transmitted to Germany, France and Spain with higher intensity than positive-type ones. Thereafter, producers in Germany, France and Spain are likely to lose from price decreases (in UK). On the other hand, consumers are likely to benefit from the negative shocks in United Kingdom than to suffer from price increases in the same country.

The dominant EU poultry markets under investigation appear to be integrated as a stable long run relationship between them is confirmed. Specifically, the elasticity of the transmitted price shocks is relatively high for the pair ES-UK. However, the pattern of the long run spatial price transmission among the principal EU poultry markets is asymmetric. Thus, the validity of the LOP is rejected and by definition, leading to welfare losses as arbitrage opportunities are not fully exploited. Therefore, the examined markets cannot be characterized as efficient.

Concerning the speed of adjustment to the equilibrium results suggested that all the examined market prices respond significantly to UK price changes in deviations from the equilibrium below a threshold value. This means that German, French and Spanish wholesalers reduce their prices faster than wholesalers in the United Kingdom in order to retain their market share.

Overall, the speed of adjustment is generally slow for all the price pairs apart from that of ES-UK. Hence, this pair is more integrated than the others. This is partly confirmed due to intensive trade and proximity between this country pair. Indeed, Spain is a leading exporter while UK is a major importer in the EU broiler market.

It also implied that Germany attains the highest prices followed by France and then Spain, which is in line with real world data. Therefore, the Ballassa – Samuelson effect, which postulates that prices in richer countries are higher than in poorer ones (the Penn effect) is supported. About the short run dynamics, results do not provide evidence of causality between the examined markets.

The empirical findings of this paper concerning spatial price transmission in terms of market integration in the EU broiler markets are mixed. Evidence of a partial degree of market integration, in the sense of a stable co-movement between the examined EU broiler markets is provided. However, price dependence is asymmetric, meaning that positive and negative shocks are transmitted from one market to the other with different intensities.

Full price transmission is likely to be prevented from policy interventions regarding animal diseases. In addition, both transaction costs and product differentiation may facilitate non-linearities. Additionally, the asymmetric price adjustments between the examined

markets may be attributed to the presence of market power obtained through consolidation. Hence, concerns are raised regarding the efforts made by the European Commission to enhance efficiency in the EU broiler markets. The need for adopting more targeted policies in order to isolate any form of market inefficiency appears to be of high importance.

Further research could expand on this study by completing analysis along the broiler supply chain of each country including all levels (producer-processor-wholesaler-retailer-consumer). This could give valuable insight into the market structure of each country, thus, providing further explanation on the pattern of price transmission.

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