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Is there a significant change in the price transmission between producer and retail prices within the British Pork industry?

By Dimitrios PAPARAS [a†] Thomas PICKERING [b] Ourania TREMMA [c] & Líis De AGUIAR [d]

Abstract. The purpose of this study is to examine price transmission between the producer and retail in the UK pork industry. It aims to find the direction of causality in the long and short-run, and whether there is a long-run relationship between producer and retail prices. This study used monthly time series data for producer and retail prices ranging from 1988-2016. Econometric tests were used such as the Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) Unit Root tests; Bai-Perron (1998) Unit Root test allowing for multiple structural breaks; Johansen (1991) and Engle-Granger (1987) Co-integration tests; Granger (1988) Causality, and the Error Correction Model showing the speed of recovery in the long-run after a shock. The results of the Unit Root tests found both producer and retail prices to be integrated of order one I(1). Three structural breaks were found occurring in the years of 1996, 2002 and 2012. The Co-integration tests found that there is one long-run relationship between producer and retail prices. The Error Correction Model showed the return to a new equilibrium after a shock was 9% per month totalling over 11 months for a full recovery from a shock. The Granger (1988) Causality test indicated that producer prices do Granger cause retail prices in the short-run. In this study the latest econometric techniques were used including structural breaks which some previous studies overlooked. This study into the producer and retail prices in the UK pork industry is the latest study of this kind since the Brexit decision.
Keywords. Price transmission, producer, Retail, Pork, Unit root, Bai-Perron co-integration, Structural breaks, Error correction model, Causality, Brexit.
JEL. L60, L70, L80.

1. Introduction

The UK pork industry has seen the average pig price fall steadily from the end of 2013 up until 2016 (AHDB, 2016). Despite this, due to the UK's increased efficiency and productivity, pig production has increased leading to larger quantities of pork in the market. Between 2015 and 2016, the Agriculture and Horticulture Development Board (AHDB) has reported that consistently heavier pigs were produced (AHDB, 2016). The UK pork industry is characteristics of a large number of producers and a small number of large processors which dominate the supply chain. Moreover, 80% of pork in the UK is purchased from a small number of multiple of retailers (IMTA, 2015).

The UK pork industry is closely linked to that of the rest of the EU with imports of bacon alone totalling around 240,000 tonnes per year from the EU

[a†] Land, Farm and Agribusiness Management Department, Harper Adams University, U.K.
. + +202 26300013
. dpaparas@harper-adams.ac.uk
[b] Land, Farm and Agribusiness Management Department, Harper Adams University, U.K.
[c] Land, Farm and Agribusiness Management Department, Harper Adams University, U.K.
[d] Food Science and Agri-food Supply Chain Management, Harper Adams University, U.K.

(IMTA, 2015). The UK pork industry have to continuously compete with cheaper imports from the EU where efficiency is higher. The main exporters of pork to the UK are Denmark, the Netherlands and Germany (AHDP, 2016). The UK meat industry imports around 45% of its needs and almost 25% of the meat produced in the UK is also exported.

Household pork consumption at retail level have been declining in the UK despite the fall in the prices. This can be put down to consumers favouring more convenient foods which the pork industry does not yet have a strong share (IMTA, 2015). In addition to this, the increased production efficiency has meant more pork is entering the market, thus contributing to a downwards pressure on the price of pork. In 2016, pork prices reached their lowest since 2000 in real terms (AHDP, 2016).

In order to better understand the UK pork industry, this study will look into price transmission between producers and retailers. Price transmission is the study of the relationship between prices where a change in one price causes another to change (Maddala & Lahiri, 2009). There are two kinds of price transmission: horizontal and vertical. On the one hand, vertical price transmission refers to the relationship between upstream and downstream supply chain prices and how they affect each other within a certain market. On the other hand, horizontal price transmission looks at the effects of price changes between different markets (Greene, 2012). There have been many studies investigating both horizontal and vertical price transmission in agricultural markets across different countries. The effect of asymmetric price transmission may indicate that producers would not reap the benefit when retail prices go up, or consumers would not feel the benefit when a producer's price decreases (Meyer & Cramon-Taubadel, 2004). Hence, examining the price transmission between variables is important as it can allow future policy decisions to be based on the results found from the research. In the case of the agricultural industry in Europe, this could include common agricultural policy reforms, trade deals inside and outside of the EU and the potential implementation of tariffs or quotas.

This study investigates the vertical price transmission between producers' and retailers' prices within the British pork industry. The investigation considered any structural breaks found during the period of analysis and their impact in the long-run. The study also focused on the causality between the producers' and retailer's prices to determine which direction the causality was from, either the producers' or retailers' prices. The speed of recovery for the prices to return to a new equilibrium after a shock to the market in the long run were also analysed. Firstly, a literature review was carried out looking at current publication on the matter which have focused on the analysis of price transmission among a variety of different products. The findings were discussed in the light of the literature regarding methodologies and the results.

The review of the literature also presented an opportunity to find gaps in the knowledge which could be explored here or in future studies. Below, a methodology section sill explain the rationale for using the tests which generated the results. The empirical results are presented followed by a discussion and conclusions which considered the likely policy implications and suggestions were made for future research.

2. Literature review

Many studies have been conducted looking into price transmission within agricultural markets. Mclaren (2015) investigated the asymmetries of price transmission in both international and local markets indicating that market power was reflected in the strength of the price transmission. For example, large intermediaries in the grain industry such as Cargill caused stronger asymmetric price transmission when they were not included in the test. Murphy (2006) found that there was stronger price transmission when prices fell with large intermediaries holding stronger power over many smaller producers. About 40%

of the USA grain was being exported by only two companies. That gave the large intermediaries a greater market power which is accentuated when production prices fell. Research into market power in the USA strawberry industry backs up this study showing that market power influenced price transmission. However, in that case, it was found that large intermediaries were less likely to exercise their power when supplies were less readily available (Acharya *et al.,* 2011). Moreover, seasonality caused price changes with the largest changes taking place during peak harvest seasons. That resulted in further lowering prices because that was when large produce buyers exerted their power the most to drive down farm prices (Acharya *et al.,* 2011). Von Cramon-Taubadel (1998) found that in the food industry market power derived from the market structure. That meant a small number of large retailers buying from a large number of small producers, therefore, retailers exercised their power to drive down prices to maximise their profits which can lead to imperfect price transmission (Verreth *et al.*, 2015).

Conforti (2004) investigated price transmission and proposed that factors such as Market Power, Domestic Policies, Product Differentiation, Transaction Costs and Exchange Ratescould impact the results of research into price transmission and, thus, needed to be considered. Conforti (2004) found regularity in the results indicating that vertical price transmission in individual countries was greater then when analysing world prices. That was explained due to differences in infrastructure between countries and transaction expenses. Conforti also established that the livestock markets presented a slow price transmission as opposed to crop markets where the transmission was generally faster. That was due to the integration levels in those markets and it was concluded to be due to product homogeneity (Conforti, 2004).

Different methods have been used within price transmission research to measure stationarity using Unit Root tests. They show whether the data is reliable and can be used to test for Co-integration which is a method used to analyse whether there is a long-run relationship between the sets of data. Methods used in Unit Root tests include the Augmented Dickey-Fuller test (ADF) (Dickey & Fuller, 1979) and Phillips-Perron (PP) test (Perron, 1997). Sanjuan and Dawson (2003) used the Phillips-Peron test to investigate price transmission between producers and retailers in the UK meat industry. Despite using long-run data, Sanjuan & Dawson (2003) presents a limitation as they only used one method to show stationarity. It is believed that if both the Augmented Dickey-Fuller test and Phillips-Perron test were used resulting in the same findings it would demonstrated the results to be valid and reliable. Yet, their research did include structural breaks to test for stationarity which took into account exogenous shocks which can cause inaccurate results. Furthermore, Bojnec (2002) researched price transmission in Slovenian beef and pork markets. Unit Root ADF and PP tests were carried out to increase validity. Both Sanjuan & Dawson (2003) and Bojnec (2002) also used the Johansen (1988, 2000) Co-integration technique. Despite, Bojnec (2002) not finding a long run relationship in the Slovenian pork industry, in the Slovenian Beef market the Co-integration tests showed there was one.

The investigating on price transmission have been carried out in many studies using a range of commodities and industries. However, the data sets varied from one study to another. Studies such as Bakucs *et al.,* (2012); Ghoshray & Ghosh (2011); Rezitis & Pachis (2016), and Sanjuan & Dawson (2003) have all used monthly data sets over a long period of time (at least 15 years) to ensure reliability of the results. In spite of the most common data set used was monthly increments some studies also use yearly or weekly data sets when analysing price transmission. Bernard & Willet (1998) took that into account and compared both weekly and monthly data sets when examining the poultry sector in the USA. The authors used two different nine-year data sets to test price transmission between producer, wholesale and retail prices. They found that the Granger (1988) Causality test came up with different results for the monthly and the weekly data sets. The monthly findings showed the producer prices do Granger-cause retail

prices but not the wholesale prices. Whereas the weekly findings showed the wholesale prices do Granger- cause both producer and retail prices as well as the producer prices do Granger-cause the wholesale prices. As a result, there was evidence that data collected both regularly or not regularly enough affected the Causality tests (Bernard & Willet, 1998).

Whilst there have been several studies investigating the price transmission of pork, there are a few which have focused in terms of price transmission within the UK. Moreover, many of the studies are not recent. For example, Sanjuan & Dawson (2003) examined pork price transmission in the UK and looked at the vertical price transmission between retailers and producers across the UK meat sectors including beef, lamb and pork. Their investigation looked at the long-run monthly data over fourteen years which also included breaks to ensuremore accurate results. The methods that were used included Unit Root, Causality and Co-integration tests. An outbreak of disease is likely to cause a break in the data. That was the case in 1996 for beef and lamb, and in April 1997 caused by the outbreak of swine fever in the Netherlands causing an increase in world prices and increased pig herds in the UK. Furthermore, similar research was carried out in the USA by Goodwin & Harper (2000). Yet, weekly data was used for only one year which is a shorter period thus not allowing for it to capture shock events which might have occurred during that time and may have affect price transmission. The results, however, were consistent with that by Sanjuan & Dawson (2003) on the UK on the drastic fall of pork prices in the USA to more than four times lower than the previous six months in December 1998. It was found that information travelled downstream starting at the farm through to retail markets.

Pokrivcak & Rajcaniova (2014) studied the price transmission of pork in Slovakia and found the monthly data to be stationary and co-integration, excluding structural breaks, to exist for pork. Their study used both the ADF and PP Unit Root tests which strengthen the validity of the results. The study concluded that consumer pork prices reacted the quickest to a decrease in producer prices as opposed to an increase. The same study found that was also true for the Slovakian milk industry (Pokrivcak & Rajcaniova, 2014).

Kuiper & Lansink (2013) analysed asymmetric price transmission between producer and consumer prices in the USA broiler and pork industries. A long data set was used from between 1990 – 2011 using monthly increments which should allow for strong validity of the results. The study found that in the pork industry the price asymmetry showed that the market power was in the hands of the retailers and was exerted over the producers. The findings coincided with those of Verreth *et al.,* (2015) and Von Cramon-Taubadel (1998) regarding market power. Yet, when they considered the USA poultry industry, price transmission indicated that the producers did possess some bargaining power but only occasionally.

Various studies have investigated the effect the seasonality of a product had on the price transmission. including Verreth *et al.,* (2015) researched onions and peppers in the Netherlands using weekly data. Their findings showed that due to the seasonality wholesalers could generate stocks to then be used to implement market power throughout the supply chain causing asymmetric price transmission. That was done to such a degree that the study showed three companies had been fined for forming price cartels to drive up prices (Verreth *et al.,* 2015). Their investigation was backed up by another study by Acharya *et al.,* (2011) which also demonstrated market power for wholesalers in the peak season of strawberry production in the USA.

In the UK, 80% of pork is bought by a small number of large retailers who dominate the market typical of an oligopolistic market (IMTA, 2015, Acharya, *et al.,* 2011). Such a market power can result in retailers exerting pressure on producers to lower their prices, which in some cases can be to below the cost of production (McCorriston, *et al.*, 2001). This can lead to farmers and producers going out of business or, even worse, as in some countries, falling below the

poverty line (Mosley & Suleiman, 2007). Retailers normally prioritise what they think is best for the consumers aswell as to widen their margins. This leads to the failure in passing on prices downstream to producers which can result in decreased food security (Von Braun & Tadesse, 2012).

The UK producers of Pork are spread across 10,000 farms with numerous varying production systems including 40% of the UK's herd being in outdoor units (AHDB, 2016). Despite the UK industry has been increasing its efficiency and productivity by producing heavier pigs, consumer demand for pork is not increasing (AHDB, 2016). This in turn gives the retailers even more market power as there is excess supply in the market. A range of studies in different countries have found that in the pork industries price transmission indicated that the producers had very little bargaining power (Kuiper & Lansink, 2013; Verreth, *et al.,* 2015; Von Cramon-Taubadel, 1998).

The Common Agricultural Policy (CAP) of the European Union (EU) has a large impact on producers and general farm practices. The objectives of the CAP are to deliver a stable and secure supply of food whilst being affordable for consumers as well as to provide a good standard of living for farmers (EC, 2016). Presently, the CAP accounts for 30% of the European Union's total budget which amounts to €58 billion per year that is paid out to farmers and producers in the form of subsidies (EC, 2016). The CAP has been adapted over the years with various reforms changing the way farmers and producers receive the subsidies according to the use of land including green initiatives such as set aside and countryside stewardship schemes (EC, 2016). Numerous studies demonstrate how changes in domestic policies can have an effect on price transmission and how results of price transmission analysis can be used to influence future policies (Conforti, 2004; Baffes & Gardner, 2003). With the UK voting for Brexit, it is unclear what will happen in respect of the CAP in the UK. Matthews (2016) produced a study to look at the potential impacts of Brexit on CAP and suggested that the UK could implement a new policy based on CAP. On the other hand, there is the possibility that no new policies will be implemented after Brexit which could disadvantage the UK agricultural industry leaving the UK more at risk to cheaper imports from the rest of the world not to mention the EU, which is already an issue even with the CAP in place (Matthews, 2016; AHDP, 2016).

In view of the above, there is a need to investigate the relationship between producer and retail prices within the British pork industry due to the lack of previous research and the new challenges on the horizon on the light of Brexit. The literature on the matter indicated that there are no recent studies which focus price transmission between producer and retail prices in the UK pork industry. Sanjuan & Dawson (2003) investigated price transmission within the UK pork industry, however, since it only used Phillips-Perron (1988) Unit Root test, that was a limitation. Serra *et al.,* (2006) and Abdulai (2002) investigated price transmission within the pork industry in various EU countries and Switzerland, but failed to consider the UK pork industry.

Since many studies on price transmission tend to employ different methodologies, this makes the difficult for the purpose of comparison. Therefore, it is unclear which method would be the most reliable in generating valid results. Thus, a wide range of methods need to be used when analysing data especially long-run one to ensure the results are accurate and truly representative of price transmission in the British pork industry. It is felt that a study which included breaks would cover a gap in the literature as it can highlight abnormal results and consequently increase accuracy. Despite short data sets studies such as Goodwin & Harper (2000), the analysis of long data sets increases the validity of the results as they tend to be more representative for any shocks which might have occurred within the data set.

3. Methodology

3.1. Rationale

This study is an investigation about price transmission between producer and retail prices in the British pork industry. The literature has indicated that a few studies have used several tests to ensure validity and reliability. Therefore, to ensure the validity and reliability of the results producer and retail prices have been analysed regarding their long-run relationship and causality.

3.2. Research Question

Is there a significant change in the price transmission between producer and retail prices within the British Pork industry?

3.3. Research Objectives

- To investigate the price transmission within the British Pork industry.
- To examine if there is a long-run relationship between producer and retail prices.
- To examine the price transmission causality between producer and retail prices of pork in the UK.

3.4. Research Approach

This study has used secondary data as opposed to primary one when analysing price transmission in the pork industry. Quantitative data analysis was used which allows for statistical tests to be carried out. One key advantage to using quantitative data is that the findings can be analysed accurately using statistics as the data is standardised and numerical, therefore comparable to previous research findings (Burns, 2000).

This study has examined a time series data which consists of a set of information over a time period collected at set point in time (McQuarrie, 2015). The data in this study represents monthly observations over a total period of 28 years. The data used in this study was in the form of natural logarithms which allows itto be more easily comparable (Greene, 2012).The data used for the study is based on monthly pork prices from producers and retailers in the United Kingdom from 1988 until 2016. The set comprises of 672 observations, allowing for a long data set which hopefully would improve the quality and the validity of the results. The data was collected from the Office for National Statistics (ONS) and is shown in Figure 1 below (ONS, 2016).

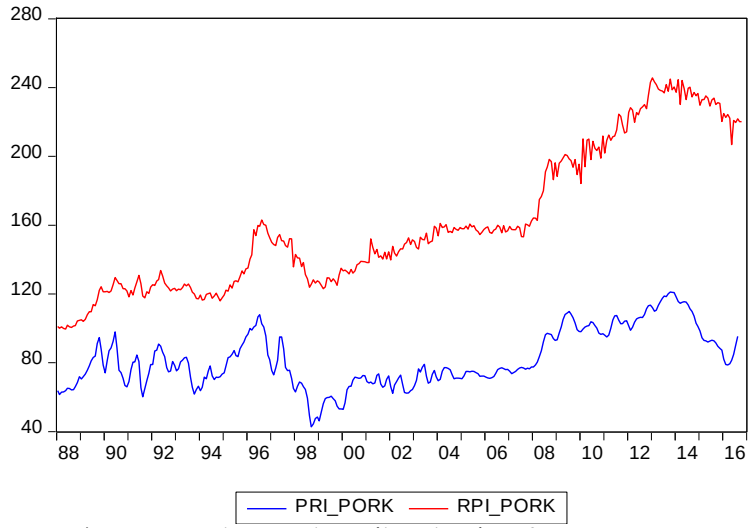

Figure 1. *Producer and Retail Pork Prices from 1988-2016*
Source: Adapted from ONS, 2016.

From Figure 1, a strong long-run relationship between the prices is expected since it is clear the two sets of data correlate with one another. Yet, the causality of a change is unclear and needs to be investigated.

3.8. Unit Root Test

Unit Root tests were used to indicate whether the prices were stationary or non-stationary, and also to show whether the prices gathered around the mean value. The Unit Root tests are conducted individually for each variable and produce a t-value to compare with an estimated t-statistics (Griffiths *et al.,* 2012).

Firstly, the data series were tested at different levels. In cases when the estimated t-statistic was greater than the provided t-statistic it could be concluded that the series were not stationary. The test was then replicated using the data at its first difference. In the case that the estimated t-statistic was greater than the provided t-statistic it could be then concluded they were integrated of order one I(1). Conversely, if the estimated t-statistic was smaller than the provided t-statistic it could be concluded the data series was stationary.

If a data series had become stationary after testing for the First Difference, then it could be said it was integrated of order one I(1) and Co-integration analysis was required.

Two techniques of testing the Unit Root have been used in this study: Augmented Dickey-Fuller (1979) and Phillips-Perron (1988). The literature indicates that authors have used one of these tests to test for Stationarity. However, few have used both which would ensure the accuracy and validity of the results.

3.9. Unit Root with Breaks

The initial Unit Root test has the limitation of not including any structural breaks in the data series which may affect the long-run relationship between the producer and retailer prices (Maddala & Lahiri, 2009). There can be various reasons which cause structural breaks in the data which could include changes in government policies, disease outbreaks or an economic downturn. If theses breaks are not considered whilst examining the long-run relationship, then the linear methods may not conclude that there is a long-run relationship despite it might still be the case. Thus, a long-run relationship with the breaks was considered. Including the structural breaks analysis would ensure the reliability of the results and prevent misleading results. It is felt that this might be the case of many previous research findings in the literature which have failed to include breaks. The data series was tested for single breaks regarding each variable using the modified Dickey-Fuller Unit Root test.

3.10. Bai-Perron Test

The second test used to indicate structural breaks is the Bai-Perron test which can indicate multiple structural breaks in the data up to a total of five. The Bai-Perron test investigates both the producer and retail prices in terms of the relationship between them and shows the breaks that cause the prices to stray away from the equilibrium in the long-run (Bai & Perron, 1998).

3.11. Co-integration Test

To test if there was a long-run relationship between the producer and retail prices Co-integration test was used. This shows whether two variables move together following each other regardless of any breaks or shocks occurring and over time. Various methods have been used in previous studies to investigate Co-integration and in this study two techniques were used: Johansen (1991) and Engle-Granger (1987). The Johansen technique will be tested with and without breaks therefore showing any changes in the long-run relationship the breaks may have caused (Johansen, 1991). The Engle-Granger technique consists of two steps. Firstly, an Ordinary Least Square was estimated and the residuals were

kept. Secondly, using a Unit Root test the residuals were then tested for Stationarity (Engle & Granger, 1987). If the estimated t-stat was smaller than the provided t-statistic then Co-integration exists between the data series. If Co-integration was found between the two variables it meant the spurious regression problem has been avoided and that further investigations could proceed as there was a long-run relationship (Koop, 2013).

3.12. Error Correction Model

Once it was determined that there was Co-integration between the variables, ensuring they move together in the long run, the Granger representation theory (Granger, 1983, Engle & Granger, 1987) declares that a valid error-correction representation of the data exists. This means that if the variables are co-integrated of order one, a co-integrating vector must exist (Verbeek, 2012).

The Error Correction Model investigates the result of a shock to the data resulting in movements away from the equilibrium. The model examines whether the variables return to the long-run equilibrium and the speed of recovery (Brooks, 2014). The speed of recovery to equilibrium is estimated using the Error Correction term (Engle & Granger, 1987). Using the Error Correction Model produces a monthly catch-up of the variables towards the equilibrium as a percentage. This is due to the data used in this study being in monthly increments.

3.13. Granger Causality

Using the Johansen (1991) and Engle-Granger (1987) Co-integration techniques, it enables to test the long-run relationship between the variables. This means the short-run relationship can be tested using the Granger Causality test. Granger (1988) stated that causality was able to be sub-divided between the long-run and short-run. The concept of Granger causality is that previous events or actions can cause future events to happen, however future events cannot cause present events (Koop, 2013). Using the Granger Causality test shows the variable that Granger-causes the other in the short run (Granger, 1988).

3.14. Validity and Reliability

This study has used various econometric tests which have been used in the literature, however, to improve validity, multiple tests have been added to make the results more powerful. A long data set has been used and the data has been collected from a reliable source such as the Office of National statistics which contributes to ensuring reliable data.

3.15. Research Limitations

It is expected for any to study to have limitations and the limitations of this study include the lack of previous research on the pork industry to compare the results to. Using secondary data could be a limitation as the data has been collected by someone else meaning there may be issues or biases with the data. Data availability was a limitation as ideally wholesaler prices would also be used to compare with the producer and retail prices, however this data was not available. Finally, the restricted time frame the analysis is also a limitation.

4. Empirical Results and Discussion

4.1. Unit Root Test

The null hypothesis for the Unit Root tests is that the data has a Unit Root and is non-stationary. The alternative hypothesis being that there is no Unit Root and the data is stationary. As stated in the methodology the data series needed to be integrated of order one I(1) to then conduct Co-integration analysis.

Table 1. *Augmented - Dickey Fuller (ADF) Unit Root Test*

(ADF) 1988 – 2016			
Variables	t-statistic	Critical Values 5%	Prob*
LPRI	-2.712062	-2.870057	0.0730
LRPI	-1.155825	-2.869726	0.6943
D LPRI	-4.002837***	-2.870057	0.0016
D LRPI	-26.04326***	-2.869726	0.0000

Note: ** denotes rejection of the hypothesis at the 0.05 level, *** denotes rejection of the hypothesis at the 0.01level, *MacKinnon (1996) one-sided p-values.
Source: Authors' Own, 2017.

Unit Root tests have performed for both retailer and producer prices to determine the order of integration of the examined variables. The results suggest that both prices (producer and retailer) were not stationary when examining the levels and they have a Unit Root. The ADF t-statistic exceeded the critical value at the 5% level of significance. This is shown specifically for producer prices with the t-statistic at -2.712062 compared with the 5% critical value at -2.870057. The retail prices had a t-statistic of -1.155825 compared with the 5% critical value at -2.869726. This is also supported by the p values provided on Table 1 exceeding 0.05. Thus, the null hypothesis is supported.

This meant there was a need to examine the First Differences of each variable in terms of stationarity. Results show that both producer and retailer prices do not have a Unit Root and were stationary when converted in the First Difference since the ADF t-statistic was less than the critical values provided in Table 1 at the 5% level of significance. This is shown specifically for producer prices with the t-statistic at -4.002837 compared with the 5% critical value at -2.870057. The retail prices had a t-statistic of -26.04326 compared with the critical value at -2.869726. With the p value for the first differences not exceeding 0.0100 it means the results are lower than the 1% critical value.

These results therefore reject the null hypothesis and state the both series of data are stationary when turned into First Differences and therefore can be characterised as integrated of order one I(1).

Table 2. *Phillips-Perron (PP) Unit Root Test*

(PP) 1988 - 2016			
Variables	t - statistic	Critical Values 5%	Prob*
LPRI	-2.229635	-2.869750	0.1962
LRPI	-1.157801	-2.869701	0.6934
D LPRI	-10.08376***	-2.869775	0.0000
D LRPI	-25.83140***	-2.869726	0.0000

Note: ** denotes rejection of the hypothesis at the 0.05 level, *** denotes rejection of the hypothesis at the 0.01level, *MacKinnon (1996) one-sided p-values.
Source: Authors' Own, 2017.

Alongside the ADF Unit Root test a PP Unit Root test has been carried out to strengthen the validity of the results. The PP test had the same outcome as the ADF test when examining the levels with the results suggesting that both prices (producer and retailer) are not stationary and have a Unit Root. Since the ADF t-statistic exceeds the critical value at the 5% level of significance. Thus the null hypothesis is supported.

The PP test also yielded the same results when examining the First Difference showing that both producer and retailer prices did not have a Unit Root and were stationary when converted in the First Difference since the ADF t-statistic was less than the critical values provided in Table 1 at the 5% level of significance.

This means that the PP test also rejects the null hypothesis and state the both series of data are stationary when turned into First Differences and therefore can be characterised as integrated of order one I(1).

4.2. Unit Root Test with Breaks

The next step in the methodology was to test for structural breaks in the data which can cause a shock to the long-run relationship. The modified Dickey-Fuller Unit Root test was used to test for single breaks in the data for each variable with the results shown in Table 3 below:

Table 3. *Augmented Dickey Fuller (ADF) Unit Root Test with breaks*

	ADF 1988 – 2016			
Variables	t – statistic	Critical Values 5%	Prob*	Date of Breaks
D LPRI	-13.53546***	-4.443649	< 0.01	1991 M07
D LRPI	-26.90227***	-4.443649	< 0.01	1997 M12

Note: ** denotes rejection of the hypothesis at the 0.05 level, *** denotes rejection of the hypothesis at the 0.01level, *Vogelsang (1993) asymptotic one-sided p-values.
Source: Authors Own, 2017.

Table 3 shows that a structural break in the producer prices occurred in 1991. The break in 1991 coincides with a Bovine Spongiform Encephalopathy (BSE) outbreak in the beef industry and avian influenza in the poultry industry. In the early 1990s there was a BSE epidemic in the UK. The result of this was 170,000 cattle were infected and 4.4 million slaughtered as a precaution (Cleeland, 2009). This had an extreme effect on the beef industry and meant consumers had lower confidence in purchasing beef and, therefore, looked for alternatives (Burton & Young, 1996). The avian flu outbreak occurred in Norfolk in 1991 and was limited to a single flock of birds however that was enough to lower consumer confidence in the product Despite the avian influenza not being a large an outbreak as the BSE, it may have also contributed to the change in prices (Alexander, 2000). This structural break can also be seen on the graph in Figure 1 where there is an increase in the price in 1991. Due to the outbreaks of disease in the beef and poultry sectors it is logical that consumers turned their preferences towards pork.

A structural break for the retail prices occurred in 1997 and was caused by the swine fever epidemic in the Netherlands. That resulted in millions of pigs having to be taken out of the market due to the Netherlands being a large producer of pork (Serra *et al.*, 2006). In the UK, over 700,000 pigs had to be slaughtered during the breakout of swine fever (Elbers *et al.,* 1999). That resulted in a shortage of worldwide pork driving the prices up and clear substitution effects for other meats which, in turn, increased their prices.

4.3. Bai-Perron Test

As stated in the methodology using the Bai-Perron test allows to identify up to five structural breaks in terms of the long-run relationship between the variables. The results of the Bai-Perron test for producer and retailer prices of pork can be seen in Table 4 below:

Table 4. *Bai-Perron Test*

1988-2016	Break Dates:		
LRPI (Bai-Perron)	1996 M10	2002 M02	2012 M01

Source: Authors Own, 2017

As shown in Table 4, the Bai-Perron test found three structural breaks in the data in 1996, 2001 and 2012. For the break in 1996 it was found that the EU imposed a worldwide ban on British beef due to the BSE crisis (EC, 2004). The date coincides with the official announcement that BSE could cause variant Creutzfeldt-Jakob disease thus causing a change in demand from beef to pork and other meats (Serra *et al.*, 2006). Then there was a swine fever epidemic in the Netherlands which caused millions of pigs to be removed from the market straight after the demand had risen due to the BSE in the beef industry (Serra *et al.*, 2006; DEFRA, 2013).

The 2002 structural break could be due to the foot and mouth disease affecting pigs at the end of 2001 towards 2002 (DEFRA, 2011). Also In 2002 Avian Influenza arose in the poultry industry which caused people to substitute poultry for pork therefore leading to an increase in pork prices (EC, 2010, DEFRA, 2011).

In 2012, the cause was the rise in world grain prices which had a knock on affect to feed prices leading to pork prices to increase as a consequence (Agritrade, 2012, DEFRA, 2014).

4.4. Co-integration

The null hypothesis for the Co-integration tests is that there is no long-run relationship (co-integration) between the variables which are the producer and retail prices. Therefore, this means the opposite is true, there is a long run relationship (co-integration) between the variables. The two techniques that have been used are the Johansen (1991) and Engle-Granger (1987). All the equations satisfy all the statistical assumptions required for the Johansen approach therefore co-integration analysis could be conducted. The diagnostic tests were applied for heteroscedasticity, normality and autocorrelation in all the equations.

Table 5. *Johansen Co-integration without Breaks*

Unrestricted Cointegration Rank Test (1988 – 2016)						
	Trace Test			Max-Eigen Test		
Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	Prob.*	Max-Eigen Statistic	0.05 Critical Value	Prob.*
r = 0	16.66053	15.49471	0.0332**	15.32764	14.26460	0.0338**
r = 1	1.332888	3.841466	0.2483	1.332888	3.841466	0.2483

Note: ** denotes rejection of the hypothesis at the 0.05 level, *** denotes rejection of the hypothesis at the 0.01level, *MacKinnon-Haug-Michelis (1999) p-values
Source: Authors' Own, 2017.

Firstly, the Johansen Trace test was used as shown in Table 5 above. The first null hypothesis supports that there is no long-run relationship (r=0) and the alternative is that there is one long-run relationship. The second null hypothesis suggests that there is at most one relationship (r=1) and its alternative is that there is more than one relationship. For the first null hypothesis, the trace statistic exceeds the critical value at the 5% level of significance since 16.66053 is greater than 15.49471 as well as the probability being less than 0.05 at 0.0332. Therefore, the null hypothesis is rejected and the alternative accepted. The same results are provided by the Max-Eigen test as the Max-Eigen statistic exceeds the critical value at 5% as 15.32764 is greater than 14.26460 alongside the probability being less than 0.05 at 0.0338 meaning this test also rejects the null hypothesis and accepts the alternative.

The second null hypothesis states that there is at most one relationship (r=1). For this hypothesis both the Trace statistic and Max-Eigen statistic are below their respective 5% critical values. Both the Trace statistic and Max-Eigen statistic are 1.332888 compared with the 5% critical value at 3.841466 meaning the null hypothesis is accepted and the alternative rejected. This is also shown with both the probabilities of the Trace statistic and the Max-Eigen statistic at 0.2483 which is above 0.05 therefore accepting the null hypothesis.

Table 6. *Johansen Co-integration with Breaks*

Unrestricted Cointegration Rank Test (1988 – 2016)						
	Trace Test			Max-Eigen Test		
Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	Prob.*	Max-Eigen Statistic	0.05 Critical Value	Prob.*
R = 0	41.13013	29.79707	0.0017***	34.81307	21.13162	0.0003***
R = 1	6.317057	15.49471	0.6581	4.754904	14.26460	0.7724

Note: ** denotes rejection of the hypothesis at the 0.05 level, *** denotes rejection of the hypothesis at the 0.01level, *MacKinnon-Haug-Michelis (1999) p-values
Source: Authors' Own, 2017.

Table 6 shows the Johansen Co-integration test when the structural breaks are included. This produced the same outcome as the Johansen Co-integration test without breaks. The first hypothesis r=0 is rejected as both the Trace statistic and the Max-Eigen statistic are greater than the critical value at 5% and both probabilities being lower than 0.05. This meant the null hypothesis was rejected and the alternative hypothesis was accepted stating that there is a long-run relationship between the producer and retail prices.

The second null hypothesis r=1 which states that there is at most one relationship was accepted as both the Trace statistic and the Max-Eigen statistic are lower than the critical value at 5% and both probabilities being higher than 0.05 therefore the alternative hypothesis of there being more than one relationship rejected.

The Engle-Granger (1987) test is the next part of the methodology and consists of a two-step procedure. Firstly, an ordinary least square is estimated and the residuals are kept. Secondly using a Unit Root test the residuals are then tested for a Unit Root.

Table 7. *Engle-Granger Co-integration: First step*

Dependent Variable: LPRI_PORK				
Method: Least Squares				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRPI_PORK	0.964562	0.027071	35.63143	0.0000***
D1997	-0.294636	0.014133	-20.84686	0.0000***
C	-0.286579	0.130795	-2.191056	0.0291**
R-squared	0.789757			
Adjusted R-squared	0.788524			

Note: ** denotes rejection of the hypothesis at the 0.05 level, *** denotes rejection of the hypothesis at the 0.01level
Source: Authors' Own, 2017.

The Linear Equation is:

$$Y = C + x1 + x2 + \varepsilon$$

This is rewritten as:

$$LPRI_PORK = -0.286 + 0.964\ LRPI_PORK - 0.294D1997$$

The probability values must be less than 0.05 to be statistically significant. Table 7 shows that all the variables are statistically significant as the p-values are below 0.05. The Coefficient shows that if the retailer prices increase by 1 unit or 1% then the producer prices will increase by 0.96 units or 0.96%. This shows a very strong relationship and influence from the retailer to the producer. 0.96 shows the price transmission elasticity. According to Lloyd *et al.,* (2004) when the price elasticity exceeds 1, oligopolistic power is exercised. The coefficient is close to 1 thus supporting that market power is concentrated on the demand and therefore retailers seem to have more power than producers in the long-run. The structural change that occurred in 1997 shown in Table 8 as D1997 had a large effect on the producer prices. The influence was such that a decrease by 0.29 is reported to the producer prices.

The adjusted R-Squared and R-Squared are equal to 0.79. This shows that approximately 79% of the variability in the producer prices can be explained by changes in the retail prices. This leaves 21% of the changes in producer prices to be explained by other factors which could include, amongst other things, changes to CAP, oil prices, feed prices etc.

In order to examine the existence of co-integration between the producer and retail prices, residuals obtained from the long-run relationship were examined in terms of stationarity using a Unit Root test. The null hypothesis for the Unit Root

tests is that the residuals have a Unit Root and are non-stationary therefore the alternative being that there is no Unit Root and the residuals are stationary.

Table 8. *Augmented Dickey Fuller (ADF) Residuals Unit Root Test*

ADF 1988 - 2016

Variables	t-statistic	Critical Values 5%	Prob*
Dresiduals	-16.62921***	-2.869775	0.0000

Note: ** denotes rejection of the hypothesis at the 0.05 level, *** denotes rejection of the hypothesis at the 0.01level, *MacKinnon-Haug-Michelis (1999) p-values.
Source: Authors' Own, 2017.

The results presented in Table 8 show that the residuals are stationary as the t-statistic at -16.62921 is lower than the 5% critical value at -2.869775 indicating that the null hypothesis is rejected and the alternative that there is no Unit Root and the residuals are stationary. This is also shown with the probability being 0.000 which is lower than the 1% (0.0100) critical value therefore rejecting the null hypothesis confirming the co-integration and a long-run relationship between the variables.

4.5. Error Correction Model

After the Co-integration tests have proved there was a long-run relationship and that co-integration does in fact exist, the next step was to use the Error Correction model to investigate the result of a shock to the data resulting in movements away from the equilibrium and how quickly the data returns to a new equilibrium. As it could be confirmed that co-integration existed, an Error Correction term must exist. The Error Correction Term results shown in Table 9 below indicate the speed of recovery when there is a shock in the independent variable which was the retail prices.

Table 9. *Error Correction Term*

Dependant Variables	Error Correction Term (ECT)	t-statistic
Producer Prices	-0.091169	-3.74117
Retailer Prices	0.59222	3.78265

Source: Authors' Own, 2017.

The Error Correction Term must be negative and statistically significant to show the speed of adjustment to the new long-run equilibrium. Table 9 shows that for the producer prices as the dependant variable, the Error Correction Term is -0.091169, therefore it is negative and statistically significant as the t-statistic equals -3.74. The Error Correction Term (-0.091169) shows that the monthly recovery to a new equilibrium as a result of a shock is 9% per month. This shows that it would take slightly over 11 months for the prices to fully recover to a new equilibrium. The retailer prices as dependant variable, since the ECT is not negative, it indicates that there was no relation regarding the direction from the producer to retailer in the long-run. This could be explained by retailers exercising market power characteristically of a concentrated grocery sector with a handful of large companies over pig producers.

4.6. Granger Causality

In addition, the short-run relationship between the variables using the Granger causality test was investigated. The Granger causality shows the variable that Granger-causes the other in the short run. The first null hypothesis is that retail prices do not Granger-cause producer prices. The alternative hypothesis posits that retail prices do Granger-cause producer prices. The second null hypothesis is that producer prices do not Granger-cause retail prices with the alternative hypothesis that producer prices do Granger-cause retail prices. The results are shown below in Table 10:

Table 10. *Granger Causality Test*

Null Hypothesis	Critical Value	F-statistic
LRPI_PORK does not Granger Cause LPRI_PORK	3.84	0.99097
LPRI_PORK does not Granger Cause LRPI_PORK	3.84	8.26587

Source: Authors' Own, 2017.

To reject the null hypothesis the f-statistic must be larger than the critical value. The first hypothesis that retail prices do not Granger-cause producer prices is accepted as the F-statistic of 0.99097 is lower than the critical value of 3.84 therefore the null hypothesis is accepted and the alternative rejected. The second null hypothesis that producer prices do not Granger-cause retail prices is rejected as the F-statistic of 8.26587 is higher than the critical value of 3.84. This means the alternative hypothesis is accepted that producer prices do Granger-cause retail prices in the short-run. This is to be expected in the short-run as there are many factors which immediately affect the producers for example disease outbreaks or increases in feed prices which will then be passed on to the retailer.

5. Conclusion

Using monthly data between the years of 1988 and 2016 totalling 672 observations this study investigated the long-run relationship between producer and retail prices in the UK pork industry using econometric tests. The first test to be completed was the Unit Root test which used the Phillips-Perron (1988) and Augmented Dickey-Fuller (1979) techniques. The results of these tests showed that for both the producer and retail prices both data series were stationary when turned into the first difference and characterised as integrated of order one I(1).

The Unit Root test was then carried out again but included single structural breaks using a modified Dickey-Fuller test. This showed a structural break in the producer prices in 1991 and a structural break in the retail prices in 1997. The 1991 structural break was caused by an increased demand for pork due to a BSE epidemic causing 4.4 million cattle to be slaughtered. In 1997, the swine fever epidemic in the Netherlands led to shortages of pork driving prices up.

The Bai-Perron (1998) test was then conducted to find multiple structural breaks throughout the long-run relationship between the producer and retail prices. The dates of the structural breaks found were: 1996, 2002 and 2012. Sanjuan & Dawson (2003) found a similar break in 1996 which was caused by the BSE crisis causing the EU to impose a worldwide ban on British beef shifting demand from beef to pork and other meats. Serra *et al.,* (2006) studied various different EU countries pork industries and their findings conform the 1996 break caused by BSE in the beef industry which affected the whole of the EU. The 2002 structural break coincided with foot and mouth disease affecting the pork industry concurrently to avian influenza outbreak in the UK poultry industry. The 2012 structural break was due to increases in feed prices as a result of a rise in grain prices.

Co-integration tests using the Johansen (1991) test were used to check for a long-run relationship between the producer and retail prices. The results showed that at most one long-run relationship existed between the producer and retail prices therefore confirming co-integration. The Engle-Granger (1987) technique reached the same result that a single relationship existed and also confirmed for co-integration, thus supporting the findings of Sanjuan & Dawson (2003) who also found a long-run relationship to be true.

Once co-integration was confirmed the Error Correction Model was used to test the speed of recovery due to the result of a shock in the long-run relationship. This showed that the monthly recovery from the result of a shock was 9% per month meaning it would take slightly over 11 months for the prices to fully recover to a new equilibrium. This test also showed that there was no relation with the direction from the producer to the retailer in the long-run. However, it

confirmed that there was a strong relationship with the direction from retailer to producer in the long-run.

Finally, the Granger Causality test (1988) examined the short run relationship between the producer and retail prices. The Granger Causality test showed that in the short-run producer prices Granger-cause the retail prices. This supports previous studies carried out by Sanjuan & Dawson (2003) for the UK pork industry and Goodwin & Harper (2000) for USA pork industry. However Goodwin & Harper (2000) used a short data set which may have affected the overall results.

5.1. Policy Implications

The results from this study are expected to throw some light into the topic and influence future policy making regarding the agricultural industry and, more specifically, the UK pork industry. From the results, it is clear that the retailers hold power over the producers. To balance out the power imbalances in the agricultural sector, policies could be introduced to give producers more bargaining power to ensure they are not operating at a loss which can be the case when pressure is applied by retailers to get producers to lower their prices. Retailers also generally focus on doing what is best for the consumers rather than producers. As a result, there could be a need to introduce or adapt policies to guarantee prices for producers as proposed by Wen (2001). In the UK, the pork industry struggles to compete with cheaper imports from the rest of the EU (AHDP, 2016). Change to the CAP could help counteract this to make British pork more competitive compared with other EU countries. Regarding the CAP it is unclear if such a support scheme will remain at all or in any form after Brexit.It is expected that a much less interventionist policy would replace the CAP of the EU in a UK after Brexit. Government officials could attempt to influence the implementation of tariffs or quotas for EU pork during the detachment transition period. With the UK set to leave the EU it could be an ideal time to implement policy changes or implement new policies to proceed with after the exit from the EU.

5.2. Future Research

Future research could be carried out to include the wholesale prices which could then be analysed and compared with the producer and retail prices to see if there are changes in the price transmission. This study focused on the UK pork industry, however further studies could be carried out using other products from the UK agricultural industry which could then be compared to the results from the pork industry. Future investigations should also not be limited to the UK but focus on pork prices between different countries across the EU regarding vertical price transmission with other countries. To further this analysis horizontal price transmission for various products could be undertaken across different countries too. The results in this study were collected and analysed before the British exit from the EU (Brexit) meaning after the split policies and trade agreements may have changed which would see the need for more research to be carried out post Brexit.

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