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Price Transmission: The Case of the UK Dairy Market

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Abstract: The UK milk market has faced major economic difficulties over the last 20 years, seeing the smallest milk producers exit the industry. The key objective of this study is to examine price transmission within the UK milk market to understand the market's efficiency and influences. An Augmented Dickey–Fuller unit root test identified all the examined series were stationary at the first difference. A modified Dickey–Fuller test allows for levels and trends that differ across a single break date and Bai–Perron test identified multiple structural breaks, including January 2012, July 2015, and November 2017. The Johansen cointegration test identified one cointegrating factor. The Error Correction Model results identified that prices would regain equilibrium at 14%, roughly 7 months after a price shock. Granger Causality identified the producer to granger cause retailer prices. The Threshold Autoregressive model suggests the dataset is symmetric. Econometric research into the UK's liquid milk market is limited. As such, this study will provide an understanding as to whether current econometric policies are working, alongside the potential to aid the improvement or development of new policies while the UK exits the EU. Additionally, this study includes structural breaks as previous studies have failed to do so, which has led to a mixture of results.

Keywords: price transmission; asymmetry; causality; dairy

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1. Introduction

Price transmission is widely studied using a multitude of econometric tests. Vertical price transmission is used to measure the upstream and downstream effects of a relationship within a supply chain, including how price shocks are exchanged between producer and retailer and vice versa [1]. It is assumed that, within a perfectly competitive market, price shocks are fully and instantaneously transferred throughout the supply chain [2]. Agriculture is renowned for being a volatile commodity, which suggests that an increase in producer price is transmitted to the consumer more thoroughly and quickly than a decrease in price [3]. Therefore, an asymmetry exists within the supply chain. Awareness of this asymmetry is vital for examining a value chain's efficiency and information flow [4].

Price transmission has become of increased interest to agricultural commodity producers due to continuous change within the industry. UK dairy producers are scaling up their businesses to increase efficiency, ensuring survival in response to reduced prices received from retailers [5]. Within the last three decades, the four biggest retailers, Tesco, Sainsburys, Asda, and Morrisons, have formed an oligopoly within the UK market, resulting in the retailers holding significant bargaining power over dairy producers, allowing the retailers to dictate the price producers receive for liquid milk [6]. This has resulted in smaller dairy producers exiting the industry due to the decreasing prices paid by retailers alongside the continuous increase of on-farm costs [7].

Despite previous studies conducted on agricultural commodity price transmission, the direction of price transmission and causality are often mixed. In recent years there has been significant improvement in econometric testing, resulting from the access and ability to test larger datasets that span over a larger time frame, among other factors. Furthermore, improved research designs and more robust estimation methods help to question the validity of previous studies [8].

This paper examines price transmission within the UK dairy market. The study will focus on liquid milk, due to the commodity's current volatility. Producers have faced continuous fluctuations in the price paid for milk due to retailers using the commodity as a loss leader to gain custom [9]. Additionally, this study will identify the direction of causality, aiding the examination of information flow efficiency within the UK dairy market. If asymmetry is identified, it would suggest that the current economic policies within the UK dairy market are ineffective, allowing us to conclude that the market is not perfectly competitive.

Examining asymmetric price transmission between consumer and producer prices in the UK dairy market is vital for several reasons. Asymmetric price transmission can lead to unfair pricing practices where one group, either consumers or producers, are unfairly affected by price changes in the market. By examining this asymmetry, policymakers can identify potential market failures and take corrective measures to ensure fairness in pricing. Additionally, asymmetric price transmission can indicate inefficiencies in the market, such as the lack of competition or the market power of certain players. Addressing these inefficiencies can lead to a more efficient market with increased competition and better pricing mechanisms for consumers and producers. Moreover, asymmetric price transmission can have important policy implications. For example, if producers face lower prices while consumers pay higher prices, policymakers may consider interventions to support producers, such as subsidies or price controls. Alternatively, if consumers face higher prices while producers receive lower prices, policymakers may consider measures to increase competition or improve market transparency. The dairy industry is an important sector in the UK economy, and asymmetric price transmission can significantly impact consumers and producers. By examining the asymmetry, policymakers and industry players can better understand the economic consequences of pricing practices and take appropriate actions to mitigate adverse effects. Overall, examining asymmetric price transmission in the UK dairy market is important for ensuring fair pricing, promoting market efficiency, guiding policy decisions, and understanding the economic impact on consumers and producers.

This paper will be conducted as follows. First, a literature review will be conducted to review the theory behind price transmission and previous empirical studies. A methodology will be presented in detail, displaying the research design and data analysis methods used within the study. Empirical results will be presented and analyzed. The results will then be discussed, considering the research objectives and findings of the study and previous literature. Finally, the implications for policymakers will be discussed, and areas for further study will be drawn upon.

2. Literature Review

This section will review theoretical principles, including types and causes of asymmetry, alongside analyzing previous empirical findings to identify the causal factor(s) of price transmission in the UK dairy industry and other global agricultural commodities. The literature review will also identify a research gap within the current empirical findings.

Additionally, this section will discuss the UK and global dairy market structure, alongside analyzing the impact of the Common Agricultural Policy (CAP) within the dairy industry.

UK dairy producers have faced severe economic difficulty due to the price volatility of milk over the last 20 years [10]. The price volatility of milk has led to a substantial fall in farmgate prices, to an average of 19.8 pence per liter (ppl) in 2000 [11], compared to an average of 29.35 ppl in 2019 [12]. The constant price change received by producers has resulted in many small-scale dairy farmers exiting the industry. In 2019, there were 8610 dairy-producing farms in the UK compared to 9285 in 2018, a 7.3% annual producer reduction [13]. The reduction in dairy producers has seen an increase in herd size to create more significant economies of scale [14].

The UK has an oligopolistic milk market, with 40% of liquid milk sales moving through the top four retailers [15]. This provides the large retailers bargaining power over dairy producers, reducing prices for dairy producers supplying retailer milk contracts [16]. As shown in Figure 1, secondary data from the Agriculture and Horticulture Development Board (AHDB) will be used to examine price transmission in the UK liquid milk market. Monthly retailer (RPIMILK) and producer (PPIMILK) price index data was collected from January 2009 to October 2019, totaling 121 observations.

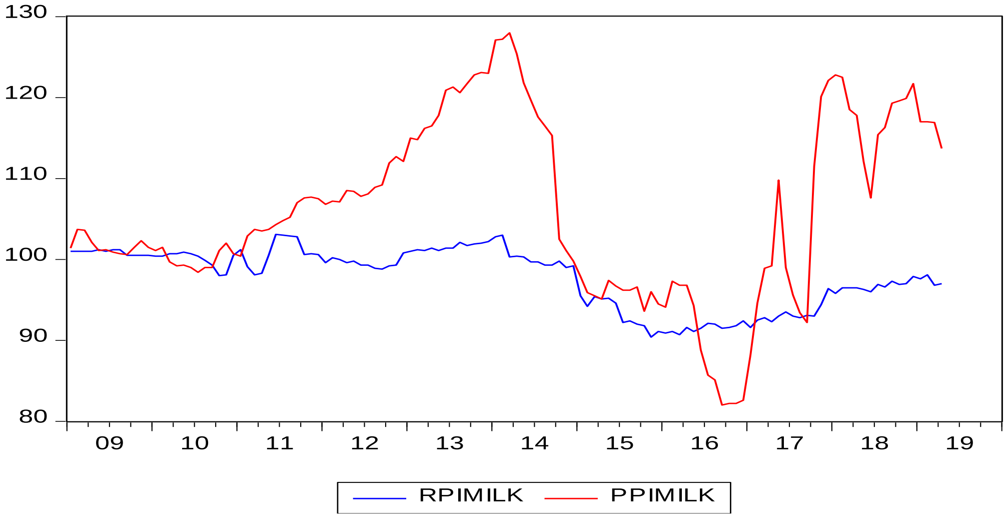

Figure 1. Monthly retailer and producer price relationship for UK milk (Source: Authors Own, 2020).

The retailer price index is much more stable than the producer price index, with the retailer price experiencing regular but less significant fluctuations. In contrast, the producer faces magnified fluctuations in price. As shown above, until 2013, the producer saw a significant increase in farm gate price. However, the milk market crashed in 2016, which left UK producers to face the lowest ppl recorded in the previous 8 years [12] (AHDB, 2020). This suggests that large UK milk producers would have increased herd sizes until 2013 as farm gate prices rose. Due to the economies of scale created, large UK producers would have been able to survive when faced with significant cuts to farmgate payments in 2016. In comparison, most small milk producers were forced to exit the industry, as milk production would no longer be economically viable [13].

In 2018, there were 141 million dairy cows globally. The EU was the largest milk producer, with 23.3 million head, producing 154.8 million metric tons of milk [17]. Limited stocks and reduced supply growth, resulting from a decline in dairy production in Germany, France, and the Netherlands, have significantly benefitted the global dairy market by limiting the downward movement of wholesale prices [18]. In 2014, it was noted that the liquid milk market had become an incredibly volatile commodity within the global agricultural market [19]. Policymakers have found it extremely difficult to develop a policy that would increase the stability of milk pricing. The result of the market experiencing major price shocks and falls is because of issues with supply and demand, as well as changes in production costs and food security [10].

The CAP was introduced in the 1950s to support European farmers and ensure stable and affordable food production [20] by implementing interventional buying, import tariffs, and export subsidies [21]. CAP subsidies include the Single Farm Payment, that aims to safeguard the European agricultural sector, ensuring the maintenance of a reasonable living while producing affordable food and drink [22]. The Luxembourg CAP reform in 2003 significantly impacted the economic environment of the UK's agricultural industry. Due to the decoupling of support to producers through subsidy and removal of quotas [23], milk prices fell by up to 5% as a result of overproduction [24].

The reform impacted the Single Farm Payment, that began making payments for good agricultural practices rather than production decisions. Alongside rising production costs, many dairy producers fell into a non-viable state, resulting in many departing the industry [25]. With the current uncertainty of Brexit and the removal of the European CAP subsidy, there may be a detrimental effect on the UK's agricultural industry, depending on whether the UK creates a similar or improved subsidy to support British agriculture [26].

Price transmission identifies and analyses market efficiency, and analysis is conducted to understand the relationship of price between different levels of a supply chain [27,28] and to identify the speed and extent of a price shock's impact on the supply chain [4]. Price transmission is separated into two different categories: horizontal and vertical [29]. Horizontal price transmission considers how a price shock transmits through different commodities produced and sold in countries that are horizontally linked, for example, the European Union. Vertical price transmission refers to identifying the results of a price shock in a given value chain [1]. The economic theory suggests price transmission should be perfect within a market. Therefore, any price change would be wholly and instantly passed on to all levels of the value chain [2] The elasticity of price transmission mechanisms helps determine the severity and distribution of a welfare effect [30]. Therefore, the transmission of price shocks has attracted interest over recent years, especially regarding global commodity price peaks and the effects on agricultural markets [31], such as the livestock crisis, BSE, Foot and Mouth, and outbreaks of E. coli O157 in the milk supply chain [32].

Agricultural and food retail supply chain markets are typically oligopolistic [33,34]. This organization allows downstream industries (retailers) to exercise market power, so long as the direction of price transmission is vertical [6]. It is believed that retailer growth and market power cause a price increase to the consumer at a greater speed of adjustment than a price decrease [3]. Often within the dairy industry, if a price increase is incurred at the last stage of the supply chain (the retailer), the increase in value of the product is not fully transmitted backward or reflected in the farmgate price received by the producer [35]. Moreover, this influences welfare distribution and policy reform, as a change to the farmgate price received by the producer may not be passed entirely to the consumer [6,36].

Asymmetric price transmission has four primary characteristics: magnitude, speed, nature, and direction [37]. Magnitude relates to how fully price change is transmitted through the levels of a supply chain [38]. Speed refers to the rate at which a price change is transmitted and how the market reacts, often determined by the actions of market agents that link the market chain (wholesalers, distributors, and processors) [39]. Meyer and Von Cramon-Taubadel [37] believe the magnitude of asymmetric price transmission creates a permanent price transfer, whereas speed forms a temporary asymmetry. Nature determines whether the price asymmetry is positive or negative [40]. Positive asymmetry occurs when the output price reacts more fully to a price increase than a price decrease. Negative asymmetry reacts more fully to a decrease in input price [6]. The direction of asymmetry refers to whether the shock is transmitted upward or downward within the supply chain [41].

Research has provided many explanations to describe vertical price asymmetry, though there is no definitive reason as to why vertical price asymmetry takes place. The most identified causative factors of vertical price asymmetry are discussed below.

Market power is the most frequently cited cause of price asymmetry in agricultural and food retail markets due to downstream concentration [42]. Market power is often used to explain retailers not passing on a price reduction as quickly or thoroughly as they do an increase in price to the consumer [4]. Positive asymmetry is often believed to result from market power, especially in the producer-to-retailer direction. However, Meyer and Von Cramon-Taubadel [37] suggest that most studies conducted on price transmission in agriculture are relatively self-evident and not sufficiently supported through empirical theory. In a study undertaken by Čechura et al., [43] focused on the European dairy industry, there was a lack of evidence to suggest that retailers enforce market power in the UK, Bulgaria, Lithuania, or Sweden.

Studies also suggests asymmetric price transmission can cause an oligopolistic market [44], resulting in non-competitive market behavior [45]. Von Cramon-Taubadel [46] suggests firms may act collusively, meaning that when one retailer increases price, so do competitors. Bailey and Brorsen [47] identified a kink in the demand curve, whereby positive price transmission only occurs if retailers believe competitors are likely to respond to a price increase more fully than a price decrease. Dhar and Cotterill [48] also add that retailers are concerned about price wars. Therefore, they are unlikely to transmit a negative price shock fully. Therefore, an asymmetric response has been generated in the food industry toward both positive and negative price shocks [49].

Adjustment or 'menu' costs are those associated with a change in retail price [50], including packaging, labelling, and advertising [3]. Simioni et al. [51] note that the adjustment cost is often the causal factor for retailers not fully transmitting a price change to the consumer. Fixed costs associated with a change to retail price may result in the retailer not amending price immediately [15]. Instead, the retailer must meet a price threshold to justify any cost associated with a product price returning to equilibrium [52]. Additionally, Bakucs et al. [50] suggest that inflation and nominal price change cause retailers who use adjustment costs to transmit a price increase more fully than a price reduction.

Government intervention is another causal factor of asymmetric price transmission. Retailers believe government intervention depends on the direction of a price shock (Peltzman, 2000) [53]. Rajendran [54] states that government intervention is more likely to occur due to a downwards price shock than an upwards price shock. Therefore, a price increase is transmitted quicker and more fully than a decrease in price [39].

Time lags identified within price transmission are suggested to be caused by factors such as inventory management [55]. Often retailers are reluctant to reduce product prices to match a price decrease at the farmgate level, due to the 'fear of running out' [44]. Inventory management systems such as first-in-first-out create time lags, as the retailer does not adjust product price immediately. Instead, the retailer will wait for the old stock bought at the original price to be depleted in order to prevent a loss of retailer profit margin [56].

The perishability of goods can also affect price transmission, often contributing to short-term market price fluctuations [57]. The literature suggests retailers may be cautious of an increase in farmgate price, in fear that a price increase would deter customers, resulting in unsold produce that would spoil [58]. In contradiction, Heien [55] suggests that a price change to a product with a long life cycle is more detrimental due to the additional cost of loss of goodwill from consumers who prefer stable pricing [51].

The empirical findings of previous studies conducted on price transmission within global dairy markets have been reviewed. Additionally, price transmission in other UK agricultural commodities has been reviewed. Price transmission in the Polish and Hungarian milk market was analyzed using monthly milk retail and producer price data collected from the Hungarian and Polish Central Statistical Offices between January 1995 and July 2007 [35]. The research used an Augmented Dickey–Fuller (ADF) unit root test to understand the stationarity of the price series followed by a Johansen cointegration test to ensure cointegration and identify whether a long-run relationship was present within the dataset. A Gregory and Hansen test for structural breaks was also conducted. A Threshold Vector Error Correction Model (TVECM) identified the asymmetry of the value chain. Results found that long- and short-run asymmetry was present in the farm-to-retail price relationship within Poland. Research notes that Poland's milk production is dominated by large-scale agricultural enterprises, with the biggest producer accounting for 30% of all Polish raw milk. This results in farm bargaining power toward downstream segments of the supply chain. Asymmetry in farm-to-retail price transmission of major dairy products was examined by Kinnucan and Forker [59]. Monthly data from January 1971 to December 1981 was collected to examine four dairy commodities in America. A Chow-type and Houck test identified asymmetry in the farm-to-retail price relationship. This suggests that changes to farm prices are reflected to a similar degree in retail price. Additionally, price elasticity was studied, and findings suggest retail prices are sensitive to farm-level price changes, especially when there is a decrease in price.

Price transmission and market power within the Polish milk market were examined by Falkowski [45]. An ADF test was used to examine monthly average milk procurement prices at farmgate and retail levels between January 1995 and December 2006; data were collected from the Polish Central Statistical Office. The analysis identified that the consumer price is quick to readjust to equilibrium, while the producer price is much slower to respond to a price shock. These results were the same as those found in Jurkenaite and Paparas [60]. Vertical price transmission within the Russian dairy supply chain was examined by Kharin [61]. Using an auto-regressive distributed lag model, monthly farmgate and retail prices were collated between 2002 and 2014 by the Federal State Statistics Service of Russia. Analysis found that retail price was the causal factor, significantly impacting farmgate prices. In the short-run, a 1% increase in retail price led to a 0.31% increase in farmgate price. Furthermore, in the dynamic long-run a 1% increase in retail price led to a 1.35% increase in farmgate price.

Asymmetric price transmission between the producer, retailer, and wholesaler in the Slovakian liquid milk market was analyzed by Weldesenbet [62]. Monthly data from 1993 to 2010 was examined using a Granger causality test, Johansen cointegration test, the Houck approach, and an Error Correction Model (ECM). Results found the Slovakian liquid milk market is asymmetric and that retailer and producer prices are cointegrated, with feedback from the retailer to the producer.

A study was conducted on price transmission across different levels of the US dairy market [63]. Farm, retail, and wholesale prices were examined to find that the wholesaler price was the causative factor. Asymmetry was noted, whereby the consumer saw wholesale prices increase more so than price decrease. This is due to retailers responding more fully and quickly to a wholesale price increase.

Price asymmetry within the UK dairy supply chain was examined by Jaffry and Grigoryev [64]. Farmgate, retail, and wholesale prices were examined to identify the causal factor. Results found asymmetry within the market and identified the wholesale price as the causal factor, suggesting that wholesalers exercise their market power and maintain profit margins by manipulating the farmgate prices. Vertical price transmission in the US dairy supply chain was examined by Kim and Ward [65]. Monthly price data from January 1990 to December 2011, published by the US Bureau of Labour Statistics, examined multiple dairy commodities, including liquid milk, butter, cheese, and ice cream. A Wolffram–Houck's model was used to test the dataset for the asymmetry between farmgate to wholesale price and farmgate to retail price. Results indicate a degree of asymmetry, with wholesale price being the causal factor in the case of US cheese.

The integration of selected European milk markets were analyzed by Katrakilidis [66]. A multivariate cointegration approach was used to explore milk's short- and long-run price linkages. The study found that EU milk markets are heavily interdependent, and that market integration can be considered 'perfect', implying that the implementation of the EU dairy policy has created a symmetric and efficient milk market. Price transmission within Poland and Hungary's milk markets were analyzed by Bakucs et al. [67] using monthly data spanning from January 1995 to July 2007. Although asymmetry was present within Poland's milk market, results found no asymmetry in Hungary's milk market's short- or long-run. Therefore, the market can be considered symmetric. Research notes that regional milk prices in Hungary are spatially integrated, supporting the result of symmetry and a perfectly competitive and efficient milk market. The UK's dairy market was examined for price transmission by Stubley et al. [68] using monthly data collected from the Office of National Statistics (ONS), spanning from 1998 to 2016. Results found symmetry within the UK dairy industry, suggesting the market is perfectly competitive, meaning that price shocks are distributed equally between producers and retailers. Jurkenaite and Paparas [69] found symmetry across the supply chain of potatoes.

The impact on producer and retailer prices of UK-produced beef, lamb, and pork were analyzed by Sanjuan and Dawson [70] in relation to the 1996 BSE outbreak. Considering structural breaks, a Johansen cointegration test was conducted on monthly producer and retailer price data between 1986 and 2000. The analysis found that a long-run price relationship between variables was present for each meat sector. The test found that the structural break in February 1996 was linked to media exposure of the BSE outbreak, increasing the producer-to-retailer margin by £1.12/kg, benefiting the retailers. This suggests that food scares do not impact the producer and retailer in the same manner.

The UK's pork industry was analyzed using monthly producer and retailer price data collected from the Office for National Statistics, between 1988 and 2016 [71]. Results found that cointegration was present, therefore a long-run relationship between the producer and retailer is present. An ECM test found the market would return to equilibrium after a price shock at a monthly rate of 9%; as a result, it would take 11 months for the market to regain equilibrium. The test also identified that the direction of causality is from the retailer to the producer. This suggests that UK pork prices are retailer driven and do not reflect price changes due to production costs. Other studies that found asymmetry in price transmission are Rose et al. [72] and Jurkenaite and Paparas [73].

Price transmission is a widely examined area of agricultural economics. However, the UK dairy industry has lacked scholarly attention in recent years, with the most recent study produced by Stubley et al. [68] in 2016. Therefore, this investigation will be used to update the current dataset. Previous empirical findings have produced mixed results; producer, retailer, and wholesaler prices have been considered as the causal factor, and few have tested for asymmetry within the market. A Threshold Auto-regressive model (TAR) will be applied in the investigation. Furthermore, structural breaks will be considered throughout testing, improving the validity of results; these breaks have not been considered in all previous empirical studies.

With the current uncertainty of Brexit, this study will analyze UK liquid milk price data before leaving the EU. Once the UK has left the EU, agricultural policies will be reformed by the UK, which could positively or negatively affect the UK dairy industry depending on how the policy reform will affect farmgate pricing. Furthermore, current trade deals may be blocked, reducing UK dairy exports to the EU.

Investigating the liquid milk market will generate a greater understanding of the UK's market efficiency, which could later be compared with other global market data in a future study, enabling a greater understanding of global market efficiencies.

3. Methodology

3.1. Methods

This chapter will identify the primary research questions to be investigated, alongside analyzing the advantages and disadvantages of different types of data collection. Furthermore, the source of dairy market data will be identified and the econometric methods used within this investigation will be outlined. Limitations of the methodology will also be explored.

3.1.1. Research Questions and Objectives

This study identifies whether asymmetry exists within the UK liquid milk industry. The findings from previously published studies are outdated and offer mixed results as to whether asymmetry is present within the UK dairy industry. Therefore, this study seeks to update the dataset and provide a greater understanding of the efficiency of the UK dairy market. The research questions of this study are stated below:

1. Is there a long-run relationship between producer and retailer pricing?
2. What is the direction of causality?
3. Is asymmetry present within the UK dairy market?

3.1.2. Sources of Data

Monthly producer and retailer price index data for UK liquid milk market were obtained from the Agriculture and Horticulture Development Board (AHDB). The data spans from January 2009 to January 2019, for a total of 121 observations.

3.1.3. Theoretical Framework

The following theoretical frameworks will examine asymmetric price transmission, including Johansen cointegration, the Error Correction Models (ECMs), Granger causality tests, and the Threshold Autoregressive (TAR) model. Those methods will be explained in the following subsection.

Johansen cointegration is a statistical technique for testing for a long-run equilibrium relationship between two or more non-stationary variables. It is based on cointegration, that occurs when two or more non-stationary variables are linearly dependent in the long-run. In the context of asymmetric price transmission, Johansen cointegration can be used to test whether consumer and producer prices are cointegrated, indicating a long-run equilibrium relationship between the two prices. If a cointegrating relationship exists, any deviations from the equilibrium relationship are only temporary, and the two prices will eventually return to their long-run equilibrium level. Johansen cointegration tests estimate the number of cointegrating vectors, that represent the number of linear combinations of the stationary non-stationary variables and, thus, indicate the presence of a long-run equilibrium relationship. The estimated cointegrating vectors can also be used to estimate the error correction mechanism, that captures the short-run dynamics that adjust towards the long-run equilibrium. Asymmetric price transmission can be identified if the estimated error correction coefficients are different for price increases versus price decreases. For example, if producer prices adjust more quickly in response to increases in consumer prices than to decreases in consumer prices, it suggests the presence of asymmetric price transmission. Johansen cointegration is a powerful tool for analyzing the long-run relationship between non-stationary variables and can help identify the existence and direction of asymmetric price transmission.

Error Correction Models (ECMs) are econometric models commonly used to analyze the dynamics of time series data. They are beneficial for examining relationships between two or more variables that are non-stationary, meaning their mean and variance change over time. ECMs estimate the long-run equilibrium relationship between variables and the short-run dynamics that adjust toward that equilibrium. An ECM can estimate the long-run and short-run relationships between consumer and producer prices in asymmetric price transmission. The long-run relationship represents the equilibrium relationship between the two prices, while the short-run dynamics capture how the two prices adjust to shocks in the system. Asymmetric price transmission can be detected if the adjustment speeds differ for price increases versus price decreases.

Granger causality is a statistical concept used to test for the presence of causal relationships between two variables. Granger causality tests evaluate whether past values of one variable provide useful information for predicting another variable, above and beyond what is predicted by the other variable's own past values. In the context of asymmetric price transmission, Granger causality tests can be used to evaluate whether changes in consumer prices "Granger-cause" changes in producer prices, or vice versa. A significant causal relationship in one direction but not in the other would indicate the presence of asymmetric price transmission.

The TAR model is based on the idea that different thresholds or levels of price changes trigger adjustments in consumer and producer prices. In the TAR model, changes in producer prices are regressed on changes in consumer prices, and the coefficient of the consumer price variable is allowed to vary depending on the consumer price level. The model assumes that if the consumer price changes by a small amount, the producer price remains unchanged, but if the consumer price changes by a more considerable amount, the producer price also changes by a corresponding amount. The TAR model helps capture nonlinear relationships between consumer and producer prices, where price changes may not occur immediately or may not be proportional. This model can be used to identify the presence of asymmetric price transmission, where the response of producer prices to changes in consumer prices is not equal in magnitude or direction.

3.1.4. Methods of Data Analysis

Data analysis will be conducted using the EViews econometric computer software. The software will run the retailer and producer price data through different econometric models to identify the relationship between producer and retailer liquid milk prices. The process used to test for asymmetry has been outlined below.

Unit Root Test

First, an Augmented Dickey–Fuller (ADF) (1979) [74] unit root test was applied to the farmgate and retail price indices to identify stationarity and whether a long-run relationship between variables was present within the dataset [75]. When the mean and variance of a dataset does not differ systematically over a set period, the data are considered stationary. Non-stationarity can lead to spurious regression, creating low-value results [76]. The ADF test examines the null hypothesis, the non-stationarity of the dataset; the alternative being stationarity [77]. However, it can be argued the Dickey–Fuller test has low power against stable autoregressive and fractionally integrated alternatives as the method does not consider structural breaks and can result in biased rejection of the unit root null hypothesis [78]. To avoid this, the dataset will be tested further using both modified Dickey–Fuller tests, which allow for levels and trends that differ across a single break date, and Bai–Perron tests, which incorporate singular and multiple structural breaks in the data.

Test with Structural Break (s)

A test with structural breaks was then conducted/ A structural break can be caused due to change factors such as changes to government policy, taxation, or a price shock resulting from food scares or scarcity of produce [79]. Structural breaks must be incorporated when testing the long-run relationship of two variables as linear methods may fail to identify any relationship [80]. Two different tests with structural breaks were applied. First, modified Dickey–Fuller tests, which allow for levels and trends that differ across a single break date, were applied to identify a single break. The framework follows the work of Perron, where the break occurs either slowly or immediately. The break consists of a level shift, a trend break, or both a shift and break. The break date is either known or unknown and estimated from the data. The data are non-trending or trending.

Second, a Bai–Perron test [81] was applied, identifying multiple sequential breaks within the dataset by estimating multiple shifts within a linear model through the least squares method. Depending on the dataset, three different methods can be used to identify multiple breaks [82]. The Bai–Perron method is advantageous as structural breaks do not need to be identified prior to testing [83].

Johansen Cointegration

Cointegration is used to understand how variables are interrelated in the long-run [84]. The dataset was tested using the Johansen cointegration [85,86] (1998, 1990) method; the analysis uses a maximum likelihood estimate in a Vector Autoregression (VAR) model [87]. The method creates and tests the trace statistic and the maximum Eigenvalue [88]. The trace statistic is used to examine the null hypothesis [89] and the maximum Eigenvalue examines the number of cointegrated vectors and the alternative to the null hypothesis [90]. The trace statistic null hypothesis is that no relationship or cointegration is present; the alternative is that a relationship or cointegration is present. The maximum Eigenvalue null hypothesis is that at least one relationship or cointegration is found. The alternative is that more than one relationship or cointegration is present. The Johansen cointegration model has many advantages over other models such as the simpler Engle–Granger test [91]. The Johansen test is a multivariate system that can detect and estimate multiple cointegrating vectors [92]. Furthermore, testing restrictions can be set on the long-run coefficients to exclude a variable; this is an advantage in identifying whether a variable has an essential impact on cointegration [93].

Error Correction Model (ECM)

Once cointegration has been identified, the dataset is tested for equilibrium. This is because there can be equilibrium or disequilibrium in the short- and long-run relationship of a dataset [90]. The Error Correction Model (ECM) is used to identify the dynamics of price relationships to understand the length of time required for a price trend to return to equilibrium after a shock [94]. The Error Correction Term (ECT) is used to calculate the speed of adjustment, giving a percentage of the monthly rate at which the variable returns to equilibrium [95].

Granger Causality

Granger causality is considered a linear regression model [96] that aims to identify a short-run relationship between variables and understand whether one variable impacts another and, therefore, whether asymmetry is present [97]. Granger causality is used to identify whether there is a unidirectional, bidirectional, or no relationship within a value chain [90]. In terms of the UK's dairy market, the potential outcomes are:

(1) Unidirectional causality—the retailer price causes producer price.
(2) Unidirectional causality—the producer price causes retailer price.
(3) Bilateral causality—retailer and producer prices have the same effect on one another.
(4) No causality—neither retailer nor producer price influence one another.

Threshold Auto-Regressive Model (TAR)

Price relationships are not always linear; therefore, if a dataset is tested using only linear models, incorrect conclusions can be drawn [98]. The Threshold Auto-Regressive (TAR) model is a nonlinear time series model [99]. The TAR model identifies whether a dataset reacts differently to a change in the long-run equilibrium and whether the dataset is symmetric [100]. The TAR model has two steps: ensuring the dataset is cointegrated and, if cointegrated, the dataset is tested for asymmetry in the value chain [101]. Conducting multiple methods to test a dataset for cointegration and asymmetry will benefit the results with improved reliability and validity.

Limitations

This study is faced with some limitations. As the study will be conducted using secondary data, the accuracy and validity of data could be questioned. Therefore, government data will be used. Another limitation is that we have not included the marketing costs, demand, and supply shifters. The research design and econometric tests used could also be a limitation, as there are a variety of different methods that can be used to test for the same result. The ADF unit root test is used to identify whether the dataset is stationary, but it is limited by the fact that it cannot test for structural breaks, which may lead to spurious results. Therefore, additional modified Dickey–Fuller tests, which allow for levels and trends that differ across a single break date, and Bai–Perron tests will be applied to the dataset to consider singular and multiple break dates. The Granger causality test is limited because a causal relationship could be inferred across all cross-sections, even if present in only one. However, Granger causality has many benefits compared with other tests, including the ability to test a significantly larger number of observations simultaneously. Therefore, the most suitable tests for this study have been used. Finally, due to the nature of this project and the time constraints faced, both quantitative and qualitative research could not be conducted.

4. Results

This chapter presents the findings from the five-step econometric testing procedure conducted through E-Views software, which is listed in the methodology above.

4.1. Unit Root Test

The variables must be identified as stationary to ensure the following statistical analysis is accurate and valid. First, the LPPI (producer price) and LRPI (retailer price) variables are tested to identify a unit root, using an Augmented Dickey–Fuller (ADF) test. The ADF identifies the stationarity of a dataset. The test is first completed in the level time series to understand if market trends or seasonality impact the time series [76]. Non-stationarity was used as the test's null hypothesis; the alternative being stationarity within the dataset. In order to reject the null hypothesis, the value of the ADF must be more negative than the critical value, or the *p*-value should be less than the 5% significance level. As shown in Table 1, neither the UK LPPI nor LRPI are more negative than the critical value. Therefore, the null hypothesis cannot be rejected, suggesting the data are not stationary at the level time series.

Table 1. ADF Unit Root Test.

			UK 2009–2019 Augmented Dickey–Fuller			
Variables	**t(ADF)**	***p*-Value**	**Variables**	**t(ADF)**	***p*-Value**	**Critical Value**
LPPI	−2.04	0.26	**ΔLPPI**	−8.96 ***	0.00	−2.88
LRPI	−1.40	0.57	**ΔLRPI**	−10.27 ***	0.00	−2.88

(Source: Authors Own, 2020).Please note that *** indicates rejection of the null hypothesis at the 5% level of significance. Δ represents first difference.

As the data series is not stationary in the level time series, it can be further tested in the first difference. By differencing the data series, the data can be stabilized by removing variations in the level time series and therefore removing any trends [94]. The null and alternative hypotheses stay the same as when tested in the level time series. As shown in Table 1, when LPPI and LRPI are tested, both the t-statistic of ADF is more negative than the critical value and the *p*-value is less than 5% significance. Therefore, the null hypothesis is rejected, and the alternative of stationarity is accepted. As both LPPI and LRPI are integrated in the first order, all further testing will be conducted using the first difference, to ensure validity and prevent seasonality from affecting the data series.

According to Phillips–Perron test (Table 2) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test (Table 3), we obtain the same results as ADF test, showing that both LPPI and LRPI are integrated in the first order. All further testing will be conducted using the first difference to ensure validity and prevent seasonality from affecting the data series.

Table 2. PP Unit root test.

2009–2019						
Variables	**PP**	***p*-Value**	**Variables**	**PP**	***p*-Value**	**Critical Value (5%)**
LPPI	−2.03	0.27	ΔLPPI	−8.97 *	0.00	−2.88
LRPI	−1.44	0.55	ΔLRPI	−10.27 *	0.00	−2.88

Please note that * indicate rejection of the null hypothesis at the 5% level of significance.

Table 3. KPSS Unit root test.

2009–2019				
Variables	**LM Stat**	**Variables**	**LM Stat**	**Critical Value (5%)**
LPPI	0.33	ΔLPPI	0.06	0.146
LRPI	0.41	ΔLRPI	0.10	0.146

The PP test has been shown to have improved power when compared to the ADF test, meaning that it can better detect the presence of a unit root when it is actually present. The PP test is more robust to the presence of outliers and structural breaks in the data, which can often lead to misleading results with the ADF test. The null hypothesis of the KPSS test is the absence of a unit root, while the null hypothesis of the ADF test is the presence of a unit root. This makes the KPSS test more appropriate for testing the stationarity of a time series. The KPSS test is also designed to detect the presence of a trend, which is not explicitly modelled in the ADF test.

4.2. Modified Dickey–Fuller Tests, Which Allow for Levels and Trends That Differ across a Single Break Date

A structural break within the dataset can affect the long-run relationship between the different variables (LRPI and LPPI). Many factors can cause structural changes, including policy change or animal disease that can cause variations of the economic structure of an industry or country [102]. Therefore, structural breaks are considered when testing for a long-run relationship of variables, preventing biased results that could see the identification of a false unit root [103]. Table 4 identifies a single break date for the producer and retailer prices.

Table 4. Modified Dickey–Fuller test (Single Break).

		UK 2009–2019		
Variables	**t(ADF)**	***p*-Value**	**Critical Value**	**Break Date**
ΔLPPI	−10.27 ***	<0.01	−4.44	2017M10
ΔLRPI	−10.97 ***	<0.01	−4.44	2015M01

(Source: Authors Own, 2020). Please note that *** indicates rejection of the null hypothesis at the 5% level of significance. Δ represents first difference.

As the time series data analyzed is given as a monthly figure, the result of the modified Dickey–Fuller tests, which allow for levels and trends that differ across a single break date, provides the month within a year that the structural break occurred. Structural breaks usually correspond with a period of a year; therefore, when reviewing the reasons behind the break dates, the full year of the result will be explored. October 2017 was identified as the structural break for producer prices. In January 2017, there was a global increase in milk price [104] that led to an increase in farmgate payments throughout the year, from 27 ppl in January to 32 ppl in October [105]. October also follows the spring flush of milk due to cows going out to pasture, which increases milk yields and offsets the relationship between supply and demand. Throughout winter, milk production decreases as dairy cows end lactation in December [106]. This may reflect the price increase as demand and supply balance out.

The retail price had a structural break in January 2015. Following increased farm gate payments in 2013, and good weather conditions in 2014, UK milk yields increased dramatically throughout 2014–2015. Alongside reduced demand from China and a ban on EU dairy products in Russia, an imbalance of supply and demand was created [107]. The overproduction in UK liquid milk saw retailers reduce farmgate payments by 25% to 20 ppl, eight pence less than production cost, making it difficult for small dairy producers to continue production [108].

4.3. Test with Multiple Breaks

Considering only one structural break in the long-run relationship of time series data can lead to a loss of information if more than one break has occured in the dataset [109]. Therefore, a Bai–Perron test was applied to the dataset, which considers up to five unknown structural break dates between cointegrating variables [81]. The test also trims the data, which helps to increase the reliability of results [110]. As shown in Table 5, the test identified three structural breaks present between the UK producer and retailer price for milk.

Table 5. UK RPI and PPI Bai–Perron Tests (Multiple Breaks).

Dependent Variable	**Break Dates**
LRPI and LPPI	2012M01, 2015M07, 2017M11

(Source: Authors Own, 2020).

The first date identified is January 2012, due to dairy processors such as Muller causing the reduction in farmgate prices by reducing payments to 24 ppl, compared with the 29 ppl cost of production [111]. Therefore, any UK dairy producers supplying contracts directly to retailers received a higher price for their milk [112].

The test also identifies August 2015 as a structural break; after the 25% farmgate price reduction in January, April 2015 saw the abolition of the EU milk quota, removing production restrictions in EU countries, causing a surge in global milk supply [108], further reducing the price received by UK dairy farmers [113]. Additionally, during 2015, the UK experienced milk producer strikes due to the reduced farmgate price producers were receiving from retailer contracts, creating a shortage of liquid milk supply [114]. Finally, November 2017 was also identified as a structural break, with farmgate prices increasing to 32 ppl, a 25% increase from the previous year [105]. The rise in farmgate prices followed the four largest UK retailers increasing on-shelf milk prices by 4.4 ppl [115].

4.4. Johansen Cointegration Test

The dataset was analyzed twice using a Johansen cointegration test: once conducted without a dummy variable and once conducted with a dummy variable (a known break-point). The cointegration test combines two tests: trace and maximum Eigenvalue. The null hypothesis of the trace test being r = 0, where no relationship or cointegration is found; the alternative is that a relationship is found. The maximum r = 1 is then tested, where at least one relationship or cointegration can be found, with the alternative being that more than one relationship is found. To accept the null hypothesis, the trace statistic or maximum Eigenvalue must be greater than the critical value of 0.05.

The dataset was tested using a dummy variable; testing with a singular break point aims to identify whether cointegration is present when a structural break is considered. The null hypothesis remains the same: r = 0 is no relationship between two variables, and the alternative is that there is a relationship (Table 6).

Table 6. Johansen Cointegration test with breaks.

		2009–2019 UK Unrestricted Cointegration Rank Test (Trace)		
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.**
r = 0 ***	0.21	42.42 ***	35.01	0.006
r = 1	0.08	13.46	18.39	0.213
r = 2	0.02	2.60	3.84	0.106
		Unrestricted Cointegration Rank Test (Maximum Eigenvalue)		
Hypothesized No. of CE(s)	Eigenvalue	Max—Eigen Value	0.05 Critical Value	Prob.
r = 0 ***	0.21	28.96 ***	24.25	0.011
r = 1	0.08	10.85	17.14	0.323
r = 2	0.02	2.60	3.84	0.106

(Source: Author's Own, 2020). Please note that *** indicates rejection of the null hypothesis at the 5% level of significance (the equations satisfy all statistical assumptions required for the Johansen cointegration method and we can deploy the cointegration analysis. All diagnostic tests have been conducted for heteroskedasticity, normality, and autocorrelation).

Within the UK dairy industry, 2015 was identified as the most significant break date in both singular and multiple break tests; therefore, 2015 was included as the dummy variable. As shown in Table 5, the null hypothesis of r = 0 can be rejected and the alternative (a relationship) can be accepted. The cointegration test is then completed using r = 1 as the null hypothesis, which cannot be rejected as the critical value is greater than the trace and maximum Eigenvalue; therefore, only one cointegrating relationship is present within the dataset.

4.5. Error Correction Model (ECM)

The ECM identifies the speed of adjustment (length of time) for cointegrated variables to return to equilibrium after a price shock has occurred to the independent variable (retail price). The speed of adjustment can be estimated using an Error Correction Term (ECT). To ensure valid cointegration, the ECT must be negative and statistically significant to the t-statistic. To ensure the validity of the results, structural breaks are considered. When the structural break of 2015 is considered, the speed of adjustment changes. As shown in Table 7, the ECT (−0.14) is both negative and statistically significant to the t-statistic of −4.85; therefore, the retail price will recover at 14% per month, suggesting it would take just over seven months to return to equilibrium.

Table 7. Error Correction model with structural breaks.

Error Correction:	D(LRPIMILK)
ECT (−1)	−0.14 [−4.85]

(Source: Authors Own, 2020). The t-statistic value is found in the square brackets. Critical value of 1.96 at 5% significance.

4.6. Granger Causality

As previously identified using a Johansen cointegration test, a long-run relationship is present between the variables. The next step is to run the data through a Granger causality test to identify whether a short-run relationship exists. The null hypothesis used throughout testing can be seen in Table 8. In order to reject the null hypothesis, the F-statistic must be greater than the critical value. The critical value was 3.07 for this case and can be identified in published statistical tables.

Table 8. Granger causality test.

	2009–2019 UK
Null Hypothesis	**F-Stat**
LPPI doesn't granger cause LRPI	3.38 ***
LRPI doesn't granger cause LPPI	0.33

(Source: Authors Own, 2020).*** indicates rejection of the null hypothesis at the 5% level of significance.

Producer price doe not granger cause retail price; this can be rejected as the F-Stat is greater than the critical value. Therefore, the alternative (producer price does granger cause retail price) can be accepted. In contrast, the second null hypothesis, retail price does not granger cause producer price, cannot be rejected as the F-Stat is less than the critical value. Therefore, results suggest that producer price granger causes retail price.

4.7. Threshold Auto-Regressive Model (TAR)

The Threshold Auto-Regressive model determines whether cointegration and asymmetry are present within a supply chain. As shown in Table 9, cointegration under asymmetry is represented as $P^1 = P^2 = 0$; this provides an F-joint value of 8.42. The null hypothesis of the test is that no cointegration present under asymmetry, with the alternative being that cointegration is present under asymmetry. The F-joint (8.42) is compared with the critical value of 6.16 shown in the brackets. If the F-joint value is greater than the critical value, the null hypothesis is rejected and the alternative accepted. In this study, 8.42 is greater than 6.16, therefore the null hypothesis of no cointegration is present under asymmetry is rejected. The alternative of cointegration is present under asymmetry is accepted.

Table 9. Threshold Auto-Regressive model for UK RPI and PPI Milk.

Dep./Indep. Variable	T	P^1	P^2	$P^1 = P^2 = 0$	$P^1 = P^2$	K
Retailer/Producer	0.00	−0.27 (0.09)	−0.29 (0.09)	8.42 (6.16) *	0.03 (3.16) *	2

(Source: Authors Own, 2020). T represents the threshold value, K represents the lag length, SE are in parenthesis, $P^1 = P^2 = 0$ is the null hypothesis of no cointegration. The critical values are obtained from Enders and Siklos (2001) [116] pp.172. $P^1 = P^2$ is the null hypothesis of symmetry. * shows simulated critical values for 5% significance.

Asymmetry is identified through $P^1 = P^2$. The null hypothesis of the test is symmetry is present, with the alternative being asymmetry is present. The $P^1 = P^2$ value is 0.03 and the critical value stated within the brackets is 3.16. If the $P^1 = P^2$ value is greater than the critical value, asymmetry is present, therefore the null hypothesis would be rejected and the alternate accepted. In this study, 0.03 is less than 3.16. As such, we cannot reject the null hypothesis, and therefore the dataset is symmetric. As the dataset is symmetric, in the long-run positive and negative price shocks are transmitted from the retailer to producer with the same intensity. Furthermore, the magnitude of price shock has the same effect on both the producer and retailer whether an increase or decrease in price occurs.

5. Discussion

This section will discuss the study's findings in relation to the research questions stated above and the previous studies in the field.

5.1. Is There a Long-Run Relationship between Producer and Retailer Pricing?

Results from the first difference of the ADF unit root test found that the dataset was stationary and that the producer and retailer price indices are integrated into the first order. The data was then analyzed using a Johansen cointegration test with and without structural breaks. Both test results found one cointegrating long-run relationship between the producer and retailer. The result of this analysis agrees with a study conducted by Falkowski [45]. on price transmission of the Polish fluid milk sector. This is in accordance with Acosta's [117] analysis of vertical price transmission in Panama's milk prices. Results found strong evidence of a long-run single cointegrating factor between producer and wholesaler. Furthermore, a study by Capps and Sherwell [16] found producer, retailer, and wholesaler prices cointegrated within the US milk market. Moreover, Weldesenbet's [62] analysis identified that the producer and retailer prices within the Slovakian milk market are cointegrated, with a long-run relationship present.

5.2. What Is the Direction of Causality?

Results from the Granger causality test identified a unidirectional causality, where the producer price granger caused the retailer price. However, retailer price does not granger cause producer price. Therefore, the direction of causality is from producer to retailer. The result of this analysis agrees with Bakucs et al. [67] and their study on price transmission in the Polish and Hungarian milk markets, which found the producer to be the causal factor. However, unlike the UK, the Polish milk market is dominated by large-scale agricultural enterprises, allowing the milk producers to exert power [118]. Moreover, this result also agrees with a study conducted by Kinnucan and Forker [59] on price transmission within four American dairy commodities, which found producer price to be the causal factor. However, Weldesenbet's [62] study of price transmission in the Slovakian liquid milk market identified the retailer to be the causal factor. Additionally, the study conducted by Jaffry and Grigoryev [62] on the UK dairy supply chain identified wholesale price as the causal factor, suggesting wholesalers exert market power to maintain and increase profit margins through manipulating and reducing farmgate prices. Therefore, the direction of causality is heavily reliant on market structure and scales of economy.

5.3. Is Asymmetry Present within the UK Dairy Market?

Results from the Granger causality test found the producer price to be the causal factor; the producer price granger causes retailer price; therefore a short-run relationship is present. The result of this analysis agrees with a study conducted by Capps and Sherwell [16] on the farm-retail price transmission of liquid milk in the US. The Threshold Auto-regressive model confirms that the UK milk market is cointegrated. However, long-run asymmetry is absent. The result of this analysis agrees with a study conducted by Katrakilidis [16] on the econometric analysis of the EU dairy market, which found no evidence of long-run asymmetry.

As the UK dairy market is symmetric, positive and negative price shocks are transmitted with the same intensity from the retailer to the producer. Furthermore, the magnitude of an increase or decrease in price has the same effect on both the retailer and producer. Stubley et al. [68] obtained a similar result when analyzing the UK milk market with a monthly dataset from 1988 to 2016. This suggests UK milk producers and retailers have an interdependent relationship.

The price elasticity of the relationship between variables was calculated using an Error Correction Model with structural breaks. Results found that the retailer price will recover at a rate of 14% per month, taking just over 7 months to fully recover to a new equilibrium. This result is more efficient than that identified in Stubley et al. [68] and their analysis of the UK milk market, which suggested that, after a price shock, the UK milk market will return to equilibrium at a rate of 9% per month, taking just over 10 months to fully recover to a new equilibrium. For the retailer price to return to equilibrium in just over 7 months, the retailer's price relationship is relatively efficient, reflecting an area previous studies have failed to cover in the UK milk market.

6. Conclusions

In conclusion, the UK liquid milk market is relatively efficient. Johansen cointegration tests found that the producer and retailer price series are cointegrated, showing that a long-run relationship exists among the price series. A Granger causality test identified a unidirectional causality within the short-run, whereby the producer price granger causes the retailer price. Threshold Auto-regressive tests found that, although the price series is cointegrated, long-run asymmetry was absent. The Error Correction Model test found that markets return to equilibrium at a rate of 14% per month after a price shock within the market, which is relatively quick.

6.1. Policy Implications

Understanding price transmission mechanisms within the different markets of a country is essential for policymakers. The government may choose to regulate the producer price to control the retail price, as the producer price is found to significantly impact the retail price. This can help prevent unreasonable price increases for consumers and ensure that the prices farmers receive for their milk are fair. The government may implement policies to stabilize the producer price, such as price support mechanisms or buffer stocks, to prevent significant fluctuations in the retail price. These policies can help farmers plan their operations and sustain their livelihoods, even in volatile producer prices.

Policymakers may encourage more competition in the milk market by reducing barriers to entry, promoting new firms' entry, and preventing dominant firms' abuse of market power. This can help ensure that producers and retailers cannot take advantage of the unidirectional causality between producer price and retailer price, and can help prevent the exploitation of farmers or consumers. The government may support farmers through subsidies or tax benefits to help them sustain their livelihoods in the face of volatile producer prices. This can help ensure that farmers can continue producing milk, even in challenging market conditions, and can help prevent significant price increases for consumers. Overall, these policy implications aim to balance the interests of farmers, retailers, and consumers, and to ensure that the UK milk market operates efficiently and fairly for all parties involved.

As no asymmetry was found within the UK liquid milk market, the results suggest current economic policies are working effectively to ensure a perfectly competitive market. As the direction of causality runs from the producer to the retailer, it suggests the current EU measures under the CAP are protecting the welfare of UK dairy farmers. The producers have relative power over the retailers to protect themselves from fluctuating prices. One of the key objectives of the CAP is to safeguard the EU agricultural industry, ensuring producers make a reasonable living. As the UK leaves the EU, current CAP payments have been promised to the agricultural industry for the first year. However, decisions have not been made as to whether subsidies will continue to support UK agriculture in the future. Therefore, the direction of causality may change, putting UK dairy farmers in a difficult position upon the UK's exit from the EU.

6.2. Areas for Further Research

There are multiple areas for further research that would be beneficial to investigate based on the results of this study. First, this study was completed using price series data before the UK left the EU. Therefore, it would be interesting to conduct the study again once the UK has completed the withdrawal process from the EU to identify whether any policy changes have impacted the price transmission of the UK liquid milk market. Additionally, another study could be conducted to investigate the price transmission of the liquid milk markets in different countries. Conducting a study to investigate the price transmission in these liquid milk markets can provide valuable insights into the universality of the findings from our study of the UK milk market. This could help to determine whether the results of our study are specific to the UK market or if they are applicable in other markets as well. By comparing the price transmission in these liquid milk markets, we can identify similarities and differences in how producer prices impact retail prices. This can help identify common patterns and factors that influence price transmission across markets and provide a more comprehensive understanding of the dynamics of the liquid milk market.

Moreover, a study could also be conducted to consider additional dairy products, such as yoghurt, cheese, and ice-cream. Furthermore, this study provides the foundation for the analysis of all sectors of the UK supply chain, including producers, retailers, wholesalers, and consumers, to fully understand how fully price shocks are passed through supply chain tiers.

The current COVID-19 pandemic is predicted to harm the UK dairy industry. As restaurants and pubs have been closed, and will remain so for the foreseeable future, dairy farmers supplying the catering industry will likely be impacted. Therefore, a similar study concerning the UK's economy and UK milk prices could be conducted before, during, and after the pandemic. Finally, this study used secondary quantitative analysis. Therefore, conducting a similar study using a mixed method approach of primary and secondary research and quantitative and qualitative data analysis would enable a greater understanding of the UK's liquid milk market. Finally, asymmetric causality tests can be applied in order to obtain a comprehensive examination of the relationship between variables. The examined variables may react differently to positive and negative disturbances. By using asymmetric causality analysis, it is possible to uncover the causal connection between the positive and negative parts of the series. This enhances understanding of the causal interplay between variables and leads to more robust analysis and effective policy formulation.

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