



Market Power and Price Transmission Mechanism in the Supply Chain

Thesis submitted for the degree of

Doctor of Philosophy at the
University of Leicester

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December 2022

Abstract

This thesis is divided into two areas of investigation. Firstly, acknowledging the use of New Empirical Industrial Organisation Techniques (NEIO) on prior market power literature, this study extends the literature by examining the market power of retailers towards the consumers and of retailers towards their providers across the UK Milk/Dairy products, Road fuels, and Electricity sectors. Due to high market concentrations of the retailers in all three supply chains and scarcity of relevant literature; the UK provides a novel setting for the estimation of each chain's degree of market power. The Fully Modified Ordinary Least squares (FMOLS) estimator and the Dynamic Ordinary Least squares (DOLS) estimator methods are used for the first time in the market power literature, considering endogeneity. Secondly, this thesis examines the cost pass through mechanism for the three supply chains. While distributed lag models are used by prior literature to estimate cost pass through, this thesis is the first to use this method to examine the cost pass through of an input cost change to the wholesale price and the cost pass through of a change in the wholesale cost to the retailer price for the UK supply chain. The data sample used, is time series with quarterly observations for the milk sector, starting from the first quarter of 1996 up to the last quarter of 2019, with a total of 96 observations and 228 monthly observations for the road fuels sector starting from the first month of 2000. For electricity, 243 observations are considered for the period January 2000 to end of March 2020. For the electricity cost pass through mechanism, 178 observations are used starting from the third month of 2003 until December 2017.

Sufficient evidence supports the oligopsonistic and oligopolistic market power of the retailers towards the providers and the retailers towards the consumers, respectively. This applies to all supply chains. In the case of electricity, not enough evidence is provided for market power of the retailers towards the consumers. In the case of milk, ample evidence demonstrates the oligopsonistic and oligopolistic market power of the processors. Similar evidence is provided for an incomplete cost pass through of an input cost change to the wholesale price and a wholesale cost change to the retail price across all three supply chains. In the case of road fuels, this study also yields compelling evidence for asymmetric price transmission.

Acknowledgements

Firstly, I would like to express my deep gratitude to my supervisors, Professor Peter Jackson and Mr Mark Burridge, for their tremendous support and guidance throughout my PhD studies. It has been an honour to have been their student and I have learned a lot from each of them. I also owe a big thank you to Leicester Business School for giving me the opportunity to teach Economics undergraduates. I would also like to express my sincere thanks to Professor Eoin Reeves, Professor Helena Lenihan, and the Department of Economics at the University of Limerick, Ireland, for their support during my stay there. I also wish to thank my parents for their support during my academic studies.

This thesis is dedicated to the memory of Professor Peter Jackson and the memory of my late grandparents, Ivi and Andreas.

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ACRONYMS

2SLS	TWO STAGE LEAST SQUARES
3SLS	THREE STAGE LEAST SQUARES
AC	AVERAGE COST
ADF	AUGMENTED Dickey FULLER
AIC	AKAIKE INFORMATION CRITERION
APT	ASYMMETRIC PRICE TRANSMISSION
ARDL	AUTOREGRESSIVE DISTRIBUTED LAG MODEL
CMA	COMPETITION MARKETS AUTHORITY
CPT	COST PASS THROUGH
DEFRA	DEPARTMENT FOR ENVIRONMENT FOOD & RURAL AFFAIRS
DLM	DISTRIBUTED LAG MODEL
DOLS	DYNAMIC OLS
ECM	ERROR CORRECTION MODEL
EIA	ENERGY INFORMATION ADMINISTRATION
EUA	EMISSION ALLOWANCES
FMOLS	FULLY MODIFIED OLS
HHI	HERFINDAHL INDEX
FSA	FOOD STANDARDS AGENCY
GDP	GROSS DOMESTIC PRODUCT
GIM	GENERAL IDENTIFICATION METHOD
MC	MARGINAL COST
NEIO	NEW EMPIRICAL INDUSTRIAL ORGANISATION
OFGEM	OFFICE OF GAS AND ELECTRICITY MARKETS
OFT	OFFICE OF FAIR TRADING
PP	PHILIPS PERRON
PTA	PRICE THEORETIC APPROACH
SCP	STRUCTURE CONDUCT PERFORMANCE
UKPIA	UNITED KINGDOM PETROLEUM INDUSTRY ASSOCIATION
VAR/VECM	VECTOR AUTOREGRESSIVE/VECTOR ERROR CORRECTION

Chapter 1

Introduction

1.1 Introduction

Market power has attracted considerable research attention due to its effects on the prices and quantities available to the consumers and its greater economic and social welfare implications. Bresnahan (1982), Lloyd et al. (2006), Perloff et al. (2007) and Perekhozhuk et al. (2015) are among examples of studies that deal with market power. Uzunidis (2016) maintains that such market power studies are motivated by policymaker and academic concerns about distortions in the market and effects on competition. Estimating the degree of market power is an evolving strand of industrial organisation literature a range of implications for policymakers; particularly for regulators and competition authorities, and in terms of highlighting sectors where intervention is needed.

More specifically, the author contends that estimation of market power is of vital importance to policymakers and the economy as it can influence the prices and quantities available to consumers and have an overall effect on consumer surplus and societal welfare, violating pareto optimality. Cost pass through can be directly linked to abusive business practices or imperfections in the market, providing the grounds for the second pivot of this thesis. Furthermore, the inelastic nature of the three sectors under study: milk; road fuels; electricity; as well as their high contribution towards the UK's GDP, motivate the empirical applications of this study. Lastly a rare number of updated studies exist, investigating market power for the UK.

Much of the early literature on market power rests on the Structure Conduct Performance Paradigm (SCP) which is rooted in the work of Mason (1939) and Bain (1956). The SCP paradigm postulates the relationship between the market structure, the conduct of the firms, and ultimate performance. Market structure affects the conduct of the firms which determines performance. Indeed, this method has been extensively applied to market power studies using cross-sectional data. However, serious concerns arose regarding the dual causality between structure, conduct and performance: an issue described as 'feedback effects' (Lee 2007; Nabieu 2013). In short, performance may affect conduct and structure, while a specific conduct may affect structure. (Lee 2007; Uzunidis 2016). By the 1970's these issues gave rise to the development of alternative techniques to properly estimate the existence and degree of market power known as the New Empirical Industrial Organisation (NEIO) methods. As a leading

model of industrial organisation studies on market power, the Bresnahan (1982) and Lau (1982) model estimates a demand function using prices, quantities, and exogenous demand shifters such as income, and the inverse supply function using upstream supply prices, quantities, and supply shifters. Based on these functions, and using profit optimisation, a perceived marginal revenue is equated to the marginal cost and a conduct parameter λ is estimated, that lies between 0 and 1. Thus, case $\lambda=0$ indicates perfect competition and zero market power, while case $\lambda=1$ indicates monopoly. More recent studies estimate a demand and supply function and by using profit optimisation condition derive a retail input price spread and check for the statistical significance of the demand and supply shifters to detect for market power (Cavicchioli 2010; Lloyd et al. 2006; Nakajima 2014; Perekhozhuk et al. 2015).

They also estimate the conduct parameters λ and ϕ which correspond to a market power degree. These techniques are generally accepted throughout the literature and used in cases where aggregated data are available; usually at the industry level. However, the findings of these studies vary in line with the period of study and frequency of the data, as well as the precise country and product under investigation. NEIO techniques are deemed more accurate than the SCP since they are based on formal neoclassical optimisation models (Lee 2007; Uzunidis 2016).

Studies estimating market power in the food supply chain and milk/dairy products sector include that of Lloyd et al. (2006) which establish the existence of market power for the UK beef supply chain using a Vector Autoregressive Model (VAR). Likewise, Anders (2008) estimates market power in the German meat market 1995-2000, and Nakajima et al. (2014) estimate market power for the Japanese fish supply chain. The difference from previous studies is that the estimation is applied to both the upstream and downstream levels of the chain. Imperfect competition and market power is estimated at the downstream level, but insufficient evidence is provided for the upstream level. Furthermore, they demonstrate the oligopsonistic power of the milk processors of the Ukrainian dairy industry at a regional level. (Perekhozhuk et al. 2015, Perekhovzhuk et al. 2017).

Conspicuously few market power studies exist with regards to petroleum products such as road fuels: in the context of the UK, such literature is even rarer. Examples of studies include the work of Lakuma (2013) which estimates market power for the US crude oil industry and Ones et al. (2018) which interrogate market power in the Swedish market for road fuels. In terms of electricity, several academic studies have examined the market power of wholesalers and retailers (Merit et al. 2015; Amountzias et al. 2017). Indeed, focusing on the period 1998-

2012, the latter identify low degree of market power in the UK electricity wholesale sector and anticompetitive behaviour of the retailers.

The rationale of such prior studies is further developed to achieve some of the main objectives of this thesis: namely, to estimate the degree of market power of the retailers towards the consumers and the degree of market power of the retailers towards their providers. Moreover, the econometric methodology of FMOLS and DOLS is applied.

This differs from the methodology of two Stage Least Squares (2SLS) which is considered the norm in the literature. The current study employs econometric analysis to estimate market power of the retailers in respect of consumers and market power of the retailers in respect of their providers. The empirical analysis focuses on three separate supply chains in the UK: namely, milk (dairy products), petroleum products (road fuels) and electricity supply chains. Due to the high concentration at the milk product processor level, this thesis delves further back within the supply chain to estimate the degree of market power of the processors towards retailers and the degree of the market power of the processors towards providers. The high market concentration at the retailers' level, along with the significance of these products to the UK GDP drives the main rationale for the empirical analysis of this thesis. Based on Uks department of energy business and milk accounted for 16.4% of total agricultural output in the UK in 2020.

Kite Consulting (2019) provides information about only three currently existing milk processors in the UK, that hold the highest market share; Arla, Muller and Freshways. Moreover, according to Kite consulting (2019), Tesco, Morrison's, Asda, and Sainsbury's hold a 40% market share of the UK'S milk demand.

Similarly, the Fuel Market Review (2019) found the same four supermarkets boast a 43% market share at retailer level, along with BP, Shell and ESSO at 84%, while Ofgem (2019) reports that the 'Big Six' firms dominate 70% of the retail electricity market.

To the best of this author's knowledge, up-to-date literature on the estimation of market power for UK dairy products, road fuels, and electricity is extremely scarce: a gap which this empirical study seeks to readdress. In the context of electricity, the study of Amountzias et al. (2017) rests on 2012 data and does not reflect the ensuing application of the Ofgem price cap (2019). This thesis therefore proposes an alternative methodology of estimating the oligopsonistic and oligopolistic market power of the UK electricity retailers, comparing the results with the earlier

work of Amountzias et al. (2017) and the work of the Competition and Markets Authority. (CMA) (2016).

The purpose of this thesis is twofold. In addition to estimating market power for the supply chains, this study also estimates the cost pass through of an input cost change to the wholesale price and the cost pass through of a wholesale cost change to the retail price. Furthermore, asymmetric price transmission is fully examined. This is motivated by the high market concentration which may be a factor behind market power and incomplete cost pass through. Feenstra (1987) suggests that imperfect competition is a significant factor behind incomplete 'cost pass through'. Dagoumas and Polemis (2018) explain cost pass through as the change in prices as resulting from an input cost shock.

In fact, over the last 20 years, economists and policymakers alike have wrestled with the issue of this mechanism across the fields of Industrial Organisation, Macroeconomics, and Applied Econometrics. Findings vary based on the empirical method applied, the country under scrutiny, the variable used to estimate the input cost, and the frequency of the data. Studies examining the cost pass through for road fuels, for instance, have estimated an incomplete cost pass through of the EU emissions allowances to retail prices by using a Vector Error Correction model for the period 2005-2007 (Alexeeva-Talebi 2010; Alexeeva-Talebi 2011), while De Bruyn et al. (2015) use an ARDL to estimate the complete CO₂ cost pass through to diesel prices.

Studies examining the cost pass through for electricity, include that of Fabra and Reguant (2014) who estimate an almost complete cost pass through of the emission costs to the electricity wholesale prices by using distributed lag models for the period 2004-2006. Duso and Szucs (2016) also estimate the cost pass through of a change in the wholesale cost to the retail price of electricity in Germany (2010) wherein they establish an incomplete pass through of 40% and which indicate that increased competition increases the cost pass through. Dagoumas and Polemis (2018) demonstrate the cost pass through mechanism in the Greek electricity sector, while Guo and Gisse (2019) examine the pass through of the cost of electricity generation to the UK wholesale price for the period 2015-2018, indicating a complete pass through. A number of these studies, as well as research from different strand of the literature, examine the asymmetric price transmission of a change in the input cost to the wholesale and, to retail price, and a change of a wholesale cost to the retail price.

It is worth mentioning here, that the incomplete cost pass through mechanism can arise from: a) Nominal price rigidities due to barriers to entry and high market concentration; b) imperfect competition; and/or c) a mismatch between firms observed cost shocks and opportunity costs (Fabra & Reguant 2014; Nakamura & Zerom 2010).

This thesis is mindful of the fact that the supply chains of all three products under study are highly concentrated at the retailer level. Thus, the hypothesis for potential market power and its abuse, forms a foundation for the examination of the cost pass through mechanism in the supply chain of dairy/ milk products, road fuels, and electricity in the UK. A vast amount of literature in a variety of sectors exists. The author evaluates that the high market concentration as well as the rare relevant literature for the sectors under study, makes them susceptible for investigation.

Using the rationale of the studies, the current study employs econometric analysis, and more specifically, distributed lag standard cost pass through models, to estimate the cost pass through of an input cost change to the wholesale price and the cost pass through of a wholesale cost change to the retail price.

In the case of the pass through of the wholesale cost change to the retail price, instrumental variables are also applied to address attenuation bias.

Empirical analysis focuses on UK milk (dairy products), petroleum products (road fuels) as well as electricity supply chains using Newey West standard errors are used to consider for heteroskedasticity. Asymmetric price transmission is also examined.

This thesis aims to address gaps in the literature by utilising up-to-date data to estimate any degree of market power of the UK retailers across the milk/dairy products, road fuels, and electricity sectors. To this end, the present empirical analysis employs a newly proposed model based on the seminal work in the field (Bresnahan 1982; Lloyd et al. 2006; Perekhozhuk et al. 2015, 2017). This model has influences from Bresnahan (1982) and Lau (1982), Perekhozhuk et al. (2015) and is further developed by the author. This research also incorporates analysis of the probable effects of the period of financial recession of 2008-2014 by using a dummy variable which takes the value of 1 for the recession period, and 0 otherwise.¹

This study further aims to address the gaps in the literature by estimating an up-to-date cost

¹ A financial recession dummy for the period 2008-2014 is also included in the milk market power functions, however the dummy is not statistically significant for the relevant regressions, not affecting the results and therefore this thesis does not report the corresponding findings.

pass through of a change in the input cost to the wholesale cost and a change in the wholesale cost to the retail price for milk/dairy products, road fuels, and electricity sectors. Following Nakamura and Zerom (2010), distributed lag models are therefore used: a methodology not previously applied to cost pass through studies for these UK supply chains. Since the cost change is filtered down through numerous layers before affecting the final retail price, this thesis does not attempt to follow the vast amount of studies procedure entailed in estimating the cost pass through of an input cost shock to the retail price and of the wholesale price change to the retail price, contributing to the current methodology procedure applied in the cost pass through literature.

By highlighting the existence of market power and anticompetitive effects in sectors where intervention has been minimal, the findings of this study may be of considerable use to policymakers and regulators and of interest to authorities such as the CMA.

Boyle (2004) claims that the ability to conduct tests of market power at the lowest possible level of aggregation of firm groupings is highly desirable to examine the abuse of market power within the context of imposing, excessive costs to economic agents.

Due to the lack of the availability of the firm level data, this analysis uses time series industry data. Since a core responsibility of the CMA is monitoring the existence and/or potential abuse of market power, robust empirical tests for market power can assist them, providing an evidential basis for legal interventions.

Lastly, this study highlights imperfect competition in cases where evidence for incomplete cost pass through and evidence for asymmetric price transmission is provided. As such, it has potential implications for competition policy, and to assist comprehension of how cost savings from horizontal mergers are passed on to consumers. It can be useful to policymakers which are concerned about the extent to which consumers benefit from a reduction in the input prices in such sectors as agricultural markets.

1.2 Research Motivations

1.2.1 Market power

Based on Akomea & Michael (2013), market concentration measures the number of firms in each industry and the relative market shares of each.² This thesis is motivated by the high

² Market concentration is usually evaluated using the Herfindahl-Hirschman Index, or HHI. It is measured by adding the sum of the squares of the market shares of the biggest companies in the market.

market concentrations which occur in specific UK supply chains for products that are both everyday necessities and significant contributors to the UK's GDP.³

To reiterate; Kite Consulting (2019) mentions that there are only three currently extant milk processors in the UK and Tesco, Morrison's, Asda, and Sainsbury's together have a 40% market share at the retailer level. This is an indication of the high market concentration. Similar rationale applies to the road fuels sector, as due to the high market shares at the retailers' level, there is ground for research relevant to market power existence and abuse. Referring to the Fuel Market review (2019), the four main supermarkets have 43% market share at the retailer level and along with BP, Shell and ESSO at, 84%, while Ofgem (2019) reports that six big firms occupy 70% of the retail electricity market share. To the best of this author's knowledge, the dairy products sector has received limited attention by competition authorities to date; especially at the retailer's level. Market power abuse can manifest as practices governed by competition law, such as excessive or predatory pricing policies. The existence of oligopolistic market power is fundamentally detrimental to the individual consumer and can exert a negative impact on social welfare provision. Considering this, accurate estimates of the degrees of market power may assist regulators to compile evidential basis for legal intervention. Market power abuse can come in the form of practices examined by competition law, such as excessive pricing and predatory pricing.

1.2.2 Cost pass through

Cost pass through represents the change in prices which results from an input cost shock and is an issue of perennial concern to both policymakers and academics across fields as Industrial Organisation and Applied Econometrics. Building on the above market power motivations, according to Charalambous & Clerides (2020), incomplete cost pass through is a crucial indicator of market imperfections and potential collusive or abusive practices. The same holds true for road fuels and electricity since the high market shares and high concentration is linked to potential market power and this can be a possible reason behind incomplete cost pass through. Incomplete cost pass through and asymmetric price transmission findings may therefore be invaluable to both regulators and the CMA in assessing post-merger impacts and enabling them to weigh the efficacy of regulating input or wholesale price for the ultimate consumer. Moreover, since inflated prices can trigger social tensions and political pressure, an

³ Based on Department of Energy Business and Industrial Strategy. milk consists of 16% of agricultural output. In 2021, 77.6 metric tons of oil equivalent were needed to create one million British pounds indicating the contribution of energy to UK's GDP. In 2021, the motor industry in the United Kingdom contributed around 14.1 billion British pounds in added value to the UK economy. (Statista 2022)

understanding of cost pass through and asymmetric price transmission is of great importance: especially for three products which together represent a substantial proportion of the UK's GDP and everyday essentials to the consumer.

1.3 Research Objectives

This thesis is designed to realise the following aims with respect to market power in the supply chain and cost pass through as follows:

- i. Investigate the extent of market power in the UK's supply chain with empirical applications on specific products;
- ii. Investigate the extent of cost pass through of a change in input cost to the wholesale price with empirical applications on specific products;
- iii. Investigate the extent of cost pass through of a change in wholesale cost to the retail price with empirical applications on specific products;
- iv. Investigate the existence of asymmetric price transmission of a change in the input cost to the wholesale price and of a change in the wholesale cost to the retailer's price along the supply chain in the UK and investigate this with empirical applications on specific products.

1.4 Research Contributions

The contribution of this study to the existing literature takes several forms which pivot around two main economic phenomena: namely, market power and cost pass through. Therefore, the thesis offers an initial description of the contributions relevant to market power followed by those relevant to cost pass through and concludes with policy contributions.

1.4.1 Market power

Firstly, to the best of this author's knowledge, this is the first up-to-date investigation of market power in the supply chain of milk and dairy products in the UK. Driven by high market concentration at the retailer level during the period of study, it provides empirical evidence of the level of market power of retailers towards consumers and retailers towards providers. While considerable literature has previously examined market power in the food and milk products supply chain (Cavicchioli 2010; Nakajima 2014; Perekhozhuk et al. 2015, 2017), literature which specifically deals with the UK milk industry is scarce.

Secondly, motivated by the low number of dairy processors in the UK, this study interrogates the degree of market power of the processors towards retailers and processors towards farmers.

Since no prior study has researched the milk market dairy industry in the UK, up-to-date literature estimating the market power of processors is limited.

Thirdly, this research estimates the degree of market power of retailers towards consumers in the UK supply chain of petroleum products (road fuels) and the market power of retailers towards their providers. To the best of this author's knowledge, the general literature of market power on road fuels is low relatively compared to other industries, and conspicuously scarce in the context of UK.

Fourthly the degree of market power is estimated for the retailers of electricity in the UK: market power the retailers have towards the consumers; and market power they have towards their providers.

The empirical estimations of the above are all based on a newly proposed model obtained from the seminal NEIO work of Bresnahan (1982) and follows the recent work of Lloyd et al. (2006), Cavicchioli (2010), and Perekhozhuk et al. (2015, 2017).

The study estimates demand, supply, and production functions separately for the three products, along with an obtained market power regression that indicates the conduct parameters of market power which correspond to the parameters λ and ϕ , commonly estimated in industrial economics academic literature. Further separate estimations are undertaken including a dummy variable for the financial recession period 2008-2014.

The proposed empirical approach is useful when time series aggregated data are available and when demand supply and production functions are characterised as cointegrating relationships. In addition, FMOLS and DOLS methods have not been previously applied on market power studies; an omission which comprises of the final contribution of this thesis in terms of market power.

Since such techniques allow for potential endogeneity and serial correlation as well as the fact that all these relationships are cointegrated. The empirical findings elicited are for the long run period.

1.4.2 Cost Pass Through

The contribution relevant to the cost pass through mechanism, can be described as follows.

Firstly, to the best of this author's knowledge, this is the first up-to-date research which estimates the degree of cost pass through as well as asymmetric price transmission along the milk and milk products supply chain in the UK. Cost pass through is estimated for the change

in the input cost to the wholesale price and for the change in the wholesale cost to the retail price.

Secondly, this is the first up-to-date study which estimates cost pass through for the road fuels supply chain in the UK as well as asymmetric price transmission. Cost pass through is estimated for both a change in the input cost to the wholesale price and for a change in the wholesale cost to the retail price.

Thirdly, this is the first up-to-date study which estimates cost pass through for the electricity supply chain in the UK as well as asymmetric price transmission. Cost pass through is estimated for both the change in the input price to the wholesale price and for the change of a wholesale price to the retail price.

All the above empirical estimations are based on a methodology that its application to the UK cost pass through and the asymmetric price transmission literature is not wide. Following Nakamura and Zerom (2010) and Dagoumas et al. (2018), this thesis estimates the degree of cost pass through in the supply chain as well as the extent of asymmetric price transmission. Standard cost pass through regressions are estimated, and in the case of the wholesale to retail relationship, instrumental variables are also used to consider attenuation bias.

This thesis proposes a different empirical methodology to the standard empirical approaches of Error Correction Models (ECM) and Vector Error Correction Models (VECM) widely adopted throughout the literature. Instead, this study estimates the degree of cost pass through using the distributed lag model cost pass through regression as applied by Nakamura and Zerom (2010), as well as asymmetric price transmission using a similar type of model.

Newey West standard errors are applied to correct any potential heteroskedasticity. This has not been commonly used in the distributed lag models' literature and application of this method to the literature of price transmission is limited, especially in up-to-date UK studies.

Concluding the above, in terms of empirical contributions, this thesis uses a new method that of FMOLS and DOLS to estimate the degree of market power, something which has not been applied in the market power literature. To the best of this author's knowledge, within the context of UK's milk, road fuels and electricity sectors, this is the first time that the specific methodology is applied. Furthermore, the distributed lag models' methodology is applied for the first time in the cost pass through literature within the setting of the UK's three sectors under investigation.

Concluding the above, in terms of policy contributions, the findings of this thesis could be useful to policymakers and the CMA, should they turn their attention towards sectors where intervention has been minimal and market imperfections exist. Such imperfections can be to the detriment of the consumer, with negative social welfare consequences. Fair pricing can help prevent economic turmoil and social tension. As Boyle (2004) argues, estimating the degree of market power can be particularly useful when the abuse of market power is examined within the context of imposing, excessive cost to economic agents, or excessive pricing practices. It can also highlight imperfect competition in cases where evidence for incomplete cost pass through and asymmetric price transmission is provided. This study can have implications on competition policy and elucidate how cost savings from horizontal mergers are passed on to consumers. Lastly, this thesis can be useful to deal with policymaker concerns regarding the extent to which consumers benefit from reduction in the input prices.

This author contends that the dairy sector, especially at the retailer's stage, requires increased protection from the UK's competition authorities, given the fact that this thesis provides significant market power parameters and evidence for incomplete cost pass through. Furthermore, the road fuels sector merits increased attention and has grounds for further research, given the fact that sufficient evidence is provided for statistically significant market power of retailers towards consumers and retailers towards providers. Contrary to the bulk of the existing literature, this study demonstrates that the phenomenon of asymmetric price transmission also exists in this sector. In contrast, the research findings on electricity confirm the use of the price cap by OFGEM, as market power on behalf of the retailers towards the consumers is not statistically significant.

1.5 Research Questions

Market Power

This study aims to detect and estimate market power: any market power retailers exert over providers, and any market power retailers exert over consumers. As such, the scope of this thesis is dual.

In addition to estimating market power, the study aims to estimate cost pass through as well as test for asymmetric price transmission in the supply chain. More specifically, the research questions to be answered are as follows:

- 1) Does market power exist in the supply chain?
 - a) Is there any market power on behalf of the retailers towards their suppliers?

b) Is there any market power on behalf of retailers towards the consumers?

Therefore, this thesis is looking at detecting and estimating market power of the retailers at two stages/levels of the supply chain. It aims to estimate the market power of retailers towards the consumers and the market power of retailers towards their providers. These are the main general questions regarding market power, which are addressed for the purpose of this PhD.

The choice of products and supply chains is not left to luck. Empirical work is done on milk products, petroleum and electricity supply chains, as these are industries within which one can expect the existence of market power as well as the existence of asymmetric price transmission. This expectation is based on recent UK data that will be illustrated below. As far as these industries are concerned, few to rare recent studies exist for the UK. For the case of milk products, due to high market concentration at the processor's level this thesis goes further back the supply chain and answers the following question:

- a) Is there any market power on behalf of the processors towards the retailers?
- b) Is there any market power on behalf of the processors towards the farmers?

Cost Pass Through and Asymmetric Price Transmission

The second part of this thesis aims to answer the following research questions:

- 1) What is the amount of cost pass through of a change in the input cost to the wholesale price?
- 2) What is the amount of cost pass through of a change in the wholesale cost to the retail price?
- 3) Does asymmetric price transmission exist between a change in the input cost and the supply chain's wholesale price?
- 4) Does asymmetric price transmission exist between a change in the wholesale cost and the supply chain's retail price?

1.6 Research Methodology

This thesis applies a quantitative methodology using secondary data from diverse sources; principally the Office for National Statistics (ONS), the Department of Business Energy and Industrial Strategy and the U.S Energy Information Administration (EIA). It consists of two main empirical chapters; one of which applies a market power estimation model based on seminal work in the field (Bresnahan 1982; Perekhozhuk et al. 2015, 2017; Lloyd et al. 2006; Cavicchioli 2010). The degree of market power in the supply chain is then estimated. This empirical chapter delineates the estimates of demand supply and production functions for the

milk (dairy products), petroleum (road fuels), and electricity supply chains, by means of Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS). The degree of market power of retailers towards consumers is estimated, as well as the degree of market power of retailers towards providers. The second empirical chapter applies standard distributed lag models to estimate the cost pass through for a change in the input cost to the wholesale price and a change in the wholesale cost to the retail price. Empirical results are reported for the pass through of an input cost change to the wholesale price and a wholesale cost change to the retail price. In the case of the change in wholesale cost to the retail price, instrumental variables are used to weigh attenuation bias. Newey West standard errors are used to correct for heteroskedasticity and autocorrelation. Asymmetric price transmission is also examined.

1.7 Thesis Structure

This thesis is structured in thirteen chapters as follows:

Chapter One, the Introduction, offers background to the research in terms of the motivations, research questions, objectives, contribution, methodology, key terms, and overall structure.

Chapter Two presents an overview of the market power sources and consequences as well as a description and an evaluation of the Structure Conduct Performance Paradigm (SCP). New Empirical Industrial Organisation (NEIO) methods are presented drawing from the seminal work of Bresnahan (1982) and Lau (1982), as well as other relevant papers. The chapter further provides empirical findings relevant to the market power literature. Specific findings of work on the milk and dairy products supply chain, road fuels, and electricity, are presented.

Chapter Three elucidates the concepts of the Cost Pass Through (CPT) mechanism and Asymmetric Price Transmission (APT). The theoretical factors behind APT are delineated along with early models of APT and CPT as used in the literature. The chapter also discusses empirical findings relevant to the Cost Pass Through and Asymmetric Price Transmission literature. Specific findings of work on the milk and dairy products supply chain, road fuels, and electricity are presented.

Chapter Four presents an overview of the three supply chains interrogated in this thesis. The defining characteristics of the three different products under study are also considered.

Chapter Five presents the model used to estimate market power in the supply chain. Largely drawn from the seminal work of Bresnahan (1982) and Lau (1982), it also builds on the paradigms of Perekhozhuk et al. (2015, 2017).

Chapter Six outlines the methods used to estimate market power in the three UK supply chains. The methods used for the estimation of CPT and APT are also elucidated.

Chapter Seven presents an extensive empirical analysis of the results of this thesis relevant to the estimation of market power and milk, road fuels, and electricity supply chains analysed.

Chapter Eight presents a comprehensive empirical analysis of the results of this thesis relevant to the estimation of cost pass through and asymmetric price transmission and the results for the milk, road fuels, and electricity supply chains are analysed.

Chapter Nine presents a synoptic discussion on the market power results.

Chapter Ten presents a synoptic discussion on the cost pass through and APT results for the three supply chains.

Chapter Eleven presents the limitations of the thesis, conclusions, and summative remarks on policy implications and future research.

Chapter 2

Market Power

2.1 Introduction

This chapter begins with an overview of market power; its various sources, and how it can be measured. The potential economic and social consequences of market power are also taken into consideration.

The chapter then provides a description of the theoretical models behind market power. A description of one of the early market power paradigms is provided. The Structure Conduct Performance paradigm (SCP). As one of the first such assessment paradigms, this model provides a theoretical overview of the theory some empirical findings from its application to banking, further developments of the model with regard to modifications based on feedback effects, as well as criticisms of the paradigm. The chapter then elucidates New Empirical Industrial Organisation or NEIO models, presents a comparison with SCP, and offers a critique of this paradigm.

This chapter presents the empirical findings relevant to the detection and estimation of market power. It delineates the empirical findings relevant to the food supply chain along including milk and dairy products, and those of petroleum products and electricity. The studies chosen and the results vary based on the methodology, specific country, timespan, frequency of data, and product. Empirical findings are presented for UK studies where applicable, in addition to other territories of interest. It is notable that the greater part of the literature establishes market power in the output market while the effects of market power over the input market, monopsony, and oligopsony, is comparatively overlooked.

2.2. Defining Market Power

The concept of market power can be best explained by reference to the models of perfect competition and monopoly. In the case of perfect competition, price is equal to marginal cost, MC, in the long run, and firms in the industry have no market power. The firm operating under perfect competition is a price taker. The price is determined by the supply and demand forces in the market. In contrast, in the case of monopoly, price is greater than marginal cost (in both the short run and long run), with the extent determined by the price elasticity of demand. The firm has monopoly power and makes excess profits. The monopolist is a price maker. This distinction forms the basis of “one of the standard traditional ways” of measuring market power

– the Lerner Index. The Lerner index measures the difference between price and marginal cost with respect to the price. The value of the Lerner index can then be used, to identify the level of market power.

$$L = (P - MC) / P \quad (2.1)$$

The value of the Lerner index can be associated to the level of market power. In the case that there is no market power in the market, then the Lerner index equals to zero. In the case that there is market power in the market then the Lerner index is greater than 0.

In addition to monopoly, market power can also exist in the case of other types of market structure which are collectively referred to as imperfect competition. Ferrer (2013) describes in a few words these different cases of imperfect competition.

On the supply side, he describes the three types of imperfect competition: monopoly, oligopoly and monopolistic competition. For monopoly there is only one supplier of the product, for oligopoly there are a few suppliers of the products and for monopolistic competition, many producers sell products that are differentiated from one another. This holds in the case of barriers to entry, opposing the theory of Baumol et al. (1982) - theory of contestable markets. On the demand side there is monopsony and oligopsony. Under monopsony there is only one buyer and under oligopsony there are a few buyers of the product.

It is important to differentiate between normal profit and economic profit or excess profit. Under the case of perfect competition, the firm settles to a normal profit in the long run. This means zero economic profit. Economic profit is the difference between accounting profit and implicit costs. When price is greater than marginal cost, this indicates excess profit, which is the difference between the revenues and explicit and implicit costs. Implicit costs can include opportunity cost of an economic activity. In the case that price is greater than marginal cost, significant market power occurs, and the firm makes excess profit.

2.3 The Nature and Significance of Industry Differences

One important finding of the economics literature is the significant degree of variation across industries in terms of antitrust and competition. Studies have consistently demonstrated that market power differ according to specific industries and products.

2.4 Sources of Market Power

Various factors which may act as sources of market power are categorised as barriers to entry. According to Bain (1956) barriers such as ownership of a unique resource, economies of scale, and high sunk costs, can create a competitive disadvantage to potential entrants.

- a. *Ownership of a unique resource*: where a firm or a group of firms have the unique ownership of a resource, a patent for producing a specific product, or an exclusive government franchise such as the rights to a specific bus route for a bus company.
- b. *Economies of scale*: these indicate that as production increases the long run average costs go down. Potential entrants to the market may therefore be disadvantaged with regard to costs compared to firms that enjoys economies of scale.
- c. *High sunk costs*: when entering a market is accompanied by very high sunk costs, such as investing in expensive machinery, potential firms are less likely do so. Since such costs are irrecoverable, should the firm fail to attract an adequate market share or perform profitably, it cannot recoup these costs.

It is also worth mentioning that in instances when firms collude in oligopolistic strategies, the likely market outcome is equivalent to that of a monopoly enhancing market power. Based on the aforementioned, the number of firms is not a direct indication of market power. Thus White (2013) maintained the associated Lerner index could be that of a monopolist since when oligopolists sell different products, it problematises the index calculations. On the other hand, if an oligopolist chooses to unilaterally reduce the price, then both oligopolists would reduce the price down to MC resulting in an outcome like perfect competition; that of no market power.

2.5 Consequences of Market Power

In the context of enhancing both social and consumer welfare, Kaplow (2017) underscores the potential social consequences of market power. Deadweight loss is the reduction in consumer surplus due to the increased price: i.e., the difference between the consumer surplus under the competitive outcome and consumer surplus under the monopolist. Under perfect competition there is zero marginal deadweight loss. However, as in cases of monopoly, once price increases exceed the marginal cost, the deadweight loss goes up. Kaplow (2017) defines consumer surplus as the difference between what the consumers are willing to pay and what they pay, as represented by the area below the demand curve and above the price level. Furthermore, there is a transfer of consumer surplus to the excess profits of the monopolist/oligopolist.

Market power can also result in inefficiency. Economic inefficiency occurs when the average cost (AC) is above the minimum AC. Efficiency requires $P=MC$, which is the case of zero market power. In the case that price is not equal to marginal cost, there is a violation of the pareto optimum, which is also related to economic efficiency, and which Adam et al. (1991) deemed a necessary condition for maximising societal welfare.

Market power gives firms the opportunity to charge a price which is much higher than the perfectly competitive price which maximises societal welfare. In short, in any reallocation of resources, it is difficult to benefit one person without burdening another. (Brown & Olmstead 2017; Lee 2007).

2.6 The Structure Conduct Performance Paradigm

Originating in the work of Mason (1937) and Bain (1956), one of the earliest empirical models relevant to market power studies is the Structure Conduct Performance Paradigm (SCP).

The model is predicated on the concept that the structural characteristic of a market determines conduct, which, in turn, determines performance. Under SCP, structure refers to characteristics such as the number of the firms and concentration of the market, barriers to entry product differentiation, and buyer concentration; conduct refers to business activities such as pricing strategies, exploitation of market power, and tacit collusion; and performance refers to such aspects as profitability, and allocative and productive efficiency. For example, the use of accounting performance measures such as ROE (return on equity) have been applied to indicate profitability (Boru & Kuhil 2018; Nabieu 2013; Tan 2016).

A remodification of the SCP paradigm has led to the inclusion of public policy regulation. Neuberger (1997) maintains that market power is likely to exist and to be abused in industries comprised by a small number of large firms, something which can lead to a reduction in output and increase of prices above the equilibrium level. Since such a decrease of competition is likely to have a negative impact for the consumer welfare, Neuberger (1997) asserts that government or regulatory bodies must intervene in order to enhance competition and prevent abuses of market power.

The basic assumption behind SCP model based on Nabieu (2013), is that market structures are identified by many firms providing the same goods and services that are competitive despite being of relatively equal size. As such, the extent of competition among these firms is affected by the concentration degree of firm output in a market: a concept predicated on assumptions that a market structure with higher concentration makes effective collusion more probable, that

firms target profit maximization as a main goal, and also possess perfect information. An inverse relation between market concentration and competition level is also assumed, with the higher concentration seen to provide an incentive for collusion. Indeed, Nguyen and Stewart (2013) posit that a reduction in concentration leads to a decrease in market power.

The SCP paradigm has been much criticised in the literature; particularly in terms of the predicate that conduct directly impacts market structure, just as market structure causes conduct. The literature challenges this issue of causality or 'feedback effects' which as Lee (2007) describes, this creates a problem of endogeneity of the market structure within the model. While Nabieu (2013) enhances this by suggesting a reverse causality direction or feedback effects between conduct and performance; performance like profitability may affect conduct like pricing strategies and abuse of market power.

Academics and policymakers have raised serious concerns with regards to the strength of the SCP paradigm based on the grounds of this causality and endogeneity issue.

Further questions were raised by proponents of Baumol et al. (1982) contestable market theory. Here, entry barriers are a determining factor of performance, and an important criterion for assessing performance is profitability. Thus, when there are no barriers to entry, there are no profits for the monopolist. Under the theory of contestability, no profits exist and therefore if there is an increase in profits, this increases competition. As such, in the case of a positive profit and the case that price is higher than marginal cost, the non-existence of barriers to entry encourages the entrance of new firms and nullifies the necessity for government to intervene.

Perloff et al. (2007) note that the SCP approach has also been criticized in terms of the data and methods used. Two crucial problems have been identified in this regard: first, many such studies reveal substantial measurement error or related statistical problems. More specifically in an attempt to reduce bias, price cost on concentration regressions studies include advertising and capital variables; which contain error. Since the regression equations used in these studies do not have a solid theoretical foundation, they are unlikely to yield consistent estimates of structural parameters. In addition, Perloff et al. (2007), draw attention to two conceptual anomalies which limit SCP ability to identify the relationship between structure conduct and performance. The first questions whether long run measures are used to indicate performance and whether structural variables are exogenous. Based on standard economic theory, market structure determines long run profits. Therefore, if short run profits are used to indicate performance in the process of an SCP empirical study, no solid conclusion can be reached. The second. and

more serious conceptual problem with many SCP studies is that the structural variables are not exogenous. This problem is similar to the causality or feedback effects issue referred to above. While research that establishes high profits and high concentration may conclude that such high concentration has negative consequences since it increases profits, there may be an endogeneity issue arising from the fact that the high profits could increase market concentration, thereby reversing the direction of causality. That said, Perloff et al. (2007) acknowledge that infrequent research using the SCP approach continues.⁴

A further development in the empirical study of market power includes the use of the New Empirical Industrial Organisation (NEIO) methods. These methods are largely built up from the criticisms of the SCP paradigm wherein: (i) marginal costs are not directly observable; (ii) institutional characteristics of the industries affect the conduct of the firm and it is deemed beneficial to use time series in empirical studies at the industry level; (iii) the analysis uses the neoclassical principles of firm optimisation; and (iv) identifying conduct is much clearer than SCP.

2.7 New Empirical Industrial Organisation Methods

A foundation of NEIO techniques is the estimation of the conjectural variation. This represents the expectation that a firm has on how its rivals will change output, (q_j) in response to its own change in output (q_i). The expectation of the firm in terms of its conjectural variation (dq_j/dq_i) can be inferred if one is able to obtain estimates of marginal cost ($MC(q_i)$) and the slope of the industry demand curve. If the value of the conjectural variation (CV) can be estimated, the marketplace implications can be identified. The following table presents specific conjectural variation terms and what is implied in the market. The simple static case is taken into account.

Table 2.1. Conjectural Variations

Behaviour	dq_j/dq_i	Lerner index
Price taking	-1	0
Cournot	0	$1/2 \epsilon$
Explicit or tacit collusion	1	$1/\epsilon$

Source: Cassy Lee 2007, p. 15.

In accordance to Rasmussen (1999), in the case that Conjectural Variation, $CV = -1$, the firm maintains that should it change its output, by increasing it for example; its output is matched

⁴ A very descriptive analysis of the criticisms of the SCP paradigm can be found in Perloff et al. (2007).

by a collective decrease in the output of the rival firms and the total industry output remains the same. In equilibrium, the industry output is at the competitive level.

In the case that the Conjectural Variation equals zero, the firm maintains that if it deviates by producing more, other firms would not deviate. This corresponds to the Cournot-Nash equilibrium model of oligopoly; wherein the firm does not expect its rivals to change output, and there is interdependence between the firms who compete in terms of output. Within the Cournot duopoly model, each firm selects the production at the same time with consideration of the competitor. Thus, market price depends on the total output of both firms (Parkin et al. 2004) and each duopolist regards the output level of its competitor as fixed. In the case that Conjectural Variation equals to 1, firm j does expect that the rival would match its output. In the case of two firms with identical cost curves, the industry output is at the collusive level. An n player game needs a $CV=n-1$ to achieve that level.

To date, the NEIO approach has been applied to several industries and a variety of countries. Products under study include banks, petroleum, and cars, and Lee (2007) confirms the findings of some of these studies have established substantial market power or even collusive strategies.

In fact, Uzunidis (2016) argues that the empirical techniques developed under the NEIO studies on market power and inference on conduct are grounded in the growing concerns of policymakers and academics regarding issues of market power, market distortions, and competition. Uzunidis (2016) further notes that NEIO studies also consider the dual causality between conduct and market structure and the endogeneity of market structure. As such, the endogeneity problem is not of immediate concern under the studies using NEIO methods as exogenous variables are used for the market structure.

Moreover, and like the SCP, NEIO methods do not rely on accounting data for performance measures that do not resemble economic data, but they are based on the formal neoclassical optimisation theory.

NEIO methods have been widely used in a plethora of market power studies. What is of tremendous importance is that these studies estimate a degree of market power that can correspond to the various market structures of monopoly, oligopoly, oligopsony, and perfect competition. However, NEIO models require a large amount of complex data and the functional form used affects the results. (Uzunidis 2016; Grau 2018).

It is here noted that the present study narrows its focus on NEIO methodology using industry level data which are more easily available. As such, the following section outlines theoretical frameworks in the literature of direct relevance to the NEIO perspectives of detecting and measuring market power. The empirical findings from NEIO studies are then presented. The seminal NEIO model of Bresnahan (1982) and Lau (1982) is described, followed by recent studies.

2.8 Bresnahan (1982) and Lau Model (1982)

Drawing on the above model, this thesis presents Bresnahan (1982) and Lau's (1982) more formal NEIO model of estimating market power conduct parameter wherein the degree of market power is related to the difference between the price and the marginal cost as a ratio to marginal cost. In this paradigm, $R(Q, X)$ is defined as the inverse demand function for the output of an industry, with Q the quantity of the output and $X = (X_1, \dots, X_n)$ a vector of an industry demand shifters that do not affect the marginal cost of the firms. $MC(Q, N)$ is defined as the marginal cost function with $N = (N_1, \dots, N_m)$ a vector of m exogenous variables that affect the marginal cost but not the industry demand.

Bresnahan (1982) and Lau (1982) introduce the conduct parameter λ which satisfies the optimality condition of Marginal revenue = Marginal cost.

In this case the marginal revenue is:

$$R(Q, X) + \lambda R_Q Q \quad (2.2)$$

R_Q is the first derivative of price with respect to quantity.

The optimality condition is:

$$R(Q^*, X) + \lambda R_Q Q^* = MC(Q^*, N) \quad (2.3)$$

The optimum quantity is a function of the demand and cost shifters. λ is the estimated market power conduct parameter which can be related to market structure. It takes the values between zero and 1. In the case that it equals to 1 then the relevant market structure is monopoly. If $\lambda=0$ the relevant market structure is perfect competition. If λ is between zero and 1 the relevant market structure is oligopoly.

Bresnahan (1982) and Lau (1982) derive the necessary and sufficient conditions for which the conduct parameter is identified. There is a unique λ which corresponds to the conduct parameter based on the exogenous shifters and retail price. Bresnahan (1982) introduces the interaction term between the exogenous variable in the demand side, let it be the variable (X) with price

R. In other words, the exogenous variable (X) included as an interaction term with price (R) in the demand side shifts the intercept and changes the rotation of the slope of the demand curve. Including the interaction term which changes the intercept and the slope of the demand curve assists in identifying the degree of market power.

[\(link to ped with interaction\)](#)

2.9 Interpretations of λ

The literature provides at least two interpretations of λ used in Bresnahan (1982). According to Perloff et al. (2007), λ is the difference between price and marginal cost:

$$R - MC = -\lambda R_Q Q \quad (2.4)$$

R_Q is the first derivative of the price with respect to quantity.

Here, Lerner's measure is $L = \frac{R-MC}{R} = \frac{-\lambda R_Q Q}{R} = \frac{-\lambda}{\varepsilon}$

where ε is the market elasticity of demand. Since λ lies in the closed set $[0, 1]$, it follows that $L \in [0, -1/\varepsilon]$.

That is, λ takes on the role of $1/n$, s_i , or HHI (Herfindahl index). λ can be therefore related to a specific market structure showing the extent of market power. As such in combination with $-1/\varepsilon$ it can resemble conditions of perfect competition, monopoly or perfect cartel, or oligopoly.

The second interpretation of λ according to Perloff et al. (2007) is that it represents conjectural variation. In the case where there are n firms in an oligopolistic market and each firm faces the same costs. Firm i has a constant conjecture, v , about how its $n - 1$ rivals will respond to a change in its output: $v = \frac{dQ_{-i}}{dq_i}$, where Q_{-i} is the collective output of all the firms except for Firm i .

Following on from the above, and according to Perloff et al. (2007), the optimality condition for Firm i , is $MR = R + R_Q q_i [1 + v] = MC$ (2.5)

Under the assumption that all firms produce the same quantities, the second term of the optimum condition, Marginal revenue=Marginal cost can be divided and multiplied by the number of firms.

In that case: $MR = R + R_Q Q \left(\frac{1+v}{n} \right) = MC$ (2.6)

Since $MR = R + \lambda R_Q Q$, $\lambda = \frac{1+v}{n}$ (2.7)

Since $\lambda \in [0, 1]$, then $v \in [-1, n - 1]$. The case that $\lambda=0$, reflects the case of perfect competition and therefore zero market power. The case that $\lambda=1$ reflects the case of a monopoly or a perfect cartel, or collusion. The case that λ is between zero and 1 is an indication of an oligopolistic market structure. λ therefore represents a measure of conjectural variation since it represents the expectation of the firm about the reaction of the rival firm should it change the quantity produced.

2.10 Reduced Form and Non-Parametric Approaches

Alternative proposals to the above models have been made by several academics in the use of a reduced form and non-parametric approach.⁵ This thesis briefly refers to both Hall's and Panzar-Rosse approach although such reduced form methods do not provide a direct indication of the market structure, but rather indicate the existence of market imperfection.

2.10.1 Hall's Approach (1986)

Hall's (1986) early reduced form approach which has been widely implemented, used comparative statics to test for market power. The null hypothesis in the test is competition. The key weakness he indicated is that the researcher must maintain the assumption of constant returns to scale.

According to Hyde and Perloff (1995), Hall's test is a joint test with constant returns to scale. Hall's method estimates the mark-up $\mu=p/MC$. Using this method, the test for competition is whether $\mu=1$. While this method does provide an indication of imperfection in the market, it does not provide an indication of the market structure. "If the market is not competitive $\mu>1$, however, it is difficult to interpret μ unless one has additional information, such as demand elasticities" (Perloff et al. 1994, p. 4).⁶

2.10.2 Panzar-Rosse Approach

Hyde and Perloff (1995) also refer to the Panzar-Rosse (1987) approach to testing for market power. To conduct the test based on Hyde and Perloff (1995), a revenue function is estimated using reduced form as well as a statistic called H . H is obtained by adding the elasticities of revenue with respect to each of the factor prices. There are three hypotheses the Panzar-Rosse (1987) approach can test based on this formula (Hyde & Perloff 1995): i) the monopoly rent hypothesis which states that in the case of a monopoly the statistic H is non positive; ii) the market equilibrium hypothesis which states that in the case that firms are profit maximisers

⁵ More on this can be found in Perloff et al. (2007), which refer to reduced form approaches made by Summer (1981) and Sullivan (1985)

⁶ The description of Hall's theoretical framework can be found in Perloff et al 2007.

and some market forces like entry lead profits to zero, $H \leq 1$; and iii) the competition hypothesis which states that in the case that firms are in the long run competitive equilibrium with free entry, $H=1$.

Unfortunately, this test cannot distinguish market structures like monopolistic competition. Hyde and Perloff (1994) also note two further problems in running the test. It is extremely difficult to obtain the revenue function using the reduced form since it is non-linear and bias can be created and in the cases that Cobb-Douglas production function is used, the Panzar-Rosse approach is inherently powerless. Nonetheless, the literature reveals that similar examples of estimating oligopsony power have been developed; recent examples of which are described later in this thesis.⁷ Both the structural and reduced form approaches to estimating or testing market power have strengths and weaknesses. The Bresnahan (1982) and Lau (1982) model, estimates λ , which corresponds to a certain market structure. On the other hand, the reduced form methods detect imperfection in the market but cannot differentiate whether the market is a monopoly perfect competition and oligopoly.

One note regarding models like Bresnahan (1982) is the careful selection of the appropriate functional form. If, for example, as Hyde and Perloff (1995) contend, a translog function is used, this could lead to a reduction in efficiency and inability to determine imperfection in the market. Considering this, Perloff et al. (2007) undertakes simulations to check whether the application of a model that includes inverse demand and marginal cost is effective. Their findings indicate that using the translog function substantially increases the probability of wrongly rejecting a Cournot oligopolistic structure.

While Hyde and Perloff (1995) concede that Hall's method is viable in cases where the returns to scale are constant, the main problem is that the method detects the existence of imperfection but cannot provide an accurate estimate of market power. It is this author's opinion that the Bresnahan (1982) and Lau (1982) model is therefore far more effective in estimating market power, since in addition to using readily available aggregate data, it also estimates the degree of market power.

2.11 Recent Models of Market Power

⁷ An example of early oligopsony model in the literature can be found in Perloff et al. (2007)

2.11.1 Market Power in the Beef Supply Chain by Lloyd et al. (2006)

Lloyd et al. (2006) influential study examines the effect of the BSE⁸ crisis and the estimation of market power in the UK beef supply chain. Their findings indicate the existence of market power. Assuming fixed proportions technology and the constant returns to scale, and after proceeding to the estimation of demand and supply functions, the study explores the effects of exogenous factors affecting demand and exogenous factors affecting supply on which the farm retail price spread was estimated. In the case that these factors or ‘shifters’ are statistically significant, there is imperfect competition in the market and market power is detected. For the purpose of their study, Lloyd et al. (2006) are motivated by high concentration in the retail sector and the potential market power retailers might exert on consumers. The concentration level within the wholesale stage of the chain proved very low, and therefore unlikely to be susceptible to exploitation of market power. The study further estimates the effect of the BSE crisis on the UK beef supply chain as the impact of a negative demand shock on the retail price which is beyond the scope of the present study aims. More analytically Lloyd et al. (2006) proceed as follows:

The demand function for the product at the retail level is estimated as a function of retail price R , price of substitutes R^s or complements and an exogenous factor that might affect demand or demand shifter.

$$Q = h(R, R^s, X) \quad (2.8)$$

The inverse supply function is the following:

$$P = k(A, N) \quad (2.9)$$

where P is the input upstream supply price, A is the quantity supplied of the agricultural raw material and N is the exogenous factor affecting supply or supply shifter.

The study uses the profit of the retail firm and then applies the profit maximization condition. Based on Lloyd et al. (2006), for a representative retail firm, profit is given by:

$$\Pi_i = R(Q)Q_i - P(A)A_i - C_i(Q_i) \quad (2.10)$$

where C_i is other costs and $Q_i = A_i/a$ where a is the input-output coefficient assumed to equal 1. Applying the profit maximization condition.

$$R + Q_i \left(\frac{\partial R}{\partial Q} \cdot \frac{\partial Q}{\partial Q_i} \right) = \frac{\partial C_i}{\partial Q_i} + P + Q_i \frac{\partial P}{\partial Q} \cdot \frac{\partial Q}{\partial Q_i} \quad (2.11)$$

⁸ The BSE crisis, otherwise known as Mad Cow Disease.

Using the above together with the demand and supply functions in linear form follows:

$$Q = h - bR + eR^S + cX \quad (2.8')$$

$$P = k + gS \quad (2.9')$$

S represents domestic supply and is represented as:

$$S = Q + N$$

where N is the factor that exogenously determines supply for example net exports.

From this, (2.11) can be rewritten as:

$$R - \frac{\theta}{b}Q = M + P + \mu gQ \quad (2.11')$$

where θ and μ are average output and input conjectural elasticities respectively:

$$\theta = \frac{\sum_i \left[\frac{\partial Q}{\partial Q_i} \right] \left[\frac{Q_i}{Q} \right]}{n} \quad \text{and} \quad \mu = \frac{\sum_i \left[\frac{\partial Q}{\partial Q_i} \right] \left[\frac{Q_i}{Q} \right]}{n}$$

The above can be used as an indication of the level of market power with $\theta=\mu=0$ representing perfect competition and $\theta=\mu=1$ representing collusion.

M represents all other costs that affect the retail-farm price spread. In order to allow for cost changes during the crisis, a linear marketing cost function is assumed of the form:

$$M = y + zE + G \quad (2.12)$$

where y is a constant, zE represents the costs of inputs from the marketing sector (for example, wages) and G represents exogenous regulations costs.

Using (2.8'), (2.9'), (2.11') and (2.12), and for convenience suppressing the constants y and k, an explicit solution is derived for the endogenous variables:⁹

Quantity demanded:

$$Q = \frac{(h+eR+cX - bzE-bG-bgN)}{(1+\theta)+bg(1+\mu)} \quad (2.13)$$

With the use of a derived retail price expression and a derived farm price, the papers estimate the spread between the retail price and the farm price:

$$R - P = \frac{h \left(\frac{\theta}{b+g\mu} \right) + (1+bg)(zE+G) + \left(\frac{\theta}{b+g\mu} \right) (eR^S + cX) - (\theta + bg\mu)(gN)}{(1+\theta) + bg(1+\mu)} \quad (2.14)$$

⁹ The full derivation of the equations is provided in Lloyd et al. (2006) p. 11.

Note that if $\theta=\mu=0$, the case where neither oligopsony nor oligopoly power matter, then equation (2.14) reduces to:

$$R - P = zE + G \quad (2.15)$$

Under perfect competition the retail farm price spread is unaffected by demand and supply shifters which are absent from 2.15, and only affected by regulation and marketing costs. Furthermore, in cases where the demand and supply shifters are greater than zero, the market power of either oligopoly or oligopsony obtains. Each shifter affects retail price and farm price separately, but ultimately have a joint effect on the retail farm price spread.

The literature demonstrates that market power studies results are affected by the choice of the functional form, assumptions of the constant returns to scale, and technology assumptions. Considering this, it is worth investigating the role of scale economies on the margin equation (2.14).

To do so, Lloyd et al. (2006) assumes that marketing costs are independent of the level of output in the beef sector due to the multi-product nature of retailers. The inverse farm supply function is therefore adapted to allow for variable marginal costs and rewritten as:

$$P = gS + sS^2 \quad (2.9)$$

If there are constant returns to scale, $s=0$. If $s>0$ there are increasing returns to scale and average costs increase. The opposite occurs for the case where $s<0$. Lloyd et al. (2006) amends the above model based on this assumption with the resulting retail farm price spread as follows:

$$\begin{aligned} R - P = & \frac{\left(\frac{\mu g + \theta}{b}\right)(h) + [(1 + bg + bs(Q + 2N))(zE + G) + \mu g + \theta/b]cX(eR^S + cX)}{(1 + \theta) + bg(1 + \mu)(Q + 2N)} \\ & + \frac{\left[\left(\mu g + \frac{\theta}{b}\right)eR^S - bg\left(\mu g + \frac{\theta}{b}\right)N - bs\left(\mu g + \frac{\theta}{b}\right)N\right]}{[(1 + \theta) + (1 + \mu)bg + bs(Q + 2N)]} \end{aligned} \quad (2.14')$$

The above suggests caution should be exercised in the interpretation of market power as in McCorriston et al. (2001). In other words, non-constant returns to scale matter only insofar as they interact with market power. This implies that market power is detected from the statistical significance of the exogenous variables which are used as demand and supply shifters. Non-constant returns to scale will not affect the sign of the shifters. While the price spread shown above is theoretically derived by Lloyd et al. (2006) to consider returns to scale, it cannot be

applied in practice since it is unknown. In case of important returns to scale the market power effect on the spread will be enlarged. However, returns to scale cannot change the margin size on their own.

2.11.2 Market Power in the Italian Fluid Milk Supply Chain by Cavicchioli (2010)

A similar approach to Lloyd et al. (2006) is Cavicchioli's (2010) application of the same modelling philosophy to the fluid milk market in Italy. Like Lloyd et al. (2006) the market power is examined at the retail stage. He examines the market power of the retailers towards consumers (oligopoly) and the market power of the retailers towards the farmers (oligopsony). Demand and supply functions are also estimated in the same way as Lloyd et al. (2006). Using profit maximisation condition and a linear form of demand and supply, a retail farm price spread expression is derived which depends on exogenous factors affecting demand and supply.

In the case that these demand, supply or otherwise shifters are not statistically significant, they do not affect the retail farm price spread and the market outcome is competitive. In other words, there is perfect competition in the market. In the case that demand and supply shifters are statistically significant, one cannot accept the null of perfect competition and market power exists. Using the concept of conjectural elasticities, Cavicchioli (2010) estimate the conduct parameters θ and μ . θ ranges from zero to 1 indicating perfect competition and monopoly, and μ ranges from 0 to 1 indicating perfect competition and monopsony. The study demonstrates market power at retailers level in the Italian milk industry.

2.11.3 Synopsis of Recent Market Power Theoretical Frameworks herein

Lloyd et al. (2006), attempts to estimate market power in the UK beef supply chain. Focus is targeted at the retail level since the concentration is very low at the wholesale level. Demand and supply functions are defined using supply shifters. Profit maximisation is used and an indication of perfect competition or monopoly in the market is indicated. Based on conjectural elasticities, two conduct parameters are obtained. $\theta=\mu=0$ indicate perfect competition.

Using the linear forms of demand and supply as outlined above, an expression is obtained for the retail farm price spread. In the case that the demand and supply shifters are statistically significant, imperfect competition exists in the market along with market power. In the case that the demand and supply shifters are insignificant, the market can be characterised by perfect competition.

By comparison, Cavicchioli (2010) tests for the presence of imperfect competition along the food supply chain whilst Lakuma (2013) tests for the exercise of market power in the crude oil

industry. Both studies are country specific. The main difference is that Lakuma (2013) applies the Bresnahan-Lau dynamic Oligopoly model in an Error Correction framework. The model is estimated for a more aggregate level of the industry and static and dynamic short and long run indices of market power are estimated.

Echoing both Lloyd et al. (2006) and Cavicchioli (2010), in the case that the supply and demand shifters are found statistically significant in the retail farm price spread, this indicates evidence of imperfect competition in the market. The study focuses on the fish supply chain in Japan and evaluates possible imperfect competition from the perspective of sellers. What differentiates Nakajima from the other studies is his application of the model to both the upstream and downstream parts of the chain: upstream supply price being the producer price, and retail price as the wholesale price towards retailers; downstream being the retail price towards consumers, and upstream supply price is the wholesale price of the wholesale seller.

Comparing to the above studies such as Perekhozhuk et al. (2015, 2017) focus on oligopsony power estimation in the dairy processors stage. The studies are country specific and emphasise the estimation of market power. Unlike the other studies reviewed here, the coefficient of market power can be estimated and interpreted as oligopsony. This concurs with the econometric procedure of Lloyd et al. (2006), whereby market power can be estimated and comparison between countries facilitated. However, the specific method used by Perekhozhuk (2015) is difficult to apply via any commonly used statistical software.

In this thesis I develop a model that is based on the seminal work of Bresnahan (1982), to estimate the degree of market power of retailers towards the consumers and I use influences from Perekhozhuk et al (2015, 2017), to develop a new model that also estimates the degree of market power of the retailers towards their providers.

In the model a newly proposed regression is estimated, which gives the researcher the opportunity to estimate separately the degree of market power of the retailers towards the consumers and the degree of market power of the retailers towards their providers. The same model can be used to go further back the supply chain and estimate the degree of market power of the processors towards the retailers and the degree of market power of the processors towards their providers. This thesis goes further back the supply chain in the case of milk products where processors are characterised by high market concentration based on Smith and Thanassoulis (2015). After the above models, empirical literature findings are presented.

2.12 Literature Empirical Findings on Market Power Within the Three Supply Chains

Table 2.2: Literature review on market power

	Author	Sector	Country	Period	Method	Findings
Milk Sector	Lloyd et al. (2006)	Meat	UK	1990-2000	NEIO	Market Power
	Anders (2008)	Food	Germany	1995-2000	NEIO	Limited Market power
	Nakajima et al. (2014)	Fish	Japan	1976-2009	NEIO	Market power
	Cavicchioli (2010)	Milk	Italy	1996-2003, 1996-2008, 2000-2008	NEIO	Market power
	Salhofer et al. (2012)	Dairy products	Austria	1997-2008	NEIO	Limited Market Power
	Bacuks et al. (2014)	Dairy	Hungary	1993-2006	NEIO	Market Power
	Perekhozhuk et al. (2015)	Dairy	Ukraine	1996-2003	NEIO	Market power
	Grau (2018)	Dairy	Germany	2000-2011	NEIO	No market power
Road Fuels Sector	Ersham et al. (2007)	Road Fuels retailers	Sweden	1993-2004	NEIO	No market power
	Lakuma (2013)	Crude oil industry	US	1986-2012	NEIO	Market power
	Ones et al. (2018)	Road Fuels retailers	Sweden	2012	NEIO	Limited market power
Electricity Sector	Vasilopoulos (2003)	Electricity	Nordic countries	1996-2003	NEIO	No market power ¹⁰
	Merit et al. (2015)	Electricity	France	2009-2012	NEIO	No market power
	Amountzias et al. (2017) ¹¹	Electricity	UK	1998-2012	VECM	Market Power

¹⁰ This study does not consider transmission constraints that could give rise to market power.

¹¹ As far as electricity is concerned, to the best of this author's knowledge, the very recent literature; especially with reference to the UK; is rare to none.

2.13 Specific Findings: Food Supply Chain Milk¹²

Moving from the above discussion on market power, this thesis presents and evaluates empirical findings for market power in the food and milk supply chains. The work of Lloyd et al. (2006) is concerned with the BSE¹³ crisis in the UK and focus on market power in vertically-related markets. Using monthly price data on retail price series on beef, pork, and lamb drawn from the Department of Environment, Food and Rural Affairs (DEFRA) spanning from January 1990 to December 2000, their survey covers 21 locations in England and Wales. A vector autoregressive (VAR) framework is used after the establishment of non-stationarity and cointegration. The results of the empirical analysis for the UK beef chain indicate that the importance of market power cannot be rejected. The impact of the BSE crisis on farm prices is found to be more than double than that of retail prices; heightening public concern around the varying impact of food scares on retailers and producers.

Anders (2008) focus on the simultaneous measurement of oligopoly and oligopsony power in the German food retail industry. The rationale for the analysis echoes that of other studies: concerns that high level of concentration in the German supermarket sector is driving retail dominance throughout the food supply. Based on a set of monthly state-level data on beef and pork marketing in the state of Hessen for the period 1995–2000, the study includes specifics of the German meat market to estimate the impact of the European Mad Cow Disease outbreak which led to a sharp fall in beef consumption throughout Germany. Anders (2008) concludes that limited retail oligopoly power exists in the sales of beef and pork products. These findings contradict the corresponding findings in meat processing. The oligopoly power analysis reveals an 11% markdown in processor-retail unit margins for beef and a 2.7% markdown for pork, compared to the expected outcome under perfect competition. The findings of Ander's study indicate the exertion of market power at the disaggregate level.

Nakajima et al. (2014) sought to determine the existence of imperfect competition in the supply chain of fisheries products in Japan for the period 1976-2009. Applying the rolling window methodology to estimate the model as previously mentioned, the products under scrutiny include as many fish species as possible in order to establish with accuracy the existence of imperfect competition in the Japanese fish supply chain.

¹² The empirical findings are summarised in Table 2.2.

¹³ BSE Crisis/ Mad Cow Disease.

One aspect which differentiates Nakajima et al.'s study from others is consideration of both the upstream and downstream sub-chains: from producer to wholesaler, and from wholesaler to retailer. The analysis detects the existence of imperfect competition in the distribution stage of several fisheries products in Japan. Furthermore, when comparing the upstream and downstream markets, the number of periods within which imperfect competition exists are found to be greater in the upstream markets. It should also be noted that the study demonstrates imperfect competition for the downstream markets of some products, but no corresponding evidence in the upstream markets. According to Nakajima et al. (2014), this conclusion is consistent with earlier findings which argued that the emergence of large supermarkets as buyers in the wholesale markets has caused the reduction of power for the sellers in these markets, therefore lessening market power or imperfection in the upstream market.

In terms of the milk / dairy markets, Cavicchioli (2010) attempts to contribute to the empirical literature by applying a theoretical framework to detect market power exertion in the Italian food supply chain (milk). To this end, the study examines the periods 1996-2003, 1996-2008, and 2000-2008, using 29 monthly publicly available time series.

All the data are in index form “and refer to retail milk price, producer milk price, index of wages in dairy processing, retail price indexes all good, food, food and alcoholic beverages (as a proxy for demand shifter) and for farm supply shifter, farm input price shifter” (Cavicchioli 2010, p.7).

Based on this work, unit root tests, cointegration tests and error correction models are estimated. The existence of market power is detected at some stage of the Italian fluid milk supply chain over the period 1996-2008. For the period 1996-2003 there are no concrete results. According to Cavicchioli (2010) “the absence of clear evidence of market power does not imply perfect competition as in this case both demand and supply shifters should not affect the retail price.” (Cavicchioli 2010, p.12).

Moving on to a paper by Salhofer et al. (2012), market power is estimated for the market of dairy products in Austria. This is motivated by high concentration levels of food retailers and dairy processors in Austria. The analysis uses a NEIO model, to focus on market power of Austrian food retailers with respect to milk products.

The study estimates supply functions at the dairy processor level and the consumers demand functions. Due to availability of data, the analysis is undertaken for drinking milk, cheese products and for other milk products.

Monthly data are used for the period January 1997-December 2008. Data are obtained by the Austrian household panel RollAMA managed by Keyquest. In this panel about 1,400 households are recording food purchases at the retail level both in value and quantity. Based on the results of the study, market power exists on behalf of the retailers towards the consumers and towards the input suppliers. The evidence indicates stronger power towards the input suppliers than towards the consumers. The paper further estimates an inelastic demand of drinking milk. The low supply elasticity for other dairy products could be a contributing factor to the exercise of oligopsony power towards input suppliers. This author highlights that all of the above reviewed studies described in Table 2.2, are motivated by high market concentration of the retailers in the food/milk supply chain. This provides the basis for this author's choice about the supply chains under study; milk sector, road fuels; electricity.

Perekhozhuk et al. (2015) estimate whether Ukrainian dairy processors enjoy oligopsony power at the regional level during the period 1996-2003. To this end, a market structure model based on the NEIO methodology which is accompanied by non-linear three stage least squares is applied. According to Perekhozhuk et al. (2015), negative production elasticities of labour and capital in the estimated production function of the industry are supported by the small degree of capacity utilization and by major political and administrative interventions. The empirical results of the study establish the existence of oligopsony power in two of the six regions under scrutiny: findings which agree with the investigations conducted by the Antimonopoly Committee of Ukraine. The conclusions demonstrate oligopsony power to be more pronounced in specific central regions of Ukraine.

Bakucs et al. (2014) similarly use firm-level data to estimate market power in the Hungarian dairy sector, and more specifically, oligopsony power in the Hungarian milk processing sector. Like Perekhozhuk et al. (2015), a non-linear three stage least square (NL3SLS) methodology is used, along with the translog production function. For this purpose, four econometric models are estimated. The study estimates positive capital and labour production elasticities but with low significance. Evidence of perfect competition is insufficient. This implies imperfection in the market and agrees with the findings of Perekhozhuk et al. (2015). Their findings indicate the estimated parameter oligopsony market power at 0.22 and 0.30 in the estimated periods 1993 until 2006, respectively. The results confirm expectation of the existence of market power in the Hungarian processing sector due to high firm concentration levels. The studies of both Perekhozhuk et al. (2015) and Bakucs et al. (2017) are based on a similar methodology and establish similar findings for two separate countries.

Utilising data from periodicals of the State Committee of Statistics of Ukraine, a further study of Perekhozhuk et al. (2017) finds that the degree of oligopsony power in the Ukrainian milk processing industry varies according to the regional levels at which the market structure models are estimated. While at the national level, no oligopsony power is detected, the evidence of individual regional levels support the hypothesis of oligopsony power. Thus, imperfect competition is found to exist in two regions at a 10% statistical significance level, and in two others at a level of statistical significance of less than 15%.

The results of estimating and detecting market power in different stages of milk industry/food supply chain are clearly heterogeneous; depending on country and industry characteristics. As well as the data frequency. As evident in Table 2.2, this review throws up a wide spectrum of findings; ranging from the existence of market power at the retail level, higher degrees of market power of retailers towards input suppliers than towards consumers, absence of clear evidence of market power, and degrees of oligopsony power relative to specific regions. Several of the studies are motivated by enhanced concerns around high market concentration at the retailers' level.

This section concludes with summative insights drawn from an extensive literature review of Perekhozhuk et al. (2017) estimations of market power dominance in the agri-food sector. Perekhozhuk et al. (2017) observe that the majority of investigations relevant to beef packing estimate a significant degree of oligopsony/oligopoly power in markets for meat products (beef and livestock). As such, most of the studies utilise market level data. However, evidence for the presence of oligopsony power at the firm level is only detectable using plant level data (Morrison 2001 cited in Perekhozhuk et al. 2017, p. 311).

More recent articles refer to two widely- used PTA and GIM empirical methodologies. PTA is an approach for measuring the degree of oligopoly power as pioneered by Appelbaum (1982) in the analysis of the Canadian food processing industry. Introducing the assumptions of fixed proportions and output this work modifies the approach to simultaneously measure oligopoly and oligopsony power (Schroeter 1988 cited in Perekhozhuk et al. 2017, p. 311). Based on this, differing information cannot be provided about market power for input and output markets. The approach is modified further by using a production rather than a cost function and by the choice of a more flexible specification which enable variable input proportions (Azzam & Pagoulatos 1990 cited in Perekhozhuk et al. 2017). However, Perekhozhuk et al. (2017) note

“the Achilles heel of the model is that this higher degree of flexibility comes at the cost of fixed exogenous value supply and demand elasticities” (Perekhozhuk et al. 2017, p. 311).

The GIM approach formulated by Bresnahan and Lau (1982) enables market data to be evaluated using aggregated price and quantities data. As such, Perekhozhuk et al. (2017) purport that market power can be estimated when no production data are available.

In this context Hyde and Perloff (1995) stress that an essential aspect of market power estimation is specification of the cost function and the model. Hyde and Perloff (1995) support the view that the translog production function results loss of efficiency in the estimator. This can occur due to the existence of multicollinearity between the translog functions independent regressors.

2.14 Petroleum Empirical Findings

While the study of asymmetric price transmission (rockets and feathers) of petroleum products, especially gasoline, is evident throughout the literature, estimation of market power in petroleum industry has been less frequently examined; especially in the context of the UK. This section therefore outlines the relatively recent studies of estimating market power in petroleum products industry.

Erhsam et al. (2007), conduct a study in the spirit of the NEIO, where in market power is inferred from conduct rather than attributed to industry structure, and price cost margins are unobservable since marginal costs cannot not be directly extracted from the accounting data. Rather, information on marginal costs is inferred indirectly by observing firms’ conduct on related upstream markets. Focusing on the Swiss petrol-retailing industry for the period 1993-2004, the study establishes the existence of competition and no collusion. The level of market power in the industry is found to be significantly low, and the competitive pricing of petrol largely consistent with fluctuations in oil prices.

Due to perceptions of unusually high level of collusion and mergers, Lakuma (2013) utilises data from the US Department of Energy and the IMF international financial statistics website to determine the degree of market power in the American crude oil industry for the period 1986-2012. Since autocorrelation and unit root presence can affect the static model results, a dynamic reformulation of the Bresnahan and Lau model (1982) is applied. The study presents conclusions for both the short and long run, with the exercise of market power estimated for both time spans, and a long run mark-up of 37% established.

While the two studies deal with two separate countries, it is evident that Lakuma (2013) estimates higher levels of market power in the American crude oil industry than Erhsam et al. (2012) does for their Swiss counterparts.

One very recent paper by Ones et al. (2018) utilises microdata obtained through SCA for Sweden for the period Jan 2012 - Dec 2012 inclusive. The study considers many gas stations, and like that of Perekhozhuk et al. (2017), the analysis allows for regional variation.

The study contributes to the literature by relying on rarely available microdata rather than the usual aggregate data. A Bresnahan-Lau (1988) model is applied using information of contractual arrangements and local competition factors for each station. The paper addresses the impact of station characteristics on competition. The demand estimates of the study demonstrates an inelastic gasoline demand that concurs with comparable findings. The Bresnahan (1982) and Lau (1982) approach requires the addition of an interaction term between exogenous demand side variables and the retail price in the demand specification. For these interactions, local income and local population is used. The elasticities estimated are both significant. Income elasticity confirms the theory of normal good and substitutability between public transportation and the demand for gasoline. Using the information from the demand estimates, they identify market power through the estimated supply relations. According to Ones et al. (2018), a significant amount of market power is exercised by the retailers in the Swedish market on average; with the level of market power very limited at the downstream level. The study further establishes that the competition level varies significantly with local station characteristics such as contractual forms and local competition. They also conclude that the degree of market power varies with both the distance to the nearest station and the number of gasoline stations in the area.

In conclusion and as evident in Table 2.2, market power studies relevant to the petroleum sector are undertaken less frequently than those of other sectors, extant research estimates modest market power or limited market power in the downstream level; although findings differ based on country and level of the supply chain. However, this author expects that based on the current high market shares of UK road fuel retailers, a high degree of market power will be determined.

2.15 Empirical Findings Market Power and Electricity

A very different type of literature relates to market power in electricity markets with particular indices developed to measure market power in this sector. The HHI index built on the SCP paradigm of the 1930s is one of the first (Meritet et al. 2015) and holds that an industry

performance depends on the conduct of sellers and buyers, which depends on the structure of the market. Structure is often summarised by the market shares (HHI index). Twomey et al. (2006) maintain that while such indices can act as a detecting tool for market power, evidence supporting their application in successfully predicting market power in electricity markets is scarce. Indeed, Meritet et al. (2015) mention that studies using these indices do not account for such factors such as the demand characteristics which can impact the potential exercise of market power.

Other indices formulations consider various demand conditions which can impact market power. The Pivotal Supplier Index (PSI) and Residual Supply Index (RSI) are examples of indices specifically designed for the electricity market by California ISO in 2002 (Meritet et al. 2015). Such structural indices, however, do not provide the basis for actual estimation of market power rather than the potential of existence of market power. Wolak (2000) develops a more advanced method of estimating market power which entail the estimation of the residual demand curve faced by a company. According to Meritet et al. (2015), market power is properly measured by the distribution of slopes of residual demand curves for a given hour. However, this method necessitates the use of large datasets which were not available for the scope of this thesis.

While market simulation models are another advanced method developed to measure market power by treating it as an unknown factor to be estimated (Meritet et al. 2015; Twomey et al. 2006), SCP studies look at the factors that lie behind market power. Market simulation models in the literature mainly emphasise the measuring of marginal cost and oligopoly equilibria in wholesale electricity markets. Meritet et al. (2015) refer to engineering data of fuel costs as the main cost component for fossil fuel plants to derive marginal costs.

Various studies using simulation models as well as oligopoly equilibria models also exist. Yet more studies use a simple Cournot, Bertrand, Nash equilibrium (Borenstein & Bushnell 1999; Borenstein et al. 2000). One frequently cited paper establishes the exercise of market power in California's wholesale electricity market during June-November 1998. The core study's aim is to determine the existence of market power and imperfect competition in the market. They establish the existence of market power by comparing the actual energy prices and the estimated energy prices (Borenstein et al. 2000 cited in Meritet et al. 2015, p. 123). They also examine the intersection of the residual demand curve and the estimated industry marginal cost curve and compare the competitive outcome to the imperfect competition outcome. They then

proceed to compare the competitive outcome to the actual observed outcome and find that the ratio between the total cost of energy and the cost due to market power is 48% and 58% during July and August, respectively. Ratios are very low during off-peak hours. While these models have been applied to numerous electricity markets throughout the world due to their firm grounding in oligopoly theory, the large and complex dataset involved makes them particularly difficult to apply in the real world.

Vassilopoulos (2003) purports that NEIO techniques are used to offset the fact that marginal costs are unobservable. Bresnahan (1982) is the first to illustrate a technique for estimating the level of competitiveness in the absence of detailed cost information. “The central ideas of this approach are that firm’s price-cost mark-ups are not taken to be observable and firm and industry conduct are viewed as unknown parameters to be estimated” (Vassilopoulos 2003, p. 57). Such techniques estimate behavioural equations by which price and quantity are set and parameters are estimated that can infer firm and industry conduct.

Using weekly data for the period 1996-2003, Vassilopoulos (2003) applies the Bresnahan (1982) and Lau (1982) model to test and measure the level of market power in the Nordic Market for electricity. Prior to 1998, the system price refers only to Norway and Sweden, but after Finland and Denmark joined the market in 1998 and 1999, respectively, the weighted average of Norwegian, Swedish, Finnish, and Danish data by entry date is used. Vassilopoulos (2003) finds no market power in the short or long run. The test demonstrates that Nord Pool operates under largely competitive conditions with no significant market power. However, their study did not account for transmission constraints and contradicted Johnsen et al.’s (1999) evidence of local market power in Norway. This study provides evidence for the long run period and does not consider the higher ability of the retailers to exercise market power when transmission constraints are binding.

Using panel hourly data for the period 2009-2012, Meritet et al. (2015) recently apply a structural NEIO model to examine the presence of market power abuse in the French wholesale electricity market. The model-based results suggests that, on average, no market power has been exercised during the examined period.

Market power is found to be significant but very low. There are several economic justifications to support the conclusion since in the case of high degrees of regulation the probability of actual abuse of market power is reduced. The study establishes this in the case of France, and it is

interesting to note that the electricity price in France is lower than the rest of Europe. Studying the performance of electricity spot markets is a key issue for both academics and policymakers.

Meritet et al. (2015) attribute their findings to the fact that spot prices are highly regulated with a high degree of interconnection with neighbouring markets. Meritet et al. (2015) assertion of very little correlation between market power abuse and market concentration is also worth noting. In fact, despite EDF being the single dominant wholesale electricity provider in France, there is no abuse of market power. Based on the above, absence of strict regulation, such as the absence of a price cap before the year 2019, could indicate that high probability for the existence of a high degree of electricity market power in the UK as well a high probability of its potential abuse.

In the case of UK electricity markets, Amountzias et al. (2017) find consensus following privatisation and the Pool implementation and following a growing concern with regards to market power.¹⁵ Amountzias et al. (2017) note that the literature on the UK power market has mainly considered three different factors in the analysis of prices as follows:

- a) prices of incumbents in comparison to other suppliers operating in the same area
- b) firm level or industry level price-cost margins
- c) competitive pressure from the demand side, i.e. switching customers

(Amountzias et al. 2017, p. 468).

Recent research into the market power in the UK electricity market employ a variety of methodologies. This section therefore briefly outlines a number which has identified market power as an issue in the industry:

Market power and its potential abuse could be the reason behind increased electricity prices in the UK (Ottero & Adams 2001 cited Amountzias et al. 2017, p. 469). More recent work attributes unsatisfactory retail competition in the UK electricity industry to a multimarket setting wherein parallel price is motivated and oligopolistic behaviour encouraged. Brookman (2015) conducts a comparative analysis of the UK market with the much less concentrated market of Norway, and concludes that although there is a lesser degree of market power in Norway, most developed countries enjoy a high market power level (Brookman 2015; ECME Consortium 2010 cited in Amountzias et al. 2017, p. 469).

Finally, one of the most recent studies on market power and pricing in the UK electricity markets is Amountzias et al.'s (2017) examination of the period 1998-2012. A dynamic VECM

¹⁵ More information is provided in Amountzias et al. (2017).

is used to measure market power and the findings indicate low market power in the wholesale electricity sector. The long run estimates demonstrate that the existence of low market power in the wholesale level leads to higher prices at the retail level. Their analysis also provides sufficient evidence for anticompetitive behaviour in the retail segment. This author opts estimate the degree of market power in electricity supply chain, since the market concentration ratios remain very high and the use of a novel approach is considered to shed light to the market power level of the UK'S big Six.

This is partially in agreement to the CMA (2016) energy market investigation, which concludes that the market power of the Big Six arises from lack of engagement of the customers and does not imply any tacit collusion practices.

In summary, consistent evidence is provided for local market power in the retail electricity market, albeit differing based on the region, and limited market power exercise and abuse in cases of regulated prices. Evidence of low market power is provided for the UK wholesale electricity markets.

Findings of relevant studies vary based on country, timespan, stage of the chain under investigation, and region.

2.16 Conclusion

This chapter began with an overview of market power and how it can be measured. Sources of market power focusing on barriers to entry, like unique ownership of a resource and economies of scale, were also presented and discussed. The chapter then examined the consequences of market power; particularly in terms of the loss of the consumer surplus and economic inefficiency which underscore how important the estimation of market power is for academics and policymakers.

The early theories for assessing market power were then fully delineated. A general overview of the Structure Conduct Performance (SCP) paradigm was provided along with the relevant developments and criticisms.

This laid the foundation for a discussion of the New Empirical Industrial Organisation methods and the consideration of the disadvantages of the Structure Conduct Performance Paradigm traditionally used in the relevant literature. The seminal work of Bresnahan (1982) and Lau (1982) was described, focusing on the conjectural variations method of estimating a market

power parameter for oligopoly and oligopsony, as well as a synopsis of models used to develop this thesis model. These models estimate a parameter (usually denoted as λ) that corresponds to a degree of market power.

Empirical findings from the academic literature relevant to the food supply chain and milk and dairy products were also presented and the literature based on estimating market power for electricity evaluated.

It is evident that the results of estimating and detecting market power in different stages of the milk industry/food supply chain are heterogeneous and depend on the country and the industry characteristics. Studies also differ based on data frequency and type. Data used usually reflects availability. The studies under review yielded a mixture of findings. The findings vary from the existence of market power at the retail level, higher degree of market power of retailers towards input suppliers than towards consumers, absence of clear evidence of market power and a degree of oligopsony power which depends on the region. Many studies are motivated by concerns at the high market concentration at the retailer level.

Market power studies relevant to the petroleum sector are less frequent than those undertaken in other sectors. The studies estimate modest or limited market power at the downstream level. These findings differ based on country and level of the supply chain. Summing up the above papers; evidence is provided for local market power in retail electricity market, which varies based on the region and limited market power exercise and abuse in case of regulated prices. Evidence of low market power is provided for the UK wholesale electricity markets. The findings of the CMA's investigation into market power in the UK electricity markets partially agrees with other studies. As a whole, market power findings differ in accordance with country, timespan, stage of the chain under investigation, and region.

Chapter 3

Cost Pass Through and Asymmetric Price Transmission

3.1 Introduction

This chapter outlines the theoretical concept of price transmission mechanism or cost pass through and elucidates the links between market power and asymmetric price transmission. It then provides an overview of the relation between oligopsony and cost pass through, and the relation of oligopoly and cost pass through. The chapter also delineates some early models of asymmetric price transmission used in the literature. It then presents both general empirical findings and those specific to the milk, petroleum, and electricity industries. Loy et al. (2016) used the term vertical price transmission and Cost Pass Through (CPT) “to characterize the impact of factor price (cost) changes on downstream product prices” (Loy et al. 2016, p. 184). For the purposes of the present study, the terms ‘cost pass through’ (CPT) or ‘asymmetric price transmission/asymmetric cost pass through’ (APT) are applied to both the pass through of an input price change to the wholesale price, and an input price change to the retail price.

Moreover, the chapter presents empirical findings relevant to the detection of asymmetric price transmission as well as the estimation of cost pass through. Empirical findings relevant to supply chains beyond the remit of the present thesis are also discussed, including financial services, exchange rate pass through, and the airline industry. Finally, the empirical findings relevant to the food supply chain and milk products, and petroleum products such as road fuels and electricity, are presented and discussed.

3.2 Theoretical Aspects Behind Price Transmission Mechanism

Three main aspects of academic literature examine vertical price transmission. These are typically characterised as the magnitude, the speed and the nature of the adjustments through the supply chain, and the various shocks that occur at different stages of the chain. “In the context of this definition, the underlying links across agents at different levels of activity from production to consumption, and vice versa may be summarised in a single set of measures that define the speed and size of the impacts of a shock in prices at one level on the prices up or downstream” (Vavra & Goodwin 2005, p. 4). A first aspect is the effect in terms of size and timing, on wholesale and retail prices of a shock¹⁶ in the commodity market of a chain. A second is the transmission of a price change with a time lag. The speed of adjustment is of

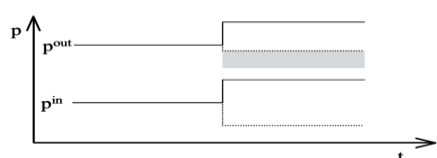
¹⁶ This thesis interprets a positive shock (increase) as a positive change in the input/wholesale price and a negative shock as a negative change (decrease) in the input/wholesale price.

equal importance. Wholesalers, distributors, processors, and retailing firms' actions can affect the speed of a price change transmission along the chain. As Vavra and Goodwin (2005) explain, in the case of high adjustment costs, price signals may be passed with time lags. High transaction costs could also lead to asymmetric price transmission. Thirdly, imperfect transmission occurs in the form of asymmetric reaction to the positive and negative shocks (Vavra & Goodwin 2005). This means that the price change which occurs at one stage of the chain is asymmetric with regards to the change that occurs at a different level of the chain. Thus, studies interrogating price transmission make a distinction between positive and negative asymmetry.

Indeed, Peltzman (2000) claims that any standard economic theory which does not account for APT in a situation is fundamentally flawed. Asymmetric Price Transmission has become increasingly relevant to policymakers due to its inherent social welfare and policy implications. Vavra and Goodwin (2005) purport that one such implication is that the consumers do not gain anything from a decrease in price at the input level or producers might not gain anything from a price increase at the retail level.

According to Meyer and Taubadel (2002), market structure is a main cause of asymmetry, with market power in the upstream level leading to a positive asymmetry. While costs increases exert an increasing and immediate effect in output prices, if costs decrease, firms keep the price higher than the competitive level and this decrease will not be transmitted. The following diagrams are taken from Meyer and Taubadel (2002) and illustrate speed and magnitude within the concept of asymmetric price transmission. The last diagram also illustrates a positive asymmetry since the literature distinguishes between positive and negative asymmetries.

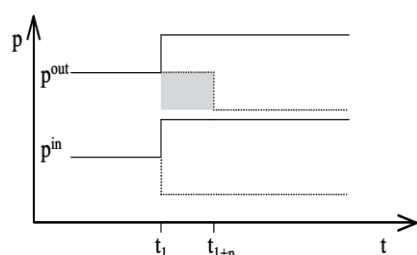
Diagram 1a. Magnitude



Source: Meyer and Taubadel 2002, p. 3

According to Meyer and Taubadel (2002), Diagram 1a illustrates that the magnitude of the response of a price change at the output level to a change in price of the input depends on the direction of this change.

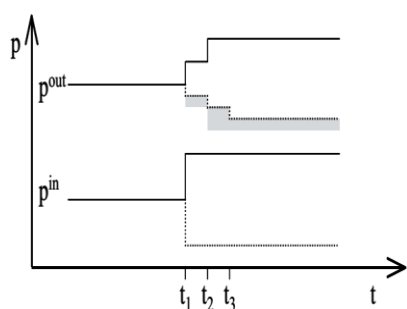
Diagram 1b. Speed



Source: Meyer and Taubadel 2002, p. 3

Diagram 1a demonstrates that the price of output goes up when there is an increase in the price of the input. When there is a decrease in the price of the input, price of output is reduced asymmetrically. Diagram 1b illustrates that when the input price goes down the output price is reduced with a time lag.

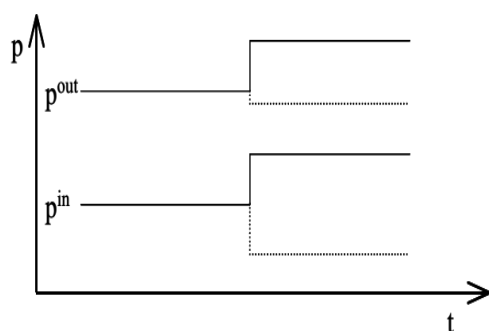
Diagram 1c. Speed and Magnitude



Source: Meyer and Taubadel 2002, p.3

In Diagram 1c, the increase in the price of the input takes two periods (t_1 and t_2) to be fully transmitted to the output, while a reduction in the price of the input takes three periods to be fully transmitted. Both Meyer and Taubadel (2002) and Peltzman (2000) make the distinction between positive APT and negative APT. If the price of the output reacts more fully or rapidly to an increase in price of the input than to a decrease as per diagram 2, the asymmetry is termed 'positive'. 'Negative' asymmetry denotes a situation in which price of the output reacts more fully or rapidly to a decrease in price of the input than to an increase. Meyer and Taubadel (2002) posit negative asymmetry as positive for the consumer creating an increase in welfare, whilst positive asymmetry is negative for the consumer and creates a decrease in welfare. At the same time, Meyer and Taubadel (2002) underline the importance of the distinction between positive and negative asymmetries and their potential welfare effects.

Diagram 2. Positive Asymmetry



Source: Meyer and Taubadel 2002, p.3

3.3 Factors Behind Asymmetric Price Transmission

Several theoretical arguments underpin the asymmetric adjustment of final prices caused by a change in costs at any part of the chain. To begin with, Vavra and Goodwin (2005) note that profit maximizing firms in competitive markets adjust retail prices to changes in input prices symmetrically. This only takes place in the case of no imperfections. Lastly, expectations of government intervention can also lead to asymmetric price adjustments. This is likely to occur when agents believe that price movements in one direction may be more likely to trigger government intervention than movements in another: e.g. the government is likely to intervene if market shocks lower producer prices than if producer prices increase (Vavra & Goodwin 2005; Szoke et al. 2019).

Although these and other explanations have been discussed and demonstrated theoretically or empirically, imperfect competition in the market has been identified or perceived as the main reason for asymmetric price transmission.

3.4 Market Power and Asymmetric Price Transmission

This section outlines another main factor of major concern: that of market power. Retailers seek to maintain their 'normal' profit margin- of the break-even-point, when input price rises. As such, when wholesale prices fall, they try to capture the larger margins that result, however temporarily.

In both cases, the situation cannot last due to facts such as consumer search costs.¹⁷ According to Ivaldi et al. (2003), following completion of highly costly search, profits are reduced, and prices revert to competitive levels.

One robust argument for the link between market power and asymmetric price transmission is that retailers holding market power may abuse it by conducting exploitive practices which culminate in asymmetric price transmission. Collusion is one practice that can take place as a result of oligopolistic market power, and tacit collusion is where agents enter unofficial agreements. In this respect, it is noted that in the case of an increase in the wholesale price, each firm sends a signal to the competitor that it follows the agreement by increasing its retail price, when wholesale prices fall, it adjusts its selling price at a slow rate. The firm does not want to send a signal that it deviates from the agreement. In terms of economic theory behind collusion and how this is linked to market power, this thesis provides the following elucidation drawn from Ivaldi et al. (2003):

- Collusion can take place either in a tacit or an explicit way
- European competition law forbids explicit collusion
- In the case of repeated interaction between firms, tacit collusion can arise
“They may then be able to maintain higher prices by tacitly agreeing that any deviation from the collusive path would trigger some retaliation” (Ivaldi et al. 2003, p. 5)
- For the retaliation to occur, it must have benefits greater than the benefits of sticking to the collusive path

Ivaldi et al. (2003) contend that retaliation occurs when the firm applies a price away from the collusive price path. In the case of retaliation there is restoration of normal profits and competition, and in the case of no retaliation the collusive act continues to occur. In short, tacit collusion is a strategy which is usually applied under the existence of market power and oligopolistic market conditions.

3.5 Asymmetric Price Transmission-Oligopsony, Oligopoly and Cost Pass Through

Following the factors behind asymmetric price transmission, this study introduces the cases of oligopoly and oligopsony and how they relate to the CPT and APT issue.

¹⁷ Ivaldi et al. (2003) describes the consumer search costs in the following way. Consumers search costs are likely to search for lower prices when prices are increasing or are expected to increase increasing competition. Competition will be fierce when margins are tight. If prices are falling consumers decrease their search efforts and reduced market power of consumers increases margins.

“Cost pass-through arises when a business changes the prices of the products or services it supplies following a change in its costs” (RBB 2014, p. 4).¹⁸

This thesis outlines the effects of oligopsony power on price transmission and cost pass through and the effects of oligopoly on price transmission and cost pass through.

3.5.1 The Case of Oligopsony

In the case of oligopsony, there are only a small number of buyers in the market. This translates to limited competition amongst a small number of firms who have the market power to lower the price they pay. In the case of oligopsony of the retailers towards the providers, (for generic purposes, the providers = the wholesalers), then a change in the input cost (increase), will be incompletely passed through to the wholesale price (the price retailers pay to the wholesalers). The same applies for asymmetric price transmission. In the case of oligopolistic power, an increase in the input cost may be transmitted to the wholesale price, at a rate less than the decrease. This is due to the market power which corresponds to an oligopsonistic market structure and draws from the high market shares of the retailers in the demand side of the wholesale product. This gives them a high discretion over the price of the product they buy. They choose the optimum amount of wholesale product aiming to maximizing profit and acting as price makers. The same applies for asymmetric price transmission. In the case of oligopsonistic power, an increase in the input cost may be transmitted to the wholesale price, at a rate less than the decrease.

3.5.2 The Case of Oligopoly

This study analyses the cost pass through for the case of oligopoly, wherein a limited number of firms compete in the market. Cost pass through mechanism under an oligopolistic setting is very similar to cost pass through mechanism under monopoly. Oxera (2004) describes the case of N firms in the market where one experiences a cost reduction, meaning the market price goes down by $1/(N+1)$ of that reduction. This is the case regardless of whether the firm that makes the cost saving has a large or small market share. Moreover, if there is a cost reduction expressed on an average basis, the market price reduces by $N/(N+1)$ of the market price. In the case that the number of firms is 1, the result is like that of a monopoly: the cost pass through is 0.5.

¹⁸ One should distinguish between industry wide pass through and firm specific pass through. This thesis focuses on industry wide pass through. “industry-wide cost pass-through relates to the way prices respond to a cost change which affects all the firms in an industry/market.” (RBB 2014, p. 17). Firm specific pass through “arises because of cost changes that affect one firm only. (Group specific cost pass-through can also occur, where a sub-set of firms is affected)”. (RBB 2014, p. 20).

In the case that many firms exist in the market the cost pass through will be equal to 1: this result is equivalent to that of perfect competition. Following from the above, the cost pass through amount does not depend on the magnitude of the cost change, but rather depends on the number of firms in the market. Under an oligopolistic setting the cost pass through can be partial.

3.6 Types of Asymmetries ¹⁹

In order to determine whether there is an asymmetric relationship between a change in the price of the input and a change in the price of the output, in other words, an asymmetric cost pass through, one should understand that asymmetry has many different meanings and forms. According to Frey and Manera (2007) asymmetric price transmission can be distinguished between LR asymmetries and SR asymmetries. They elaborate that within the short run concept, it is important to focus on the magnitude or intensity of the retail price change in response to the input price change. Within the long run concept, more focus is given to the time of adjustment, as well as the speed. Various econometric models focus on different aspects of the relation between input and output prices or on different types of asymmetries. ²⁰ A broader definition provided by Ofgem (2011), states that the asymmetric price transmission or asymmetric cost pass through can take two separate forms:

- a) *Amount asymmetry*: the rate by which cost changes are transmitted to prices. Cost increases are passed through to prices at a higher rate than the cost decreases. An implication of this is that with cost increasing over time, the gap between prices and costs (margins) would also increase.
- b) *Speed asymmetry*: the speed by which a change in cost is transmitted to the price. Cost increases are passed through to prices quicker than a fall in costs.

¹⁹ Frey and Manera (2007) provide an extensive description of the different types of asymmetries mentioned above. This thesis focuses on the main distinction and definition of the short run and long run asymmetries.

²⁰ Frey and Manera (2007) identify eight types of asymmetries which exist in the literature, namely: “contemporaneous impact (COIA/COIS), distributed lag effect (DLEA/DLES), cumulated impact (CUIA/CUIS), reaction time (RTA/RTS), equilibrium adjustment path (EAPA/EAPS) and momentum equilibrium adjustment path (MEAPA/MEAPS), regime effect (REA/RES) and regime equilibrium adjustment path (REAPA/ REAPS)” (Frey and Manera (2007), p. 354) Detailed descriptions of these different types, are provided in Frey and Manera (2007). This thesis briefly refers to these types within the literature findings. For this thesis the methods used for estimating cost pass through and examining asymmetric price transmission are indicated further below in this Chapter. Asymmetric price transmission estimation focuses on the speed asymmetry, following Nakamura and Zerom (2010).

3.7 Models

3.7.1 Early Basic Asymmetric Transmission Models in the Literature

Frey and Manera (2007) utilise the Engle and Granger (1987) two-step procedure to estimate price transmission. In the first step they estimate the equilibrium relation and tests for cointegration between the prices. The second step estimates an error correction model (ECM). According to Frey and Manera (2007), the Error Correction model is a regression that uses all the variables in first differences, except from the residuals of the first step. The error correction term is interpreted as the deviation from the equilibrium level.

Manning (1991) studies the relationship between the retail price, taxes, and crude oil price of gasoline in the UK. This seminal study applies the error correction model to examine asymmetric price transmission between input and output prices. With respect to describing the following early asymmetric price transmission process this thesis uses the following notation from Frey and Manera (2007):

R_t : retail price

I_t : input price

tx : taxes

Equation:

$$R_t = \varphi_0 + \varphi_1 I_t + \varphi tx_t + \varepsilon_t \quad (3.1)$$

The stationarity of residuals is tested using cointegration tests and in the case of cointegration, the residuals can be treated as an extra explanatory variable in the following ECM (Frey & Manera 2007; Manning 1991):

Equation:

$$\Delta R_t = \Phi + \varphi_t^+ + \sum_{i=0}^s \alpha_i \Delta I_{t-i}^+ + \sum_{j=0}^q \alpha_j^+ \Delta I_{t-j}^+ + \sum_{h=1}^r \beta_h \Delta R_{t-h} + \sum_{m=1}^z \theta_m \Delta tx_{t-m} + \lambda ECT_{t-1} + u_t \quad (3.2)$$

ECT_{t-1} are the lagged residuals from equation 4.1 and φ_t^+ is an intercept dummy which is equal to one if $\Delta I_t > 0$.

Testing the significance of the coefficients α_j^+ and φ_t^+ is the main test for determining any asymmetries in the transmission mechanism of a change in the input price (crude oil) (Frey & Manera 2007; Manning 1991).

If the two terms are statistically significant then there is no asymmetric price transmission. More specifically, it indicates the effects of a decrease or increase of the input price to be the same.

Stock and Watson (1993) propose a different method which requires the long run equilibrium and the adjustment process to be estimated simultaneously. The Stock and Watson method was compared by relevant research to the Engle and Granger method. (Manning 1991 cited in Frey and Manera 2007, p. 382). The Stock and Watson method produced the following model which does not predetermine the equilibrium between, input price and retail price:

Equation:

$$\Delta R_t = \Phi + \varphi_t + \sum_{i=0}^s \alpha_i I_{t-i} + \sum_{j=0}^q \alpha_j^+ \Delta I_{t-j}^+ + \sum_{h=1}^r \beta_h R_{t-h} + \sum_{m=1}^{\theta} \Delta tx_{t-m} + c_1 R_{t-1} - c_2 I_{t-1} + c_3 tx_{t-1} + u_t \quad (3.3)$$

The Engle and Granger method can determine the long run equilibrium. Given equation (4.3) the implied LR solution is:

Equation:

$$R = - \left(\frac{\Phi}{c_1} + \frac{c_2}{c_1} I + \frac{c_3}{c_1} tx \right) \quad (3.4)$$

According to the above, while there is no distributed lag effect in the transmission, there is a significant reaction time.

Another seminal paper which focuses on the US gasoline market between 1986-1992. In this case, it attempts to detect asymmetric price transmission at different stages of the chain. The following relationship between the retail price and the crude oil price is estimated and then is incorporated into an error correction model. (Borenstein et al. 1997; Frey & Manera 2007).

Equation:

$$R_t = \gamma_0 + a_1 I + \varepsilon_t \quad (3.5)$$

Following this brief review the earliest models to detecting asymmetric price transmission, the following section provides a description of recent models of asymmetric price transmission. The various methodologies illustrated below pivot around the vector error correction model: a model widely used in the asymmetric price transmission literature.

3.8 Recent Models of Asymmetric Price Transmission

The following section provides description of the most recent models used for the econometric estimation of the asymmetric price transmission, based mainly on the work of Hassouneh et al. (2012).

3.8.1 The Linear Vector Error Correction Model

As delineated by Hassouneh et al. (2012), the basis of the Vector error correction model is that of two non-stationary, I(1) variables which are time series cointegrated. Therefore as they move towards a long run equilibrium, their behaviour can be represented using a Vector Error correction model. If the two different commodity prices I_t and P_t , are analysed representing prices at different stages of the supply chain, then the corresponding bivariate VECM can be expressed as follows:

Equations:

$$\Delta I_t = \alpha_1 + \alpha_{p1} (\alpha + I_{t-1} - \beta P_{t-1}) + \sum_{i=1}^n \alpha_{11}(i) \Delta I_{t-i} + \sum_{i=1}^n \alpha_{12}(i) \Delta P_{t-i} + \varepsilon_{p1,t} \quad (3.6)$$

$$\Delta P_t = \alpha_2 + \alpha_{p2} (\alpha + I_{t-1} - \beta P_{t-1}) + \sum_{i=1}^n \alpha_{21}(i) \Delta I_{t-i} + \sum_{i=1}^n \alpha_{22}(i) \Delta P_{t-i} + \varepsilon_{p2,t} \quad (3.7)$$

where α and β are the parameters of the cointegration vector, $\varepsilon_{p1,t}$ and $\varepsilon_{p2,t}$ are white noise disturbances that may be correlated with each other $\alpha_1, \alpha_2, \alpha_{11}(i), \alpha_{12}(i), \alpha_{21}(i)$ and $\alpha_{22}(i)$ are dynamic short-run parameters, and α_{p1} and α_{p2} are parameters that measure the rate of price adjustment to disequilibria from the long-run cointegrating relationship. This long-run relationship is given by the expression:

$$\alpha + I_{t-1} - \beta P_{t-1}$$

If this linear combination of the I(1) price variables are stationary, then all the variables in 3.7 are stationary and the VECM can be used to demonstrate the long-run relationship between the prices and of the short-run dynamics that correct deviations from this long-run relationship.

If $\alpha + I_{t-1} - \beta P_{t-1}$, is not stationary (i.e. the prices are not cointegrated), then (3.7) contains terms of different order of integration and the specification is not valid.

3.8.2 Non-Linearity in Vector Error Correction Model

Early empirical analysis of asymmetric price transmission involves the use a variable splitting technique. The techniques do not consider the non-stationarity of data as it is established in the literature well before the cointegration techniques. As a solution, later research offset this by applying the splitting technique into an error correction model. The result of this is the asymmetric Vector error correction model which is represented by the following equations. Once again, two different commodity prices are analysed as I_t and P_t . (Granger & Lee 1989; Houck 1977; Wolfram 1971; Ward 1982 cited in Hassouneh et al. 2012, p. 10):

Equations:

$$\Delta P_{1,t} = \alpha_1 + \alpha_{p1}^- v_{t-1}^+ + \alpha_{p1}^- v_{t-1}^- + \sum_{i=1}^n \alpha_{11}(i) \Delta P_{1,t-i} + \sum_{i=1}^n \alpha_{12}(i) \Delta P_{2,t-i} + \varepsilon_{p1,t} \quad (3.8)$$

$$\Delta P_{2,t} = \alpha_2 + \alpha_{p2}^+ v_{t-1}^+ + \alpha_{p2}^- v_{t-1}^- + \sum_{i=1}^n \alpha_{11(i)} \Delta P_{1t-i} + \sum_{i=1}^n \alpha_{22(i)} \Delta P_{2,t-i} + \varepsilon_{p2,t} \quad (3.9)$$

An F-test is used to test the null hypothesis of symmetry $\alpha_{pi}^+ = \alpha_{pi}^-$, $i=1$ and 2 . Hassouneh et al. (2012) posit that under the AVECM there is one regime in the case that the error correction term is greater than 0, and another regime in the case that the error correction term is lower than zero. If the model considers variables such as input prices and output prices, the existence of a positive error correction term shows the marketing margin is above long run equilibrium. In the case of a negative error correction term the marketing margin is below long run equilibrium. This ‘rockets and feathers’ hypothesis then is equivalent to the hypothesis that positive ECT values are corrected more rapidly than negative ECT values.

3.8.3 Threshold Vector Error Correction Model

In order to engage with a more advanced VECM model, this thesis provides an overview of the threshold VECM. Due to information and search costs, in the case of a rise in the price, consumers defect to a different store only if the price increase is above a certain threshold. Every time the error correction term exceeds a certain threshold value then, asymmetric price transmission occurs. Goodwin and Holt (1999) are the first to allow for threshold effects in the vertical price transmission using a Threshold Vector Error Correction Model (TVECM).²¹

3.9 Cost Pass Through Estimation and Asymmetric Price Transmission

A separate strand of the literature gives less emphasis to detecting asymmetric cost pass through than to estimating the actual amount of cost pass through. A series of such studies not only estimate cost pass through, but also adapt their empirical estimation to test for asymmetric price transmission: i.e., to test for asymmetries in the cost pass through mechanism (Durevall 2018; Nakamura & Zerom 2010).

Following De Bruyn et al. (2015), examples of studies that use a cost-price approach to estimate cost pass through, explain the price of an output by the prices of its input components. De Bruyn et al. (2015), provide the following as the form of the cost-price approach which is usually applied:

$$P_t^j = \alpha^j + \beta_1 P_t^C + \gamma_2 P_t^L + \sum_n \gamma_{3n} P_{n,t}^E + \sum_q \gamma_{4q} P_{t,q}^M + \gamma_5 P_t K + \varepsilon_t^j \quad (3.10)$$

²¹ Hassouneh et al. (2012) provided an extensive description of the threshold VECM model as well as threshold autoregressive processes.

Where P refers to the prices, and the suffix j refers to a product, C, L, E, M and K represent Carbon, Labour, Energy, Materials and Capital. γ_1 is an estimation of the amount of pass through of CO2 costs.

A leading paper in the cost pass through approach followed by this study is that of Nakamura and Zerom (2010). The main empirical model which estimates cost pass through and is used in this study is as follows:

$$\Delta \log R_{jm}^1 = a + \sum_{k=1}^G b_k \Delta \log I_{t-k} + \sum_{k=1}^4 d_k q_t + \varepsilon \quad (3.11)$$

The dependent variable in the above model is the log retail price change of product j in market m, or the log wholesale price change of product j in market m, while the independent variables are log commodity cost index change and “ q_t is a quarter of the year dummy, b_k and d_k are parameters and ε is a mean zero error term” (Nakamura & Zerom (2010), p. 8). The study estimates the cost pass through in the US coffee industry by using both double log and level specifications. More specifically, they estimate the cost pass through coefficients for the input to the wholesale price and the input to the retail price. The following similar model is adopted to estimate the cost pass through of a change in the wholesale price to the retail price:

$$\Delta R_{jmt} = \alpha^r + \sum_{k=0}^2 \beta_k \Delta P_{jmt-k} + \sum_{k=1}^4 \gamma_k q_k + \varepsilon \quad ^{22} \quad (3.12)$$

In the above model α^r , β_k^r and γ_k^r , are parameters and ε is a mean zero error term. This thesis estimates the above two models using time series data. Some studies that estimate cost pass through use similar specifications to incorporate into their analysis the concept of asymmetric price transmission. The examined issue is whether the prices adjust asymmetrically to cost changes depending on whether there is a cost increase or a cost decrease. Asymmetry is tested using the same log specifications except those separate terms are included for commodity cost increases and decreases in the current period. A similar approach to Nakamura and Zerom (2010) is attempted by the CMA in 2016. The first part of their analysis involves estimating the rate of pass-through to the standard variable tariffs of electricity. The second part involves estimating the rate of pass through to non-standard tariff prices. As a main method, the CMA considers the following equation, where R represents the price and t represents the month:

$$\Delta \log R_t = a_k + \sum_{l=0}^L \beta_1 \Delta \cos t_{t-1} + \beta_\mu \text{controlvariables} + \varepsilon_t \quad (3.13)$$

²² For equations 3.11-3.12 this thesis incorporates a variable I^+ and a variable I^- , that correspond to a positive change in the input/wholesale price and a negative change in the input/wholesale price. Following Nakamura and Zerom (2010), this assists in the examination of asymmetric price transmission within distributed lag models.

Table 3.1: Literature on Asymmetric Price Transmission and Cost Pass Through

	Author	Sector/Product	Country	Period	Stage	Method	Findings
Milk Sector	Serra and Goodwin (2002)	Dairy	Spain	1999-2000	Farm-Retail	TECM	APT
	Von Cramon Taubadel and Meyer (2003)	Lettuce and Chicken	Germany	1995-2000	Wholesale-Retail	TECM	APT ²³
	Hassouneh et al. (2013)	Apples	Slovenia	2000-2011	Producer-Retail	TECM	APT
	Hassouneh et al. (2015)	Various products	EU countries	2000-2011	Input-Wholesale	TECM	APT- depends on product and country
	Rezitis & Rezitis (2011)	Dairy Sector	Greece	1989-2009	Producer-Consumer	TVECM	APT
	Rezitis & Tsionas (2019)	Food supply chain	European countries	2005-2016	Farmgate-processor Processor to retail ²⁴	PVECM	APT
	Kharin (2018)	Milk	South Africa	2018	Farmgate-processor Processor to retail	VECM	APT
	Villanueva & Orosco (2019)	Milk	Mexico	1990-2016	Farm-retail	AVECM	APT
	Leibtag et al. (2007)	Coffee	US	2000-2004	Input-wholesale Wholesale-retail	DLMS	APT
	Nakamura and Zerom (2010)	Coffee	US	2000-2004	Input-retail Input-wholesale	DLMS	APT
	Durevall (2018)	Coffee	US	2000-2015	Input-Retail	DLM	Incomplete CPT
Road Fuels Sector	Bacon (1991)	Gasoline	UK	1982-1989	Oil-retail	ECM	APT
	Manning (1991)	Gasoline	UK	1973-1988	Input-retail	ECM	APT
	Borenstein et al. (1997)	Gasoline	US	1986-1992	Input-retail	ECM	APT
	Deltas (2008)	Gasoline	US	1988-2002	Input-retail	ECM	APT
	Bermingham and O'Brien (2011)	Petroleum and Diesel	UK/Ireland	1985-2003	Input-retail	TAR	No APT
	Karayiannis et al. (2015)	Gasoline	EU countries	2000-2011	Input-retail	ECM	No APT
CPT	Pesaresi et al (2014)	Gasoline	UK	2000-2012	Crude oil-Retail price	ECM	NO APT
Electricity Sector	Fabra and Reguant (2014)	Electricity	Germany	2004-2006	Emission-Wholesale Wholesale -retail	DLM	Almost complete CPT
	Duso and Szucs (2016)	Electricity	Germany	2007-2014	Emission-Wholesale	ECM ARDL	Incomplete CPT
	Dagoumas and Polemis. (2018)	Electricity	Greece	2014-2017	Emission-wholesale	DLM	Incomplete CPT
	Guo and Gissey (2019, 2021)	Electricity	UK	2004-2010	Input-Wholesale	ECM	Complete CPT

²³ Apt occurs in the case that aggregate, and not individual data are used.

²⁴ For the price paid from retailer to processor, this thesis use 'Processor Price' or producer price. It corresponds wholesale price.

3.10 Specific Empirical Work Cost Pass Through and Asymmetric Price Transmission

3.10.1 Empirical findings With Regards to Cost Pass Through and Price Asymmetries for the Food Supply Chain and Milk and Dairy Products²⁵

This section provides an overview of more recent (post 2000) findings on asymmetric price transmission and estimation of cost pass through which are directly relevant to the food supply chain and milk industry. A review can be found in the above table, 3.1.

Serra and Goodwin (2002) examine the price transmission of farm prices to retail prices of dairy products in Spain using monthly data and the threshold error correction model for the period 1999-2000. The findings indicate that a unit change in the farm price is asymmetrically passed to a change in the retail price.

Von Cramon-Taubadel and Meyer (2003) investigate the price transmission of the wholesale price to the retail price for German lettuce and chicken for the period 1995-2000. They conclude that in the case that individual data are used, asymmetric price transmission exists, and in the case that aggregated data are used there it does not.

London Economics (2004) employs a variation of the von Cramon-Taubadel (2007) error correction model to determine an asymmetric price transmission of a change in the producer price to the retail price of Danish carrots, UK bread, and UK lamb. Their findings contradict those of von Cramon-Taubadel (1998) in not establishing asymmetric price transmission.

Hassouneh et al. (2013) utilise a threshold model to establish asymmetric vertical price transmission of apple producer prices in Slovenia to the consumer prices for the period 2000-2011. Similarly, Hassouneh et al. (2015), analyse the price transmission mechanism for various commodities for countries of the Euro area.

The difference with Hassouneh et al. (2013) is that their study ringfenced multiple countries in order to demonstrate how the degree of asymmetric price transmission varies between countries and products.

Moving more specifically to findings relevant to milk and dairy products, Rezitis and Rezitis (2011) are the first to attempt to analyse price transmission between producer and consumer prices in the Greek milk market. To this end, they apply the Threshold Vector Error Correction model (TVECM) to the 1989-2009 data of the Greek National Statistical Service. TVECMs

²⁵ Empirical findings with regards to APT and CPT are summarised in Table 3.1.

are a relatively recent addition to the techniques for estimating asymmetric price transmission and only a few studies have applied this approach to the dairy market. Their findings confirm that in the summer of 2010 the increase in the price of inputs, more specifically feed costs, was imposed on cow milk producers. This became evident from the fact that both producer and consumer prices remained unchanged. More recently Rezitis and Tsionas (2019) use a multivariate panel vector error correction model (PVECM) to elicit the evidence of positive asymmetric price transmission in the European food supply chain for the 2005–2016 period. The paper examines the price transmission between farm-gate price to processor price, and processor price to retail. The findings vary based on the product, the country and the existence of positive asymmetric transmission is argued to create negative welfare effects for the consumer.

Amado et al. (2010) examine the asymmetric price transmission mechanism for milk products in Austria using a TVEC (Threshold Vector Error Correction Model) to examine the asymmetric price transmission mechanism between producer and consumer prices of dairy products in the region. The findings afford evidence asymmetric price transmission in terms of both size and speed of adjustment. These align with Rezitis and Tsionas (2019) identification of asymmetric price transmission in the food supply chain.

The three studies above follow threshold VECM methodology to establish the existence of asymmetric price transmission. In a similar study on price transmission analysis of pasteurised liquid milk in South Africa, Kharin (2018) use a VECM to provide evidence that retailers react faster to price increases of processor prices, while processors react faster to price increases of farm-gate prices relevant to price decreases. As such, the study confirms that the positive asymmetric price transmission which creates negative welfare effects for consumers.

Villanueva and Orosco (2019) likewise undertake econometric analysis using monthly time series of milk prices in Mexico for the period between 1990 to 2016. To this end, they use an Asymmetric Vector Error Correction model (AVECM) to obtain evidence of asymmetric price transmission from the farm price to the retail price.

In the context of the UK dairy supply chain, the present study refers to findings of one of the most recent studies with regards to asymmetric price transmission. Stubbleley et al. (2018) is the most recent survey undertaken with regards to price transmission between producer and retailer price in the UK milk market, and based on a time series dimension for the period 1988-2016. The study tests for cointegration between producer and retailer price, and applies an error

correction model to establish any possible degree of asymmetric price transmission. The study finds evidence of cointegration and that the prices the retailers receive react slowly to a spike in producer price.

As it is evident from Table 3.1, considering the literature on food supply chain and the milk sector, more studies indicate that asymmetric price transmission exists. Since the UK's milk sector is characterised by high market concentration at both retailers and processor's level, this author expects that similar findings will be established for the UK's milk sector.

In summary, most of the reviewed studies relevant to asymmetric price transmission in the food supply chain or supply chain of dairy products reveal the existence of asymmetries. However other earlier studies such as London Economics (2004) reveal that no asymmetries exist. While the findings vary based on study, product, and country, there is general consensus that asymmetric price transmission exists between farmer to processor price, and processor to retail price. There is also evidence for a slow adjustment of UK retailer price to a change in producer price. However, no evidence exist on the existence of asymmetric price transmission in the UK's milk sector, something which provides grounds for one of the objectives of this study.

Another branch of the literature uses costs and prices to estimate cost pass through. An example of such a study is Leibtag et al.'s (2007) analysis of cost pass through for the coffee market in the US. The report uses unique data from the U.S. coffee industry and find that a change in commodity costs affects retail coffee prices. Leibtag et al. (2007) findings help to provide insights into other industries by demonstrating how changes in the commodity costs are passed through to consumer and producer prices across the board. Market level average retail prices are collected from Nielsen Scan Track, and market level wholesale prices obtained from Promo Data. They find that when green coffee prices go up by 10%, manufacturer and retail prices increase by 2% in the current quarter. If the cost change remains persistent, it is incorporated into manufacturer and retail prices approximately change cent-for-cent after a commodity cost change. Regression analysis is used to estimate the impact of change in commodity prices on retail and manufacturer prices and are undertaken for both double log specifications as well as levels specifications. Moreover, instrumental variables methodology is applied to estimate the cost pass through between the wholesale prices and the retail prices. The study uses similar specifications to test whether prices respond asymmetrically to cost increases and decreases.

Nakamura and Zeroms' (2010) study uses data for the coffee average retail prices from AC Nielsen and wholesale price data and coffee input commodity costs data from Promodata who

gather data on the manufacturer prices for packaged foods from grocery wholesalers. They estimate the cost pass through of commodity input costs to wholesale coffee prices and retail coffee prices in the US for the period 2000-2005. Distributed lag models are used in levels as well as in logs. They also check on the asymmetries of the cost pass through by running similar regressions; adding two terms, one for the increase in commodity costs and one for the decrease in commodity costs correspondingly. Lastly, they use an IV regression to check for the pass through of the wholesale prices to the retail prices. Commodity cost and its lagged values are used as instruments. The results reflect a significant degree of incomplete pass-through in percentage terms. The estimated long-run pass-through of wholesale to retail price is 0.252 and 0.262 for the input cost to the wholesale prices. In other words, a 1% increase in commodity costs eventually leads to only about a quarter of a percent increase in coffee prices. The study finds no evidence of the so-called ‘rockets and feathers’ asymmetric price transmission, but concludes that prices respond to commodity costs with delay. For both retail and wholesale prices, the greater proportion of the adjustment to a cost change is found to occur within the period after the change.

Durevall (2018), attempts something similar to Nakamura and Zerom (2010) for the Swedish coffee market. The cost pass through is estimated to be 0.69. According to Durevall (2018) the pass-through rates are dispersed and varied from 0 to slightly above 1. The methods applied are those of the distributed lag model and the error correction model.

Evaluating the above cost price studies, it is evident that incomplete pass through is estimated on the input to the wholesale price and on the wholesale price to the retail price. Insufficient evidence is provided to establish asymmetric price adjustment. With reference to table 3.1, In terms of the estimation of the cost pass through in the milk supply chain, the literature that uses cost price approach for milk products in the UK is limited to scarce. Distributed lag models are used to address this study questions. To the best of this author’s knowledge, no other study exists that applies Leibtag et al. (2007) and Nakamura and Zerom (2010) method to estimate CPT for the milk sector.

An application of the cost price approach adopted by some studies like Nakamura and Zerom (2010) and Dagumas and Polemis (2018) is therefore an addition and a contribution to the existing empirical studies. The choice of the cost price approach and distributed lag models as well as the 1996 to 2020 period under investigation, provide a different methodological lens for the estimation of the cost pass through in the UK dairy sector.

Market power as a cause of asymmetric price transmission market power is linked to imperfect vertical price transmission (Lloyd et al. 2006; McCorriston et al. 1998). Peltzman (2000), claims that the empirical establishment of market concentration is a significant factor asymmetric price transmission. As previously discussed, Lloyd et al. (2006), empirically establish that market power can lead to asymmetric price transmission, using evidence from the UK beef supply chain. Testing for market power in agricultural markets and other industries goes way back in the literature and the impact of imperfect competition on price transmission have fuelled debates on whether price asymmetry caused by market power is positive or negative.

Bailey and Brorsen (1989) insist that there is no straightforward explanation of whether market power leads to a positive or negative asymmetric price transmission, while Karrenbrock (1991) claim that market power results to positive asymmetry. Hence it is expected that increases in input prices which reduce marketing margins will be passed on to the output price faster and more completely than reductions due to market power. Ward (1982) asserted that market power can lead to negative asymmetry since oligopolists believe they will lose market share if they pass on an increase in the input price to the retail price. Therefore, positive and negative asymmetric price transmission are both based on the market structure. Based on Ward (1982), another factor which might prevent positive asymmetry is the perishability of products. In cases where the increased input price is passed on to the retail price then, a reduction in sales might lead to spoilage.

Bailey and Brorsen (1989) claim that market power led to positive asymmetry and therefore they consider firms facing a kinked demand curve which is either convex or concave to the origin. If the firm believed that no rival would increase the price after an increase in the input price and all rivals would decrease the price after a decrease in the price, then negative asymmetry occurs. In the case that the firm believes that all rivals would increase their price, and none would match a price decrease then positive asymmetry occurs. “Hence it is not clear a priori whether market power will result at positive or negative asymmetry” (Bailey & Brorsen 1989, p. 247).

Concluding the discussion on market power and asymmetric cost pass through, this thesis refers to the development of using cost pass through as a test for market power detection. Plessy and Bentham (2019) referred to the fact that the pass through can be estimated to be greater than 1. As previously mentioned, ‘over shifting’ can be attributed to a very convex demand curve.

However, there are other cases where over shifting occurs and attributed to affording market power. Thus Plessy and Bentham (2019) suggest when over shifting is estimated, it may can be used as a diagnostic tool for market power. The present study does not explore this since its stated objective is to estimate market power using the detail-oriented and more accurate NEIO methods.

This section concludes with a brief evaluation of the methods utilised in the current literature. Loy et al. (2016) observe that the use of unit roots, integration tests, and error correction is prominent in the early empirical work for asymmetric price transmission, while price transmission studies using bivariate price regressions comprise a significant part of the literature. Loy et al. (2016) refer to Palaskas (1995) as an indicative study which seeks to determine possible cointegration between the input and output prices, whether the change in the input price is fully transmitted to the change in the output price, and the speed of adjustment. With the use of the reduced form equations, cointegration and short run asymmetric price transmission are detected. However, Loy et al. (2016) note that bivariate regression has serious limitations since pass-through does not generally equal pass-back. “While causality tests can be brought to take into account this issue, what is of question is the equating of perfect price transmission with unit elasticity between retail and producer” (Loy et al. 2016, p. 10).

While critically evaluating the early methodologies used for asymmetric price transmission, it is clear that the researchers remain mindful of the various factors which can determine the results of these studies. Indeed, Loy et al. (2016) present Asymmetric Price Transmission testing as something of a methodological minefield²⁶ and stress that despite its wide-spread use in the agricultural economics literature, the ambiguity of the results creates grounds for criticism. As research demonstrates, co-integration restricts asymmetry to the speed rather than the size of adjustment, since in the case of asymmetries in size, fluctuations in prices would force prices apart over time, violating the co-integration property (Meyer & von Cramon Taubadel 2004 cited in Loy et al. 2016, p. 12). Moreover, APT is typically undertaken in the bivariate setting and is therefore subject to the problems discussed above.

One alternative approach that accommodates all the above criticisms and considerations is Nakamura and Zerom’s (2010) estimate of cost pass through using distributed lag models.

²⁶ Six methodological approaches can be found in Frey and Manera (2007).

This model also provides an idea on asymmetric price transmission by incorporating a variable that represents the percentage change in cases of increase of the input price and another that represents the percentage change in cases of decrease of the input price. This approach does not rest on formal cointegration tests since the differences of the variables used are expected to be stationary.

3.10.2 Existing literature, Empirical Findings and Leading Papers with Regards to Petroleum Products and Price Asymmetries

The issue of whether price asymmetry really exists in the fuels markets has been analysed in numerous studies; the findings of which depend on the timespan, methodology, country of study, and the nature of the fuel. This section provides an overview of the empirical findings of the literature with regard to asymmetric price transmission in the petroleum products industry including several seminal papers and the findings on estimating cost pass through for the petroleum products sector.

Bacon's (1991) renowned "rocket and feathers" hypothesis examines and establishes the existence of asymmetric price adjustment in the UK market for gasoline for the period 1982-1989 based on fortnightly data published in the "Petroleum Times". The study provides enough evidence to support that asymmetric price adjustment occurs using non-linear least squares. Based on the findings, the retail price of gasoline reacts asymmetrically to a change in the international oil price. Manning (1991) similarly estimates an Error Correction Model for the period 1973-1988 which affords evidence for the asymmetric price transmission of input prices to the retail gasoline prices in the case of the reduction in the input price of crude oil, as well as in the case of an increase in the input price. While Manning's study covers a shorter duration, the findings converge with those of Bacon in demonstrating that asymmetric price transmission exists in the UK gasoline market.

Following these initial investigations, another influential paper is that of Borenstein et al. (1997). This study uses the error correction model to examine the hypothesis of rockets and feathers in the US gasoline market for the period 1986-1992. Their findings concur with Bacon (1991) and Manning (1991) and provide sufficient evidence to demonstrate an asymmetric price transmission between input cost prices and retail prices. In fact, they confirm that in the case of an increase in the price of crude oil, the retail price of gasoline increases like a rocket, and in the case of a decrease in the price of crude oil, the price falls like a feather.

Deltas (2008) also examines asymmetric pass through in the US retail gasoline market and applies the model used by Borenstein et al. (1997) for the period 1988-2002. His findings correspond with the findings of the above three studies: the retail price of gasoline goes up like a rocket and faster in the case that crude oil price goes up, and goes down like a feather in the case that crude oil price goes down. Furthermore, they provide evidence that asymmetric price transmission is linked to the retailer's market power. It is worth noting that as an addition to the other seminal papers, the model is estimated for 48 different states, and indicates that in the low margin states there is higher speed of adjustment to an increase in costs.

Grasso and Manera (2007) employs asymmetric ECM, autoregressive threshold ECM, and ECM with threshold cointegration, in order to compare the 1985-2003 gasoline markets of France, Germany, Italy, Spain and UK using gasoline spot prices and crude oil prices as the main variables of interest. All their estimations indicate asymmetric price transmission and each model provides different results for different countries. Their study diverges from the previous studies outlined here, in that their findings vary according to the model used; thereby indicating that the source of asymmetry occurs in either the second or the last stage of the chain.

In stark contrast to the findings of all of the above, Bermingham and O'Brien (2011) ultimately provide evidence to reject the rockets and feathers hypothesis, since their use of a TAR (threshold autoregressive) model fail to provide sufficient evidence that the Irish and the UK petroleum and diesel markets are subject to asymmetric pricing. Considering their conclusions, this review presents the empirical evidence provided by more recent papers relevant to asymmetric price transmission for the petroleum products, and more specifically, for road fuel products such as gasoline.

Karagiannis et al. (2015) examine the nature of price adjustments in the gasoline markets of Germany, France, Italy and Spain based on data obtained from the EIA and EUROSTAT. Their study does not provide enough evidence to establish the phenomenon of rockets and feathers for the period of 2000-2011.

Since gasoline retail prices do not react asymmetrically to an increase or a decrease of the price of crude oil, the findings of Karagiannis et al. (2015) support those of Bermingham O'Brien's (2011).

Using an ECM, Morris et al. (2017) examine price asymmetries from the wholesale price of gasoline to the retail price of gasoline in the US, with the use of daily data from 2011-2012.

Their study provides evidence of price asymmetry from the wholesale price of gasoline to the retail price and supports the findings of the previous studies.

In summary, the mixed findings of these studies highlight the inconclusions with regards to the existence of asymmetric price transmission in the petroleum products sector. While many studies provide evidence for the asymmetric price transmission in the final or distribution stage of the supply chain, a few notable exceptions do not (Bermingham & O'Brien 2011; Karagiannis et al. 2015).

Since in addition to the academic literature, several competition authorities have examined asymmetric price transmission for petroleum products such as road fuels and gasoline, this section also presents the findings of Bundeskartellamt, the German Competition Authority, the Spanish Competition Authority and the Office of Fair Trading (OFT).

The Bundeskartellamt's 2011 Fuel Sector Inquiry examines all the stages of the road fuel sector in Germany and finds compelling evidence of asymmetric price transmission at the retail level. The phenomenon of rockets and feathers is supported by the econometric evidence. Similarly in 2012, Comisión Nacional de la Competencia (CNC) establishes asymmetric price transmission from the wholesale price to the retail price in the road fuels sector in Spain to support the rockets and feathers hypothesis.

In order to test whether asymmetric price transmission exists in the UK road fuels sector, the OFT undertakes an econometric analysis by using data on crude oil prices, ex-refinery fuel prices, and pump prices in the UK in 2013. Firstly, they analyse the phenomenon at a national level using weekly data for the period 2000-2012 for both petrol and diesel. They then proceed to analyse the phenomenon at a local level from different local areas from 2011-2012. Their analysis finds no asymmetric price transmission in the UK road fuels sector. While this contradicts the findings of the German and Spanish competition authorities, it does concur with those of Bermingham and O'Brien (2011).

The most recent UK study in the literature is Pesaresi et al.'s (2014) evaluation of whether there is asymmetric cost pass through of a change in the input cost along the supply chain for road fuels. (2014). Following Chesnes (2012), Pesaresi et al. (2014), estimate an error correction model for petrol and diesel for two levels in the supply chain, ex-refinery and retail on weekly price series of crude oil ex-refinery, and retail diesel and petrol prices 2000-2012.

They provide evidence that a significant part of shocks in the price of crude oil is transmitted to the price of refined products within two weeks from the time of the shock. According to Pesaresi et al. (2014) the pass through is found to be slower between ex-refinery and retail prices; taking approximately five weeks to occur. The presence of asymmetric pass through is rejected for both levels of the supply chain for road fuels for the period 2000-2012.

They do not find sufficient evidence of rockets and feathers to justify an investigation by the CMA. This confirms the finding of the OFT investigation (2013).

Following the above discussion relevant to asymmetric price transmission findings from the academic literature and competition authorities, this section presents findings of studies that do not focus on finding potential asymmetries, but rather on the actual estimation of the cost pass through between input prices to wholesale prices or wholesale to the retail prices or input to retail prices.

Meyler (2009) uses an error correction model to estimate the cost pass through of oil spot prices to gasoline and diesel prices in the Euro area and concludes the pass through of input prices to gasoline and diesel prices is complete within two to three months. Log specifications indicate incomplete pass through whilst levels specifications indicate complete pass through. The study further concludes that 90% of oil price pass through occurs at a fast speed and within three to five weeks from the input change. As such, it highlights the fact that spot prices are used for refined prices rather than crude oil prices which improves the fit of the estimated models.

Alexeeva-Talebi (2010) use a VECM to provide evidence that refineries can pass through the prices of EUAs (emission allowances) completely to consumers for the period of 2005-2007. The study also provides evidence that the reaction of petrol prices to EUA price changes are heterogeneous among EU member states.

The paper employs four weekly time series for the period September 16, 2005 to March 22, 2007. Likewise, De Bruyn et al. (2015) estimate cost pass through for the refineries sector using a VECM, indicating that complete cost pass through is likely for products of the refineries sector. They also provide evidence that pass through can be higher than 100%. One study examines the cost pass-through of carbon emission prices to the retail prices of various UK products, including diesel. An autoregressive distributed model provides evidence for a cost pass through of 0-100%. The period under study is 2001-2007, and in some cases a pass through in excess of 100% is estimated (Oberdorfer 2010 cited de Bruyn et al. 2015).

Using a VECM, Alexeeva-Talebi (2011) also estimates how the pass through of EU allowances to retail prices in the period 2005-2007. According to the study the cost pass through of EUA prices towards petrol prices is estimated at approximately 0.01-0.09% across Europe. The pass through is therefore estimated to be incomplete at a significant degree.

The above is among the rare studies which examine the pass through of EUAs for petroleum products, since most studies aim to examine this for the electricity sector. As de Bryun et al. (2015) notes, unlike Alexeeva-Talebi (2010), Oberdorfer (2010) also takes into consideration heteroskedasticity and asymmetries in the cost pass through.

In summary, these studies demonstrate mixed findings with regards to the asymmetric price transmission in the petroleum products sector, wherein asymmetric price transmission is only found in the last stage or distribution stage of the supply chain. The studies also indicate high degrees of cost pass through as well as evidence for complete pass through of input prices or cost of carbon emissions. Insufficient evidence is provided to establish the phenomenon of rockets and feathers or asymmetric price transmission in the UK context. The commonality of these studies is that they use VECM to estimate APT and CPT. This thesis proceeds to apply an approach that has not been used before within the UK's Road fuels context and this would give a more direct estimate of the amount of CPT. The mixed findings provide grounds for examining CPT and APT within the UK road fuel sectors as there is no apriori consensus on the result of the study, despite expectations of incomplete cost pass through and APT.

There is also an evident disconnection between the frequency of time series used in the study and its final conclusions. With reference to Bermingham and O'Brien (2011), the absence of asymmetry has already been identified with daily data and weekly data as well as with monthly data. The same applies to testing for the presence of asymmetry.

It is clear from the above that literature on estimating cost pass through as well as asymmetric price transmission for road fuels in the UK is scarce. Therefore, the present study represents an addition to Pesaresi et al.'s (2014) efforts to interrogate the data for an extended timespan.

3.10.3 Existing Literature, Empirical Findings and Leading Papers with Regards to Cost Pass Through and Price Asymmetries for Electricity

The following section presents an overview of the literature relating to the estimation of cost pass through of input costs or carbon emissions to electricity wholesale or retail prices, as well as asymmetric price transmission.

Sijm et al.'s (2006) empirical estimation of the CO₂ cost pass-through for Germany and the Netherlands establishes a cost pass through rate of 60-100%. More recently, in 2016, Duso and Szucs (2016) analyze the pass through of network charges and electricity wholesale prices to retail tariffs in the German Electricity Market: highly disaggregated data used-on energy retail prices obtained from the German price comparison site, Verivox. Their study concludes that the extent of pass-through varies across firms depending on such factors as structural differences, degree of vertical integration, geographical scale, ownership structure objectives, and downstream market power. Thus it should differ in different segments of the markets reflecting consumer willingness to switch suppliers. Their findings indicate 40% pass through of wholesale prices and 50% of network charges. Higher competition was linked with higher pass through.

The study furthermore establishes the asymmetric price transmission of emission prices to electricity future prices in Germany through application of both an ECM and ARDL model. They conclude that the price transmission is asymmetric and the cost pass through greater for independent firms than operators which are vertically integrated. Based on Duso and Szucs (2016) reasoning, market power among electricity generators can be the potential explanation for this asymmetric pricing.

More relative to cost pass through estimation can be found in the 2014 study of Fabra and Reguant, which examine the pass through of emission costs to the wholesale electricity prices in the Spanish electricity market. Focusing on the period January 2004-February 2006, they follow the standard cost pass through regressions but also undertake estimations with an instrumental variables' methodology. They estimate the pass through of a marginal increase in emission costs on electricity wholesale prices. With their dependent variable, the hourly price of electricity and their main independent variable the marginal emission costs, they conclude that emissions costs are almost fully passed on to electricity prices. With various specifications applied for added robustness, their cost pass through estimate is approximately 0.862. As such, they demonstrate that emission costs are almost fully passed through to electricity prices. A very low elasticity of demand is a possible explanation behind their findings. Fabra and Reguant (2014) contradict the findings of Duso and Szucs (2016) in providing evidence for incomplete pass through from emission costs to electricity future prices.

A very recent contribution in the literature of carbon cost pass through to wholesale electricity prices which supports Fabra and Reguant (2014) is that of Dagoumas and Polemis (2018). This

study examines the carbon cost pass through mechanism in the Greek electricity market, and like Nakamura and Zerom (2010), use a distributed lag model for the standard cost pass through estimation. The study utilises micro level panel data spanning January 2014-December 2017. Their dependent variable is the change in wholesale electricity prices on each hour, and the independent variable is the change in the carbon emission price from $t-1$ to day t and the corresponding lagged values.

Initially fixed effect and random effect estimators are used. In order to consider potential heteroskedasticity and correlation between residuals as well as endogeneity of the emission price, Dagoumas and Polemis (2018) estimate extra specifications using the instrumental variables methods, and undertake estimations for linear specifications as well as log linear ones. OLS estimations provide evidence for an incomplete long run cost pass through of 0.475 from the log linear specification and 0.433 from the level specification. What is more; when they employ the instrumental variables methodology, they provide evidence for more than complete pass through: a 1% increase (decrease) in emission prices causes a 1.08% increase (decrease) in wholesale prices. The findings of the IV methodology, partially support the findings by Fabra and Reguant (2014), as they both find an almost complete pass through of emission cost prices to the wholesale electricity prices, despite examining two separate countries.

An earlier finding which contradicts Dagoumas et al. (2018) is that of Zachmann and Von Hirschhausen (2008). They provide evidence that the EU emission allowances changes are asymmetrically transmitted to the change in electricity wholesale prices. Thus, a price increase is transmitted faster to the wholesale price than a price decrease. ARDL is used across a similar time series data to that of Duso and Szucs (2016). However, it must be noted that while the two studies study cost pass through at the same stage of the chain, they do so for different countries using different data types.

More immediately relevant to the UK, it is significant that by applying an error correction model, in 2011, Ofgem establishes asymmetric price transmission and the phenomenon of rockets and feathers in the UK electricity market for the period 2004-2010. Yet more recently, Guo and Gissey (2019) use a VECM to investigate the relationship between input costs, such as fuel and carbon prices, and wholesale electricity prices throughout the UK for the period 2015-2018. Guo and Gissey (2019) conclude that the pass through is complete. Similar findings are obtained by Guo and Gissey (2021).

One recent study partially interrogates the symmetry in the pass through of changes in wholesale costs to the retail prices in the Dutch electricity market. Monthly prices are collected by the Authority for Consumers and Markets for the period 2008-2014. However, Mulder et al. (2019) do not derive sufficient evidence for asymmetric transmission of wholesale costs to retail costs.

There has also been more recent enquiry into asymmetric price transmission in electricity markets, and more specifically, possible explanations for the rockets and feathers phenomenon. Willems et al. (2016) posit the reason to be the existence of capacity constraints at the retailer level: in short, firms have an incentive to pass on the cost reductions. Conversely, when prices are reduced the search intensity on behalf of the consumers is decreased, creating less incentive to pass on these cost reductions.

This review concludes with a brief look at the recent theories which aim to explain asymmetric cost pass-through by different consumer search efforts depending on whether prices increase or decrease. Sven Heim (2019), who also establish asymmetric price transmission for the German retail electricity market, underscores the fact that any decrease of search intensity provides less motive to pass on these reductions. (Heim 2019, p. 27).

In summary, the above studies provide diverse evidence for incomplete pass through of emission to wholesale electricity prices as well as complete. With reference to the UK, the input cost pass through is complete for the wholesale stage (input cost to wholesale price), while the pass through from wholesale to retail price is incomplete.

3.11 Conclusion

This chapter provides a description of theoretical factors behind asymmetric price transmission. It then provides an overview of the relation between oligopsony and cost pass through, and the relation of oligopoly and cost pass through. The chapter also presents some early models of asymmetric price transmission used in the literature.

Furthermore, the chapter presents an overview of the empirical evidence relevant to asymmetric price transmission and cost pass through. To do so, it drew upon both academic literature and competition authorities' investigations into the food supply chain, milk and dairy products, the petroleum products supply chain (road fuels), and electricity. Overall, the evidence is mixed and inconclusive.

Chapter 4

The Three Supply Chains

4.1 Introduction

The following chapter presents the supply chains for the milk (dairy products), petroleum (road fuels) and electricity in the UK. A brief discussion is provided on the characteristics of these products which renders them susceptible to exploitation of market power as well as chains whose cost pass merit research. The description of the supply chains provides an overview of the market participants and the stages of the chain where market power may exist. The chapter also delineates the market shares of the retailers of each of these supply chains as an indication of market concentration. The above highlight the stages of the chain where data can be collected, and the extent of market power estimated and the degree of cost pass through in order to fully explore the core research questions.

4.2 Main Characteristics of Milk

Bouamra-Mechemache et al. (2008) contend that the dairy products exhibit a very low-price elasticity of demand. Thus, the responsiveness of the quantity demanded to a change in price is less than proportionate. The consensus is that milk is deemed a necessity by most British people. As CMA (2016) defines a necessity is a good required by consumers to maintain a certain standard of living. According to the Dairy UK, Dairy Manifesto 2019, milk is found in 96% of British households, 92% of adults frequently purchase cheese, and 81% of adults frequently purchase yoghurt. The fact that a 65-70% of the milk demand is captured by four big supermarkets facilitates the existence of an oligopolistic setting at the retailers' end of the chain and the basis for the potential existence and abuse of market power. It also enables an examination of asymmetric price transmission and cost pass through in the chain.

Smith and Thanassoulis (2015) demonstrate a high number of price-taking UK farmers while the number of cooperatives, processors, and supermarkets is low. In order to ensure effective competition in the raw milk market, the competition authorities intervened to split up the cooperatives, but failed to intervene to prevent the emergence of a highly concentrated market structure at the processor stage. Currently, there are just three processors: down from the six that existed previously.

Thus, a heavy degree of concentration exists at the retailers' level, with a proportion of 65-70% market share to be supplied to the retail market by four supermarket giants.

The low number of processors and the high market concentration at the retailer level forms an excellent basis for estimating the degree of market power on behalf of both retailers and processors at the milk products supply chain. As a complement to the market power analysis, it is also wise to explore the issue of cost pass through and asymmetric price transmission since market power is directly linked to practices which lead to these phenomena.

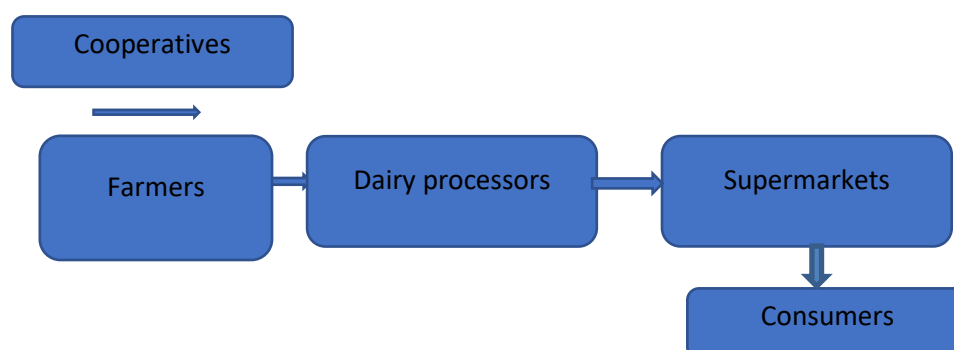
4.3 The General Food Supply Chain

With regards to Buceviciute et al. (2009) the food supply chain consists of the agricultural sector, the food processing industry, and the distribution sectors which include wholesale and retail markets. Moving through the different stages of the supply chain various inputs are processed, packaged, and distributed to final consumers.

4.4 The UK Milk Supply Chain

The illustration of the milk /dairy products supply chain presented below is intrinsic to the present study:

Diagram 4.1

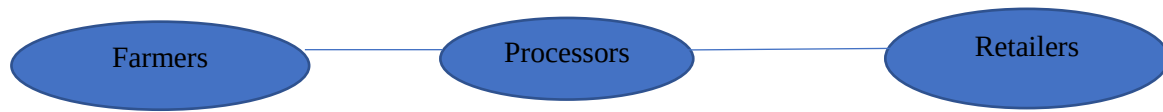


The above diagram²⁷ shows farmers as the initial participants in this supply chain. These are followed by dairy processors, followed, in turn, by supermarkets and consumers. At the production stage of liquid milk, cooperatives can also participate. Farmers sell to cooperatives who sell on to dairy processors to produce various products such as liquid milk, cheese, butter, and yoghurt. The cooperatives act as an intermediary, buying milk from farmer members to sell to processors (Sufisa 2018, p.12). For the purpose of estimating market power, the milk industry must be examined in two stages:

²⁷ The above diagram has been created using information from the Dairy Industry.org, ADHB and Smith and Thanassoulis (2015).

Diagram 4.2

First part of the supply chain which is described as 'First Stage'



Second part of the supply chain which is described as 'Second Stage'



Data from the Food Standard Agency for England and Wales indicate that the producers' part of the chain has fallen in 807 in just 17 months. The FSA reports a total of 8820 dairy producers in Britain in October 2019. According to DEFRA (2018), the milk processors' part of the chain comprises just three companies and a further 17 companies processing the output for the cheese market. The arguable oligopolistic market of the milk retailers (Stubbley et al. 2018) is therefore of major concern for the scope of this thesis. Table 4.1 presents the latest information on the major retailers' milk demand in million litres from a report of Kite Consulting in 2019.

Table 4.1: Market Shares of Milk Retailers

Retailer	m litres	Share
Tesco	1000	15%
Sainsbury's	500	8%
Morrison's	450	7%
The Coop	400	6%
Aldi	300	5%
Lidl	250	4%
Waitrose	100	2%
Asda	580	9%
M&S	80	1%
Other	3000	45%

Kite Consulting (2019)

The table confirms that Tesco, Sainsbury's, Morrison's, and Asda have a combined 40% share of milk demand in million litres: ample grounds for oligopsony power of the retailers towards the processors as well as oligopoly power of the retailers towards the consumers.

The first stage of the milk and dairy products chain illustrated in Diagram 4.2, confirms grounds for the existence of a degree of oligopoly power on behalf of processors towards the retailers

and a degree of oligopsonistic power on behalf of processors towards farmers. Therefore, data can be collected for the farmer to processor level, and for the processor to retailer level. This provides the basis to achieve one of the objectives of this thesis: to estimate market power in the supply chain. The second stage of the milk and dairy products chain illustrated in Diagram 4.2 confirms grounds for the existence of a degree of oligopoly power on behalf of retailers towards the consumers and a degree of oligopsonistic power on behalf of the processors towards the farmers. Therefore, data can be collected from the processor to the retailer level, and from the retailer to the consumer level. This provides the basis to achieve another objective of this thesis: to estimate oligopsonistic market power in the supply chain. Furthermore, the potential existence of market power lays the foundation for examining the cost pass through mechanism in the supply chain; focusing on the pass through of an input cost change to wholesale price (from farmer to processor) and the pass through of a wholesale cost change to the retail price (from processor to retailer) and relevant potential asymmetries. Data can be collected at the farmer to processor level, and at the processor to the retailer level. This forms the basis to achieve a further objective of this thesis: to estimate the cost pass through of a change in the input cost to the wholesale price and a change in the wholesale cost to the retail price.

4.5 Main Characteristics of Petroleum Products (Road Fuels)

It is important to note that within the scope of this thesis, particular emphasis is given to road fuels. A main characteristic of road fuels is that they are a necessity. Eitches and Crain (2016) note the general absence of alternatives for road fuels, at least in the short run.²⁸ The potential substitutes of electric vehicles require changing embedded consumption habits which can be both costly and time-consuming. The alternative of public transportation depends on public provision of frequent and affordable services. The fact that road fuels are perceived as a necessity for many consumers creates an inelastic demand which render road fuels susceptible to exploitation of market power.

This is a rising cause of concern to policymakers as the abuse of market power can have welfare implications which are detrimental to the consumer and society.

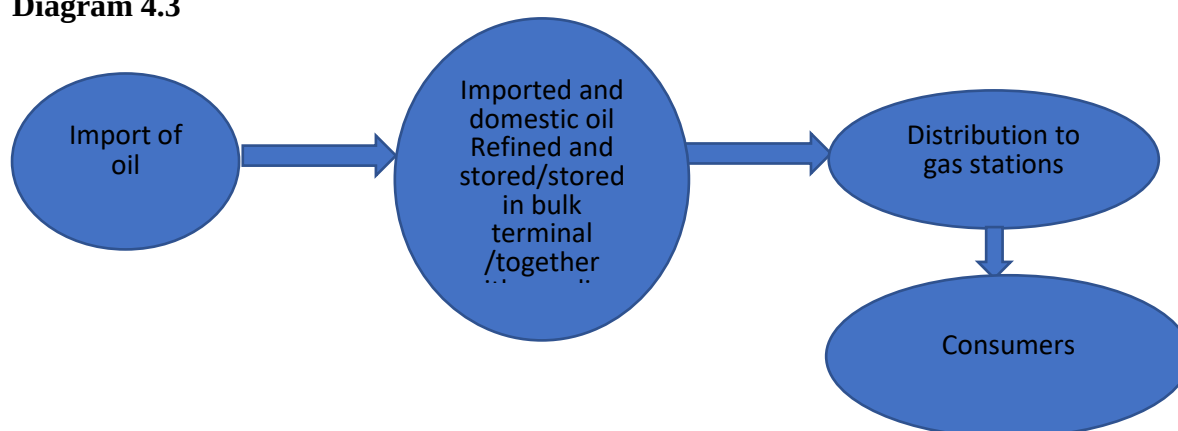
Since the physical and economic characteristics of road fuels increase the probability of potential abuse of market power by retailers, detection and estimation of market power of road

²⁸ This thesis is looking at road fuels as a good in general, as opposed to gas from a particular station

fuels retailers is essential in order to prevent and/or intervene in possible distortions in the market. Lastly, as illustrated below, the highly concentrated market for road fuels in the UK render the market for road fuels vulnerable to the exploitation of oligopolistic as well as oligopsonistic market power (power of retailers over processors). The combination of these characteristics accompanied by high concentrations, provide the basis for examining cost pass through and asymmetric price transmission for the road fuels supply chain as a complement to the market power estimation.

4.6 The UK Petroleum Supply Chain

Diagram 4.3



The above diagram shows the supply chain for petroleum products as deduced from OFT (2013). The raw materials of imported and domestic oil are initially refined and stored.²⁹ The four key stages involved in the process of manufacturing and transporting road fuels to the retailer according to (OFT 2013), are as follows: 1) Extraction: crude oil is either extracted or imported; 2) Production or import of road fuel: crude oil is refined into fuels in the refineries; 3) Wholesale transportation: transporting the wholesale road fuel to a distribution terminal from a UK refinery or a coastal terminal; and 4) Retailing: sale of final product to the consumers.

At present there are six major crude oil refineries operating in the UK. The refined product is ultimately distributed and supplied by pipeline, rail, and sea from UK refineries.

According to the UKPIA (2018) statistical review, the oil refining and marketing sector plays an important role in the UK's economy and growth, sourcing around 85% of total inland UK fuel demand for air passenger, car, road, and rail transport, domestic and commercial heating,

²⁹ The above diagram is based on the OFT report (2013).

and the manufacturing sector. As far as the distribution is concerned, the refined product is distributed, supplied by pipeline, rail and sea, from UK refineries.

Looking at the side of the retailers, three types of retail dealers are recognized by the OFT report (2014): namely, the oil company owned sites; the independent dealers; and the supermarket courts. Based on the OFT report (2014), the oil company owned sites are those owned by the oil companies such as BP, Shell, Esso or Murco. Company owned sites can be either company-operated or company-owned/dealer-operated. Independent dealers, are often referred to as ‘dealer-owned/ dealer-operated’. Supermarket courts are forecourts owned and operated by supermarkets including Tesco, Asda, Sainsbury’s and Morrison’s.

As it is evident from the Table 4.2 below, Tesco, Asda, Morrison’s and Sainsbury’s boast a 43% combined market share as road fuel retailers. When combined, the BP, SHELL and ESSO oil companies figure reaches 84%. Such a high concentration renders the road fuels market particularly susceptible to oligopolistic and oligopsonistic (power of retailers over processors) exploitation and provides the grounds for examining market power in the supply chain of road fuels in the UK along with potential implications like asymmetries or the cost pass through mechanism.

Diagram 4.2 demonstrates grounds for the existence of oligopoly power on behalf of retailers towards consumers and oligopsonistic power on behalf of the retailers towards wholesalers (refiners). Therefore, data can be collected from the wholesaler to the retailer level, and from the retailer to the consumer level. This forms the basis to achieve one of the objectives of this thesis: to estimate market power in the supply chain.

There are also grounds to investigate incomplete cost pass through of a change in the input cost to wholesaler and a change of a wholesale cost to retailer price.

Therefore, data can be collected from wholesaler to retailer level, and retailer to consumer level. This forms the basis to achieve another objective of this thesis: to estimate cost pass through in the supply chain.

Table 4.2. Market Shares of Road Fuels Retailers

	No of outlets	Average Volume (kl pa)	Market share
Tesco	510	11357	16
Bp	1211	4329	14.5
Shell	1053	4710	13.7
Esso	1197	3721	12.3
Sainsbury's	314	11799	10.2
Morrison's	335	10536	9.7
Asda	323	8668	7.7
Texaco	327	2540	5.1
Certas energy	733	1255	2.5
Jet	321	2424	2.1
Applegreen	105	3511	1.0
Coop	93	3963	1.0
Unbranded	545	510	0.8
Minor brand	212	1173	0.7
Murco	183	1207	0.6
Harvest energy	80	2383	0.5
Maxol	96	1571	0.4
Essar	70	1444	0.3
Circle K	48	1680	0.2
Solo	63	847	0.1
Food store	32	1417	0.1
Star	37	1181	0.1
Gleaner	55	793	0.1
Rix	27	775	0.1
Thames	29	718	0.1

The above table indicates the market shares of supermarkets and oil companies at the road fuels chain retailers' level. The source is Fuel Market Review 2019.

4.7 Main Characteristics of Electricity

Various inherent characteristics of electricity render it susceptible to exploitation of market power and to potential imperfections in the cost pass through mechanism and asymmetric price transmission. Based on CMA (2016) electric energy is a necessity and a fundamental requirement for all households.

Furthermore, the price of energy is of particular importance to the consumer since electricity is a homogeneous good. Hope (2005) identifies electricity as a good with inelastic price elasticity of demand, especially in the short run.

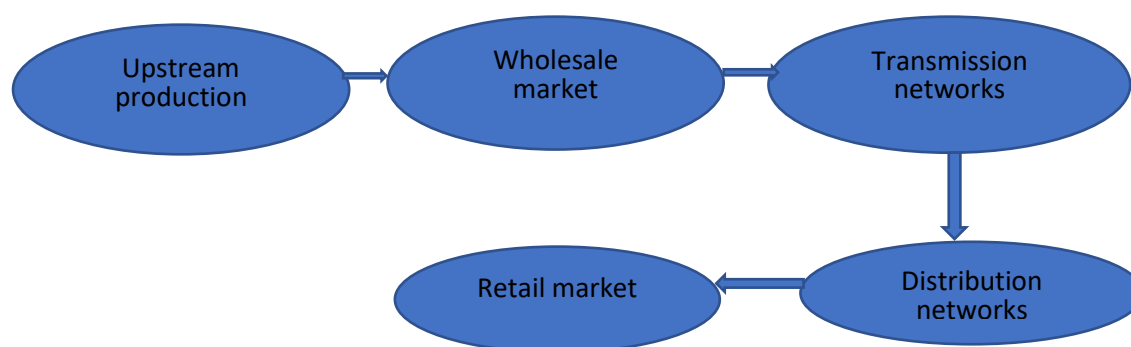
In fact, because by its nature electricity cannot be stored, consumer responsiveness to a change in price is even less elastic since consumers cannot draw upon available stored product in times of a change in price. It is a consensus that electricity is a necessity. Households are also likely to evaluate other aspects of the supplier, including convenience of payment method and quality of customer service. Lastly, according to CMA (2016) traditional meters do not allow for short-term demand response and are likely to create other barriers to engagement in energy markets.

The supply side characteristics of electricity are also unique. Hope (2005) mentions that the supply of electricity is somewhat inelastic in the short run, particularly when approaching capacity constraints in production. In addition, suppliers do not operate any of the physical assets used for production or delivery of the product. Rather, they are engaged in the various aspects of selling energy to customers, such as sales, marketing, metering, and billing (CMA 2016).

The physical and economic characteristics which render the UK retail electricity markets vulnerable to exploitation of market power are of increasing concern to policymakers and justify further investigation and analysis of potential asymmetric price transmission and estimation of the degrees of cost pass through in the case of an input cost change.

4.8 The UK Electricity Supply Chain

Diagram 4.4



The above diagram illustrates the electricity supply chain.³⁰ Electricity is produced in the upstream production and energy is sold in wholesale markets. For the purposes of this study, since a high concentration of firms is found in the retail market (retailers), emphasis is given to the market power which retailers have over consumers (oligopoly power) and the market power that retailers might have over wholesalers (oligopsony power). The analysis will further

³⁰ The above diagram was created based on information from the CMA Energy market investigation (2016).

extend to the associated estimation of cost pass through in the supply chain and the potential existence of asymmetries. Ofgem's market report 2019 states that Britain's electricity industry consists of Generation, Transmission network, Distribution and retailers.

Coal oil and gas is used to generate electricity which is then supplied to retailers through the wholesale markets. The Ofgem transmission network (2019) delivers electricity nationwide. Thus, while there are regional transmission companies which own and maintain the network, the system is operated under a single operator. There are 14 licensed electricity distribution network operators (DNOs) working under six different groups. This study focuses on the wholesale and retail markets of electricity.

Following the findings of Amountzias et al. (2017) and in line with CMA (2016), it is evident that the concentration in the wholesale electricity market is very low. As such, there is no urgency to examine potential market power at that stage of the chain. However, it is necessary in terms of the electricity industry and the market participants: the electricity suppliers who buy energy from the wholesale market and sell it to consumers. One specific characteristic of the electricity market is that customers' power to choose their supplier creates a downward pressure on prices. The UK retail market is dominated by the Big Six firms: namely, Centrica; EDF; EON; npower; Scottish Power; and SSE. Based on Ofgem (2019), the group currently holds around 70% market share of the retail electricity market in the UK.

Table 4.3 further below, indicates the possible existence of market power on behalf of electricity retailers towards the consumer and form a basis for the investigation of electricity in this regard. Amountzias et al. (2017) also argues that the high gross margins in relation to the retail costs from 2009-2013 further justify scrutinising market power in the electricity retail market.

Diagram 4.4 confirms grounds for the existence of both oligopoly power and oligopsonistic power on behalf of retailers towards consumers. Therefore, data can be collected from the wholesalers to the retailer level, and retailer to consumer level. This forms the basis to achieve one of the objectives of this thesis: to estimate market power in the supply chain.

In addition to the market power analysis, this study proceeds to the estimation of cost pass through as well as the estimation of potential asymmetries in the cost pass through mechanism. These phenomena could occur from the existence of the market power of retailers towards the consumers and of retailers towards wholesalers.

Table 4.3. Market Shares of Electricity Retailers

	British Gas (%)	EDF (%)	EON (%)	Npower (%)	Scottish power (%)	SSE	Total market shares
2013 Q1	24.80	12.90	16.70	13.40	11.70	18.30	97.8
2013 Q2	24.90	13.00	16.60	13.20	11.70	18.20	97.6
2013 Q3	25.00	13.00	16.50	13.20	11.70	18.10	97.5
2013 Q4	24.30	13.40	16.60	11.90	11.70	17.70	95.6
2014 Q1	23.90	13.30	16.10	11.70	11.60	17.50	94.1
2014 Q2	23.80	13.10	15.90	11.50	11.50	17.20	93
2014 Q3	23.60	13.00	15.60	11.30	11.30	17.00	91.8
2014 Q4	23.60	12.90	15.70	11.00	11.20	16.60	91
2015 Q1	23.60	12.50	15.70	10.90	11.20	16.30	90.2
2015 Q2	23.50	12.40	15.70	10.80	11.20	16.10	89.7
2015 Q3	23.50	12.20	15.50	10.50	11.10	15.90	88.7
2015 Q4	23.50	12.20	15.30	10.20	11.10	15.60	87.9
2016 Q1	23.10	12.00	15.10	10.10	10.80	15.40	86.5
2016 Q2	22.80	12.00	14.60	9.90	10.90	15.30	85.5
2016 Q3	22.60	11.90	14.20	10.10	10.80	15.20	84.8
2016 Q4	22.80	11.80	14.00	9.90	10.70	15.10	84.3
2017 Q1	22.40	11.70	13.50	9.50	11.00	14.90	83
2017 Q2	22.30	11.50	13.40	9.60	10.60	14.40	81.8
2017 Q3	21.30	11.70	13.40	9.70	10.40	14.30	80.8
2017 Q4	20.50	11.40	13.50	9.60	10.20	14.20	79.4
2018 Q1	20.30	11.20	13.50	9.30	10.00	13.90	78.2
2018 Q2	19.90	11.10	13.30	8.90	9.70	13.60	76.5
2018 Q3	19.40	10.80	13.10	8.60	9.50	13.40	74.8
2018 Q4	19.20	10.80	13.00	8.20	10.00	13.00	74.2
2019 Q1	18.90	10.80	12.50	8.00	9.80	12.80	72.8
2019 Q2	18.90	10.60	12.10	7.70	9.30	12.60	71.2
2019 Q3	18.70	10.60	12.00	7.30	9.10	12.40	70.1
2019 Q4	18.70	10.70	12.00	6.90	9.20	12.10	69.6

The above table indicates the market shares of the electricity big six suppliers from 2013 onwards.

The source is Ofgem (2019).

4.9 Conclusion

This chapter provided an overview of the supply chains for the milk (dairy products), petroleum (road fuels), and electricity in the UK. As such, it set out the basis for the supply chains on which the present study will focus. A brief discussion was provided on the characteristics of these products which render them susceptible to exploitation of market power, as well as chains for which cost pass through is worth researching. The description of the supply chains provided an overview of the market participants and the specific stages of the chain where market power may exist. The market shares of the main retailers for each of these products are fully delineated. The high market concentration at the retailer level of these chains affords the main opportunity

to focus this empirical study on these three specific products. Thus, it is held that the questions under investigation of this research, can be satisfactorily answered through empirical analysis of milk and dairy products, petroleum products (road fuels), and electricity.

Chapter 5

The models

5.1 Introduction

This chapter provides a description of the models used to address the main research questions of this study. Firstly, the model used to estimate the extent of market power in the supply chain is based on Bresnahan (1982) and Perekhozhuk et al. (2015, 2017) and influenced by the work of Lloyd (2006), Cavicchioli (2010) and Nakajima (2014) is outlined in full. The demand supply and production functions to be estimated for each product are presented as well as the market power estimation of the parameters which are well known in the academic literature as φ and λ .

5.2 The Model to Estimate Market Power

The following model on which the first part of this thesis is based, follows those of market power mentioned above and estimates the market power parameters for the retailers. The model is based on Bresnahan (1982) and Lau (1982) and Perekhozhuk et al. (2015, 2017) and influenced by the work of Lloyd (2006), Cavicchioli (2010) and Nakajima (2014) described above. The model is also linked to the work of Appelbaum (1982) and Azzam and Pagoulatos (1990), who provide the basis for the PTA (price theoretic approach) approach commonly used in the literature. Azzam and Pagoulatos (1990) use an inverse demand function of the output market and an inverse supply function of the input market to determine the own price elasticity of output demand and the price elasticity of input supply. The j th firm conjectural elasticity in the output market is determined as well as the j th firm conjectural elasticity in the input market. These elasticities test for price taking behaviour or for the degree of competitiveness. (Appelbaum 1982).³¹

The model based on Bresnahan (1982) also has links to another frequently used approach: that of GIM. The GIM approach enables market data can be evaluated using aggregated price and quantities data. For the purposes of this thesis, demand, supply, and production functions are estimated separately for each product.

Demand indicates the demand of consumers from the retailers. Supply indicates supply towards the retailers. Production indicates final production of the product.

³¹ Further on this can be found in Azzam and Pagoulatos (1990).

Furthermore, a market power regression based on these three functions is estimated for each product to measure the parameters of market power of retailers towards their providers, and the market power of retailers towards consumers.

In the case of milk products, this thesis delves further back along the chain to determine the market power parameters of the processors. It therefore estimates potential market power of processors towards retailers, and potential market power of processors towards farmers using notation like that of Lloyd et al. (2006). This thesis describes the model used to estimate market power below:

Following Bresnahan (1982) but with logarithmic demand function

$$\ln Q = a_1 + a_2 \ln R + a_3 \ln R^S + a_4 \ln R \ln R^S + a_5 \ln Y \quad (5.1)$$

Q: Quantity demanded by consumers

R: Retail Price

R^S : Price of substitutes /complements

Y: Disposable income

Lloyd et al. (2006), Nakajima (2014) and other papers call R^S and Y as demand shifters.

If firms (retailers) are price takers in the output retail market

$$MR=R$$

If firms, retailers act as a monopoly,

$$MR = R \left(1 + \frac{1}{\varepsilon} \right)$$

ε =own price elasticity of demand

Bresnahan (1982) and others consider the intermediate case (where firms exert some monopoly power) by specifying MR as follows:

$$MR = R \left[1 + \frac{\lambda}{\varepsilon} \right]$$

λ =degree of market power (Bresnahan 1982), oligopoly power (Cavicchioli 2010).

Bresnahan (1982) indicates that λ is identified because R enters interactively with the R^S in the demand equation. An explanatory analysis and diagrammatical explanation can be found in Bresnahan (1982). The change in Y and R^S combine elements of vertical shifts and rotation in

demand. R_s is the price of substitute goods and the rotations of the demand curve around the equilibrium point reveal the degree of market power.

Input supply is similarly specified in logarithmic form. In inverse form it is given by:

$$\ln P = b_1 + b_2 \ln A + b_3 \ln N_1 + b_4 \ln A \ln N_1 + b_5 \ln N_2 \quad (5.2)$$

P =supply price of input

A =supply of input

N_i =input prices

Following Bresnahan (1982) and Lloyd et al (2006), input prices represent a vector of exogenous supply shifters such as labour cost per hour. They do not necessarily correspond to the upstream supply price.

Lloyd et al. (2006), Nakajima (2014) Perekhozhuk (2015) etc call N_i supply shifters.

If firm retailers are price takers in the input markets, marginal factor MFO will equal the input price.

$MFO = P$

If firms act as a monopsony

$$MFO = P \left(1 + \frac{1}{\eta} \right)$$

η = own price elasticity of supply

Hyde and Perloff (1994) and others, consider the intermediate case (where firms exert some monopsony power by specifying MFO as follows:

$$MFO = P \left(1 + \frac{\varphi}{\eta} \right)$$

φ =degree of monopsony power

φ is identified because A enters interactively with N_1 in the supply equation

Profit maximising firms will determine their input use by equating marginal revenue product MRP to MFO.

$MRP = MR * MPP$

MPP =marginal physical product

MPP can be determined by an appropriately specified production function. This study follows the Cobb-Douglas production function although the translog can also be used. The translog

production function has been used by Perekhozhuk et al. (2017)³² and Azzam and Pagoulatos (1990). This thesis follows Cobb Douglas as illustrated below:

$$Q = {}^{33}A^{c_1}K^{c_2}L^{c_3}$$

$$\ln Q = c_1 \ln A + c_2 \ln K + c_3 \ln L \quad (5.3)$$

K=Capital

L=Labour

$$\text{MPP} = \frac{\partial Q}{\partial A}$$

$$\frac{\partial \ln Q}{\partial \ln A} = \frac{\partial Q}{\partial A} \times \frac{A}{Q} = c_1$$

$$\frac{\partial Q}{\partial A} = c_1 \frac{Q}{A}$$

Equating MRP and MFO at the industry retail level gives

$$R \left(1 + \frac{\lambda}{\varepsilon}\right) c_1 \frac{Q}{A} = P \left(1 + \frac{\phi}{\eta}\right)$$

$$R c_1 \frac{Q}{A} + \left(\frac{\lambda}{\varepsilon}\right) c_1 R \frac{Q}{A} = P + \left(\frac{\phi}{\eta}\right) P$$

$$R c_1 \frac{Q}{A} - P = \left(\frac{\phi}{\eta}\right) P - \left(\frac{\lambda}{\varepsilon}\right) c_1 R \frac{Q}{A} \quad (5.4)$$

c_1 is known, as it is the coefficient of $\ln A$ in the logarithmic demand equation, and so a new variable representing the LHS of the equation can be constructed.

$$\eta = \left(\frac{\partial A}{\partial P}\right) \frac{P}{A} = \frac{\partial \ln A}{\partial \ln P}$$

$$\frac{\partial \ln A}{\partial \ln P} = \frac{1}{\partial \ln P / \partial \ln A}$$

And an estimate is provided by the specified supply function.

$$\frac{\partial \ln P}{\partial \ln A} = b_2 + b_4 \ln N_1$$

$$\text{so } \eta = \frac{1}{b_2 + b_4 \ln N_1}$$

The 1st expression on the RHS of equation (5.4) is therefore $\phi[P[b_2 + b_4 \ln N_1]]$

³² Estimations of the translog production function are also undertaken however they are not included in this thesis as they are not used for the subsequent analysis. The reason behind this, is the fact that a lot of multicollinearity exists in the translog function, causing estimation issues and insignificant estimates. The thesis therefore bases its analysis on the Cobb-Douglas estimations.

³³ A refers to Total Factor productivity. According to Sickles and Velentyn (2019) total factor productivity is inversely proportional to the amount of inputs, caused by change in efficiency, or scale of operation of firms. This thesis uses Upstream supply of inputs as a proxy for Total factor productivity, A.

b_2 and b_4 are known so a new variable representing the square brackets can be constructed:

$$\varepsilon = \frac{\partial Q}{\partial R} x \frac{R}{Q} = \frac{\partial \ln Q}{\partial \ln R}$$

And an estimate is provided by the specified demand function:

$$\varepsilon = a_2 + a_4 \ln R^S$$

The second expression on the RHS of equation (5.4) is therefore

$$-\lambda \frac{c_1 R Q}{(a_2 + a_4 \ln R^S) A}$$

c_1 , a_2 and a_4 are known so a new variable representing the square brackets can be constructed.

Equation (5.4) therefore becomes:

$$D = \phi Oligopsony - \lambda Oligopoly$$

$$D = R c_1 \frac{Q}{A} - P$$

$$Oligopsony = P(b_2 + b_4 \ln N_1)$$

$$Oligopoly = \frac{c_1 R Q}{(a_2 + a_4 \ln R^S) A}$$

This can be estimated as follows:

$$D = d_1 + d_2 Oligopsony + d_3 Oligopoly \quad (5.5)$$

$$D = \phi Oligopsony - \lambda Oligopoly$$

$$\phi = d_2 \text{ and } \lambda = -d_3$$

Therefore, oligopsony and oligopoly power can both be estimated. This study constructs and estimates equation (5.5). This aims to estimate the parameters of oligopsony and oligopoly power for each of the three products under study. The model provides the opportunity to estimate the market power of the retailers towards the consumers as well as market power of the retailers towards their providers.

If applied further back in the supply chain as this study attempts to do in the case of milk products, equation (5.5) can be constructed to estimate the market power of processors towards the farmers and the market power of processors towards the retailers.

5.3 Conclusion

This chapter fully outlined the main model used to estimate market power. The model of estimating market power has foundations on Bresnahan (1982) and Lau (1982); Cavicchioli 2010; Lloyd et al. 2006; Nakajima 2014; Perekhozhuk et al. (2015, 2017). The above model can be applied in the case that aggregate time series data are available and estimates market power at the industry level. Contributing to the market power literature this thesis develops a newly proposed model based on the seminal work of Bresnahan (1982).

Chapter 6

Data and Methods

6.1 Introduction

This chapter presents the econometric methods used to analyse the part of this study relating to the detection and estimation of degrees of market power in the various supply chains. This thesis uses time series data and it considers essential to test for the stationarity of the series. Consequently, this chapter presents the Augmented Dickey Fuller (ADF) test for stationarity. Then it includes a description of the Philips Perron test for stationarity. This is followed by a contextualisation of cointegration and the method to test for cointegration using the autoregressive distributed lag model, ARDL, in cases of a mixture of time series variables, both $I(0)$ and $I(1)$. In addition, the Johansen test for cointegration is outlined as it is appropriate in cases of more than one independent variables of the same order of integration $I(1)$.

The chapter also introduces the methods used to estimate the equations of the Fully Modified OLS estimator; (FMOLS) and Dynamic OLS estimator (DOLS) as selected models following confirmation that cointegrating relationships exist in the estimated demand, supply and production functions for all the three products under study. Furthermore, the econometric methods used to estimate the cost pass through as well as asymmetric price transmission are fully elucidated: more specifically, an overview of the distributed lag models, as well as the instrumental variable methodology and the issue of endogeneity and attenuation bias provided.

This chapter also provides a general description of the variables to be used in the econometric model for the estimation of market power for milk products, petroleum, and electricity. The variables used for the estimation of cost pass through, and asymmetric price transmission are also delineated and tables with exact data sources provided in Appendix A.

6.2 Stationarity

6.2.1 Augmented Dickey Fuller Test for Unit Roots

The present thesis utilises the Augmented Dickey Fuller (ADF) (1979) to test each of the variables used for the estimation of market power for stationarity. Since these are time series, the study tests for the order of integration: In the case that variables are not stationary, the use of the OLS regression result in spurious regression. Dickey and Fuller (1979) thus proposed the following regression is estimated based on the ADF tests with a null hypothesis of non-stationarity and an alternative of stationarity. In the case of non-stationarity $\alpha=0$. The test provides the McKinnon critical values which can be used to test for the null hypothesis:

$$y_t = \alpha y_{t-1} + x_t \delta + \sum_{p=1}^P \Delta y_{t-p} \quad (6.1)$$

x_t are exogenous regressors with a constant term only, a constant and a trend, or none, while y_{t-p} is included in the regression to account for autocorrelation. To test whether a trend is included in the Augmented Dickey Fuller tests, this thesis conducts a time graph for each variable. In the case a trend is established, a trend is included. While the graphs are not reported for the purpose of this research, the tables of stationarity results demonstrate whether a trend is used or not. The number of lags for each of these variables is then chosen using the widely used Akaike Information Criterion (AIC). Stata statistical software automatically runs the ADF procedure with the `dfuller` command.

6.2.2 Philips Perron Test for Unit Roots

In order to crosscheck the ADF stationarity results this thesis uses the Philips Perron (1988) (PP) test for unit roots. As with the ADF test, the null hypothesis indicates the non-stationarity or the existence of a unit root. The alternative hypothesis is that of stationarity. According to Stata (2013) the Philips Perron test accounts for autocorrelation by using Newey West standard errors whilst ADF tests use lagged values of the first differenced variables. Philips and Perron test statistics can be viewed as ‘‘Dickey fuller statistics that have been made robust to serial correlation by using the Newey West (1987) heteroskedasticity and autocorrelation consistent’’ (Stata 2013).

To test whether a trend is included in the PP tests, this thesis proceeds with a time graph for each variable. In the case a trend is established, a trend is included. For the purpose of this research the graphs are not reported however the tables of stationarity results in the Appendix, include whether a trend is used or not. Based on Walter Enders (2014) and similarly, to the ADF test, the number of lags for each of these variables is chosen using the Akaike Information Criterion (AIC).³⁴

6.3 Cointegration

According to Asteriou & Hall (2015), cointegration is the equilibrium that sets the long run relationship between the variables. For cointegration to exist, there must be a linear combination between the dependent and independent variables that is stationary: in other words, constant mean and variance over the long run. Extending the analysis from the point where the variables are tested for stationarity, this study uses the relevant technique to

³⁴ Information on the AIC and the number of lags can be provided upon request.

determine possible cointegration between the variables included in the demand supply and production functions to be estimated. Tests for cointegration between the variables of the demand supply and production functions help to clarify the optimal method for the estimation of each of these functions.

6.4 Autoregressive Distributed Lag Model (ARDL)

Irrespective of whether the variables are $I(0)$, $I(1)$, or both, the researcher can apply the ARDL technique to test for cointegration between the variables. Unlike other methods of testing for cointegration, Pesaran and Smiths' (2001) procedure does not lie on any preliminary testing of variables for unit roots. Nonetheless, the present study opts to proceed with such tests to confirm that there are no $I(2)$ variables.

Kripfganz (2018) notes that the Stata statistical software ARDL package relies on the Akaike Information Criterion (AIC) to select the optimal number of lags to be used. Based on Nkoro and Uko (2016), the test is applied as follows:

- The ARDL regression derives a test statistic which can be compared to two asymptotic (upper and lower) critical values
- The null hypothesis is that of no long run relationship
- In cases where the statistic is greater than the upper critical value, the null hypothesis of no cointegration is rejected
- In cases where it is less than the lower critical value, the no cointegration hypothesis is accepted.

The ARDL is particularly effective in testing for cointegration since it also considers autocorrelation and endogeneity. The researcher therefore opts to use ARDL in the case that the variables included in the function are a mixture of $I(0)$ and $I(1)$. This means that some of the variables are stationary in levels and some are stationary when first differenced. The order of integration is established using ADF and Philips Perron Tests.

6.5 Johansen Test

Sjo (2008) argues that the Johansen cointegration test is commonly used in cases where variables are of the same order of integration and where there are many independent variables. For the purposes of this thesis, the Johansen Cointegration test is implemented using Stata statistical software which automatically runs the procedure based on the null hypothesis of no more than r cointegrating relationships amongst the variables. Based on Johansen (1995), the number of cointegrating relationships is the first r for which the null hypothesis cannot be

rejected. Based on Kerror et al. (2020) the number of lags is chosen by minimising the AIC and SBIC criterion. Selection of the optimum lag length is necessary before a test for cointegration can be done in order to remove any autocorrelation in the series, make the error white noise and ensure that the model is not misspecified.

The trace statistic or the eigen values can be used to test for cointegration. The present study reports and compares the trace statistic with the corresponding critical values,³⁵ and in cases where the trace statistic is greater than the critical value, the null hypothesis is rejected. The Johansen test for cointegration is chosen as the most suitable when the function under test has more than two variables, wherein the number of independent variables is greater than 1.

6.6 Fully Modified Ordinary Least Squares (FMOLS)

Following tests for cointegration between the dependent and independent variables, this study applies the Fully Modified OLS estimator to estimate demand supply and production functions for the UK milk and milk products, road fuels, and electricity supply chains. This method was first introduced in 1990 for the estimation of a cointegrating relationship between I(1) variables (Bashier & Siam 2014; Phillips & Hansen 1990). Based on Bashier and Siam (2014), the FMOLS estimator considers the cointegration existence and controls for endogeneity and autocorrelation and provides asymptotically efficient estimates.

The FMOLS estimator can be obtained as follows:

$$O_{FME} = [\sum_{t=1}^T z_t z_t']^{-1} \sum_{t=1}^T Z_t Y_t - T \begin{bmatrix} \hat{\kappa}_{12}' \\ 0 \end{bmatrix} \quad (6.2)$$

The last two terms of the above expression correct endogeneity and serial correlation.

6.7 The Dynamic OLS Estimator (DOLS)

Masin et al. (1996) finds that the DOLS (Dynamic OLS Estimator) (Stock & Watson 1993) can estimate cointegrating relationships even in variables with different orders of integration. Lagged values and lead values of the change in the independent variables are included. The scope of lagged and lead values is a separate stochastic error term of all past innovations in stochastic regressors (Camacho 2010). The model deals effectively with both simultaneity and small sample bias. Moreover, even under endogeneity, unbiasedness, asymptotic efficiency, and serial correlation are considered.

³⁵ For a detailed description of the procedure, see, for example, Johansen (1995).

The present study therefore applies the DOLS methods in order to verify the consistency of the FMOLS estimates. To obtain the Dynamic OLS estimator the following equation devised by Priyankara (2018) is used:

$$y_t = a + bX_t + \sum_{i=-k}^{i=k} \phi_i \Delta X_{t+1} + \varepsilon_t \quad (6.3)$$

X represents all the independent variables, while ϕ indicates the coefficients for the lead or lag of first differenced independent variables, and b is the long run elasticity.

Based on Priyankara's formulation (2018), coefficients help to consider endogeneity and autocorrelation. This study specifies the Stock Watson DOLS model as follows:

$$y_t = \beta_0 + \beta X + \sum_{j=-q}^p d_j \Delta X_{t-j} + u_t \quad (6.4)$$

y_t dependent variable

X matrix of explanatory variables

β cointegrating vector; i.e., represent the long-run cumulative multipliers or, alternatively, the long-run effect of a change in X on Y

p lag length

q lead length

In summary, the researcher opts to use the FMOLS estimator as well as the DOLS as the methods most appropriate for estimating cointegrating relationships and weighing endogeneity and serial correlation. This study offers an alternative proposal to the current most commonly method used for the estimation of market power which can be applied when time series data is available and cointegration established. This is an alternative to the current most commonly method used in the literature that of two stage least squares (2SLS) and three stage least squares (3SLS) (Genakos n.d., Zeidan & Resende 2009). However, the 2SLS and 3SLS estimation of market power under an NEIO model is challenged by Corts' (1999) who suggests that the estimated conduct parameter and the instrumental variables used can be of high correlation. Such a correlation could make the conduct parameter to be an endogenous variable which would make it hard to identify.

This research prioritises the FMOLS and DOLS with consideration of endogeneity. This aspect is enhanced by the inclusion of a dummy variable for the financial recession in the estimation of all demand, supply and production relations in order to accommodate a main exogenous shock to the economy which may cause structural changes during the period under study.

In this way, any potential estimation biases are prevented. FMOLS and DOLS control for endogeneity issues and therefore are appropriate to apply in the case of cointegrating relationships. These methods therefore consist of a novel approach used in this setting. This alternative method is not commonly applied in market power studies. As such, the present study challenges and extends beyond the conventional methodological wisdom in the literature. What is more is that since time series aggregate data is used; contradicting to a bulk of studies that use panel data; the establishment of cointegration for the different functions estimated; deems the use of econometric methods that are appropriate for this setting. Establishing cointegration as well as considering potential endogeneity, makes DOLS and FMOLS appropriate for the specific estimation. DOLS is used to enhance robustness. Based on Kao and Chiang (2000), DOLS is computationally simpler, but it reduces bias better than FMOLS.

6.8 Econometric Methods Relevant to the Estimation of Cost Pass Through and Asymmetric Price Transmission

6.8.1 Distributed Lag Models (DLM)

The time series analysis which illustrates the delayed effects arising from the temporal structure of the data are known as Distributed Lag Models (DLMs) (Gasparini 2011). Originating in econometrics (Almon 1965), this methodology allows for the effect of a single event to be distributed over a specific period by using multiple parameters to estimate the contributions at different lags. For the purposes of this study, the single event in question is the change in the cost of either the input price or the wholesale price. Estimating the contributions at different lags based on Gasparrini (2011) helps to provide a comprehensive picture of such time effects. Conventional DLM wisdom assumes a linear effect between the event and the outcome, despite certain attempts to incorporate non-linearities.

This thesis uses distributed lag models to estimate the cost pass through of a change in the input cost to the wholesale cost, and a change in the wholesale cost to the retail price. Following Nakamura and Zerom (2010) this research analyses time series data by regressing current changes in prices on current and past changes in costs. Since the first differences of the variables used, proved to be stationary, a standard cost pass through regression can be used; with no necessity to proceed to cointegration analysis and other types of modelling. To consider heteroskedasticity and serial correlation, this thesis uses Newey West standard errors. The estimated coefficients of the regressions represent ‘what fraction of the change in the input or wholesale cost at a certain point in time is reflected in current price changes, either retail or wholesale’ (Nakamura & Zerom 2010 p. 10).

The sum of the lagged values coefficients and the coefficient of the first independent variable which is the change in cost derives the long run response of prices to costs.³⁶

This thesis does not use the Vector Error Correction Model (VECM), or the Threshold Vector Error Correction Model (TVECM) commonly applied in the literature as these have been linked to inconsistent estimates resulting from the imposition of the wrong cointegration vector on the model. (Aliyu et al. 2009; Favero 2001). The present research employs the distributed lags model which to date, has not been applied for the estimation of cost pass through for these products in the UK. Serial correlation and heteroskedasticity are considered using the Newey West standard errors.

6.9 Endogeneity

Further below this study explains the issue of endogeneity as well as the issue of attenuation bias. Following Nakamura & Zerom (2010), this thesis considers that in the case that wholesale price time series is used to represent wholesale cost, attenuation bias maybe involved. This is since wholesalers face other costs not just the wholesale price. This can also cause the problem of endogeneity as one of the independent variables include an error.

To begin with, consider the following bivariate linear regression model:

$$Y_i = \beta_0 + \beta_1 X_i + u_i \quad (6.5)$$

Where Y is the dependent variable, the intercept β_0 and the slope β_1 are the coefficients of the population regression line (also called slope parameters), X is the independent variable, and u is the error term. According to the well-known in econometrics Gauss Markov theorem, OLS yields the best linear unbiased estimator (BLUE) under the assumptions of least squares and homoscedastic errors (i.e., the variance of the error term u, conditional on the regressor, is constant). However, in cases of endogeneity there is no consistency in the OLS estimator since there is no convergence between the estimator and the population parameter. This induces bias into the estimator and best linear unbiased estimator no longer holds.

Wooldridge (2006) purports that since endogeneity occurs when X is correlated with the error term, it violates the exogeneity condition assumptions of the OLS estimation:

$$E(u|X_1, X_2 \dots X_k) = 0$$

³⁶ The number of lags in the regression are selected such that adding more lags will not affect the long run rate of pass through. In the case that lagged values are not significant they are dropped out of the model.

Based on econometric principles, Bascle (2008) proposes two main cases when endogeneity occurs: namely, errors-in-variables; and omitted variables.

6.9.1 Reasons Behind Endogeneity

a. Errors in Variables

Bascle (2008) emphasises the errors-in-variables problem arises when the true value of a regressor, X_i , is unobserved. In most of the empirical studies measurement errors are overlooked.

b. Omitted Variables Bias

The omitted variables bias is observed as the most encountered problem. According to Wooldridge (2002) and Bascle (2008), this occurs when a variable which affects the dependent variable and is correlated with one or more explanatory variables, is omitted from the regression. This is a violation of the exogeneity condition and endogeneity is present.

6.10 Attenuation Bias

According to Amman et al. (2010), ordinary least squares fit provides the best linear unbiased estimates (BLUE) of parameters. In cases where the explanatory variables (X) include error(s) the slope of the regression is attenuated towards zero, thereby causing bias to the resulting signal in the prediction. Random noise in any linear system affects the estimates of the regression coefficients which demonstrate the relationship between the explanatory variable and the dependent variable(s), Y .

Amman et al. (2010) illustrate why the existence of noise in the predictors causes attenuation bias by providing an example of a simple linear regression model: $Y = \beta_0 + \beta_1 X + \varepsilon$ (6.6) with observations of Y the dependent variable and the noisy proxy: $W = X + u$. (6.7). X is the desired variable; in this case this would be wholesale costs; and u is a contaminating noise. W is the noisy proxy; in this case this would be wholesale prices. Y is regressed on a variable that contains a noise or a degree of contamination and this results to a contaminating noise.

Nakamura and Zerom's' (2010) study of the cost pass through in the US coffee market refers to the issue of attenuation bias cases when they estimate the cost pass through of the wholesale price to the retail price. Retailers are also faced with other costs. More specifically, the researchers suggested the 'wholesale price data are likely to be a noisy proxy for the wholesale costs faced by any retailer. To avoid attenuation bias, this study estimates this equation by instrumental variables regression with commodity costs as instrument' (Nakamura & Zerom

2010 p. 10). Therefore, they propose and apply the use of instrumental variables to prevent the effects of possible attenuation bias. This study follows their example and employs instrumental variables method and two stage least squares estimator. The present study follows this paradigm in terms of use of changes in commodity costs and lagged values as instruments for wholesale prices. Moreover, it enriches the analysis by conducting rigorous identification, over-identification, and exogeneity tests to ensure the instruments are relevant and exogenous. In addition, standard distributed lag model regressions are estimated for the cost pass through of the wholesale to the retail price using Newey West Standard errors to evaluate heteroskedasticity as well as serial correlation.

6.11 Instrumental Variables

Instrumental variables (IV) are commonly used to engage with such issues as endogeneity and attenuation bias. Philip G. Wright originally proposes the IV method in 1928. Bascle (2008) latterly elucidates that the IV method considers the fact that x as the explanatory variable, may be correlated to the error term providing bias results and estimates.

Consider the following regression with single endogenous variables following Bascle (2008) paper on endogeneity.

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 w_{1r} + \cdots \beta_{1+r} w_{ri} + u_i \quad (6.8)$$

The above is a regression of the dependent variable on independent endogenous variables and covariates. The regression also includes the error term.

The instrumental variables methodology must satisfy two conditions to ensure the estimator is efficient and consistent in terms of relevance and exogeneity (Bascle 2008; Wooldridge 2006).

1) The instrument must be correlated to the endogenous variable; and 2) the instrument must be uncorrelated to the error term. In cases of high correlation between the instrument and the independent variable, the instrument is characterised as strong; in cases of weak correlation between the instrument and the independent variable, the instrument is characterised as weak; and in cases of zero correlation between the instrument and the independent variable, the instrument is characterised as irrelevant. The weaker an instrument, the higher the asymptotic bias within the results and statistics and confidence intervals decrease their reliability. These instruments are described as Z_i (there must be at least as many instruments as endogenous regressors). In a two-step procedure, the effect of x_i on y_i is estimated, conditional to the covariates $w_{1i}, \dots, w_{ri}$.

While various IV methods are demonstrated in the literature, this study presents the widely applied two-stage least squares estimation (2SLS). During the first stage or reduced form equation, the endogenous regressor is regressed on instrument(s) and occasionally covariates. The dependent variable is then regressed on fitted values of the first stage and sometimes also on the covariates (Bascle 2008; Asteriou & Hall 2015). The first-stage regression is:

$$x_i = \pi_0 + \pi_1 z_{1i} + \cdots + \pi_m z_{mi} + \pi_{m+1} w_{1i} + \cdots + \pi_{m+r} w_{ri} + v_i \quad (6.9)$$

The second stage regression then follows in this way:

$$y_i = \beta_0 + \beta \hat{x}_i + \beta_2 w_{1i} + \beta_{1+r} w_{ri} + u_i \quad (6.10)$$

Covariates are used in the assumption of no correlation with the error term. As such they act as exogenous variables which are used to control for any bias caused by the instrument. The inclusion of covariates can increase statistical efficiency since they reduce the standard errors which are a function of the variance. In many cases in the empirical literature the two stage least squares estimation is applied without the use of covariates, provided that the instruments used are strong and exogeneity tests are applied accepting the null hypothesis that the instrument is exogenous. Ivreg2 statistical package may be employed to implement the two stage least squares estimation in Stata, and the statistics for testing under-identification, over-identifying restrictions, and exogeneity are provided.

6.12 Testing for Instrument Exogeneity

When the instruments used for the two stage least square estimation do not correlate with the error term, exogeneity is satisfied. Failure to achieve the exogeneity of an instrument leads to inconsistent IV estimates. Wooldridge (2006) describes that the exogeneity tests or tests of overidentifying restrictions have a greater number of instruments than endogenous regressors (i.e., the ‘equation is overidentified’) and assume exogeneity of one instrument. Bascle (2008) also underscores the fact that these tests must be undertaken after an instrumental variables two stage least squares estimation.

Exogeneity can be tested based on three statistics: Sargan (1958) or Hansen J (1982); Basman (1960), or difference in Sargan (Hayashi 2000). Under Sargan and Basman, the assumption of homoskedasticity holds; meaning that the variance of the error term given to the regressor is constant. However, the Hansen J-statistic provides robust results of heteroskedasticity. If no instrument is exogenous, Sargan, Hansen and Basman are biased and inconsistent. One solution for this is the use of the difference in Sargan statistic. The test for exogeneity is usually based on this statistic, wherein the number of instruments is two or more than the number of

the endogenous regressor. Known as the C-statistic, Stata software provides this under the `ivreg2` statistical package, the `orthog` option.³⁷

6.13 Conclusion

This chapter presented the econometric methods used to estimate market power and explore the main research questions. Preliminary tests methods of stationarity were described as well as the methods to determine cointegration. The chapter also outlined the FMOLS (Fully Modified OLS estimator) and DOLS (Dynamic OLS estimator) methods devised to estimate equation models of market power.

These methods were chosen following confirmation that cointegration exists in the estimated demand supply and production functions for all the three products under study.

The econometric methods used to estimate the cost pass through as well as asymmetric price transmission were described in full and the chapter elucidated distributed lag models, as well as instrumental variable methodology and the issue of endogeneity and attenuation bias. Such methods are deemed intrinsic to answering main research questions relevant to the estimation of cost pass through to a change in the input cost to the retailer price and a change in the wholesale cost to the retailer price.

³⁷ This thesis does not consider necessary to provide descriptive statistics for the above variables even though they can be provided upon request. A description of the variables sources is provided in Appendix A.

Chapter 7

Market Power Empirical Results

7.1 Introduction

This chapter presents the results relevant to estimating market power and a brief discussion of the results of the Augmented Dickey Fuller and Philips Perron tests for the demand, supply and production functions of milk road fuels and electricity supply chains. Full test tables are provided in Appendices B & C. The chapter then delineates the results of cointegration tests for each of the equations involved in the econometric model used for the purpose of this study.

The ARDL method or Johansen procedure is used to test both the demand, supply and Cobb-Douglas production function for the existence of cointegration. The choice of the cointegration test used depends on the order of integration of the variables: in cases where all the variables are integrated of order 1, this study uses the Johansen procedure; in cases where the variables have a mixture of integration order $I(1)$ or $I(0)$, this study uses the ARDL method. This is undertaken for the three industries involved, and an interpretation of the cointegration results are provided.

Lastly, the demand, supply and production functions are illustrated, together with the FMOLS and DOLS estimated market power parameters for each product.

7.2 Stationarity Tests: Augmented Dickey Fuller Results

7.2.1 Milk ADF Results First Stage

For all the variables used for the analysis of the milk first stage in levels, this study provides evidence that all the variables used for the analysis of the milk first stage they are non-stationary in level, since the Mackinnon approximate p-value for all of them is very high. As such, there is insufficient evidence to reject the null hypothesis of non-stationarity.

This thesis provides evidence that all the first differenced variables are stationary at the 1% level, since the MacKinnon approximate p-value for all of them is very low. As such, there is sufficient evidence to reject the null hypothesis of non-stationarity. Full details of the results are provided in Appendix A. Similar tests are undertaken for the market power parameter variables of the FMOLS and DOLS estimation and a mixture of $I(0)$ and $I(1)$ variables is established.

7.2.2 Milk ADF Results Second Stage

When the variables are in levels for milk second stage, there is evidence that they all are non-stationary and the null hypothesis of non-stationarity (unit root) cannot be rejected. This results from the fact that they have high MacKinnon approximate p-values of far greater than 0.05.

Only the variables of Quantity demanded, and Labour seem to be stationary with a p-value less than 0.05. The statistic is greater than the critical value at both levels. At 5% level, labour is stationary since the statistic is greater than the 5% critical value. However, at the 1% level it is not stationary since the statistic is less than the critical value.

This study finds all the above first differenced variables to be stationary since the MacKinnon approximate p-value for all of them is very low at less than 0.01. As such, the null hypothesis of non-stationarity can be rejected. All the variables are stationary at the 1 % level. Full details of results are provided in Appendix C. Similar tests are undertaken for market power parameter variables of the FMOLS and DOLS estimation, establishing a mixture of $I(0)$ and $I(1)$.

7.2.3 Petroleum ADF Results

Evidence demonstrates that the variables used in the analysis of petroleum products (road fuels) are non-stationary in levels and the null hypothesis of non-stationarity (unit root) cannot be rejected. This is based on the fact that they have high MacKinnon approximate p-values of far greater than 0.05. This study concludes that the variables are stationary since the MacKinnon approximate p-value for all of them is 0.000. Therefore, the null hypothesis of unit root is rejected.³⁸ Full details of results are provided in Appendix A.

7.2.4 Electricity ADF results

This thesis concludes that all the variables used in the electricity analysis are non-stationary in levels. A detailed table with the results is provided in Appendix A and that the null hypothesis of non-stationarity (unit root) cannot be rejected. This is based on the fact that they have high MacKinnon approximate p-values. Only the variables of the quantity demanded and upstream supply appear stationary with a p-value <0.01 . This statistic is greater than the critical at both levels.

³⁸ This thesis undertakes similar ADF tests for the three variables that are constructed based on the functions that consider the financial recession dummy and obtains similar results and for the three variables of the regression that does not include the dummy. The variables are established to be a mixture of $I(0)$ and $I(1)$.

For all the first differenced variables, this thesis concludes that they are stationary since the MacKinnon approximate p-value for all of them is 0.000. Therefore, the null hypothesis of non-stationarity can be rejected.³⁹

7.3 Philips-Perron Test for Stationarity

7.3.1 Philips-Perron Results Milk First Stage

This thesis concludes that all the variables included in the electricity analysis, are non-stationary in levels, and the null hypothesis of non-stationarity (unit root) cannot be rejected, since they have high MacKinnon approximate p-values of far greater than 0.05. Only the upstream supply and the quantity demanded are stationary at the 1% level: the upstream price is stationary at the 5% level; and Income and Input price2 are stationary at the 10% level. Examining only the 1% level, only Upstream supply and Quantity demanded are stationary. This study concludes that all the above first differenced variables are stationary since the MacKinnon approximate p-value for all of them is 0.000. Therefore, the null hypothesis of non-stationarity cannot be rejected.

7.3.2 Philips-Perron Results Milk Second Stage

This thesis concludes that all the variables included in the milk second stage variables are non-stationary and the null hypothesis of non-stationarity (unit root) cannot be rejected, based on the fact that they have high MacKinnon approximate p-values of far greater than 0.05. Only the variables Upstream supply and Quantity demanded appear stationary with a p-value <0.05. The statistic is greater than the critical value at both levels. At the 1% level upstream supply is non-stationary and quantity demanded is stationary.

This thesis concludes that all the first differenced variables are stationary since the MacKinnon approximate p-value for all of them is 0.000. Therefore, the null hypothesis of non-stationarity (unit root) can be rejected at the 1% level. A detailed table of results is provided in Appendix A.

7.3.3 Philips-Perron Results Petroleum

This thesis concludes that all the variables included in the road fuels analysis are non-stationary and the null hypothesis of non-stationarity (unit root) cannot be rejected, because they have

³⁹ This thesis undertakes similar ADF tests for the three variables that are constructed based on the functions that consider the financial recession dummy and obtains similar results. Since it has been confirmed that they are similar, these results are not reported.

high MacKinnon approximate p-values of far greater than 0.05. Only $\ln A$ is stationary at the 5% level.

This thesis concludes that all the above first differenced variables are stationary at 1% level, since the MacKinnon approximate p-value for all of them is 0.000. Therefore, the hypothesis of a unit root can be rejected at 1%.

7.3.4. Philips-Perron Results Electricity

This thesis concludes that all the variables included in the electricity analysis are non-stationary in levels as they have high MacKinnon approximate p-values, much greater than 0.05 and the null hypothesis of non-stationarity (unit root) cannot be rejected. Only Quantity demanded and Upstream supply are stationary with a MacKinnon approximate p-value of 0.000. Therefore, only these two variables are stationary at 1%.

For all the 1st differenced variables, this thesis concludes that they are stationary since the MacKinnon approximate p-value for all of them is 0.000. Therefore, the null hypothesis of non-stationarity can be rejected at 1% level. A detailed table is provided in Appendix C.

7.4. Cointegration Interpretation of Results

This section presents the results from cointegration tests for the milk, petroleum, and electricity industries. The test is applied to the demand function, inverse supply function, and Cobb-Douglas production function from the theoretical models. The study considers the double log form of the model. In cases where the variables of the specification tested are a mixture of $I(1)$ and $I(0)$, the present research conducts the ARDL cointegration test. In cases where the variables of the specification tested are all $I(1)$, the research conducts a Johansen cointegration test. The synoptic cointegration results obtained via Stata software are presented with a brief discussion, and full details of individual results are presented in Appendix D.

The Pesaran Shin and Smith (2001) bounds test with a null hypothesis of no level relationship (no cointegration) or the Johansen cointegration test is fully interpreted. The Johansen cointegration test is used as the most suitable in cases of many independent variables that are all $I(1)$. The null hypothesis is that there are no more than r cointegrating relationships among the variables. Further cointegration tests are also undertaken for the relationship between the three constructed variables of the market power regression, the dependent variable as described in the model in Chapter 7, and the oligopsony and oligopoly variables which are used for the estimation of the market power conduct parameters.

7.4.1 Cointegration Results Milk First stage

Table 7.1. Cointegration Results Milk First Stage

Milk First Stage				
Demand Function Johansen test	r	Trace Statistic	5% Critical Value	1% Critical Value
	4	11.8681	12.25	16.26
Supply Function ARDL	F Statistic	I(1) 10% Critical Value ⁴⁰	T-Statistic	I(1) 10% Critical Value ⁴¹
	4.098	3.668	-3.846	-3.547
Production Function Johansen Test	r	Trace Statistic	5% Critical Value	1% Critical Value
	1	37.7471	42.44	48.05
Market power regression Johansen Test	r	Trace Statistic	5% Critical Value	1% Critical Value
	1	21.3560	25.32	30.45

The demand function of the milk first stage in terms of the null hypothesis of no more than 4 cointegrating relationships finds the trace statistic less than both 5% and 1% critical values, 12.25 and 16.26, respectively. The hypothesis of no more than 4 cointegrating relationships cannot be rejected and cointegration is demonstrated among the dependent and independent variables. Based on Johansen (1995), this thesis' analysis accepts for number of cointegrating relationships, the first number of r cointegrating relationships, for which hypothesis is not rejected.

When using the ARDL test for cointegration, this study uses the following criteria to test for the null hypothesis of no cointegration:⁴²

Do not reject H_0 if: both F and t are closer to zero than the critical values for $I(0)$ variables (if p -values $>$ desired level for $I(0)$ variables).

Reject H_0 if: both F and t are more extreme than the critical values for $I(1)$ variables (if the p -values $<$ desired level for $I(1)$ variables).

⁴⁰ The 10% critical value is reported since this is the level at which cointegration has been established. This thesis accepts that cointegration can exist at the 10% level and therefore proceeds to analyse the relationship based on this result.

⁴¹ The 10% critical value is reported since this is the level at which cointegration has been established. This thesis accepts that cointegration can exist at the 10% level and therefore proceeds to analyse the relationship based on this result.

⁴² These criteria are used for every ARDL test undertaken for this thesis.

Table 7.1 provides evidence for cointegration between the variables of the supply function at the first stage of milk products chain, F , which corresponds to 4.098 and is above the $I(1)$ critical threshold of 3.668.

A recheck of the t -statistic confirms the above. $T = -3.846$ is more extreme than the critical values -3.547 . Thus, one can say there is evidence for cointegration at the 10% level. If this study takes 10% as a statistically significant level, the supply function can be estimated using the fact that there is cointegration among the variables.

At the production function of the milk first stage, for the null hypothesis of no more than 1 cointegrating relationships, the trace statistic is less than both the 5% critical value and 1% critical value, at 42.44 and 48.05 respectively, and therefore the hypothesis of no more than 1 cointegrating relationships cannot be rejected. Therefore, there is cointegration. Based on Johansen (1995), this thesis accepts the first number of cointegrating relationships r , for which hypothesis is not rejected.⁴³

With regards to the market power regression of the milk first stage, for the null hypothesis of 1 cointegrating relationship, the trace statistic is less than both the 5% and 1% critical values, 25.32 and 30.45, respectively, and therefore one cannot reject the hypothesis that there is no more than 1 cointegrating relationship. Thus study provides evidence of cointegration between the variables. Based on Johansen (1995), this thesis accepts the first number of cointegrating relationships r , for which hypothesis is not rejected.⁴⁴

7.4.2 Cointegration Results Milk Second Stage

The below table 7.2 indicates evidence of cointegration in the demand function of milk second stage, with F above than the $I(1)$ critical thresholds of 3.648 at 10% level, 4.224 at 5% level, and 5.490 at 1% level. A recheck of the t -statistic confirms the above. $T = -6.264$ is more extreme than the critical values of -3.585 at 10% level, -3.950 at 5% level, and -3.463 at 1% level. There is therefore evidence for cointegration at the 1% level. Further below this thesis interprets the results for the milk second stage supply function as well as production function.

⁴³ This thesis also undertakes similar cointegration tests for the variables of the market power regression estimated using the DOLS methodology. The findings confirm the existence of cointegrating relationship, and therefore are not reported in detail.

⁴⁴ This thesis also undertakes similar cointegration tests for the variables of the market power regression estimated using the DOLS methodology. The findings confirm the existence of cointegrating relationship, and therefore are not reported in detail.

Table 7.2. Cointegration Results Milk Second Stage

Milk Second Stage				
Demand Function ARDL	F Statistic	10% 5% 1% critical values	T Statistic	10% 5% 1% Critical values
	3.648	3.638, 4.224, 5.490	-6.244	-3.585, 3.950, -3.463
Supply Function Johansen Test	r	Trace Statistic	10% critical value	5% Critical Value
	1	53.8383	62.99	70.05
Production Function ARDL	F Statistic	10% 5% 1% Critical values	T Statistic	10% 5% 1% Critical values
	3.918	3.846, 4.485, 5.878	-3.814	-3.437, -3.780, -4.438
Market power regression Johansen Test	r	1	5% Critical Value	1% Critical Value
	1	19.25	25.32	30.45

In terms of the null hypothesis of 1 cointegrating relationship the trace statistic is less than both the 5% and 1% critical value, at 62.99 and 70.05, respectively, and therefore the hypothesis that there is no more than 1 cointegrating relationship cannot be rejected. In short, based on this thesis there is cointegration in the supply function of the second stage of the milk and dairy industry. Based on Johansen (1995), this thesis' analysis accepts the number of cointegrating relationships, r , for which the hypothesis is not rejected.

The above table indicates evidence for cointegration in the Cobb-Douglas production function of the milk second stage at the 10% level. F is above the $I(1)$ critical threshold of 3.846. If this thesis accepts that the null can be rejected at the 10% level, then cointegration exists.

For the null hypothesis of 1 cointegrating relationship the trace statistic is less than both the 5% and 1% critical value, 25.32 and 30.45, respectively, and one cannot reject the hypothesis that there is no more than 1 cointegrating relationship. Therefore, this thesis provides evidence that there is cointegration between the variables of the Cobb-Douglas production function of petroleum (road fuels) products.

Based on Johansen (1995), this thesis accepts as number of cointegrating relationships, the first number of cointegrating relationships r , for which hypothesis is not rejected.

Below this thesis provides the cointegration results for the demand supply and production functions of the road fuels supply chain, as well as the cointegration results for the road fuels market power regression. The results are interpreted to assess for cointegrating relationships for each case.

7.4.3 Cointegration Results Petroleum (Road Fuels)

Table 7.3. Cointegration Results Road Fuels

Road Fuels				
Demand Function	r	Trace Statistic	5% Critical Value	1% Critical Value
Johansen test	2	32.11505	42.44	48.45
Supply Function	r	Trace Statistic	5% Critical Value	1% Critical Value
Johansen test	3	14.6180	25.32	30.45
Production Function	r	Trace Statistic	5% Critical Value	1% Critical Value
Johansen test	2	13.1384	25.32	30.41
Market power regression ARDL	F Statistic	10% 5% 1% Critical Value	T Statistic	10% 5% 1% Critical Value
	8.683	4.137, 4.862, 6.248		-3.217, -3.539, -4.150

The demand function cointegration results for petroleum fuels in terms of the null hypothesis of 2 cointegrating relationships demonstrate the trace statistic is less than both the 5% and 1% critical value, at 42.44 and 48.45, respectively, and therefore the hypothesis of no more than 2 cointegrating relationships cannot be rejected. As such, this study establishes cointegration among the variables of the petroleum products (road fuels) demand function. Based to Johansen (1995), this study accepts the first number r of cointegrating relationships and thus the hypothesis that no more than r cointegrating relationships exist cannot be rejected.

The road fuels supply function in terms of the null hypothesis of 3 cointegrating relationships demonstrates the trace statistic is less than both the 5% and 1% critical values, at 25.32 and 30.45, respectively, and therefore the hypothesis of no more than 3 cointegrating relationships cannot be rejected. As such, this study establishes the existence of cointegration among the variables of the petroleum products (road fuels) supply function.

Based on Johansen (1995) this thesis accepts the first number of cointegrating relationships (r) for which the hypothesis that no more cointegrating relationships exist cannot be rejected.

The petroleum production function in terms of the null hypothesis of the 2 cointegrating relationships demonstrates the trace statistic is less than both the 5% and 1% critical value, at 25.32 and 30.45, respectively, and therefore the hypothesis of no more than the 2 cointegrating relationships cannot be rejected. As such, this thesis provides enough evidence of cointegration between the variables of the Cobb-Douglas production function of petroleum (road fuels) products. Based on Johansen (1995), this thesis accepts the first number of cointegrating relationships (r) for which the hypothesis that no more cointegrating relationships exist cannot be rejected.

As far as the regression for market power of road fuels is concerned, there is evidence for cointegration at 1% level since the F statistic is above the $I(1)$ critical threshold of 4.137, 4.862 and 6.428. These thresholds correspond to a 10%, 5%, and 1% significance level, and the null hypothesis of no cointegration cannot be rejected.

In the case that the DOLS methodology is applied, there is evidence for cointegration between the dependent and independent variables of the market power regression at the 1% level. F corresponds to 11.107 and is above than the $I(1)$ critical threshold of 4.138, 4.862 and 6.426, respectively. These thresholds correspond to 10%, 5%, and 1% significance level, and the null hypothesis of no cointegration can be rejected.

7.4.4 Cointegration Results Electricity

The below table 7.4, indicates the cointegration results for the demand, supply and production functions of the electricity supply chain. Cointegration results for the relevant market power regression are also discussed.

Based on the below table, this thesis provides evidence for cointegration for the variables of the electricity demand function. F statistic is above than the $I(1)$ critical threshold of 3.550, 4.066, 5.165, at 10%, 5% and 1% level correspondingly. Checking the T statistic, it agrees with the above. $T = -18.669$ is more extreme than the critical values; -3.610, -3.947, -4.582.

Based on this thesis, there is evidence for cointegration amongst the variables of the supply function of electricity.

F which corresponds to 4.682, is above than the $I(1)$ critical threshold of 3.557, 4.075 at 10% and 5% level. Therefore, the hypothesis of no cointegration can be rejected.

This thesis also provides evidence for cointegration amongst the variables of the production function of electricity. F is above the I(1) critical threshold of 3.549, 4.064 and 5.159. Checking the T statistic, $T = -10.161$ is more extreme than the critical values -3.409, -3.740, -4.367. This holds for all 10%, 5% and 1% level.

As far as the market power regression is concerned, for the null hypothesis of 3 cointegrating relationships, the trace statistic is less than both the 5% critical value and 1% critical value, 12.25 and 16.26 correspondingly and therefore one cannot reject the hypothesis that there are no more than 3 cointegrating relationships. Therefore, this thesis provides evidence that there is cointegration between the variables of the FMOLS market power regression for Electricity. Based on Johansen (1995), this thesis takes as the number of cointegrating relationships the first number of r for which the hypothesis that there are no more than r relationships cannot be rejected. After establishing establishment of cointegration for all the estimated demand, supply and production functions as well as market power regressions, this thesis presents below the FMOLS and DOLS estimated demand, supply and production functions results as well as market power parameters.

Table 7.4. Cointegration Results Electricity

Electricity				
Demand Function ARDL	F Statistic	10% 5% 1% Critical Value	T Statistic	10% 5% 1% Critical Value
	72.549	3.550, 4.066, 5.165	-19.004	-3.610, -3.947, -4.582
Supply Function ARDL	F Statistic	10% 5% 1% Critical Value	T Statistic	10% 5% 1% Critical Value
	4.682	3.557, 4.075, 5.176	-2.782	-3.652, -3.896, -4.618
Production Function ARDL	F Statistic	10%, 5%, 1% Critical Value	T Statistic	10% 5% 1% Critical Value
	36.081	3.785, 4.387, 5.678	10.161	-3.409, -2.854, -3.740.
Market power Regression Johansen Test	r	Trace Statistic	5% Critical Value	1% Critical Value
	3	3.1081	12.25	16.26

7.5. Market Power Results Milk First Stage

Table 7.5. Milk First Stage Demand, Supply and Production

Demand			Supply			Production		
	Lags	Lags		Lags	Lags		Lags	Lags
	2	1		4	1		1	1
Quantity demanded	FMOLS	DOLS	Upstream price	FMOLS	DOLS	Quantity produced	FMOLS	DOLS
Retail price	-7.1101***	-13.8879**	Upstream Supply	136.6312***	-4.5181	Upstream Supply	1.7144***	2.3408***
Income	-1.8262***	-0.1949*	Input price1	225.7005	-9.6777	Capital	-0.0648	-0.2091
Price of complements	-5.7942***	-10.6868***	Input price2	0.2723***	0.4214***	Labour	0.4346	0.4815***
lnRlnRs	1.4181***	2.7434***	lnAlnN1	-27.6109***	1.3225			
Linear	0.0126***		Linear		-0.0126***	Linear	0.0041***	0.0048***
Constant	56.0821***	61.7756***	Constant	-114.7741	-2.3421	Constant	-9.6789	-18.459***
Adj R2	0.69	0.67	Adj R2	0.69	0.68	Adj. R2	0.48	0.75
N	96	96	N	96	96	N	96	96

***Statistically significant at 1% p<0.01 **Statistically significant at 5% p<0.05 *Statistically significant at 10% p<0.1

The above table 7.5 shows the estimated demand, supply and production functions for the milk first stage. ⁴⁵The number of lags chosen is based on the Akaike Information Criterion. $\ln R \ln R_s$ represents the interaction term between the natural logarithm of the Retail price and the natural logarithm of the Price of complements. $\ln A \ln N1$ represents the interaction term between the natural logarithm of the upstream supply and the natural logarithm of Input price1. In cases where a linear trend or a quadratic are included and are not statistically significant or do not alter the results, they are not reported. All the variables are in natural logarithms. Further below this thesis provides a description of the relevant econometric results for the three functions of demand, supply and production. Results are provided for both FMOLS and DOLS estimations for each of these functions.

As indicated in Table 7.5, after estimating the demand function for milk using the FMOLS procedure and the choice of lags to be 2, it is evident that all of the independent variables in the FMOLS regression are statistically significant with very low associated p-values. Retail price, Income, Price of complements and the interaction term are statistically significant at the 1% level. Below this thesis provides independent interpretations for each of the coefficients. An independent examination of each individual variable confirms evidence for the following:

In terms of the Retail price which is paid by the retailers to acquire milk products from the producers, the sign of the coefficient is negative: this aligns with the predictions of economic theory predicts. An increase in the product price causes a decrease in its quantity demanded. Since the model used is a double log model, this thesis uses natural logs for all the variables, and the coefficient of retail price can be interpreted as the price elasticity of demand. This is the responsiveness of the quantity demanded to a change in price. The literature generally concurs that the demand for raw milk is price inelastic, meaning that an increase in the price causes a less than proportionate decrease in the associated quantity demanded. Based on the general literature and economic theory the coefficient is negative and less than 1. Contrary to expectation the coefficient of the retail price in the estimated demand function is higher than one. More specifically, its absolute value is 7. This means that a 1% increase in the price will cause a 7% decrease in the quantity demanded. This confirms that the demand is elastic with respect to price. What is puzzling here is that one would expect a coefficient that is negative and less than one. Contrary to the expectation, the coefficient of the retail price in the estimated demand function is higher than one. More specifically, its absolute value is 7. *Ceteris paribus*,

⁴⁵ It should be noted that this thesis includes a recession dummy, for the case of the milk demand supply and production functions, however since it is not statistically significant not altering the results in either of these three functions, it is not included.

this means that a 1% increase in the price will cause a 7% decrease in the quantity demanded. This indicates that the demand is elastic with respect to price. It should be noted that the author takes into account that this thesis estimates a logarithmic demand function that includes an interaction term of $\ln R$ and $\ln R_s$. Taking this into account and evaluating as price elasticity of demand $b_2 + b_4 \ln R_s$, the actual price elasticity is calculated as -0.87. Therefore it is as expected; negative and less than one.

In terms of Income, the sign of the coefficient of the real household income is estimated to be negative.

When a good is normal by definition, an increase in income increases its quantity demanded and thus the income elasticity of demand should be positive. Income elasticity of demand is the responsiveness of quantity demanded to a change in income.

This is a puzzling result since raw milk is considered to be a normal good. Therefore as Income goes up demand for the good also goes up. Under DOLS, however, income is statistically significant at only the 10% level.

Furthermore, the coefficient of the Price of complements shows the cross-price elasticity of demand between the price of complements; which in this case is the price of processed tea and coffee, and the price of milk products. Tea and coffee can be seen as a complement for milk. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case demand of milk and dairy products from the retailers, to the price of another good, in this case tea and coffee. The sign of the cross-price elasticity of demand between quantity demanded and price of complements is negative; this aligns with expectations, since the two goods are complements.

In the generic case of two goods, Y and X; when the price of good Y rises, the quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient is according to economic theory.

After estimating the demand function for milk and dairy products using the DOLS procedure and the choice of lags to be 1, this study demonstrates that all of the independent variables in the DOLS regression are statistically significant with very low associated p-values. The retail price is statistically significant at the 1% level, income at the 10% level, and price of substitutes and the interaction term at the 1% level. Examining each independent variable individually it is observed that:

In terms of the Retail price which is paid by the retailers, the sign of the coefficient is negative as expected. An increase in the price of the product causes a decrease in its demand. Since the model used is a double log model natural logarithms are used for all the variables, the coefficient of Retail price can be interpreted as the price elasticity of demand. This is the responsiveness of the quantity demanded to a change in price. The literature generally concurs that the demand of milk and dairy products is price inelastic. This means that an increase in the price causes a less than proportionate decrease in the associated quantity demanded. Contrary to expectations, the coefficient of Retail price in the estimated demand function is higher than one.

More specifically, its absolute value is 13. This means that a 1% increase in the price will cause a 13% decrease in the quantity demanded. This indicates that the demand is elastic with respect to price.

In terms of income, the sign of the coefficient of the real household income is estimated to be negative. When a good is normal by definition, an increase in income increases its demand, therefore the income elasticity of demand should be positive. Income elasticity of demand, is the responsiveness of quantity demanded to a change in income. However, it should be noted that under DOLS, this study provides evidence that income is not statistically significant at either the 5% level or 1% level. Therefore this thesis does not provide further interpretation of the unexpected sign of the variable representing income.

Furthermore, the coefficient of the Price of complements demonstrates the cross-price elasticity of demand between the price of complements which in this case is price of processed tea and coffee, and the price of milk. Tea and coffee can be seen as a complement for milk.

The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case consumer demand of milk and dairy products to the price of another good, in this case tea and coffee. The sign of the cross-price elasticity of demand between quantity demanded and the price of substitutes is negative as expected, since milk and processed tea and coffee are complements.

For a generic case, when the price of good Y rises, the quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient is according to economic theory.

After estimating the supply function for milk and dairy products first stage using the FMOLS procedure and the choice of lags to be 4, one can see that all of the independent variables in the FMOLS regression are statistically significant with very low associated p-values. Upstream

supply, Input price1, Input price2 and the interaction term are all statistically significant at the 1% level. Looking at each independent variable individually, this study provides evidence for the following:

With regards to the upstream supply; manufacture of dairy products; the sign of the coefficient is positive as expected. The price and the supply are positively related. As far as the inputs are concerned the coefficient of Input price1 which corresponds to feed for animals cost is positive. This confirms a positive relationship between the price of the input and the price of the output. A percentage increase in Input price1 causes a percentage increase in the price of the output (upstream supply price) as foreseen.

Furthermore the coefficient of Input price2 which corresponds to the cost per labour hour is positive and confirms a positive relationship between the price of the input and the price of the output. A percentage increase in Input price2 causes a percentage increase in the price of the output (upstream supply price) as foreseen.

Estimating the Cobb-Douglas production function of milk and dairy products first stage using the FMOLS procedure, this study provides evidence that labour is statistically significant at the 1% level since it is associated with a very low p-value. The coefficient of Labour is positive as one would expect; increasing the input increases the production. This shows the production elasticity of labour. A percentage increase in the labour input causes an output increase of 0.4346%. The coefficient of capital, which is the production elasticity of capital, is statistically insignificant.

After estimating the supply function for milk and dairy products towards the retailers using the DOLS procedure and the choice of lags to be 1, this study provides evidence that all of the independent variables of the regression under the DOLS methodology are insignificant with low p-values. The Upstream supply, Input price1, and the interaction term are statistically insignificant, while Input price2 is statistically significant at the 1% level. Only the second input of the price of processed tea and coffee appears statistically significant. The coefficient of Input price2 is positive and confirms a positive relationship between the price of the input and the price of the output. A percentage increase in Input price2 causes a percentage increase in the price of the output (upstream supply).

Estimating the Cobb-Douglas production function of the milk and dairy products using the FMOLS procedure, this study provides evidence that labour is statistically significant at the 1% level since it is associated with a low p-value. The coefficient of Labour is positive as

expected, since increasing the input increases the production. This confirms the production elasticity of labour. A percentage increase in labour input causes an increase of 0.4346% to the output. The coefficient of capital is statistically insignificant. Estimating the Cobb-Douglas production function of milk and dairy products using the DOLS procedure, it is evident that labour is statistically significant since it is associated with a very low p-value.

The coefficient of labour is positive as one would expect, increasing the input, increases the production. This shows the output elasticity of labour. Since capital is statistically insignificant, this study does not provide any further elucidation about its coefficient.

Table 7.6 illustrates the estimated FMOLS and DOLS market power parameters of the milk first stage. The number of lags is chosen based on the Akaike Information Criterion (AIC). The dependent variable is $D = Rc_1 \frac{Q}{A} - P$ as presented in the market power model in Chapter 5. The coefficient of Oligopsony represents any potential market power of the processors towards farmers and the coefficient of Oligopoly represents the market power of processors towards retailers. N is the number of observations. In the case that a trend is included but not sufficiently statistically significant to alter the results, it is not reported.

Table 9.6 indicates that when estimated under the FMOLS method, the market power parameter of the processors towards the farmers is statistically significant with a p-value of 0.01, while the market power parameter of the processors towards the retailers is statistically insignificant.

There is therefore evidence to support that there is some degree of oligopsonistic power from the processors towards the farmers, and no evidence of oligopoly power from the dairy processors towards the retailers of dairy products. Despite the fact, that some of the coefficients in the supply function estimated by the DOLS procedure are insignificant, this study proceeds to the estimation of market power parameters using DOLS results because there are statistically significant coefficients for demand and production when estimated using the DOLS. Below this thesis illustrates the market power results for the estimated parameters.

Table 7.6. Market power Regression for Milk First Stage

	Lags	Lags
	4	4
	FMOLS	DOLS
Oligopsony	0.0176***	0.2895***
Oligopoly	0.1952	-0.2856***
Constant	-0.3754	13.6197***
Adj R2	0.23	0.87
N	96	96

***Statistically significant at 1% p<0.01**Statistically significant at 5% p<0.05*Statistically significant at 10% p<0.10

The above table further shows the estimated DOLS market power parameters of the milk first stage. The number of lags is chosen based on the Akaike Information Criterion and the standard errors are in parentheses. The coefficient of oligopsony represents any potential market power of the processors towards the farmers, while the coefficient of oligopoly represents the market power of processors towards the retailers. N is the number of observations. Table 7.3 reveals that the DOLS market power parameter of the processors towards farmers is estimated to be -0.2895 and statistically significant with a p-value of 0.000. The market power parameter of the processors towards the retailers is estimated to be -0.2856 and statistically significant with a p-value of 0.000. There is some evidence for oligopolistic power on behalf of retailers towards the consumers. When evaluating the coefficient -0.2895 with hypothesis testing, evidence demonstrates that this is not less than 0, and confirms the oligopsonistic power of the processors towards the farmers.

7.6. Market Power Results Milk Second Stage

The below table 7.7, shows the estimated FMOLS and DOLS coefficients for the milk second stage. The number of lags is chosen based on the Akaike Information Criterion. $\ln R \ln R_s$ represents the interaction term between the retail price and the price of complements. It should be noted that in the cases that a linear or quadratic trend are included in the regressions and are not statistically significant not altering the results, then they are not reported. In the case that a linear trend or quadratic is statistically significant, and it is reported, it is included in the estimated econometric results.

After estimating the demand function for milk and using the FMOLS procedure and the choice of lags to be 1, it is evident that all of the independent variables in the FMOLS regression are statistically significant with very low associated p-values. Looking at each independent variable individually one can notice the following. This author takes into account that the price elasticity of demand can be estimated as $b_2 + b_4 \ln R_s$, since the interaction term of the price and price of complements is included in the estimated demand function. This is the responsiveness of the quantity demanded to a change in price. The literature generally concurs that the demand for milk and dairy products is price inelastic. An increase in the price causes a less than proportionate decrease in the associated quantity demanded. What is puzzling here is that one would expect a coefficient that is negative and less than 1. Contrary to expectation, the absolute value of the price elasticity of demand is much higher than one. This indicates that the demand is elastic with respect to price.

Table 7.7. Milk Second Stage Demand, Supply and Production

	Demand			Supply			Production	
	Lags 1	Lags 4		Lags 2	Lags 3		Lags 1	Lags 2
Quantity demanded	FMOLS	DOLS	Upstream Price	FMOLS	DOLS	Quantity produced	FMOLS	DOLS
Retail price	-5.7765***	-3.2421***	Upstream Supply	-5.1601	20.6168***	Upstream Supply	-0.0940	0.2576
Income	3.3412***	2.0089***	Input price1	-3.9233	19.8553***	Capital	0.9571**	-0.1291***
Price of complements	-8.4766***	-4.3786***	Input price2	-0.1140	0.4071***	Labour	0.6591**	0.7083***
lnRlnRs	1.4684***	0.8169***	lnAlnN1	1.0769	-4.3799***			
Linear	-0.2719***	0.0001***						
Quadratic	0.0001***	108.1946***						
Constant	41.7734***	0.0170***	Constant	24.1308	90.8160***	Constant	3.6791*	3.3811***
Adj R2	0.88	0.47	Adj R2	0.99	0.22	Adj. R2	0.26	0.95
N	96	96	N	96	96	N	96	96

***Statistically significant at 1% level $p < 0.01$ **Statistically significant at 5% level $p < 0.05$ *Statistically significant at 10% level $p < 0.10$

Moving on to the other variables of the FMOLS demand function, in terms of Income, the sign of the coefficient of the natural logarithm of GDP is estimated to be positive. Begg et al. (2020) states what is well known in economics, that when a good is normal by definition, an increase in income increases its demand; therefore the income elasticity of demand should be positive. Income elasticity of demand is the responsiveness of quantity demanded to a change in income. Therefore this study's estimate agrees with the standard economic theory. The coefficient of income is greater than 1 which confirms that milk products are income elastic in the long run.

Furthermore the coefficient of the Price of complements, shows the cross-price elasticity of demand between the price of complements; which in this case is bread, and the price of dairy products. Bread can be seen as a complement for butter and milk. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good; in this case milk products to the price of another good; in this case bread.

The sign of the cross price elasticity of demand between the quantity demanded and the price of complements is negative. In a generic case; when the price of good Y rises, the quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient aligns with standard economic theory.

After estimating the demand function for milk products and using the DOLS procedure and the choice of lags to be 4, it is evident that all of the independent variables in the DOLS regression are statistically significant with very low associated p-values. Retail price, Income, Price of complements, and the interaction term are statistically significant at the 1% level. Examining each independent variable individually, this thesis provides evidence for the following:

In terms of the Retail price of milk products, the sign of the coefficient is negative as expected. An increase in the price of the product causes a decrease in its demand. Since the model is a double log model natural logarithms are used for all variables, and the coefficient of retail price can be interpreted as the price elasticity of demand. This is the responsiveness of the quantity demanded to a change in price. Generally in the literature the demand for milk and milk products is price inelastic. This means that an increase in the price causes a less than proportionate decrease in the associated quantity demanded. What is puzzling here is that one would expect a coefficient that is negative and less than one.

Contrary to expectation, the estimation of $b_2 + b_4 \ln R_s$ in the estimated demand function is higher than 1. More specifically, its absolute value is greater than 10%. This means that a 1%

increase in the price will cause a more than 10% decrease in the quantity demanded. This indicates that the demand is elastic with respect to price.

In terms of Income, the sign of the coefficient of the natural logarithm of GDP is estimated to be positive. When a good is normal by definition, an increase in income increases its demand; therefore the income elasticity of demand is normally expected to be positive. The income elasticity of demand is the responsiveness of the quantity demanded to a change in income. This study's estimate aligns with economic theory.

Furthermore the coefficient of the price of complements, shows the cross-price elasticity of demand between the price of complements, which in this case is bread, and the price of milk products. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good; in this case milk products to the price of another good; in this case bread. The sign of the cross-price elasticity of demand between quantity demanded and price of substitutes is negative which is to be expected since the two goods are complements.

When the price of good Y rises, the quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient corresponds to standard economic theory. It is also worth mentioning that the estimated demand function has a moderately high adjusted R square of 0.48. This indicates that around 48% of the variation in the dependent variable is explained by the independent variables.

After estimating the supply function for milk and dairy products second stage, using the FMOLS procedure and the choice of lags to be 2, this study confirms all of the independent variables in the FMOLS regression to be statistically significant with very low associated p-values. Upstream supply, Input price1 and Input price2 are statistically significant at the 1% level, and the interaction term has a p-value of 0.000. Examining each independent variable individually, this study provides evidence for the following: In terms of the upstream supply in manufacture of dairy products the sign of the coefficient is positive: this aligns with standard economic theory predictions. The price and the supply are positively related.

In terms of the inputs, the coefficient of Input price1, which is the price index of inputs in the manufacture of dairy products, is positive; this shows a positive relationship between the price of the input and the price of the output. A percentage increase in Input price1 causes a percentage increase in price of the output (upstream supply price) as expected. Furthermore the coefficient of Input price2 which is cost per labour hour, is positive, which demonstrates a

positive relationship between the price of the input and the price of the output. A percentage increase in Input price₂ causes a percentage increase in the price of the output (upstream supply price); again in line with expectations.

After estimating the supply function for the second stage of the milk products supply chain, using the DOLS procedure and the choice of lags to be 3, it is evident that all of the independent variables in the DOLS estimation are statistically insignificant with very low associated p-values. If the number of lags is increased, the variables are still insignificant. Despite the fact that there are insignificant estimates for the supply of milk products under DOLS, this study uses these results to estimate the market power regression that estimates oligopsony and oligopoly power parameters. This is mainly for the purposes of comparison and the researcher remains cautious in interpreting these results or emphasising the results of the FMOLS methodology for the second stage of the milk products market.

Estimating the Cobb-Douglas production function of dairy products, using the FMOLS procedure confirms that capital and labour are statistically significant at the 1% and 5% level, respectively since they are associated with very low p-values. The coefficient of Labour is positive as one would expect, since increasing the input increases the production. According to Perekhozhuk et al. (2017), this indicates the production elasticity of labour.

A percentage increase in labour causes a less than proportionate increase in output. The coefficient of Capital, however, is not as expected and indicates the production elasticity of capital. One would expect this to be positive. This study provides a possible explanation for this in the synoptic market power results chapter. Estimating the Cobb-Douglas production function of dairy products using the DOLS procedure confirms that Capital and Labour are statistically significant since they are associated with very low p-values. The coefficient of labour is positive as one would expect since increasing the amount of input, increases the production. According to Perekhozhuk et al. (2017), this indicates the production elasticity of labour. A percentage increase in labour causes a less than proportionate increase in output. The coefficient of Capital is not as expected. The above findings show that a 1% increase in capital, decreases output by 0.95%. However, this is not statistically significant, at either 5% or 1% level:

The below Table 7.8 shows the estimated market power parameters for the milk second stage. The dependent variable is $D = Rc_1 \frac{Q}{A} - P$ as discussed in the market power model in Chapter

5. The coefficient of oligopsony represents the market power parameter of retailers towards processors, while the coefficient of oligopoly represents the market power parameter of retailers towards consumers. The number of lags is chosen based on the Akaike Information Criterion.

Table 7.8. Market Power Regression for Milk Second Stage

	Lags	Lags
	4	4
	FMOLS	DOLS
Oligopsony	1.3111*** ⁴⁶	-1.0884*** ⁴⁷
Oligopoly	0.6527***	-0.9107***
Constant	5.6717***	-55.8901***
Linear	253.3354*	-0.9795***
Adj R2	0.51	0.97
N	96	96

***Statistically significant at 1% level. $p < 0.01$

** Statistically significant at 5% level. $p < 0.05$

*Statistically significant at 10% level. $p < 0.10$

Table 7.8 demonstrates the parameters of oligopsony and oligopoly market power which correspond to oligopsony power of retailers towards processors and oligopoly power of retailers towards consumers. Both parameters are statistically significant at the 1% level when estimated with the FMOLS methodology. The coefficient of oligopoly of between 0 and 1 corresponds to oligopoly.

⁴⁶ Due to the magnitude of the FMOLS market power parameter of retailers towards the processors, that is greater than 1, this thesis tests the null hypothesis that the coefficient of oligopsony is greater than 1. The Z-statistic is 126 and the corresponding critical value at 1% level is -2.37. The null hypothesis is rejected at 1% level since the absolute value of the Z-statistic is greater than the critical value, therefore this confirms that the oligopsony parameter is statistically significant but is not greater than 1.

⁴⁷ Due to the magnitude of the coefficient of the DOLS market power of the retailers towards the processors parameter, this thesis proceeds to hypothesis testing with a null hypothesis that the coefficient is less than 0. The Z-statistic is -37.5 and the critical value at 1% is -2.37. Therefore, since the absolute value of statistic is greater than the absolute critical value, the null hypothesis is rejected, and the coefficient is not negative. It is therefore statistically significant since the p-value for the null hypothesis that the coefficient is different than zero, is 0.000, with a magnitude not less than 0.

Due to the magnitude of the FMOLS market power parameter of the retailers towards the processors at greater than 1, this study tests the null hypothesis, H_0 that the coefficient of oligopsony is greater than 1. The Z-statistic is 126 and the corresponding critical value at the 1% level is -2.37. The null hypothesis is rejected at the 1% level since the absolute value of the Z-statistic is greater than the critical value; thereby confirming the fact that the oligopsony parameter is statistically significant but is not greater than 1. Based on the DOLS estimation, this study provides evidence that both parameters of the market power of the retailer towards providers and the retailers towards the consumer, which are oligopsony and oligopoly, respectively, are statistically significant at the 1% level. They are both associated with very low p-values of 0.000. However, the researcher remains cautious since these findings are based on a supply function which gives insignificant estimates.

The coefficient of oligopoly is between 0 and 1 and with a high value towards 1, indicating oligopolistic power of the retailers towards the consumers. For this parameter, this study interprets the value – (-0.9107), therefore 0.9107. Due to the magnitude of the coefficient of the DOLS market power of retailers towards the processors parameter, this study proceeded to testing the null hypothesis that the coefficient is less than 0. The Z-statistic is -37.5 and the critical value at 1% is -2.37. Therefore, since the absolute value of statistic is greater than the absolute critical value, the null hypothesis is rejected, and the coefficient is not negative.

7.7. Market Power Results Road Fuels⁴⁸⁴⁹

Table 7.9 presents the synoptic results for the demand supply and production functions for road fuels. Estimations that include a recession dummy are also included and the choice of lags based on the Akaike Information Criterion. $\ln R \ln R_s$ represents the interaction term between the natural logarithm of the retail price and the natural logarithm of the price of complements. $\ln A \ln N1$ represents the interaction term between the natural logarithm of the upstream supply and the natural logarithm of Input price1.

⁴⁸ When the dummy for recession is included in the demand estimation under FMOLS, the dummy is not statistically significant not altering the results. This thesis does not include this estimation in the analysis.

⁴⁹ The relationship between these three variables has been tested for cointegration using the Johansen procedure and enough evidence is provided to suggest cointegration. Augmented Dickey Fuller tests are undertaken by this thesis for the three variables of the estimation that takes into account the recession, establishing that the variables are $I(1)$.

Table 7.9. Road Fuels Demand, Supply and Production

	Demand			Supply				Quantity produced	Production			
	Lags 3 FMOLS	Lags 3 DOLS	Upstream price	Lags 0 FMOLS	Lags 0 FMOLS with recession dummy	Lags 3 DOLS	Lags 1 DOLS with recession dummy		Lags 0 FMOLS	Lags 1 FMOLS with recession dummy	Lags 0 DOLS	Lags 0 DOLS with recession dummy
Quantity demanded								Quantity produced				
Retail price	-9.5407**	-16.1376***	Upstream Supply	0.5008	0.3764	0.4506*	0.4844	Upstream Supply	0.2164***	0.2902***	0.2787***	0.2209**
Income	-1.1295***	-0.9184***	Input price1	1.8024***	1.3717**	1.5094***	1.7276**	Capital	0.1909***	0.6475***	0.2334	0.0702
Price of complements	-8.3463**	-14.3294***	Input price2	0.0781***	0.1208***	-0.0767**	0.0743*	Labour	0.2973***	-0.2782*	-0.2590	-0.1387
lnRlnRs	1.9897**	3.4052***	lnAlnN1	-0.1083	-0.0563	-0.0729	-0.0955					
Recession			Recession		-0.0374***		-0.0342***	Recession		-0.0566***		-0.0386*
								Linear	-0.0330***		-0.0036***	-0.0028***
Constant	52.3867***	79.3796	Constant	-4.2754	3.5734	-2.8954	-0.0342***	Constant	8.1757***	11.4667***	0.9716	6.8720***
Adj R2	0.87	0.92	Adj R2	0.98	0.98	0.99	0.95	Adj R2	0.94	0.90	0.95	0.96
N	228	228	N	228	228			N	228	228	228	228

***Statistically significant at 1% level p<0.01 **Statistically significant at 5% level p<0.05 *Statistically significant at 10% level p<0.1

After estimating the demand function for petroleum products (more specifically, road fuels), using the FMOLS procedure and the choice of lags to be 3, it is evident that all of the independent variables in the FMOLS regression are statistically significant with very low associated p-values. Retail price and income, price of substitutes, and the interaction term are all statistically significant at the 1% level. Looking at each independent variable individually this thesis provides evidence for the following:

In terms of Retail price of vehicle fuels and lubricants the sign of the coefficient is negative: this aligns with economic theory. An increase in the price of the product causes a decrease in its demand. However, this author considers that for the estimation of the demand function of this thesis; the interaction term of the natural logarithm of road fuels retail price and the natural logarithm of the price of complements is also included as a regressor. Therefore, it is for the purpose of this thesis that the author evaluates the own price elasticity of demand as $b_2 + b_4 \ln R_s$. The corresponding value in absolute terms is greater than 10%, which is highly inelastic contradicting the expectations the expectation on which this study bases its motivation on. Based on Eitches and Crain (2018), this could be attributed to the turn towards more cost-efficient substitutes such as electric vehicles.

In terms of Income the sign of the coefficient of the natural logarithm of GDP is estimated to be negative. When a good is normal by definition, an increase in income increases its demand; thus the income elasticity of demand should be positive. Income elasticity of demand is the responsiveness of quantity demanded to a change in income. This research discusses an interpretation for this finding in the synoptic market power results.

Furthermore the coefficient of the price of complements shows the cross-price elasticity of demand between the price of complements which in this case is motor vehicles, and the price of vehicle fuels. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case vehicle fuels to the price of another good, in this case motor vehicle. The sign of the cross-price elasticity of demand between quantity demanded and price of substitutes is negative as expected, since the two goods are complements. When the price of good Y rises, the quantity demanded of its complement good X falls. Therefore the sign of our estimated coefficient aligns with economic theory.

The estimated demand function has a highly elevated adjusted R square of 0.87. This indicates that around 87% of the variation in the dependent variable is explained by the independent variables.

After estimating the demand function for petroleum products (more specifically, road fuels) using the DOLS procedure and the choice of lags to be 0, it is evident that all of the independent variables in the DOLS regression are statistically significant with very low associated p-values. Looking at each independent variable individually this thesis provided evidence for the following:

In terms of the own price elasticity of demand of road fuels this author assesses that it is price elastic. The literature generally concurs that the demand for road fuels and for gasoline is price inelastic. That is, an increase in the price causes a more than proportionate decrease in the associated quantity demanded. Based on Eitches and Crain (2016) this could be attributed to the fact that in the long run consumers have time to change their embedded habits and turn towards more energy efficient cars such as electric cars. Furthermore in the UK consumers have easy access to the alternative of public transport.

In terms of Income, the sign of the coefficient of the natural logarithm of GDP is estimated to be negative. When a good is normal by definition, an increase in income increases its demand, therefore the income elasticity of demand should be positive. Income elasticity of demand is the responsiveness of quantity demanded to a change in income. This study offers a number of some possible reasons for these findings in the market power synoptic results section below. Furthermore, the coefficient of Price of complements shows the cross-price elasticity of demand between the price of complements which in this case is motor vehicles, and the price of vehicle fuels. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case vehicle fuels to the price of another good, in this case motor vehicle. The sign of the cross-price elasticity of demand between quantity demanded and price of substitutes is negative as according to expectations since the two goods are complements. When the price of good Y goes up, the Quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient aligns with standard economic theory. It is worth mentioning that the estimated demand function has a particularly high adjusted R square of 0.92. This indicates that around 92% of the variation in the dependent variable is explained by the independent variables.

After estimating the supply function for petroleum products (more specifically, road fuels), using the FMOLS procedure and the choice of lags to be 0, it is evident that all of the independent variables in the FMOLS regression are statistically significant with very low associated p-values. Upstream supply is statistically significant at 10% level, Input price1 and

Input price2 are statistically significant at 1%, and the interaction term is statistically significant at the 10% level. Looking at each independent variable individually this study provides evidence for the following:

In terms of the Upstream supply (refinery output of petroleum products), the sign of the coefficient is positive, as expected. The price and the supply are positively related.

In terms of the Inputs, the coefficient of Input price1 which corresponds to a price index of inputs used in refinement and distribution of petroleum products is positive, demonstrating a positive relationship between the price of the input and the price of the output. A percentage increase in Input price1 causes a percentage increase in the price of the output (upstream supply price) as foreseen.

Furthermore, the coefficient of Input price2 which is the price of coal, is positive and shows a positive relationship between the price of the input and the price of the output. A percentage increase in Input price2 causes a percentage increase in the price of the output (upstream supply price) as foreseen.

The value of the adjusted R-square is 0.99. This means 99% of the variation in the dependent variable is explained by the independent variables. When estimating the supply function using FMOLS and including the recession dummy, this study confirms it as statistically significant, with a negative coefficient. This indicates that when in recession, the price of the upstream supply decreases.

After estimating the supply function for petroleum products (more specifically, road fuels) using the DOLS method and the choice of lags to be 0, it is evident that all of the regressors in the DOLS regression except from the interaction term, are statistically significant with very low associated p-values.

Upstream supply is statistically significant at the 10% level, and Input price1 is statistically significant at 5% level, and Input price2 at the 1% level. Examining each independent variable individually confirms the following:

In terms of Upstream supply (refinery output of petroleum products), the sign of the coefficient is positive as expected since the price and the supply are positively related.

In terms of inputs, the coefficient of Input price1 is positive, which confirms a positive relationship between the price of the input and the price of the output. A percentage increase

in Input price1, causes a percentage increase in the price of the output (upstream supply price) as foreseen.

Furthermore, the coefficient of Input price2 which is the price of coal, is negative, which demonstrates a negative relationship between the price of the input and the price of the output. A percentage increase in Input price2 causes a percentage decrease in upstream supply price. This may indicate the high degree of substitutability of the input. The adjusted R-square is 0.99. Therefore 99% of the variation in the dependent variable is explained by the independent variables. In the case that the recession dummy is included in the DOLS estimation, it is statistically significant at the 1% level with a negative coefficient. Upstream supply is not statistically significant, while Input price1 and Input price2 are statistically significant.

Estimating the Cobb-Douglas production function of road fuels using the FMOLS procedure, it is observed that all the independent variables are statistically significant at the 1% level since they are associated with very low p-values.

The coefficient of Capital is positive as expected since increasing the amount of the input increases the production. This shows the production elasticity of capital. The coefficient of Labour is positive indicating the output elasticity of labour. The adjusted R square of the estimated production function is very high. Thus a 94% of the variation in the dependent variable is explained by the independent variables.

By estimating the Cobb-Douglas production function of road fuels including the recession dummy and using the FMOLS procedure, this study provides evidence that all the independent variables are statistically significant since they are associated with very low p-values.

Labour is not statistically significant at either 5% or 1% level since it has a p-value of 0.069.

If the 10% level is considered, labour is statistically significant with a negative coefficient. This suggests that the industry is at the third stage of production and there is over-utilisation of labour. A higher amount of labour input decreases the output. Third stage of production in theory exists but it is rarely empirically established. Capital is statistically significant at the 1% since it has a p-value of 0.000. The output elasticity of capital is positive and aligns with economic theory. A 1% increase in capital increases production by 0.6475%.

Estimating the Cobb-Douglas production function of road fuels using the DOLS procedure, there is sufficient evidence that capital is statistically significant at least at the 10% level. The

coefficient of Capital is positive. This indicates the output elasticity of capital. A 1% increase in capital increases output by 0.23%. The coefficient of labour is statistically insignificant. The adjusted R-square of the estimated production function is very high. Thus 95% of the variation in the dependent variable is explained by the independent variables.

Estimating the Cobb-Douglas production function of road fuels using the DOLS procedure and including a recession dummy provides sufficient evidence that capital is statistically significant at least at the 10% level. The coefficient of Capital is positive and indicates the output elasticity of capital. A 1% increase in capital increases output by 0.23%. The coefficient of Labour is statistically insignificant. The adjusted R-square of the estimated production function is very high. Thus 95% of the variation in the dependent variable is explained by the independent variables.

Table 7.10 illustrates the FMOLS and DOLS estimated market power parameters and includes the estimations that consider the dummy variable for the recession period 2008-2014. The dependent variable is $D = Rc_1 \frac{Q}{A} - P$ as discussed in the market power model in Chapter 5. The coefficient of Oligopsony indicates the market power parameter of retailers towards their providers and Oligopoly indicates the market power parameters of retailers towards the consumers. The number of lags chosen is based on the Akaike Information Criterion. N indicates the number of observations. The adj R2 is also included in the table to provide some information about the fit in the model; a technique which is commonly used in the economic empirical literature.

In cases that a trend is included but not statistically significant in altering the results, it is not reported in the regression results.

Using the FMOLS methodology, Table 7.10 indicates that the parameter of market power of retailers towards their providers is statistically significant at the 1% level and the parameter of market power of retailers towards the consumers is also statistically significant at the 1% level. There is therefore oligopoly power from the retailers towards the consumers with a parameter estimation of -0.0600. Evaluating the negative value of this λ is between 0 and 1. The estimated parameter for market power of retailers towards their providers is between 0 and 1 and corresponds to 0.3350. This represents a significant degree of oligopsony power. In cases where the supply and production functions which include the recession dummy are considered,

the market power parameters of the retailers towards their providers and the retailers towards the consumers are statistically significant at the 1% level.

Table 7.10. Market Power Regression for Road Fuels⁵²

	Lags	Lags	Lags	Lags
	1	1	3	1
	FMOLS	FMOLS with recession dummy	DOLS	DOLS with recession dummy
Oligopsony	0.3350***	3.4796*** ⁵⁰	0.0001	8.2100*** ⁵¹
Oligopoly	-0.0600***	-0.0270*	3.02e ^{-0.9***}	-0.3934***
Constant	-97.7445***	-12.003***	0.001	-70.27
Adj R2	0.96	0.96	0.64	0.65
N	228	228	228	228

***Statistically significant at 1% level p<0.01**Statistically significant at 5% level p<0.05

*Statistically significant at 10% level p<0.10

Based on the above table, in the case that DOLS is used to estimate market power parameters indicating market power of retailers towards the providers; this is any potential oligopsonistic power of the retailers; is statistically insignificant with a p-value of 0.998.

On the other hand, based on DOLS, this study provides evidence that the parameter of market power towards the retailers is significant at the 5% level. The value of the coefficient of oligopoly in the case that no dummy is included is very small, but nonetheless positive. Therefore, evaluating the negative of this number, the coefficient is not as expected since its magnitude is negative. However, in the case that hypothesis testing is undertaken, the coefficient is not statistically significant less than 0. Therefore, some oligopoly power exists. In the case, that the estimations that consider the recession dummy are used, both the market power towards the providers as well as the market power parameter towards the consumers are statistically

⁵⁰ Since when including the recession dummy, the coefficient for market power of retailers towards providers is 3.4796, this thesis performs a hypothesis test for the significance of the coefficient with a null of $d_1 > 1$. The Z statistic is -4.42 and the critical value at 1% is -2.34. Therefore, since the statistic is greater than the critical value in absolute terms one can reject the null that the coefficient is greater than 1 at the 1% level.

⁵¹ Since when including the recession dummy, the coefficient for market power of providers towards the retailers, is 8.21, this thesis performs a hypothesis test for the significance of the coefficient with a null of $d_2 > 1$. The Z statistic is 8.97 and the critical value at 1% is -2.34. The statistic is greater than the critical value and one can reject the null hypothesis that the coefficient is greater than 1 at the 1% level.

⁵² The relationship between these variables of oligopsony and oligopoly power alongside with the dependent variable of the regression, has been tested for cointegration using the Johansen procedure and enough evidence is provided to suggest cointegration. Augmented Dickey Fuller Tests and Cointegration Tests are undertaken by this thesis for the estimation that takes into account the recession dummy, establishing that the variables are I(1) and cointegrated.

significant. The value of oligopoly is -0.3934 and if the $-(-0.3934)$ is evaluated, then it lies between 0 and 1. Therefore, this study provides evidence of oligopsony power as well as oligopoly. The researcher can consider both results. However, since the dummy is statistically significant and affects the supply, particular attention should be paid to the conduct parameters estimated, including the supply with statistically significant dummy. This offsets any concerns, about the coefficient of oligopoly in the first regression being positive.

7.8. Market Power Results for Electricity

The below table shows the estimated coefficients of the demand, supply, and production for the electricity sector. $\ln R \ln R_s$ represents the interaction term between the natural logarithm of the retail price and the natural logarithm of the price of complements. $\ln A \ln N_1$ represents the interaction term between the Upstream Supply and Input Price¹. In cases where a linear trend or a quadratic are included and are not statistically significant or alter the results, they are not reported. It should be noted that all the variables are in natural logarithms and the number of lags is chosen using the Akaike Information Criterion.

After estimating the demand function for electricity using the FMOLS procedure and the choice of lags to be 0, it is evident that all of the independent variables in the FMOLS regression are statistically significant with very low associated p-values. Retail price has a p-value of 0.000, Price of complements has a p-value of 0.000, and the interaction term has a p-value of 0.000. The only variable which appears statistically insignificant is the income variable with a p-value 0.120. Examining each independent variable individually this thesis confirms the following: In terms of the Retail price of electricity, the sign of the coefficient is negative, as expected since an increase in the price of the product causes a decrease in its demand. Since the model used is a double log model, as natural logarithms are used for all the variables, the coefficient of Retail price can be interpreted as the price elasticity of demand, *ceteris paribus*. This is the responsiveness of the quantity demanded to a unit change in price. However, this author takes into account that for the estimation of the demand function of this thesis; the interaction term of the natural logarithm of electricity retail price and the natural logarithm of the price of complements is also included as a regressor. Therefore, for the purpose of this thesis the author evaluates the own price elasticity of demand as $b_2 + b_4 \ln R_s$. The corresponding value is -0.22, which is negative and highly inelastic confirming the expectations the expectation on which this study bases its motivation on.

Table 7.11. Electricity, Demand, Supply and Production

	Demand				Supply			Production		
	Lags		Lags	Upstream Supply Price	Lags		Lags	Quantity Produced	Lags	Lags
	0	1	1		0	0	1		0	0
Quantity Demanded	FMOLS	DOLS	DOLS with recession dummy		FMOLS	FMOLS with recession dummy	DOLS		FMOLS	DOLS
Retail price	8.3174***	-4.9961	-6.0517***	Upstream Supply	3.4308***	4.0179***	1.3411	Upstream Supply	11.4805***	1.8481***
Income	0.2818	-0.3512	-0.1691	Input price1	2.4674***	2.4763***	1.1390***	Capital	0.0502*	0.1077***
Price of Complements	0.8407***	-5.5524	-6.4081***	Input price2	0.5858***	0.5851***	0.8314***	Labour	-0.0301	-0.0017***
lnRlnRs	0.8594***	1.1049	1.3378***	lnAlnN1	-0.7433***	-0.8160***	-0.3613***			
Recession			1.2967***	Recession		0.1033***	-4.2299**			
Constant	3.0358***	28.8391	31.8497	Constant	-10.3380***	-11.4900***		Constant	-33.1434***	-5.0563***
Adj R2	0.07	0.07	0.72	Adj R2	0.99	0.76	0.97	Adj R2	0.89	0.95
	243	243	243		243	243	243		243	243

***Statistically significant at 1% level $p < 0.01$ **Statistically significant at 5% level $p < 0.05$ *Statistically significant at 10% level $p < 0.10$.

In terms of Income, the associated p-value is 0.120 and therefore not statistically significant. Furthermore, the coefficient of Retail price shows the cross-price elasticity of demand between the price of complements, which in this case is household electrical appliances and the price of electricity. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case electricity, to the price of another good, in this case domestic electrical appliances.

The sign of the cross-price elasticity of demand between Quantity Demanded and Price of Complements is negative as expected, since the two goods are complements.

When the price of good Y rises, the quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient aligns with standard economic theory. When the price of complements; which is the price of household electrical appliances goes up by 1% , quantity demanded of electricity goes down by 8%.

Table 7.11 demonstrates that the coefficients in the demand function for electricity under DOLS are not statistically significant. Despite this, this study estimates supply and production and uses these results to estimate oligopsony and oligopoly parameters under DOLS. The researcher remains cautious of these results as the coefficients of demand function are statistically insignificant.

This study considers the results of the estimated demand function including a dummy for the recession between 2008-2014. In cases where the demand function is estimated using a dummy for the recession period between 2008-2014, all of the variables apart from income are statistically significant with low associated p-values. Retail price, Price of complements, the interaction term, and the recession dummy are all statistically significant at the 1% level. These findings contradict the estimation of the demand function by DOLS without the inclusion of the recession dummy and show coefficients are not statistically significant. Therefore the estimations of the oligopsony and oligopoly parameters based on this demand estimation merit the utmost attention.

After estimating the supply function for electricity using the FMOLS procedure and the choice of lags to be 0, this study found evidence that the independent variables in the FMOLS regression are statistically significant with very low associated p-values. Upstream supply has a p-value of 0.006, Input price1 has a p-value of 0.013, Input price2 has a p-value of 0.000, and

the interaction term has a p-value of 0.011. Examining each independent variable individually provides evidence for the following:

In terms of the Upstream supply of all available electricity generated, the sign of the coefficient is positive which corresponds with standard economic theory. The price and the supply are positively related. In terms of the inputs, the coefficient of Input price1 is positive which confirms a positive relationship between the price of the input and the price of the output. A percentage increase in Input price1 causes a percentage increase in the price of the output (upstream supply price) as foreseen.

Furthermore, the coefficient of Input price2, is positive which demonstrates a positive relationship between the price of the input and the price of the output. A percentage increase in Input price2 causes a percentage increase in the price of the output (upstream supply price) as foreseen. The adjusted R square of the estimations is also very high. Thus 89% of the variation in the dependent variable is explained by the independent variables.

In cases where the recession dummy is included in the supply function; it is statistically significant at the 1% level with an associated p-value of 0.0020. The rest of the coefficients are statistically significant at the 1% level with very low associated p-values. The signs of the coefficients of Upstream supply, Input price1, and Input price2, are positive and align with expectations.

This result echoes the estimation of the supply function using FMOLS without the inclusion of a recession dummy. The adjusted R-square is very high and 76% of the variation in the dependent variable can be explained by the independent variables.

After estimating the supply function for electricity using the DOLS procedure and the choice of lags to be 1, it is evident that all of the independent variables in the DOLS estimation are statistically significant with very low associated p-values. Upstream supply has a p-value of 0.011, Input price1 has a p-value of 0.006, Input price2 has a p-value of 0.000, and the interaction term has a p-value of 0.003. Examining each independent variable individually, this study provides evidence for the following:

In terms of the Upstream supply of total electricity generated, the sign of the coefficient is positive as expected, since the price and the supply are positively related.

In terms of inputs, the coefficient of Input price1, and the price of inputs in production and distribution of electricity is positive, reflecting the positive relationship between the price of

the input and the price of the output. A percentage increase in Input price1 causes a percentage increase in the price of the output (upstream supply price). This agrees to expectations. Furthermore, the coefficient of Input price2, cost per labour hour, is positive which demonstrates a positive relationship between the price of the input and the price of the output. A percentage increase in Input price2 causes a percentage increase in the price of the output (upstream supply price) as foreseen. The value of the adjusted R-square corresponds to 0.98. Thus 98% of the variation in the dependent variable is explained by the independent variables.

When estimating the Cobb-Douglas production function of electricity using the FMOLS procedure it is evident that Capital is statistically significant at the 10% level. The coefficient of Capital is positive as expected since increasing the input increases the production.

More specifically, the coefficient of Capital shows the output elasticity of capital. A 1% increase in capital increases output by 0.05%. The coefficient of Labour, on the other hand, is not statistically significant. Furthermore, the adjusted R square of the estimated production function is very high. Thus 89% of the variation in the dependent variable is explained by the independent variables. Similar results are obtained using the DOLS procedure wherein Capital is statistically significant at the 1% level.

Table 7.12. Market Power Regression for Electricity

	Lags 3 FMOLS	Lags 3 FMOLS with recession dummy	Lags 4 DOLS	Lags 1 DOLS with recession dummy
Oligopsony	0.6357***	0.1195***	0.6709***	0.6540***
Oligopoly	0.0003	-0.0001	0.0022*	-0.0001
Constant	58.5951***	-31.5420***	-20.9698***	-22.3393***
Adj R2	0.54	0.90	0.78	0.77
N	228	228	228	228

***Statistically significant at 1% level $p < 0.01$ **Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table 7.12 presents the FMOLS and DOLS estimations of the market power parameters. The results of the estimations that consider supply with recession dummy are also included. The dependent variable is $D = Rc_1 \frac{Q}{A} - P$ is from the market power model in Chapter 5. The number of lags chosen is based on the Akaike Information Criterion. The table demonstrates

that the parameter of market power of the retailers of electricity towards their providers is statistically significant; indicating significant oligopsony power at the 1% level. The value of the parameter is between zero and 1, and more specifically 0.6357. The parameter of oligopoly is statistically insignificant.

When considering the supply estimation for electricity under FMOLS that includes a dummy for the recession of 2008-2014, the above table shows that the parameter for oligopsony power is statistically significant at the 1% level with a coefficient of 0.1195. The parameter of oligopoly power is not statistically significant. Based on this finding retailers of electricity have an oligopsonistic power over wholesalers.

These results agree with the results obtained through the FMOLS methodology. The latter estimations do not include a dummy for recession. All these estimations establish that oligopsony power from retailers towards the wholesalers who provide electricity to the retailers.

The above results which consider the supply estimations for electricity under DOLS confirm that the parameter of the market power indicating oligopsony of the retailers towards their providers, is statistically significant at 1% level with a coefficient of 0.6709. The parameter is between 0 and 1 indicating oligopsonistic power.

The parameter of oligopoly power is statistically significant at the 10% level with a coefficient of 0.0022. Based on this finding, retailers of electricity have an oligopsonistic power over their providers at the 1% and oligopolistic power over the consumers at 10% levels. These results partially agree with the results of the FMOLS methodology which estimate a statistically significant oligopsony parameter and establish the additional fact that at the 10% level, oligopoly power cannot be rejected. The coefficient of oligopoly, however, is very low and only statistically significant at the 10% level. To reiterate: Findings relevant to the market power estimates should be treated with caution, since the estimated demand function coefficients are insignificant.

Table 7.12 indicates that in cases where the recession dummy is included in the demand function, the oligopsony power parameter is statistically significant at the 1% level with an associated p-value of 0.000. The oligopoly parameter is statistically insignificant with an associated p-value of 0.795.

These findings concur with all the other estimations obtaining to electricity retailers. The only estimation that diverges from estimates of significant oligopoly power for electricity retailers is the DOLS methodology that omits consideration of the recession of 2008-2014 dummy. As previously mentioned, this should be treated with caution as it is based on a demand function with insignificant results.

7.9 Conclusion

This chapter presented the results relevant to estimating market power and an interpretation of the preliminary tests for stationarity for the variables used to estimate the demand, supply and production functions fully elucidated. Results for testing for cointegration among the variables of the above functions were also provided, along with the demand, supply, and production functions, and the estimated market power parameters for each product using FMOLS and DOLS.

It should be noted that this research also estimated demand supply and production functions including a dummy variable for the financial recession period of 2008-2014. In this way, any effects caused by the shock to the economy were incorporated into the analysis. The market power parameters of ϕ and λ , are estimated.

For the first stage of milk and dairy products, this thesis provided evidence using FMOLS, showing that the market power parameter of processors towards farmers is statistically significant at the 5% level, and it is between 0 and 1. The estimated coefficient is 0.0176 indicating some degree of oligopsony power.

The market power parameter of processors towards retailers is statistically insignificant. In the case that DOLS is used, the market power parameter of processors towards the farmers is similar to the FMOLS estimate and statistically significant at the 1% level with a coefficient of -0.2895. After testing the hypothesis, the above chapter provided evidence that ϕ is significantly different than 0 and not less than 1. This agrees to the expected the oligopsony coefficient which lies between 0 and 1. For the coefficient of oligopoly which represents the market power parameter of the processors towards the retailers this study estimated a value of -0.2856. When evaluating the negative of this value, therefore, $-(-0.2856)$, it provided evidence of the statistically significant market power of the processors towards the retailers at the 10% level.

For the milk second stage this thesis estimated the FMOLS market power parameter of the retailers towards the processors to be statistically significant at 10% with a value for ϕ of 1.3111. After testing the hypothesis the above chapter provided evidence that ϕ is significantly different than 0 and not greater than 1. The value of λ is -0.6527 and statistically significant at 10%. The researcher should be cautious of this result as λ which is the negative of the coefficient of Oligopoly is less than 1.

In cases where DOLS was used, the estimated coefficient of market power of retailers towards the processors is -1.0884 and statistically significant at 10%. The relevant test statistic for the null $d_2 < 0$ is -37.51 and the critical value -2.37. Therefore, the hypothesis that ϕ is less than 0 was rejected. The DOLS estimated parameter of market power of retailers towards consumers is -0.9107 and statistically significant at 10% level. Evaluating the negative of this value, λ is between 0 and 1 indicating a very high degree of oligopoly on behalf of the dairy retailers towards the consumers. Since under DOLS ϕ is significantly different than 0 and not less than 1 and λ is between 0 and 1, the researcher was cautious of the DOLS results as under FMOLS the coefficient of oligopoly was not empirically negative.

For road fuels, this chapter used the FMOLS method to provide evidence that the market power parameter of the retailers towards their providers is statistically significant at the 1% level at between 0 and 1. The estimated coefficient is 0.3350 indicated some degree of oligopsony power and the market power parameter of retailers towards the consumers is statistically significant at the 1% level. The coefficient of oligopoly is -0.060 and if the negative of this value is evaluated, λ is between 0 and 1 indicating oligopoly.

In the case that FMOLS takes into account the estimations that include the recession dummy, the estimated market power parameter of the retailers towards providers is 3.4796. Using hypothesis testing this thesis establishes that it is significantly different than 0 at 1%, but not significantly greater than 0. The estimated Z statistic is -4.42 and the critical value is -2.34. Evidence for the oligopsony power of retailers is therefore provided. This study also provides evidence for oligopoly power of retailers since the coefficient of oligopoly is 0.0270 at the 1% level.

Using DOLS, this study found the market power parameter of retailers towards providers is 0.0001 and not statistically significant. Market power of retailers towards consumers is statistically significant at 1% but, the degree of oligopoly power is very limited. Evaluating the

findings of the DOLS methodology that considered the financial recession dummy for 2008-2014, the market power parameter of retailers towards the consumers is 8.21. Since this value is greater than 1, the researcher undertook hypothesis testing with a null that $d_2 > 1$. The Z statistic is 8.97 and is greater than the critical value of -2.34 in absolute terms. Therefore, the null hypothesis was rejected. The parameter of ϕ was statistically different than zero but greater than 1. The market power parameter of retailers towards the consumers is -.3934. It is statistically significant at the 1% level and if the negative of this value is evaluated, λ is between 0 and 1 indicating oligopolistic market power.

The estimation of market power for the UK's road fuels sector has received limited attention in the academic literature and limited intervention exists on behalf of relevant authorities. The potential abuse of market power by retailers and the exercise of collusive practices can directly affect the microeconomic objective of competitive prices.

Concluding the market power analysis on electricity, this chapter provided estimates that the market power parameter of retailers towards their providers is statistically significant at the 1% level with a coefficient of 0.6357 estimated under the FMOLS estimator. ϕ is therefore between 0 and 1.

In the case that a dummy for recession of 2008-2014 is included in the analysis the estimate of ϕ , 0.1195 is still significant at the 1% level. Oligopsony power therefore exists but at a lower degree.

Using the DOLS methodology, the market power parameter of retailers towards their providers is statistically significant at 1% level, with a coefficient of 0.6709 estimated, and when the recession dummy is included, a coefficient of 0.6540. ϕ is therefore between 0 and 1 and a significant amount of oligopsonistic market power exists. In terms of the electricity supply chain, this study provided evidence that the market power of retailers towards the consumers is statistically insignificant.

This chapter therefore describes and interprets the main results relevant to the first part of main questions examined by this thesis, in terms of the extent of the market power of the retailers towards the consumers, and the extent of the market power of the retailers towards their providers.

Chapter 8

Cost Pass Through and Asymmetric Price Transmission Empirical Results

8.1 Introduction

This chapter presents the main empirical analysis results for the estimation of cost pass through for milk and milk products chain, the petroleum chain and the electricity chain in the UK, and provides an estimation of the input cost pass through to the wholesale price and of the wholesale price to the retail price, for each of these three products using standard regressions. For the case of wholesale to retail pass through, and following Nakamura and Zerom (2010), an instrumental variables methodology employs changes in input costs and their lagged values as the instruments for wholesale prices. In addition, the chapter also outlines an empirical attempt to detect asymmetric price transmission.

8.2. Cost Pass Through Results Milk

Tables 8.1 and 8.1a below demonstrate the cost pass through results for the milk sector, including the estimation of the pass through of a change in the input cost to the wholesale price, the estimation of the change in the wholesale cost to the retail price (both with standard cost pass through regression and IV), and the estimation of asymmetric price transmission of a change in the input cost to the wholesale price and a change in wholesale cost to the retail price. The tables also present the IV estimation results for the effect of a change in the dairy products wholesale price to the retail price and the corresponding p-values for under-identification, over-identification, and exogeneity tests. Results are presented for the log and level specifications and the instruments applied comprise the change in input cost and the six lagged values of this change. In the case of log specification, the change in the natural logarithms of this value is used.

One can note that the number of lags is chosen in a similar way to Nakamura and Zerom (2010). Increasing the number of lags, does not change the Cost Pass Through estimation. Cost pass through is the sum of the coefficient of the change in the change in the cost and the coefficients of the lagged values used as independent variables.

Table 8.1. Milk Cost Pass Through Results

	Input to wholesale			Wholesale to retail IV		Wholesale to retail without IV		Asymmetries			
	Logs	Levels		Logs	Levels	Logs	Levels	Logs	Logs		
	Lags	Lags		Lags	Lags	Lags	Lags	Lags	Lags		
	1	10		4	10	6	10	10	10		
	Coefficient	Coefficient		Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient		
Δ Wholesale price			Δ Retail price					Δ Wholesale price		Δ Retail price	
Δ Input price	0.2253***	0.2229***	Δ Wholesale price	0.2635***	0.4128***	0.1570*	0.5052*	Positive change in input price	0.7635**	Positive change in wholesale price	-0.4296
Δ Input price _{t-1}	0.1275***	0.1142***	Δ Wholesale price _{t-1}			0.0707	0.2196**	Negative change in input price	0.2505	Negative change in wholesale price	1.7496***
								Δ Input price _{t-1}	0.1047***	Δ Wholesale price _{t-1}	0.1391
Constant	-0.0036	0.7651	Constant	0.0029	0.5396	0.0360	0.8626	Constant	-0.0017	Constant	0.0039
Long run pass through	0.3528***	0.4370***	Long run pass through			0.2277***	0.7248***				
N	96	96	N	96	96	96	96	N	96	N	96

***Statistically significant at 1% p<0.1 **Statistically significant at 5% p<0.05 *Statistically significant at 10%. p<0.10

Table 8.1a. Instrumental Variables Tests for Milk Wholesale to Retail Pass Through

	Logs	Levels
Underidentification test LM statistic	14.424	12.495
Chi Sq. P-value	0.0252**	0.0518*
Overidentification test	9.1980	9.3890
Chi Sq. P-value	0.1014	0.0945*
C Statistic-exogeneity orthogonality of main instrument dlnl	0.0220	0.0080
Chi Sq. P-value	0.8810	0.9268
Instruments: dI, L1dI, L2dI, L3dI, L4dI, L5dI, L6dI		

***Statistically significant at 1% level $p < 0.01$ **Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Using a standard regression to estimate the pass-through from input prices to the wholesale prices for milk and milk products, this thesis provides a statistically significant coefficient of cost pass through of 0.2253. The coefficient is statistically significant at the 1% level since its corresponding p-value is 0.000. The lagged value is statistically significant. If more lagged values are included, they are all statistically insignificant and do not alter the results. As it is evident a 1% change (increase) in the input costs is followed by a 0.2253% change in wholesale costs, the long run coefficient for cost pass through is the sum of the coefficients of the change in input cost and the first significant lagged value. In this case a 1% change (increase) in the wholesale costs is followed by a 0.3528% change in retail costs.

Using a standard regression to estimate the pass through from input prices to wholesale prices in levels, the above table provides a statistically significant coefficient of cost pass through of 0.2229. The lagged value is also statistically significant with a coefficient of 0.1142. Both values are statistically significant at the 1% level since their corresponding p-values are very low. If more lagged values are included, they are all statistically insignificant and do not alter the results. The quarter dummies included in this study following Nakamura and Zerom (2010), are not statistically significant and do not affect the results.

The findings demonstrate that 0.2229 of every unit of change in the input price is passed through to the wholesale price. This is the short run pass through. In the long run the coefficient for cost pass-through is the coefficient of the first lagged value which is included in the regression and is statistically significant plus the coefficient of the change in input cost. As estimated, 0.4370 of every unit of change in the input price is therefore passed through to the wholesale price.

These findings align with the cost pass through of the input cost change to the wholesale price obtained from an estimation which considers the natural logarithms (logs) of the variables. Most of the pass through occurs in the short run and is incomplete. Based on the levels specification, half of the change in input cost is passed on to the wholesale price.

Table 8.1 also confirms the cost pass through of the wholesale price of dairy products to the retail price is 0.2635, indicating that a 1% change (increase) in wholesale price causes a 0.2635% change (increase) in the retail price. The instruments used for the wholesale price are the change in the logarithm of the input price and six lagged values of this. As per Table 10.1a, the under-identification test with a null hypothesis of the model being under-identified, gives a p-value of 0.0252 which leads to rejection of the null. As such, there is not an issue of under-identification. The over-identification test provides a p-value of 0.1014. As such, the null hypothesis cannot be rejected and there is no issue of over-identification. Lastly, Table 10.1a demonstrates the C-statistic with a corresponding p-value of 0.8811. As such, the null hypothesis of exogeneity of the instrument cannot be rejected. Since the main instrument tested is exogenous, there is no issue of endogeneity.

The findings confirmed the cost pass through of the wholesale price of dairy products to the retail price is 0.4128. This indicates that 0.4128 of a unit change in wholesale price is passed through as a change in the retail price. The pass through is therefore incomplete. The instruments used for wholesale price are the change of the input cost (farm-gate price) and five lagged values of this change.

The under-identification test with a null hypothesis of the model being under-identified derives a p-value of 0.0518: sufficient evidence to reject the null hypothesis of under-identification at the margin at both the 5% and 10% level. As such, there is no issue of under-identification. The over-identification test has a p-value of 0.0945. As such, the null hypothesis cannot be rejected at 5% level and there is no issue of over-identification. Lastly, Table 10.1a demonstrates the C-statistic, and its corresponding p-value to be 0.9268. As such, the null hypothesis of exogeneity of the instrument cannot be rejected. Since her main instrument is exogenous, there is no issue of endogeneity. Comparing the cost pass through of a change in the wholesale cost to the retail price, resulting from the IV methodology, it is evident that the pass through is higher under the levels specification, since a one-unit change in the wholesale costs causes a 0.41 units change in retail costs, while under the logs specification, a 1% change in wholesale price causes a mere 0.26% change in retail prices. Using a standard regression in

logs specification, to estimate the pass through from wholesale prices to retail prices, this study provides a statistically significant coefficient of cost pass through of 0.1570. This is statistically significant at the 10% level. If this study accepts that the short run pass through can be significant at 10% level, then it is significant. The first lagged value is statistically insignificant. If more lagged values are included, they are all statistically insignificant without altering the results. The quarter dummies included in this study following Nakamura and Zerom (2010)) are not statistically significant and do not affect the results.

Table 8.1a demonstrates that a 1% change (increase) in the wholesale costs is followed by a 0.1570% change in retail costs. This estimation of cost pass through is lower than the estimation provided by the instrumental variable's regression and the coefficient of the lagged value is statistically insignificant. This indicates that the pass through is incomplete and mostly occurs in the short run.

Using a standard regression in levels specification, for the estimation of the pass through from wholesale prices to retail prices, provides a statistically significant coefficient of cost pass through of 0.5052 at 1% level. The lagged value is statistically insignificant. If the lagged value is dropped or if more lagged values are included, the results are not altered. The quarter dummies included in this study, following Nakamura and Zerom (2010), are not statistically significant and do not affect the results. Analysis found that 0.5052 of every unit of change in the wholesale price is passed through to the retail price.

This is the short run pass through. This estimation of cost pass through is higher to the estimation provided by the instrumental variable regression in Table 10.1 above. Since the lagged values are statistically insignificant. This indicates that the pass through is incomplete and mostly occurs in the short run.

Based on the levels specification, the cost pass through of change in wholesale costs to retail prices was found to be incomplete, albeit to a lesser extent.

Under the logs specification, the pass through coefficient is 0.1570, whilst under the levels specifications it is 0.5052. As such, half of the change in the wholesale cost is passed through to the retail prices. Table 10.1 does not demonstrate sufficient evidence for asymmetric pass through of a change in the milk farm-gate price to the wholesale price.

It is worth noting that for the purposes of this research, the variable of a positive change in the input price represents the percentage increase in the input price from one period to the next.

The variable negative change in the input price represents the percentage decrease in the input price from one time period to the next. The coefficient of the increase in the price of the input of 0.7635 is thus statistically significant, while the coefficient of the decrease in the price of the input variable is statistically insignificant with a p-value of 0.115. Furthermore, the estimates of this study do not provide sufficient evidence of asymmetry in the cost pass through between wholesale price to retail price and the variable which represents the positive change in the wholesale price from one period to the next is statistically insignificant.

8.3. Cost Pass Through Results Road Fuels

Table 8.2 indicates the cost pass through results for road fuels. The number of lags chosen is based on the Akaike Information criterion and the results presented for the change of the input cost to the wholesale price and the pass through of a change in the wholesale cost to the retail price. The latter is estimated both with a standard cost pass through regression and IV methodology to account for potential attenuation bias. The results of the tests relevant to the IV regression are also provided in table 8.2a. This refers to under-identification, over-identification, and exogeneity tests. This thesis illustrates the empirical results relevant to cost pass through for road fuels in the following tables and provides an analysis of the econometric results for the cost pass through of an input cost change to the wholesale price and a wholesale cost change to the retail price. Estimations for asymmetric price transmission are also provided for the input to the wholesale price relationship and for the wholesale to the retail price relationship.

Using a standard regression to estimate the pass through from input prices to the wholesale prices for road fuels, Table 8.2 indicates the statistically significant coefficient of cost pass through of 0.3202. The two lagged values are also statistically significant at the 1% level with coefficients of 0.2780 and 0.0870 and p-values of 0.000 and 0.004 respectively. If more lagged values are included, they are all statistically insignificant and do not alter the results. The monthly dummies included in this study following Nakamura and Zerom (2010), are statistically insignificant not changing results. As is evident from Table 10.2, the short run cost pass through elasticity indicates that a percentage change (increase) in the input price leads to about 0.3202% change (increase) in the wholesale price. The long run cost pass through is the sum of the coefficients of the lagged values and the change in the input cost.

Table 8.2. Road Fuels Cost Pass Through Results

Table 6.2: Road Pass Cost Pass Through Results											
	Input to wholesale		Wholesale to retail (IV)		Wholesale to retail		Asymmetries				
	Logs Lags 10 Coefficient	Levels Lags 10 Coefficient		Logs Lags 10 Coefficient	Levels Lags 10 Coefficient	Logs Lags 10 Coefficient	Levels Lags 10 Coefficient		Logs Lags 10 Coefficient		Levels Lags 10 Coefficient
Δ Wholesale price			Δ Retail price					Δ Wholesale price			
Δ Input price	0.3202***	0.3584***	Δ Wholesale price	0.3033***	0.3794***	0.3414***	0.3577***	Positive change in input price	0.0339***	Positive change in wholesale price	0.0156***
			Δ Wholesale price_t-1			-0.0351***	0.1111***	Negative change in input price	-0.0139***	Negative change in wholesale price	-0.0133***
Δ Input price_t-1	0.2780***	0.2436***	Δ Wholesale price_t-2			0.0914***		Δ Input price_t-1	0.3389***	Δ Wholesale price_t-1	-0.0701***
Δ Input price_t-2	0.0870***							Δ Input price_t-2	0.1146***	Δ Wholesale price_t-2	0.2227***
										Δ Wholesale price_t-3	-0.0339
										Δ Wholesale price_t-4	0.0654***
Constant	-0.0033	-0.5283	Constant	-0.0020	-0.1982	0.0090	-0.0817	Constant	-0.0116	Constant	-0.0015
Long run pass through		0.6020***	Long run passthrough			0.3984***	0.4688***				
N	228	228	N	228	228	228	228		228		228

***Statistically significant at 1% level p<0.01 ** Statistically significant at 5% level <0.05 *Statistically significant at 10% level p<0.10.

Table 8.2a. Instrumental Variables Tests for Road Fuels Wholesale to Retail Pass Through

	Logs	Levels
Underidentification test LM statistic	9.503	8.666
Chi Sq. P-value	0.0086***	0.0131**
Overidentification test	0.145	0.035
Chi Sq. P-value	0.7032	0.8516
C Statistic-exogeneity orthogonality of main instrument dlnl	0.145	0.035
Chi Sq. P-value	0.7032	0.8516
Instruments: L1d1, L2dI		

***Statistically significant at 1% level $p < 0.01$ **Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Following from the above, although most of the change in the input cost is passed on to the wholesale price of the refined petroleum products, the long run pass through is incomplete.

Using a standard regression to estimate the pass through from input prices to wholesale prices with a levels specification, derives the statistically significant coefficient of cost pass through of 0.3584. The first lagged value is statistically significant with a coefficient of 0.2436. If more lagged values are included, they are all statistically insignificant without altering the results. The quarter dummies included following Nakamura and Zerom (2010) are not statistically significant, and do affect the results. As such, they are not reported in table 8.2.

Furthermore, this study confirms that 0.3584 of every unit of change in the input price is passed through to the wholesale price. This is the short run pass through. In the long run the coefficient for cost pass through is the coefficient of the statistically significant lagged value and the coefficient of the change in commodity cost. What is more, in the long run, 0.6020 of every unit of change in input price is passed through to the wholesale price. This finding supports the findings from the logs specification.

To some extent, the present study findings of the incomplete cost pass through in the supply chain for road fuels run contrary to the existing literature which largely indicates complete cost pass through, even though the results differ based on the country and stage of the supply chain. This research further concludes that an almost equal amount of pass through to that of the short run occurs in the long run. This takes place for both the pass through of the change in the input cost to the wholesale price and of the change in the wholesale price to the retail price.

As it is evident from Table 8.2, the cost pass through of the wholesale price of petrol and refined petroleum products to the retail price is 0.3033. This indicates that a one percent change in wholesale price causes a 0.3033% change in retail price.

The instruments used for the change in wholesale prices are the second and third lagged values of the change in input cost, and it is again noted in the logs specification that all the variables are in natural logarithms.

As per table 8.2a, the under-identification tests with a null hypothesis of the model being under-identified has a p-value of 0.0086, which leads to a rejection of the null of under-identification at the 1% level. As such, there is no issue of under-identification of the model at the 1% level. The p-value is less than 0.01. The over-identification test has a p-value of 0.7032. As such, the null hypothesis of no over-identification in the model cannot be rejected and there is no issue of over-identification. Lastly the C-statistic provided has a p-value of 0.7032. As such, the null hypothesis of exogeneity of the main instrument cannot be rejected.

Table 8.2 confirms the cost pass through of the wholesale price of petrol to the retail price is 0.3794, indicating that a percentage change in wholesale price causes a 0.3794% change in retail price. The coefficient is statistically significant with a corresponding p-value of 0.000. The instruments used for the change in the wholesale prices are the second and third lagged values of the change in the input cost.

The under-identification tests with a null hypothesis of the model being under-identified gives a p-value of 0.0131, which leads to a rejection of the null at 5% level. As such, there is no issue of under-identification at 5% level. The over-identification test gives a p-value of 0.8516. As such, the null hypothesis cannot be rejected and there is no issue of overidentification. Lastly, the C-statistic has a p-value of 0.8516 which indicates that the null hypothesis of exogeneity of the main instrument cannot be rejected.

Using a standard regression for a logs specification to estimate the pass through from wholesale prices to retail prices, gives a statistically significant coefficient of cost pass through of 0.3414. The two lagged values are statistically significant: the first at the 5% level and the second at the 1% level, with corresponding p-values of 0.000 and 0.0040. If more lagged values are included, they are all statistically insignificant and do not alter the results. The quarter dummies included in this study, following Nakamura and Zerom (2010), are not statistically significant and do not affect the results.

As is evident from Table 8.2, a 1% change (increase) in the wholesale cost, is followed by a 0.3414% change in the retail costs. This estimation of cost pass through supports the estimation provided by the instrumental variables regression in Table 8.2.

The long run pass through is the sum of the coefficients of the lagged values and the coefficient of the change in wholesale price, which corresponds to a 0.3984% change in retail price from a 1% increase in wholesale price. The cost pass through under the logs specification and standard cost pass through regression is incomplete. Most of the pass through occurs in the short run.

Using a standard regression for the levels' specification, to estimate the pass through from wholesale prices to retail prices derives the statistically significant coefficient of cost pass through of 0.3577. The lagged value is statistically significant at the 1% level with a p-value of 0.000. If more lagged values are included, they are all statistically insignificant without altering the results. The quarter dummies included in this study are not statistically significant and do not affect the results.

Therefore, they are not reported in the table. What is more, a unit change (increase) in the wholesale costs is followed by a 0.3577, units change in retail costs. This estimation of cost pass through aligns with the estimation provided by the instrumental variables' regression in Table 8.2.

This estimation of cost pass through from wholesale to retail price is lower than the estimation of Table 8.2 of the instrumental variables' method. The long run pass through is the sum of the lagged values coefficients and coefficient of change in wholesale cost, and in this case corresponds to approximately 0.4688. It is therefore evident that based on the levels specification estimated using the standard cost pass through regression, most of the pass through occurs in the short run and is incomplete. This concurs with the findings of the log specification.

Table 8.2 provides evidence of the existence of asymmetric price transmission between input cost change to the wholesale price. Firstly, the coefficients of the negative change in input price variable and positive change in input price variables are statistically significant at the 1% and 5% level respectively, with corresponding p-values of 0.000 and 0.012. Secondly, the coefficient of the negative change in input cost variable is higher than the coefficient of the positive change in the input cost variable. This indicates that the wholesale price reacts faster to an increase in the input price rather than a decrease. This corresponds to a positive asymmetry. Monthly dummies that are included following Nakamura and Zerom (2010), are

statistically insignificant, and if excluded from the model do not affect the result. They are therefore not reported in the above table.

Table 8.2, does not provide sufficient evidence of a high degree of asymmetry in the cost pass through between wholesale price to retail price. There is a slight difference in absolute values between the coefficients of the positive change in the wholesale price variable and the negative change in the wholesale price variable. Following Nakamura and Zerom's (2010) interpretation, this leads to the conclusion that the retail price reacts faster to an increase in the wholesale cost compared to a decrease. The positive asymmetry, known as the phenomenon of 'rockets and feathers' is supported by this study. Monthly dummies that are included following Nakamura and Zerom (2010) are statistically insignificant, and if excluded from the model do not affect the result. They are therefore not reported in the above table.

The findings of this thesis contradict the previous findings (Pesaresi et al. 2014; OFT 2013), which failed to provide evidence of asymmetric price transmission in the supply chain of petroleum products, and more specifically road fuels in the UK. The methodology of this thesis in respect of asymmetric price transmission encompasses an alternative to the norm, since the use of the distributed lag model with the change in input price and the change in the wholesale price variable, following the work of Nakamura and Zerom (2010) has not previously been applied in the context of any UK study.

8.4 Cost Pass Through Results Electricity

Table 8.3 presents the cost pass through and asymmetric price transmission results for electricity. Estimations are made based on the standard cost pass through regressions for the pass through of a change in the input cost to the wholesale price and the pass through of a change in the wholesale cost to the retail price. In the case of the pass through of a change in the wholesale cost to the retail price IV regression results are also presented to consider potential attenuation bias. Asymmetric price transmission results are also included in the table. Results for the asymmetric price transmission of a change in the input cost to the wholesale price as well as the asymmetric price transmission of a change in the wholesale cost to the retail price are included. The results of the tests relevant to the IV regression are provided in table 8.3a. This refers to under-identification, over-identification, and exogeneity tests.

Table 8.3. Electricity Cost Pass Through Results

Table 6.5: Electricity Cost Pass Through Results													
	Input (Brent spot) to wholesale		Input (Natural Gas) to wholesale		Wholesale to retail IV		Wholesale to retail		Asymmetries				
	Logs Lags 6	Levels Lags 10	Logs Lags 10	Levels Lags 10	Logs Lags 10	Levels Lags 10	Logs Lags 10	Levels Lags 10		Input to Wholesale		Wholesale to retail	
	Coefficient	Coefficient	Coefficient	Coefficient		Coefficient	Coefficient	Coefficient	Coefficient		Coefficient		Coefficient
ΔWholesale price					Δ Retail Price					Δ Wholesale price		ΔRetail price	
ΔInput price	0.3006***	0.1414*	0.1909**	0.0700	ΔWholesale price	0.0520***	0.0702***	0.0016	0.0197	Positive change in input price	0.2423	Positive change in wholesale price	-0.0934***
ΔInput price_t-1	-0.1154	0.1779	-0.0401	-0.0221	ΔWholesale price_t-1			-0.0004	0.0027	Negative change in input price	1.6719***	Negative change in wholesale price	0.0404
ΔInput price_t-2	0.2321**	0.1779**	0.0225	0.0443	ΔWholesale price_t-2			0.0024	0.0113	ΔInput price_t-1	-0.1708	ΔWholesale price_t-1	-0.0031
ΔInput price_t-3			0.2287**	0.1569***	ΔWholesale price_t-3			0.0199*	0.0430*	ΔInput price_t-2		ΔWholesale price_t-2	0.0019
ΔInput price_t-4			-0.0401	-0.0124	ΔWholesale price_t-4			0.0277***	0.0491***	ΔInput price_t-3		ΔWholesale price_t-3	0.0193**
ΔInput price_t-5			0.2137*	0.0616	ΔWholesale price_t-5			0.0288*	0.0664***	ΔInput price_t-4		ΔWholesale price_t-4	0.0317**
					ΔWholesale price_t-6				0.0495**	ΔInput price_t-5	0.1875*	ΔWholesale price_t-5	0.0321**
Constant	-0.0252	-0.8525	0.0089	-0.2866	Constant	0.0127*** (0.0053)	1.1044* (0.6330)	0.0049	0.4697***	Constant	0.0166	Constant	0.0100***
Long run Pass Through	0.5327***	0.3193***	0.6333***	0.2185***	Long run Pass through			0.0910***	0.1410***				
N	178	178	178	178	N	178	178	178	178	N	178	N	178

The above table represents the electricity cost pass through results. For asymmetries, the dependent variable of the first column is the change in the wholesale price and the independent variables are positive change in input price, negative change in input price and change in input price with its three lagged values. (Input prices are brent spot prices). The asymmetries including Natural gas prices are included in an appendix. ***p <0.01 Statistically significant at 1% level. *p<0.05 **Statistically significant at 5% level. *Statistically significant at 10 % level

Table 8.3a. Instrumental Variables Tests for Electricity Wholesale to Retail Pass Through^{53 54 55}

	Logs	Levels
Under identification test LM	12.230	15.194
Statistic		
Ch Sq. P-value	0.0933*	0.0336**
Overidentification test	9.3810	11.1460
Chi Sq. P-value	0.1532	0.0840*
C Statistic exogeneity	1.6570	0.0466
Orthogonality of main instrument dlnI		
Chi Sq. P-Value	0.1981	0.4949
Instruments: dI and L1dI L2dI L3dI L4dI L5dI L6dI		

***Significant at 10% level $p < 0.01$ **Significant at 5% level $p < 0.05$

*Significant at 1% level $p < 0.10$

Using a standard regression to estimate the pass through from a change in the input price to wholesale prices for electricity, Table 8.3 provides a statistically significant coefficient of cost pass through of 0.3006. The second lagged value is also statistically significant at 5% level with a coefficient of 0.2321. If more lagged values are included, they are all statistically insignificant without altering the results. Monthly dummies that are included are statistically insignificant, and if excluded from the model do not affect the result. They are therefore not reported on the above table. Table 8.3 also demonstrates that the short run cost pass through elasticity indicates that a percentage change (increase) in the input price leads to about 0.3006% change (increase) in the wholesale price. The long run pass through indicates that a percentage change (increase) in the input price leads to 0.5327% change (increase) in the wholesale price. Using standard regression for the levels specification, to estimate the pass through of an input cost change to wholesale prices provides a statistically significant coefficient of cost pass through of 0.1414. The second lagged value is also statistically significant with a coefficient of 0.1779. If more lagged values are included, they are statistically insignificant without

⁵³ All the above regressions regarding electricity are also estimated with the inclusion of a dummy variable for the financial recession of 2008-2014. A dummy variable is used that takes the value of 1 for the period during the recession and the value of 0 for the period out of the recession. This is an addition to the methodology used by Nakamura and Zerom (2010), since the period under investigation is longer and it would be wise to take into account any potential effects of the financial recession. The dummy variable included in the regressions seems to be statistically insignificant, therefore the study does not proceed to further investigation of the issue.

⁵⁴ For electricity, this thesis also runs standard pass-through regressions for wholesale to retail prices, the results of which are not statistically significant. Therefore, this thesis takes into consideration the instrumental variables regression results.

⁵⁵ In the case that lagged values of the wholesale price are included in the estimation; the cost pass through coefficient is still statistically significant with a magnitude of 0.039. The lagged values are statistically insignificant and therefore this thesis does not give any report on long run pass through from the IV estimation. The C Statistic is estimated for each of the instruments; for the purpose of this thesis the C Statistic of the main instrument is reported.

changing results. The monthly dummies which are included, following Nakamura and Zerom (2010), are not statistically significant, not affecting the results.

As it is evident from Table 8.3, 0.1414 of every unit of change in the input price is passed through to the wholesale price. This is the short run pass through. In the long run the coefficient for cost pass through is the coefficient of the significant lagged values included in the regression and a change in the input cost. As it is evident from Table 8.3, 0.3193 of every unit of change in the input price is passed through to the wholesale price.

The cost pass through of a change in the brent spot prices to the wholesale price of electricity, is incomplete both when level specifications are used and when log specifications are used. When log specification is used, there is evidence that a higher degree of pass through occurs in the short run, whilst when the levels specification is used there is evidence that a higher degree of pass through occurs in the long run. Using a standard regression to estimate the pass through from input prices to wholesale prices provides a statistically significant coefficient of the short run cost pass through of 0.1909. The third and fifth lagged values are statistically significant at the 10% and 5% level respectively, with corresponding p-values of 0.0058 and 0.011. The monthly dummies which this thesis includes following Nakamura and Zerom (2010), are not statistically significant, and do not affect the results.

Table 8.3 confirms the short run pass through to be statistically significant, since a 1% change in the input price (natural gas) will cause a 0.1909% change the wholesale price of electricity. The long run pass through is 0.6333.

In the long run the coefficient for cost pass through is the sum of the coefficients of the significant lagged values and a change in input cost included in the estimation. As it may be deduced from Table 8.3, a 0.6333% change in wholesale prices of electricity follows a 1% change (increase) in natural gas prices.

A significant amount of pass through of a change in the natural gas prices to the wholesale prices of electricity occurs in the long run. This is due to the fact that the sum of the lagged values coefficients from the logs specification is much greater than the coefficient of the change in natural gas price variable. Using a standard regression to estimate the pass through from input prices to wholesale prices gives a statistically significant coefficient of cost pass through of 0.0700. The third and fifth lagged values are statistically significant at the 1% and 5% level respectively, with corresponding p-values of 0.002 and 0.027.

The monthly dummies which are included for the purpose of this thesis, following Nakamura and Zerom (2010), are not statistically significant, and do not affect the results.

Table 8.3 confirms that in the case a specification in levels is used, the short run pass through is statistically insignificant, while the long run pass through is 0.2185. In the long run the coefficient for cost pass through is the sum of the coefficients of the significant lagged values included in the estimation. It may thus be deduced that 0.2185 of every unit of change in the input cost (natural gas) is passed through to the electricity wholesale price.

Table 8.3 demonstrates that the cost pass through of the wholesale price of electricity to the retail price is 0.0521. This indicates that a percentage change in wholesale price causes a 0.0521% change in retail price. As indicated in 8.3a, the under-identification test, with a null hypothesis of the model being under-identified, gives a p-value of 0.0933, which leads to a rejection of the null of under-identification of the model at the 10% level. As such, there is no issue of under-identification at the 10% level. The over-identification test gives a p-value of 0.1531. As such, the null hypothesis of no over-identification in the model cannot be rejected and there is no issue of overidentification. Lastly, Table 10.3a derives the C-statistic and its corresponding p-value to be 0.1981. As such, the null hypothesis of exogeneity of the main instrument cannot be rejected. Since the instrument is exogenous, there is no issue of endogeneity.

Table 8.3 indicates that the short run cost pass through of a change in wholesale prices to retail electricity prices is statistically insignificant. An important finding is that most of the pass through occurs in the long run. The amount of cost pass through occurring in the long run is low, but it is statistically significant.

In the long run, a 1% change (increase) in the wholesale price causes a 0.091% change in the retail price. The cost pass through is therefore quite incomplete and occurs in the long run.⁵⁶ What is more, Table 8.3 confirms the short run cost pass through of a change in wholesale prices to retail electricity prices to be statistically insignificant. An important finding is that most of the pass through occurs in the long run. The amount of cost pass through occurring in the long run is low but it is statistically significant.

⁵⁶ This thesis also undertakes estimations of the pass through of a change in the wholesale price towards the retail using change in natural gas prices as the instrument for change in wholesale prices. The instruments are recognised as under identified, results are insignificant and therefore the estimations using Brent crude oil spot prices are reported.

In the long run, a unit change (increase) in the wholesale price causes a 0.141-unit change in the retail price. The cost pass through is therefore incomplete and occurs in the long run. The monthly dummies included in the estimation are statistically insignificant and if excluded do not alter the results. Therefore, they are not reported in the above tables.

The findings of the natural logarithms specification and the levels specification is similar in a sense and they contradict the findings of the IV method which estimates a low significant amount of pass through in the short run. There is insufficient evidence of asymmetry in the cost pass through of the input price (Brent spot prices) to wholesale price for electricity because the coefficient of the positive change in the input price variable is not statistically significant. The monthly dummies included in the above estimation are statistically insignificant and including them does have any effect in the interpretation of asymmetry. Furthermore, there is insufficient evidence of asymmetry in the cost pass through of the input price of natural gas to the wholesale price for electricity because the coefficient of the positive change in the input price variable is not statistically significant. Lastly, Table 8.3 confirms insufficient evidence of asymmetry in the cost pass through of the wholesale price to the retail price of electricity because the coefficient of the decrease in the input price variable is not statistically significant.

8.5 Conclusion

This chapter illustrated and discussed the results of the use of a standard cost pass through distributed lag model in order to shed light on the cost pass through mechanism of the UK dairy, road fuels, and electricity sectors. The degrees of short run and long run pass through were estimated for a change of the input cost to the wholesale price and a change of the wholesale price to the retail price.

Potential heteroskedasticity as well as serial correlation problems were considered using Newey West standard errors. Following Nakamura and Zerom (2010), an instrumental variables methodology was applied to the relationship of the wholesale to retail prices to offset any potential attenuation bias caused by the fact that wholesalers face other costs than the price, and wholesale price contains a noisy proxy as a variable representing wholesale costs.

In terms of the pass through of an input cost to the wholesale price, the logs specification indicates a cost pass through of 0.2253% in the short run. Therefore, the cost pass through is incomplete. In the long run a 1% change in the input price (increase) causes a 0.3528% increase in the wholesale price indicating an incomplete pass through.

Similar findings are obtained from the levels specification with degrees of pass through 0.2229 in the short run and 0.4370 in the long run. In the long run a 1-unit change in the input price, is followed by a 0.4370 unit change in the wholesale price. Under the levels specification, the pass through in the long run is incomplete but more complete than the logs specification.

In terms of the wholesale cost change to retail price relationship, this chapter confirmed that the cost pass through of a change in the wholesale costs to the retail price, is 0.2635 under the log' specification and 0.4128 under the levels specification. Therefore, under the logs specification the pass through is incomplete since a 1% change (increase) in the wholesale cost increases the retail price by 0.2635% and under the levels specification the pass through is incomplete, a 1-unit change (increase) in the wholesale cost increases the retail price by 0.4128 units. The pass through is therefore incomplete but higher. These IV methodology results were supported by the standard cost pass through regressions which established similar findings. For the logs specification in the short run, a 1% change (increase) in the wholesale costs causes a change (increase) to the retail price by 0.15701%. For the level's specification, a one-unit change in the wholesale price, is followed by 0.5052 units change in the retail price. The pass through of a change in wholesale costs to retail costs, was therefore generally incomplete but under the level specification much more complete. In terms of asymmetries, this study did not provide sufficient evidence to establish asymmetric price transmission from either the input cost to the wholesale price, or the wholesale cost to the retail price.

Concluding the cost pass through analysis for the road fuels sector and in terms of input to wholesale is concerned, the logs specification indicated a cost pass through of 0.3202% in the short run. Therefore, the cost pass through was incomplete.

In the long run a 1% change in the input price (increase) causes a 0.6852% increase in the wholesale price indicating an incomplete pass through. Similar findings were obtained from the levels specification with degrees of pass through 0.2358 in the short run and 0.6020 in the long run.

In the long run, a 1-unit change in the input price is followed by a 0.6020-unit change in the wholesale price. Under both levels specification and logs specification, more than half of the change in the input cost is passed through to the retail cost.

In terms of wholesale cost change to retail price relationship, this study demonstrated that the cost pass through of a change in the wholesale costs to the retail price, is 0.3033 under the logs

specification and 0.3794 under the levels specification. Therefore, under the logs specification the pass through is incomplete, a 1% change (increase) in the wholesale cost increases the retail price by 0.3033% and under the levels specification the pass through is incomplete, a 1-unit change (increase) in the wholesale cost increases the retail price by 0.3794 units. The pass through was therefore incomplete but higher. These IV methodology results are supported by the standard cost pass through regressions which established similar findings. For the logs specification in the short run, a 1% change (increase) in wholesale costs changes (increases) the retail price by 0.3414%. For the levels specification, a one-unit change in the wholesale price, is followed by 0.3577 units change in the retail price. The pass through of a change in wholesale costs to the retail costs is therefore generally incomplete but under the levels specification much more complete. The same occurs in the long run and the pass through remains incomplete. In terms of asymmetries this thesis provides evidence of asymmetric price transmission, input cost change is transmitted faster to the wholesale price than an input cost decrease. Wholesale cost increase is transmitted faster to the retail price than a wholesale cost decrease.

Finally, this chapter illustrated and discussed the findings relevant to the electricity sector. In terms of input to wholesale, the logs specification indicates a cost pass through of 0.3006% in the short run. Therefore, the cost pass through is incomplete. In the long run a 1% change in the input cost (increase) causes a 0.5327% increase in the wholesale price thus indicating an incomplete cost pass through. Similar findings were obtained from the levels specification with degrees of pass through 0.1414 in the short run and 0.3193 in the long run.

In the long run, a 1-unit change in the input price is followed by a 0.5327-unit change in the wholesale price.

Under the logs specification, more than half of the change in the input cost is passed through to the wholesale price. Under levels specification the pass through is still incomplete and occurs at a lower extent.

In terms of the wholesale cost change to retail price relationship, this study demonstrates that the cost pass through of a change in the wholesale costs to the retail price is 0.0521 under the logs specification and 0.0702 under the levels specification.

Therefore, under the logs specification the pass through is incomplete, a 1% change (increase) in the wholesale cost increases the retail price by 0.0521% and under the levels specification

the pass through is incomplete, a 1-unit change (increase) in the wholesale cost increases the retail price by 0.0702 units. The pass through is therefore incomplete but higher. These IV methodology results were supported by the standard cost pass through regressions which established similar findings. For the logs specification in the short run, a 1% change (increase) in wholesale costs changes (increases) the retail price by 0.0016%. For the levels specification, a one-unit change in the wholesale price is followed by 0.0197 units change in the retail price. The pass through of a change in wholesale costs to retail costs is therefore generally incomplete but under the levels specification much more complete. The same occurs in the long run and the pass through remains incomplete. It is notable that the estimated degree of pass through of a change in wholesale costs to retail prices is incomplete and occurs at a very low extent. This finding applies to both IV and standard cost pass through regressions. The present study did not provide evidence of asymmetric price transmission within the UK electricity supply chain.

The impact of these input cost shocks on domestic electricity prices and the consumers is of crucial importance. Complete cost pass through indicates competitive markets whilst incomplete cost pass through indicates the potential existence of imperfection in the market and incomplete internalisation of costs by wholesalers (in the case of an input cost change to wholesale price) and by retailers (in the case of wholesale cost change to the retail price). This chapter therefore shed much-needed light on the pass-through mechanism of the UK electricity sector, using the distributed lag model methodology with updated UK data: a method which, to the best of this author's knowledge, has not been previously applied to the UK.

Chapter 9

Market Power Synoptic Results and Discussion

9.1 Introduction

This chapter provides the empirical findings relevant to the market power parameters for the first stage of the chain and second stage of the chain of milk and dairy products, and for road fuels and the electricity supply chains based on UK time series data.

9.2 Market Power Results Milk First Stage

Synoptic analysis of the results of the market power section with regard to the first stage of milk supply chain (milk products) demonstrates that all variables included in the demand, supply, and production estimations are stationary when first differenced as the MacKinnon approximate p-value for all of them is very low. Using the Augmented Dickey Fuller (ADF) tests, that the null hypothesis of non-stationarity can be rejected for each of these variables, with only the variable of income at $I(1)$ at the 10% level. Therefore, this analysis considers this to be $I(1)$: results which are consistent with the Philips Perron tests for stationarity.

In terms of cointegration, the demand equation with all variables integrated of order 1 was tested using the Johansen procedure. For the null hypothesis of 4 cointegrating relationships the trace statistic is less than both the 5% and 1% critical values of 12.25 and 16.26, respectively. Therefore, the hypothesis that there are no more than (r), four cointegrating relationships cannot be rejected. Based on Johansen (1995), the number of cointegrating relationships is the first number for which the null cannot be rejected. Therefore, there is cointegration among the variables. The supply equation with a mixture of $I(0)$ and $I(1)$ variables is tested for cointegration using the ARDL procedure. The procedure found evidence for cointegration. F is above the $I(1)$ critical threshold of 3.668. A recheck of the t-statistic concurs with the above. $T = -3.846$ is more extreme than the critical value -3.547 . This study therefore demonstrates cointegration at the 10% level.

The Cobb-Douglas production function is tested for cointegration using the Johansen procedure since all the variables are $I(1)$ and cointegration is established. After estimating the demand function for milk using the FMOLS procedure and the choice of lags to be 2, this study demonstrates that all independent variables in the FMOLS regression are statistically significant with very low associated p-values. They are all associated to a p-value of 0.

Examining each independent variable individually it is observed that:

With regards to the Retail price paid by the retailers, the sign of the coefficient is negative as expected. An increase in the price of the product causes a decrease in its demand. Since the log model used natural logarithms for all variables, the coefficient of the retail price can be interpreted as the price elasticity of demand. This is the responsiveness of the quantity demanded to a change in price. Generally in the literature, the demand for raw milk is price inelastic. This means that an increase in the price causes a less than proportionate decrease in the associated quantity demanded. What is puzzling here is that one would expect a coefficient that is negative and less than one. Contrary to the expectation, the coefficient of the retail price in the estimated demand function is higher than one. More specifically, its absolute value is 7. *Ceteris paribus*, this means that a 1% increase in the price will cause a 7% decrease in the quantity demanded. This indicates that the demand is elastic with respect to price. It should be noted that the author takes into account that this thesis estimates a logarithmic demand function that includes an interaction term of $\ln R$ and $\ln R_s$. Taking this into account and evaluating as price elasticity of demand $b_2 + b_4 \ln R_s$, the actual price elasticity is calculated as -0.87. Therefore it is as expected; negative and less than one.

In terms of Income, the sign of the coefficient of the real household income is estimated to be negative. When a good is normal by definition, an increase in income increases its demand, and the income elasticity of demand should be positive. Income elasticity of demand is the responsiveness of quantity demanded to a change in income. Furthermore the coefficient of the Price of complements, shows the cross price elasticity of demand between the price of complements which in this price of processed tea and coffee, and the price of milk. Tea and coffee can be seen as a complement for milk. The cross price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case demand of milk and dairy products from the retailers to the price of another good, in this case tea and coffee. The sign of the cross price elasticity of demand between the quantity demanded and the price of complements is negative, something which is expected since the two goods are complements.⁵⁷ When the price of good Y rises, the Quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient aligns with economic theory. After estimating the supply function for milk and dairy products towards the retailers using the FMOLS procedure and the choice of lags to be 4, this study demonstrates that all of the independent

⁵⁷ This occurs when evaluating cross price elasticity as $b_4 \ln R$.

variables in the FMOLS regression are statistically significant with very low associated p-values. Examining each independent variable individually it is observed that:

In terms of the Upstream supply of manufacture of dairy products, the sign of the coefficient is positive as expected. The price and the supply are positively related. As far as the inputs are concerned the coefficients of Input price1 and Input price2 are both positive.

Table 9.1 presents the synoptic results for market power for all three products; milk (dairy products), petroleum (road fuels) and electricity. Using the FMOLS procedure, this study detects a degree of oligopsony power in the first stage of the milk products market. The parameter that estimates market power of the processors towards the farmers is statistically significant at the 5% level with a coefficient of 0.0176. The value of this is between 0 and 1, and indicates low oligopsony power.

Table 9.1 Market Power Synoptic Results

	Milk First Stage	Milk Second Stage	Road Fuels		Electricity	
	FMOLS	FMOLS	FMOLS	FMOLS with recession dummy	FMOLS	FMOLS with recession dummy
Oligopsony	0.0176**	1.3111	0.3350***	3.4796***	0.6357***	0.1195
Oligopoly	0.1952	0.6527*	-0.0600***	-0.0270*	0.0003	-0.0001
	DOLS	DOLS	DOLS	DOLS with recession dummy	DOLS	DOLS with recession dummy
Oligopsony	-0.2895***	-1.0884***	0.0001	8.2100***	0.6709***	0.6540***
Oligopoly	-0.2856***	0.9107***	3.02e-0.9***	-0.3934***	0.0022	-0.0001

***Statistically significant at 1% level $p < 0.01$ ** Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.1$

The oligopoly power of the processors towards the farmers is statistically insignificant. In addition, this study estimates demand supply and production at the first stage of the milk products supply chain and based on this the market power parameters using the DOLS methodology.

The market power parameter of processors towards the farmers is estimated to be -0.2895.⁵⁸ The parameter that estimates market power of the processors towards the retailers is estimated as -0.02856. If the negative of this value is $\lambda = -d3$, then the value is between 0 and 1, there is evidence for oligopoly power of the processors towards the retailers at the 10% level.

⁵⁸ This thesis undertakes hypothesis testing with a null hypothesis that $d2$ is not < 0 , rejecting the null and concluding that the market power parameter of the farmers towards the processors is not less than 0. There is evidence that the parameter is different than 0 and not less than 0, therefore there is significant oligopsony power of the processors towards the farmers.

9.3 Market Power Results Milk Second Stage

Synoptically, the analysis of the results of the market power section with regards to the second stage of the milk market supply chain finds that all the variables are non-stationary. The ADF tests provide insufficient evidence to reject the null hypothesis of non-stationarity (unit root) since the variables have high MacKinnon approximate p-values of far greater than 0.05.

The Philips Perron tests demonstrate variables of Quantity demanded and Labour appear stationary as they both have a p-value that is less than 0.05. The statistic is greater than the critical value at both levels. At the 5% level Labour is stationary since the statistic is greater than the 5% critical value. However, at 1%, it is not stationary since at this level the statistic is less than the critical value. If this study considers 5%, then Labour is stationary.

After estimating the demand function for milk products using the FMOLS procedure and the choice of lags to be 1, this study demonstrated that all of the independent variables in the FMOLS regression are statistically significant at the 1% level, with very low associated p-values. Retail price has a p value of 0.001, Income has a p-value of 0.000, Price of complements has a p-value of 0.002, and the Interaction term has a p-value of 0.001. Examining each independent variable individually it is observed that:

In terms of the Retail price of milk products, the sign of the coefficient is negative, which aligns with standard economic theory. An increase in the price of the product causes a decrease in its demand. Taking into account the estimate of $b_2 + b_4 \ln R_s$ for the milk second stage demand function this author assesses that enough evidence is provided for price elastic demand. The norm is that the coefficient is negative and less than one. Contrary to this expectation the estimated price elasticity of demand is higher than one. In actual fact the absolute value of $b_2 + b_4 \ln R_s$ is greater than 10%.

This indicates that the demand is elastic with respect to price. It is noted that as the FMOLS procedure estimates the demand equation for the long run, the estimated price elasticity represents the long run.

A very recent report by KPMG UK (2019) draws attention to the UK trend of decreasing dairy product consumption which is mainly attributed to such factors as increased consumption of milk alternatives such soya, almond and oat milk, and increased awareness of the health benefits of organic milk. Furthermore, the trend towards veganism which is lately observed in the UK and growing environmental concerns around the impact of farming practices on climate

change may be contributing factors for the decrease of dairy consumption. These issues help drive a higher price elasticity of the demand for milk and milk products and a change in price causes a more than proportionate change in the price of milk products. The price of milk products from the ONS represents an index and milk constitutes a large proportion of that index.

In terms of Income, the sign of the coefficient of the natural logarithm of GDP is estimated to be positive. According to any standard microeconomics textbook, when a good is normal by definition, an increase in income increases its demand, and the income elasticity of demand should be positive. Income elasticity of demand is the responsiveness of quantity demanded to a change in income. Therefore the estimate of income elasticity of demand for milk products aligns with standard economic theory. Furthermore the coefficient of the Price of complements, shows the cross-price elasticity of demand between price of complements which in this case is bread, and the price of dairy products. Bread is a complement for butter and milk. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case milk to the price of another good, in this case bread. The sign of the cross-price elasticity of demand between the quantity demanded and price of complements is negative as is expected, since the two goods are complements.⁵⁹ The sign of this study estimated coefficient therefore concurs with standard economic theory.⁶⁰

After estimating the supply function for the milk and dairy products chain using the FMOLS procedure and the choice of lags to be 2, it is evident that all of the independent variables in the FMOLS regression are statistically significant with very low associated p-values.

In terms of the Upstream supply of manufacture of dairy products, the sign of the coefficient is positive which aligns with standard economic theory. The price and the supply are positively related. In terms of the inputs, the coefficients of both Input price1 and Input price2 are positive.

This aligns with expectations as there is a positive relationship between upstream supply price and the price of the two inputs correspondingly. Input price1 is the price of inputs in distribution and manufacturing of dairy products and Input price2 is the cost per labour hour. The results obtained from the DOLS methodology are consistent with regard to signs of coefficients for

⁵⁹ This occurs when evaluating $b_4 \ln R$.

⁶⁰ For the cross price elasticity of demand this author evaluates $b_2 + b_4 \ln R$. (since the interaction term of price and price of complements is included in the demand estimated function).

the demand and production with the FMOLS methodology, with the exception of the DOLS supply function, which provided evidence for insignificant coefficients.

While the study proceeded to estimate the oligopsony and oligopoly power using the DOLS method, findings of this estimation should be treated with some caution. The findings of the FMOLS procedure in this case are to be attributed higher weight by the researcher since all estimated coefficients for demand, supply, and production therein are significant.

This section presents the synoptic market power results for the milk second stage, including an estimation of oligopsony power of retailer towards the processors and an estimation of oligopoly power of retailers towards the consumers. Table 9.1 demonstrates the estimated market power parameters from the FMOLS method and the parameters estimated using DOLS. It is evident that for the market for milk products, both oligopsony and oligopoly power parameters are statistically significant when estimated using the FMOLS procedure. More specifically the oligopsony power of the retailers towards the processors is estimated with a coefficient of 1.3111. Oligopoly power of the retailers towards the consumers is estimated with a coefficient of 0.6527 which is statistically significant at the 1% level.

Based on the existing theoretical models and applied work, the coefficient of oligopsony should be between 0 and 1. In order to test whether the estimated oligopsony parameter of 1.31 is statistically different than 1 and confirm its magnitude, this study uses hypothesis testing of the null hypothesis that $d_2 > 1$. d_2 is the coefficient of oligopsony in the case that FMOLS is used. The result of the test indicates that d_2 is not statistically significantly greater than 1. Therefore, it is statistically different than 0, market power is detected, and the coefficient is not statistically significantly greater than 1. The Z-statistic is 126 and the critical value -2.34. Therefore, the null hypothesis is rejected and the study confirms evidence of oligopsony of the retailers towards their providers.

This study estimates the parameters using the DOLS estimation for all functions, including demand, supply, and production, as well as the market power equation. By so doing, confirms that oligopsony power of the retailers towards the processors has a coefficient of -1.0884 which is statistically significant at the 1% level.

The market power of the retailers towards the consumers has a coefficient of 0.9107, indicating oligopoly in absolute value which is statistically significant at the 1% level.

Due to the magnitude of the coefficient of the market power of retailers towards the processors parameter, this study proceeded to hypothesis testing with a null hypothesis that the coefficient β_2 is less than 0. The Z-statistic is -37.51 and the critical value at 1% is -2.37.

Therefore, since the value of the statistic is to the left or less than the critical value, in absolute terms, there is not enough evidence to reject the null hypothesis. The hypothesis is rejected, and the coefficient is not less than -1. It is therefore statistically significant since the p-value for the coefficient being different than zero at 0.000 and the magnitude is not less than -1.

This study provides compelling evidence of oligopoly and oligopsony power in the market for milk products in the UK. Oligopsony power exists from the retailers towards their providers and oligopoly power from the retailers towards the consumers. Furthermore, the findings chime with the findings of various other studies from the literature. Lloyd et al. (2006) and Anders (2008) establish market power of retailers in the food supply chain towards the consumers, while other similar findings are directly related to market power and milk products. Cavicchioli (2010) demonstrates the market power of fluid milk retailers towards the consumers in Italy for the period 1996-2008, while Salhofer et al. (2012) establish the market power of Austrian milk products' retailers towards the consumers and market power towards their input suppliers. Despite the fact that findings somewhat diverge based on the specific method, timespan, and country of study, then, the results of this study are in line with findings in the field.

To the best of this author's knowledge, to date, no relevant up-to-date study has been conducted in the UK. Therefore this study offers a new empirical approach towards estimation of market power of the UK milk products retailers. Motivated by the high concentration of the supermarkets at the retail level and lack of competition authority intervention, this study provides evidence of the oligopoly and oligopsony power of the retailers towards providers.

9.4 Market Power Results Petroleum (Road Fuels)

This section synoptically presents the results for the estimated demand, supply, and production functions of petroleum products.

After estimating the demand function for petroleum products (more specifically, road fuels) using the FMOLS procedure and the choice of lags to be 3, this thesis finds sufficient evidence that all independent variables in the FMOLS regression are statistically significant with very low associated p-values.

Retail price has a p-value of 0.013, Income has a p-value of 0.000, Price of complements has a p-value of 0.019, and the interaction term has a p-value of 0.016. Examining each independent variable individually it is observed that:

In terms of the Retail price of vehicle fuels and lubricants, the sign of the coefficient is negative which aligns with standard economic theory. An increase in the price of the product causes a decrease in its demand. This means that an increase in the price causes a less than proportionate decrease in the associated quantity demanded. What is unusual here is that contrary to the expectation, the magnitude of the coefficient of Retail price in the estimated demand function is higher than 1. More specifically, its absolute value is 9.55. This means that a 1% increase in the price will cause a 9.5% decrease in the quantity demanded. However, this author takes into account that for the estimation of the demand function of this thesis; the interaction term of the natural logarithm of road fuels retail price and the natural logarithm of the price of complements is also included as a regressor. Therefore, it is for the purpose of this thesis that the author evaluates the own price elasticity of demand as $b_2 + b_4 \ln R_s$. The corresponding value is -0.46, which is negative and highly in elastic, confirming the expectations on which this study bases its motivation on.

The literature in general suggests that the price elasticity of road fuels is very low and it differs based on the country (Druzic et al. (2018)). For example, Ones et al. (2018) establishes an inelastic gasoline demand for Sweden and the fact that it is a normal good.

The findings of this study extends beyond the norm to present a different perspective on the price elasticity of demand of road fuels. The method of estimation also controls for endogeneity and serial correlation.

In terms of Income, the sign of the coefficient of the natural logarithm of GDP is estimated to be negative. When a good is normal by definition, an increase in income increases its demand, and the income elasticity of demand should be positive. Income elasticity of demand is the responsiveness of quantity demanded to a change in income.

Thus, while this estimate contradicts the norm, it is noted that the FMOLS estimator of the model is specified in natural logarithms and provides these elasticities for the long run. The variable used for income is the gross value added from the GDP time series of ONS. Therefore as income is estimated as an aggregate and following Druzic et al. (2018), negative income elasticity indicates that a developed country such as the UK can turn towards the use of more

efficient vehicles such as electric cars. In fact, the higher the GDP, the more easy the switch to fuel-efficient cars.

Furthermore, the coefficient of the Price of complements shows the cross-price elasticity of demand between the price of complements which in this case is motor vehicles, and the price of vehicle fuels. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case vehicle fuels to the price of another good, in this case motor vehicles. The sign of the cross-price elasticity of demand between quantity demanded and price of complements is negative as expected, since the two goods are complements.⁶¹ When the price of good Y rises the quantity demanded of its complement good X falls. Therefore the sign of the estimated coefficient in this study aligns with economic theory. The estimated demand function has a really high adjusted R square of 0.87. This indicates that around 87% of the variation in the dependent variable is explained by the independent variables.

After estimating the supply function for petroleum products (more specifically, road fuels) using the FMOLS procedure and the choice of lags to be 0, it is evident that all independent variables in the FMOLS regression are statistically significant with very low associated p-values. Upstream supply has a p-value of 0.063, Input price1 has a p-value of 0.001, Input price2 has a p-value of 0.002, and the interaction term has a p-value of 0.072. Input price1 and Input price2 are statistically significant at 1%. Examining each independent variable individually it is observed that:

With regards to the upstream supply of refinery output of petroleum products, the sign of the coefficient is positive as expected. The price and the supply are positively related.

In terms of the inputs, the coefficients of both Input price1 and Input price2 correspond to price index of inputs in refinement and distribution of petroleum products and cost per labour hour, respectively.

By estimating the Cobb-Douglas production function of road fuels using the FMOLS procedure this study demonstrates that all independent variables are statistically significant at the 1% level since they are associated with very low p-values. The coefficient of the natural logarithm of Capital is positive as expected, since increasing the input increases the production. The coefficient of the natural logarithm of Labour is also positive as increasing the input increases

⁶¹ For the cross price elasticity of demand this author evaluates $b_2 + b_4 \ln R$. (since the interaction term of price and price of complements is included in the demand estimated function)

the production. The adjusted R square of the estimated production function is very high. 94% of the variation in the dependent variable is explained by the independent variables.

The estimation findings provided from the DOLS procedure are consistent with the FMOLS procedure results. The price elasticity of demand of road fuels is negative, in line with economic theory. An increase in price decreases demand. Furthermore, the demand is price elastic; more specifically, a 1% increase in price leads to an increase in price higher than 10%.⁶² While this would be expected to be inelastic, the researcher draws attention to the fact that long run elasticity is generally more elastic. Furthermore, based on Eiches and Crain (2016), in the long run consumers have more time to change consumption habits and move towards more efficient substitutes such as electric vehicles. They can also move towards the use of public transport. In the UK, public transport is generally an affordable and easily accessible good.

Direct comparison of the supply and production equations estimated by the FMOLS and DOLS procedure endorse these findings. Refinery output of petroleum products is positively related to the wholesale price of petrol (upstream price) and the Inputs in production and distribution of refined petroleum products are positively related to the Upstream price. The only difference is that in the FMOLS, the second input of coal price is positively related to the wholesale price of petrol, whilst the DOLS findings derive this relation as negative. Production estimation yields similar outcomes for both FMOLS estimation procedure and DOLS.

It is noted that this study re-estimates demand, supply, and production by including a dummy for the financial recession period of 2008-2014 in order to consider a possible exogenous shock in the data. The estimations for which the dummy is statistically significant are considered in order to measure the parameters of possible oligopsony and oligopoly power.

With regard to road fuels, it is evident that for the market for petroleum products (more specifically, road fuels), oligopsony power is statistically significant when using the FMOLS procedure. The market power parameter of retailers towards providers is 0.3350.

It lies between 0 and 1 and it is statistically significant at the 1% level. Resultingly, this study provides evidence for a significant degree of oligopsonistic market power of the road fuels retailers in the UK towards providers. The oligopoly coefficient of the estimated regression is

⁶² This author considers the fact that the price elasticity of demand, is estimated as $b_2 + b_4 \ln R_s$.

statistically significant. More specifically, the market power parameter of retailers towards consumers is estimated with a coefficient of -0.0600

It is therefore statistically significant at the 10% level. If one evaluates this as $-(-0.0600)$ since $\lambda = -d_3$, then there confirms a significant degree of oligopoly power from the retailers of road fuels towards the consumers. If one estimates the same regression which comes out from the FMOLS estimations taking into account estimations that include the statistically significant recession dummy, oligopsony power of the retailers towards their providers is statistically significant with a coefficient of 3.4796.

Based on existing theory and applied work, the coefficient of oligopsony is between 0 and 1. Therefore this study conducted a hypothesis test to determine whether the estimated oligopsony parameter of 3.48 is statistically greater than 1 and confirm its magnitude. This study used hypothesis testing of the null hypothesis that $d_2 > 1$. d_2 is the coefficient of oligopsony in the case that FMOLS is used including the statistically significant recession dummy. The result of the test indicates that d_2 is not statistically significantly greater than 1. The Z-statistic is -4.42 and the critical value is -2.34. Therefore, the null hypothesis is rejected. The oligopoly power of processors towards retailers is statistically significant with a coefficient of -0.0270. If one evaluates the negative value of this since $\lambda = -d_3$, 0.0270 lies between 0 and 1 and there is sufficient evidence for some degree of oligopoly from retailers towards consumers.

These findings are in line with the expectations of this study, since the high market concentration and high market shares of oil companies and supermarkets provide the ground for enhanced market power on behalf of the retailers. This study not merely confirms this, but also provides evidence that the market power level corresponds to that of an oligopoly. Furthermore, it confirms that retailers also have power towards providers since as the largest sellers of the product, they proportionally buy the largest amount of input. Moreover, other the results of comparable studies in the literature align with the findings of this study.

Lakuma (2013), for instance, establishes the exercise of market power in the American crude oil industry, while European studies, such as that undertaken by Ones et al. (2018) in Sweden, demonstrate the exercise of market power at the downstream level.

To the best of the author's knowledge, no other up-to-date study empirically estimates market power for road fuels retailers in the UK and demonstrates firm evidence of the oligopoly and oligopsony power of the retailers of road fuels.

Retailers have high market shares providing the grounds for oligopolistic behaviour. The estimations of demand, supply, and production under DOLS, oligopsony power is insignificant.

The market power parameter of retailers towards consumers, is statistically significant, but with a very low degree of oligopoly power. This study also undertook the DOLS estimations which included the statistically significant recession dummy. In this case sufficient evidence was provided to reject the null hypothesis that oligopsony is equal to zero and the null hypothesis that oligopoly coefficient equals to zero. As such, both oligopsony and oligopoly parameters are statistically significant with coefficients of 8.21⁶³ and -0.3934, respectively.

Since the expected value of the coefficient of oligopsony is between zero and 1, in order to test whether the estimated oligopsony parameter of 8.21 is statistically greater than 1 and confirm its magnitude, this thesis used hypothesis testing of the null hypothesis that $d_2 > 1$. d_2 is the coefficient of oligopsony in the case that FMOLS is used including the statistically significant recession dummy. The result of the test indicates that d_2 is not statistically significantly greater than 1. The Z-statistic is 8.97 and the critical value at 99% confidence level is -2.34. The null hypothesis is therefore rejected. The value -0.3934, if evaluated as (-0.3934) , indicates that λ is between 0 and 1. The thesis therefore confirms a significant degree of oligopoly power of retailers of road fuels towards consumers.

With the exception of the DOLS models, estimations which do not take account of the recession dummy provide sufficient evidence that coefficients for oligopsony power and oligopoly power are statistically significant and confirm the existence of oligopsony of the retailers of the road fuels towards their providers, and oligopoly power of retailers towards consumers.

9.5 Market Power Results Electricity

After estimating the demand function for electricity using the FMOLS procedure and the choice of lags to be 4, this study provides evidence that all of the independent variables in the FMOLS estimation are statistically significant with very low associated p-values. Retail price has a p-value of 0.000, price of substitutes has a p-value of 0.000, and the interaction term has a p-value of 0.000. The only variable which appears statistically insignificant is the income variable with a p-value 0.120. Examining each independent variable individually it is observed that:

⁶³ To test whether the estimated oligopsony parameter of 8.21 is statistically greater than 1 and confirm its magnitude, this thesis uses hypothesis testing of the Null hypothesis that $d_2 > 1$. d_2 is the coefficient of Oligopsony, in the case that DOLS is used including the statistically significant recession dummy. The result of the test indicates that d_2 is not statistically significantly greater than 1.

In terms of the Retail price of electricity, the sign of the coefficient is negative as expected. An increase in the price of the product causes a decrease in its demand. Since the model uses the natural logarithms of the variables, the coefficient of retail price can be interpreted as the price elasticity of demand. This is the responsiveness of the quantity demanded to a change in price. Generally in the literature electricity is price inelastic. This means that an increase in the price causes a less than proportionate decrease in the associated quantity demanded. One point which could raise discussion is that since electricity is considered a necessity, one would expect a coefficient that is negative and less than 1. Contrary to such expectations, the coefficient of retail price in the estimated demand function is higher than one. More specifically, its absolute value is 8.31.

However, this author considers that for the estimation of the demand function of this thesis; the interaction term of the natural logarithm of electricity retail price and the natural logarithm of the price of complements is also included as a regressor. Therefore, for the purpose of this thesis the author evaluates the own price elasticity of demand as $b_2 + b_4 \ln R_s$. The corresponding value is -0.22, which is negative and highly inelastic confirming the expectations the expectation on which this study bases its motivation on.

The main focus of this research is not the estimation of the elasticities but the estimation of market power, degrees of oligopoly and oligopsony, that are derived from the estimation of demand supply and production.

In terms of Income, the associated p-value is 0.120, which confirms that income is not statistically significant. Furthermore, the coefficient of the Price of complements, shows the cross-price elasticity of demand between the price of complements, which in this case is household electrical appliances, and the price of electricity. The cross-price elasticity of demand shows the responsiveness of quantity demanded of one good, in this case domestic electricity, to the price of another good, in this case electrical household appliances. The sign of the cross-price elasticity of demand between quantity and the price of complements is negative as expected, since the two goods are complements. When the price of good Y rises, the quantity demanded of its complement good X, falls. Therefore the sign of the estimated coefficient aligns with standard economic theory. After estimating the supply function for electricity using the FMOLS procedure and the choice of lags to be 3, it is evident that all independent variables in the FMOLS regression are statistically significant with very low associated p-values.

In terms of the Upstream supply which is all available electricity generated, the sign of the coefficient is positive which aligns with standard expectations. The price and the supply are positively related.

In terms of the inputs, the coefficient of Input price1 is positive, and confirms a positive relationship between the price of the input and the price of the output. A percentage increase in Input price1, causes a percentage increase in the price of the output (upstream supply price) which is in accordance to standard economic theory expectations. Furthermore, the coefficient of Input price2 is positive which confirms a positive relationship between the price of the input and the price of the output. A percentage increase in Input price2 causes a percentage increase in the price of the output (upstream) supply price and corresponds to standard economic theory expectations.

Estimating the Cobb-Douglas production function of electricity using the FMOLS procedure, this study demonstrates that upstream supply and capital are statistically significant at the 1% and 10% level, respectively, since they are associated with very low corresponding p-values of 0.000 and 0.074. As expected, the coefficient of Capital is positive; increasing the input increases the production.

This indicates the production elasticity of capital. The coefficient of Labour is not statistically significant. Furthermore, the adjusted R-square of the estimated production function is very high. Thus 90% of the variation in the dependent variable is explained by the independent variables.

The DOLS methodology estimates were found to be consistent with the results of the FMOLS estimator. It is again reiterated that this study re-estimates demand, supply, and production by including a dummy for the financial recession period of 2008-2014 in order to consider the effect of an exogenous shock to the data. It is applied both after both the FMOLS and DOLS estimations. Thus, the estimations for which the dummy is statistically significant are considered in order to measure the parameters of possible oligopsony and oligopoly power.

The above synoptic Table 9.1, infers that for the market for electricity, oligopsony power has been detected using the FMOLS procedure since the oligopsony and oligopoly coefficients of the market power regression are both statistically significant. More specifically, the market power of retailers towards their providers, ϕ , is estimated with a coefficient of 0.6357.

Since this value is between 0 and 1 there is evidence of high degree of oligopsony power from retailers towards providers at the 1% level. The market power of retailers towards the consumers is estimated with a coefficient of 0.0003, but it is not statistically significant.

If the same FMOLS regression is estimated taking account of estimations including the statistically significant recession dummy, the market power of retailers towards providers is statistically significant with a coefficient of 0.1195. This value is evaluated at between 0 and 1, and confirms evidence of oligopsonistic power of electricity retailers towards their providers, at the 1% level. Oligopoly power of the processors towards retailers is statistically insignificant.

This thesis findings defy expectations. Based on the high market shares of the Big Six electricity retailers in the UK, market power on behalf of the retailers towards the consumers is to be expected and provides the main rationale for this research. However, the fact that no market power has been established could be attributed to the freedom of choice which UK consumers enjoy in searching, choosing, and occasionally switching, their electricity supply company. Furthermore, despite the high market shares, the power of the Big Six over the price of electricity is subject the regulation and imposed price cap of Ofgem.

Ofgem (2019) are empowered to cap the price of energy paid by consumers who are paying a standard variable or default tariff and a default tariff is paid by consumers who use a debit or credit card. Introduced in 2019, to limit the price per unit of electricity retailers can charge, the cost is based on the efficiency of the supplier. No retailer can set the price above this limit and the cap is updated every six months in order to prevent unfair retailer pricing strategies deemed detrimental to consumers. While this study analyses the electricity supply chain for the 2000-2020 period, the Ofgem price cap offsets some degree of retailer market power.

Lastly, the findings of this study are in direct contrast with the findings of previous UK studies. Both Boroumand (2015) and Amountzias et al. (2017) that provide evidence of the market power of UK electricity retailers towards consumers. These prior studies do not account for the price cap which was introduced in 2019.

However, findings which better align with the present study are obtained for the regulated French wholesale electricity market (Meritet et al. 2015) who also find that there is no market power at the French electricity market wholesale level, because of regulation.

The DOLS estimations of demand, supply, and production under DOLS found the market power of retailers towards their providers to be significant at 1% level, with a coefficient of 0.6709.

Since this value is between 0 and 1, ϕ between 0 and 1, there is sufficient evidence of a significant degree of some oligopsonistic power of the retailers towards their providers, while oligopoly power is statistically significant only at the 10% level, with a coefficient of 0.0022. When taking into account a DOLS estimation that includes a statistically significant recession dummy, the market power parameter of the retailers towards their providers is statistically significant at 1% level with a coefficient of 0.6540, indicating oligopsony. ϕ is between 0 and 1. The market power parameter of retailers towards consumers is statistically insignificant.

The DOLS results are consistent with the FMOLS results affirming a general consensus that oligopsony power obtains on behalf of retailers towards providers, but there is no oligopoly power from retailers towards consumers.

The above findings largely contradict the expectations that the Big Six's combined market share inevitably perpetuates the existence of market power of retailers towards consumers. On the other hand, the findings do confirm a degree of oligopsony power of retailers towards providers which may be attributed to the fact that retailers with high market shares also exert power over wholesale electricity providers.

9.6 Conclusion

This chapter included a synoptic description of the empirical findings relevant to the estimation of the market power parameters for milk and dairy product in the first and second stages of the supply chain, for the road fuels and electricity supply chain. All these empirical findings rest on UK data and address the first set of main research questions of this study: namely, to estimate the market power of retailers towards consumers, and market power of retailers towards the providers.

Milk price elasticity of demand is estimated to be elastic contradicting expectations. This can be attributed to a trend towards veganism as well as a rise of alternatives such soya and almond milk. (Kite Consulting 2019).

It should be noted that for electricity and milk retailers, this thesis estimated income elasticity of demand as positive, something which is in agreement to standard economic literature.

The own price elasticity of road fuels is estimated to be elastic contradicting expectations. This can be due to a trend towards veganism and a move towards public transport. Income elasticity of milk processors and of road fuels retailers is estimated to be negative. This is in contrast to the standard economic theory of normal goods expectations. However, this author follows the rationale of Druzic et al. (2018), to interpret the negative income elasticity of road fuels as a result of high GDP. Since UK is a high GDP country, the higher the GDP the higher the probability for consumers to reach out to more efficient alternatives (electric cars).

Chapter 10

Cost Pass Through and Asymmetric Price Transmission Synoptic Results

10.1 Introduction

This chapter presents the synoptic empirical results for cost pass through and asymmetric price transmission for milk, road fuels, and electricity.

10.2 Cost Pass through and APT results Milk and Dairy Products

Table 10.1 below presents the synoptic cost pass through results and asymmetric price transmission for the milk and dairy products, road fuels, and electricity supply chains.

In terms of the input to wholesale cost pass through for the milk/dairy sector, and according to table 10.1, double log specification is undertaken using the standard cost pass through regression method and provides evidence that a 1% change (increase) in the input price is followed by a 0.2253% change (increase) in the wholesale price. Out of the specification which is estimated in levels using the standard cost pass through regression, it is further inferred that a 1-unit change (increase) in the input price is followed by a 0.2229-unit change (increase) in the wholesale price. Both values are estimations of the short run pass through. In respect of the long run, out of the double log specification it is inferred that a 1% change (increase) in the input price is followed by a 0.3528% change (increase) in the wholesale price. Out of the specification which is estimated in levels using the standard cost pass through regression, it is further noted that a 1-unit change (increase) in the input price is followed by a 0.4370-unit change (increase) in the wholesale price. Both values are estimations of the long run pass through. Out of the double log specification and out of the specification in levels, the cost pass through is incomplete. Less than half of the change in input cost is passed on to the wholesale price.

As it is evident from the table 10.1, the cost pass through of the wholesale price of dairy products to the retail price is 0.2635 which indicates that a percentage change (increase) in wholesale price causes a 0.2635% change (increase) in retail price. From table 10.1a, the under-identification test with a null hypothesis of the model being under-identified gives a p-value of 0.0252, which leads us to rejection of the null at the 5%. As such, there is no issue of under-identification. The over-identification test gives p-value of 0.1014. This means so the null hypothesis cannot be rejected and there is no issue of over-identification. Lastly, the table provides the C-Statistic and its corresponding p-value to be 0.8811. As such, the null hypothesis

of exogeneity of the instrument cannot be rejected. Since the main instrument is exogenous, there is no issue of endogeneity.

From the specification of the cost pass through in levels which uses the instrumental variables method, it is inferred that a one-unit change (increase) in wholesale price causes a 0.4128 unit change (increase) in the retail price. Furthermore, Table 10.1 indicates that a 1% change in the wholesale price is followed by 0.1570% change in the retail price. This is a result of the standard cost pass through regression of the double log specification and is lower than that obtained by the instrumental variables method. The long run pass through is statistically insignificant indicating the cost pass through is largely incomplete and occurs in the short run.

From the specification of the standard cost pass through regression in levels, it is inferred that a unit change (increase) in the wholesale price causes a 0.5052-unit change (increase) in retail price. This is higher than the cost pass through of wholesale to retail prices estimated by the instrumental variables' method. The instrumental variables method estimates the cost pass through as mentioned above, is 0.2635.

The long run pass through is statistically insignificant, indicating the cost pass through is largely incomplete and occurs in the short run.

The above findings of this study are supported by the existing literature which estimates incomplete pass through in the food supply chain, and more specifically, in the supply chain for milk and dairy products. Prior research has demonstrated incomplete cost pass through between changes in commodity costs and wholesale and retail prices of coffee. (Leibtag et al. 2007; Nakamura & Zerom 2010). The present study also yields the additional result that most of the pass through occurs in the short run, as established by both the standard cost pass through regressions and the instrumental variables method.

Lastly, with regards to asymmetric price transmission, Table 10.1 demonstrates insufficient evidence for asymmetric price transmission of a change in the input price to the wholesale price or for any asymmetries in the cost pass through between wholesale to retail prices of milk products.

Table 10.1. Synoptic Cost Pass Through and APT Results

	Milk		Road Fuels		Electricity	
	Logs	Levels	Logs	Levels	Logs	Levels
Input to wholesale						
Short run	0.2253***	0.2229***	0.3202***	0.3584***	0.3006***	0.1414
Long run	0.3528***	0.4370*	0.6852***	0.6020***	0.5327	0.3193
Input to wholesale (Nat gas)						
Short run					0.1909**	0.0494
Long run					0.6335***	0.2185**
Wholesale to retail IV	0.2635***	0.4128***	0.3033***	0.3794***	0.0521***	0.0702**
Wholesale to retail						
Short run	0.1570*	0.5052***	0.3414***	0.3577***	0.0016	0.0197
Long run	0.0707	0.2196	0.3984***	0.4688***	0.0910***	0.1410***
Asymmetries						
Input to wholesale						
Positive change in input price	0.7635 **		0.0339***		0.2423	
Negative change in input price	0.2505		-0.0139***		1.6719	
Input to wholesale (Nat gas)						
Positive change in wholesale price					-0.0239	
Negative change in wholesale price					-0.0566	
Wholesale to retail						
Positive change in wholesale price	-0.4296		-0.0156***		-0.0934**	
Negative change in wholesale price	1.7496***		-0.0133***		-0.0566	
N	96		228		178	

***Statistically significant at 1% p<0.01 **Statistically significant at 5% p<0.05 *Statistically significant at 10%, p<0.10.

10.3 Cost Pass Through and APT Results Road Fuels

As far as the input to wholesale cost pass through for the road fuels sector, estimations are undertaken using the standard cost pass through regression method and the natural logarithms specification provides evidence that a 1% change (increase) in the input price is followed by a

0.3202 percent change (increase) in the wholesale price. Out of the specification which is estimated in levels using the standard cost pass through regression, it is further inferred that a unit change (increase) in the input price is followed by a 0.3584-unit change (increase) in the wholesale price.

Both values are estimations of the short run pass through. In terms of the long run, the double log specification demonstrates that a 1% change (increase) in the input price is followed by a 0.6852% change (increase) in the wholesale price.

Out of the specification which is estimated in levels using the standard cost pass through regression, it is further inferred that a 1unit change (increase) in the input price is followed by a 0.6020-unit change (increase) in the wholesale price. Both values are estimations of the long run pass through which is incomplete in both cases.

Based on the natural logarithms specification and the levels specification, the estimated short run pass through is lower than the estimated long run pass through. The pass through is incomplete and occurs partially in both the short and long run.

In terms of petroleum products (more specifically, road fuels), Table 10.1 indicates that a 1% change in the wholesale price is followed by 0.3033% change in the retail price. This result is provided from the natural logarithms specification that uses instrumental variables method.

The under-identification test presented in Table 8.2a shows a null hypothesis of the model being under-identified; giving a p-value of 0.0086, leading to a rejection of null at the 1% level. As such, there is no issue of under-identification at the 1% level. The over-identification test provides a p-value of 0.7032. As such, the null hypothesis of no over-identification in the model cannot be rejected and there is no issue of overidentification. The C-statistic provided has a p-value of 0.7032. As such, the null hypothesis of exogeneity of the main instrument cannot be rejected.

The specification of the cost pass through regression in levels which uses the instrumental variables method illustrated in Table 10.1 demonstrates that a one-unit change (increase) in the wholesale price causes a 0.3794-unit change (increase) in the retail price. Furthermore, the table indicates that a 1% change in the wholesale price is followed by 0.3414% change in the retail price. This is a result of the natural logs specification which uses a standard cost pass through regression. This finding is consistent with that provided by the instrumental variables' method.

The specification of the standard cost pass through regression in levels shown in Table 10.1 demonstrates that a one-unit change (increase) in the wholesale price causes a 0.3577-unit change (increase) in the retail price. This is almost identical to the cost pass through of wholesale to retail prices estimated by the instrumental variables method and corresponds to 0.3794.

The specification of the standard cost pass through regression in levels demonstrates that the long run pass through of wholesale to retail price corresponds to 0.4688. A 1% change (increase) in the wholesale price causes a 0.4688% change (increase) in retail price. The specification of the standard cost pass through regression in logs demonstrates that the long run pass through of wholesale to retail price corresponds to 0.3984. A 1% change (increase) in the wholesale price causes a 0.3984% change (increase) in the retail price.

Lastly, with regards to the asymmetric price transmission, Table 10.1 demonstrates that the wholesale prices respond faster to a positive change of the input cost rather than to a negative change. This confirms positive asymmetry. More specifically, the coefficient of the positive change in the input price variable is higher than the coefficient of the negative change in the input price variable.

The same is evident for the wholesale to retail pass through. The retail prices respond faster to increases rather than decreases in the wholesale cost. This also confirms positive asymmetry. More specifically, the coefficient of the positive change in the wholesale variable is higher than the coefficient of the negative change in the wholesale price variable. Positive asymmetry operates at the expense of the consumers and may be to the detriment of social welfare.

The findings of this thesis largely contest the findings of the most recent contribution relevant to the UK wherein Pesaresi et al. (2014) do not provide enough evidence for price transmission asymmetries in the UK road fuels supply chain. Furthermore, the present thesis' findings challenge the work of Bermingham and O' Brien (2011) that similarly find insufficient evidence for asymmetric price transmission for the UK petroleum supply chain. However, this research does not align with earlier work which confirms the existence of asymmetric price transmission for UK road fuels (Bacon 1991; Manning 1991).

Given that the market power is deemed as a theoretical factor behind asymmetric price transmission, the road fuels results of the present study enhance evidence for oligopolistic market power on behalf of retailers which arguably contributes towards incomplete pass

through, as well as asymmetric price transmission or so called phenomenon of ‘rockets and feathers’.

The application of the Nakamura and Zerom (2010) paradigm, together with the time series dataset collected for the purpose of this study comprises new findings which add to the knowledge and advance literature in the field.

To the best of this author’s knowledge, to date, no study has employed the distributed lag method to estimate asymmetric price transmission for UK road fuels as this research does; in respect of both the input to wholesale price relationship and the wholesale price to retail price relationship.

10.4. Cost Pass Through and APT Results Electricity

With regards to table 10.1 and in terms of the change in the input cost (Brent Spot prices) to the wholesale cost pass through for the electricity supply chain, estimations are undertaken using the standard cost pass through regression method. As it can be inferred out of the natural logarithms specification, a 1% change (increase) in the input price is followed by a 0.3006% change (increase) in the wholesale price. Out of the specification which is estimated in levels using the standard cost pass through regression, it is further inferred that a unit change (increase) in the input price is followed by a 0.1414-unit change (increase) in the wholesale price. Both values are estimations of the short run pass through.

In terms of the long run pass through of a change in input price to wholesale price, an estimation in levels infers the pass through of 0.3193 which means that a unit change (increase) in the input price is followed by a 0.3193 unit change (increase) in the wholesale price. Taking the natural logarithms of the variables, the pass through is 0.5327 which infers that a 1% change (increase) in the input price is followed by a 0.5327% (increase) in the wholesale price.

In terms of the change in the input cost (natural gas price) to the wholesale price pass through, estimation is undertaken using the standard cost pass through regression method, and the natural logarithms specification infers that a 1% change (increase) in the input price is followed by a 0.1909% change (increase) in the wholesale price. Out of the specification which is estimated in levels, it is further inferred that a 1-unit change (increase) in the input price is followed by a 0.0700-unit change (increase) in the wholesale price. Both values are estimations of the short-run pass through.

In terms of the long run pass through of a change in input price to wholesale price estimation in levels, the pass through is 0.2185 which means that a 1-unit change (increase) in the input price is followed by a 0.2185-unit change (increase) in the wholesale price. When the estimation takes the natural logarithms of the variables, the pass through is 0.6333 which infers that a 1% change (increase) in input price is followed by a 0.6333% change (increase) in the wholesale price.

The double log specifications for both Brent Spot prices and natural gas prices as input prices, derive an incomplete cost pass through of a change in the input cost to the wholesale price, for the product of electricity. This is consistent with the findings of the specification of the pass through of the price of natural gas to wholesale electricity prices estimated in levels. The only exception which does align with this finding is the specification in levels which uses the Brent Spot prices.

Table 10.1 indicates that a 1% change in the wholesale price of electricity is followed by 0.0521% change in the retail price. This result is obtained from the double log specification which uses the instrumental variables method.

The under-identification test provided in Table 8.3a demonstrates a null hypothesis of the model being under-identified and gives a p-value of 0.0086 which leads to a rejection of null at the 1% level. As such, there is no issue of under-identification at the 1% level. The over-identification test provides a p-value of 0.7032. As such, the null hypothesis cannot be rejected, and there is no issue of over-identification. The C-statistic provided has a p-value of 0.7032. As such, the null hypothesis of exogeneity of the main instrument cannot be rejected.

From the cost pass through levels specification, which use the instrumental variables method it is evident that a one-unit change (increase) in wholesale price causes a 0.0702-unit change (increase) in the retail price. Table 10.1 demonstrates that the short run cost pass through of a change in wholesale prices to retail electricity prices is statistically insignificant. An important finding is that most of the pass through occurs in the long run. The amount of cost pass through occurring in the long run is low but statistically significant. In the long run, a 1% change (increase) in the wholesale price causes a 0.091% change in the retail price. The cost pass through is therefore incomplete and occurs in the long run.

Furthermore, it is shown that, when using a levels specification, the short run cost pass through of a change in the wholesale price to the retail electricity prices, is statistically insignificant.

An important finding is that most of the pass through occurs in the long run. The amount of cost pass through occurring in the long run is low but statistically significant. In the long run, a unit change (increase) in the wholesale price causes a 0.141-unit change in the retail price. The cost pass through is therefore incomplete and occurs in the long run. The findings of the natural logarithms' specification are consistent with the findings of the levels specification in the sense that they both contradict the findings of the IV method which estimates a low significant amount of pass through in the short run.

The findings of the present study extend the literature which engages with the topic of incomplete cost pass through from the wholesale to the retail price. More significantly, they contest the findings such as those of Guo and Gissey (2019) which indicate complete cost pass through of a change in fuel cost to the wholesale prices. Moreover, Table 10.1 does not demonstrate asymmetric price adjustment, since the variable of a positive change in the input price is statistically insignificant. This occurs for the relation of input to wholesale price for both natural gas as input and Brent Spot prices. As such, it is not possible to form any definitive inference with regard to asymmetric price transmission. The variable of a negative change in the price is statistically insignificant for the wholesale to retail price pass through. Again, the present findings challenge prior research which establish asymmetric price transmission between wholesale and retail electricity prices in the context of the UK.

More specifically, they contradict Ofgem's (2011) findings which provide evidence of the rockets and feathers phenomenon in the UK electricity supply chain. The fact that UK consumers have the opportunity to search for the best provider could be a possible reason for no asymmetric price transmission in the electricity supply chain.

10.5 Conclusion

This chapter presented the synoptic empirical results for cost pass through and asymmetric price transmission for milk, road fuels, and electricity. It included the estimation of the cost pass through of an input cost change to wholesale price and of a wholesale cost change to retail price for all three sectors in order to address the second set of main questions in this study: namely, to estimate the degree of cost pass through of an input cost change to wholesale price and the degree of cost pass through of a wholesale cost change to retail price, and delineate the findings relevant to asymmetric price transmission.

Chapter 11

Conclusion and Policy Implications

11.1 Introduction

The thesis provides a comprehensive empirical insight into the degree of market power in the supply chain, and more specifically, the degree of market power of retailers towards consumers and retailers towards providers, using time series data to examine this issue in UK of milk (milk products), petroleum (road fuels) and electricity supply chains. The estimation of market power employed NEIO methods predicated on the seminal work of Bresnahan (1982) and influenced by that of Perekhozhuk et al. (2015; 2017). Estimations are undertaken for the degree of market power of the retailers towards consumers and the degree of market power of the retailers towards their providers and study applied a quantitative approach using time series mainly from ONS, the Department of Energy Business and Industrial Strategy, and the EIA. The extensive data set comprised 96 quarterly observations from first quarter 1996 - last quarter 2019 inclusive for the milk supply chain; 228 monthly observations January 2000 - December 2018 inclusive for the road fuels supply chain; and 243 monthly observations from January 2000 - March 2020 inclusive for the electricity supply chain. Due to timespan constraints in availability of wholesale electricity data, a further 178 observations for the period March 2003 - December 2017 inclusive are analysed in the case of the electricity cost pass through. The Fully Modified Least Squares Estimator and the Dynamic Ordinary Least squares estimator are also applied.

The present study contributes to existing literature on market power as the first to interrogate the degree of market power of processors and retailers in the UK milk supply chain with up-to-date data. It is also the first to examine the degree of market power for UK road fuels supply chain and for the UK electricity supply chain using reliable current information. Moreover, to the best of this author's knowledge, this is the first study which uses FMOLS and DOLS to estimate market power and incorporate the effects of the financial recession period 2008-2014 into the overall analysis. The most significant findings relevant to market power can be summarised as follows:

Both FMOLS and DOLS provide enough evidence that the milk sector first stage exerts some oligopsonistic market power of the processors towards the farmers. DOLS further confirms oligopolistic market power of the processors towards the retailers.

The study also provides compelling evidence for oligopsonistic and oligopolistic market power of retailers in the milk second stage. This general conclusion rests on both the FMOLS and DOLS results and the findings with the dummy for the financial recession 2008-2014 period are factored into the analysis.

This study provides enough evidence for oligopsonistic and oligopolistic market power of retailers in the road fuels supply chain. As far as the road fuels supply chain is concerned, this general conclusion rests on both the FMOLS and DOLS results and the findings with the dummy for the financial recession 2008-2014 period factored into the analysis.

This study provides compelling evidence for oligopsonistic market power of retailers towards providers in the electricity supply chain, but not for oligopolistic market power of the retailers towards consumers. The primary objective of this study is to examine the degree of market power in the supply chain with empirical applications on the UK milk, road fuels, and electricity supply chain. In so doing, this thesis has built extensive empirical analysis into the estimation of cost pass through, within the supply chain, and more specifically, the estimation of the cost pass through of an input cost change to the wholesale price, and the estimation of a wholesale cost change to the retail price. The study uses time series data to estimate cost pass through in the context of UK supply chains of milk (milk products), petroleum (road fuels), and electricity, as well as asymmetric price transmission. The estimation of the cost pass through is based on Distributed Lags models, the work of Nakamura and Zerom (2010). The study applies a quantitative approach using time series mainly from ONS, the Department of Energy Business and Industrial Strategy, and the EIA. Estimations are undertaken for both logs specification and levels specification throughout. In the case of the pass through of a change in the wholesale cost to the retail price, instrumental variables were used to account for attenuation bias.

The present study contributes to existing literature of cost pass through as the first to estimate the cost pass through of an input cost change to the wholesale price and the cost pass through of a wholesale cost change to the retail price for the UK milk and milk products chain with up-to-date data. It is also the first to examine cost pass through for the UK road fuels supply chain and for the UK electricity supply chain with up-to-date data. To the best of this author's knowledge, this is the first study which uses Distributed Lag models following Nakamura and Zerom (2010) to estimate market power. The most significant findings relevant to cost pass through can be summarised as follows:

There is compelling evidence of incomplete cost pass through of the change in the farm-gate price to the wholesale price and of the change of the wholesale price to the retail price in the milk supply chain. However, there is insufficient evidence of asymmetric price transmission within the milk supply chain.

There is compelling evidence of incomplete cost pass through of the change in the input price (Brent Spot prices) to the wholesale price and of the change of the wholesale price to the retail price in the road fuels supply chain. Evidence also confirms asymmetric price transmission of a change in input cost to the wholesale price and a change in the wholesale cost to the retail price.

There is also enough evidence of incomplete cost pass through of the change in the input price to the wholesale price and of the change of the wholesale price to the retail price in the electricity supply chain. However, not enough evidence of asymmetric price transmission is provided within the electricity supply chain.

11.2 Limitations of the Thesis

This researcher is mindful of a number of limitations relating to the data sample and the data frequency.

Firstly, in terms of estimating market power in the milk sector, 96 quarterly observations are considered as monthly series are not available for all the variables used, which could impact the empirical results. Due to lack of availability of prices for milk at both wholesale and retail level, dairy products variables are used.

While such conclusions can be made for milk since it consists of the greater proportion of these price indices, this thesis generalises the conclusions to milk and dairy products. The academic literature emphasises that frequency of data affects the findings. In the case of road fuels, only monthly observations are available. Thus, while extensive observations from January 2000 up to December 2018 are included in the present analysis, the availability of weekly data could arguably enhance precision and perspective on the issue.

In much the same vein, for the estimation of the electricity supply function, the retail price of domestic electricity is used as a proxy for the upstream supply price, since wholesale price is very volatile with gas price which is used a supply shifter. In this case, the available of monthly observations are used, but the availability of weekly data could further enhance the precision of estimates.

It is worth noting that while this analysis incorporates the financial recession period of 2008-2014, the impact of Brexit and the Covid 19 Global Pandemic effects are not considered at this time. These two major events have significantly affected the prices of these products, along with domestic and global demand and consequent supply. In fact, in the case of dairy products, the relevant competition authorities have intervened to loosen the enforcement of competition law within the sector.

Various limitations apply to the estimation of cost pass through and asymmetric price transmission where the availability of a higher number of observations could enhance precision. For instance, the present findings based on the variable used for input cost and the frequency of data, differ from those established by Deltas and Polemis (2020). Rather than using Brent Spot prices as input cost for road fuels, further research using the price of crude oil sold to refiners' price can be accurate.

The present cost pass through analysis does not consider the effects of Brexit and the Covid 19 Global Pandemic on the prices of the products under study. Further research and future work can be undertaken to address this issue. The intervention of the competition authorities on the dairy sector during the Covid 19 Global Pandemic and the relevant welfare effects also provide grounds for future research.

Finally, the significant fall in road fuel prices due to this exogenous shock may also provide a basis for further research in this field.

11.3 Conclusions and Policy Implications

This thesis estimated market power for the supply chain using empirical applications to the UK milk and dairy products sector, road fuels sector, and electricity sector. Based on New Empirical Industrial Organisation techniques and the seminal work of Bresnahan (1982), followed by studies of Lloyd et al. (2006) and Cavicchioli (2010), the market power of the retailers towards the consumers as well as market power of the retailers towards their providers, was estimated. Empirical applications include the supply chain of milk and dairy products, road fuels sector, and electricity in the UK. In the case of milk, the category of products is classified as dairy products due to lack of availability of more specific data. This thesis therefore went further back into the dairy and milk supply chain by estimating market power of processors towards farmers and market power of processors towards retailers. Following the establishment of cointegrating relationships among the variables for each of these functions, demand, supply,

and production functions were separately estimated, using time series data and FMOLS and DOLS methodology.

It is important to note that this research also estimated demand supply and production functions including a dummy variable for the financial recession period of 2008-2014. In this way any effects caused by the shock to the economy was incorporated to the analysis. A market power regression based on the demand supply and production functions of each industry is also estimated using both the FMOLS estimator and the DOLS estimator, and the conduct in the industry is consequently identified by estimating the market power parameters of ϕ and λ .

Applying FMOLS to the first stage of milk and dairy products, this thesis provided evidence that the market power parameter of processors towards farmers was statistically significant at 5% level, and between 0 and 1. The estimated coefficient is 0.0176, indicating some degree of oligopsony power. The market power parameter of processors towards the retailers was statistically insignificant. The application of DOLS found the market power parameter of processors towards farmers like the FMOLS estimate, and statistically significant at the 1% level with a coefficient of -0.2895. The DOLS methodology also provides evidence for the coefficient of oligopoly to be statistically significant, indicating oligopolistic market power of the processors towards the retailers.

For the milk second stage, this thesis estimated the FMOLS market power parameter of the retailers towards the processors to be statistically significant at 10% with a value for ϕ of 1.3111. After conducting hypothesis testing with a null of d_2 greater than 1, the Z-statistic was 126 and the critical value was -2.37. The null hypothesis was therefore rejected. There was evidence that ϕ was significantly different than 0 and not greater than 1. The value of λ was -0.6527 and statistically significant at 1%. The researcher urged caution here since λ , as the negative of the coefficient of oligopoly, was less than 1.

In the case that DOLS was used, the estimated coefficient of the market power of the retailers towards the processors was -1.0884 and statistically significant at 1%. The relevant test statistic for the null $d_2 < 0$ is -37.51 and the critical value was -2.37. Therefore, the hypothesis that ϕ is less than 0 was rejected. The DOLS estimated parameter of the market power of the retailers towards the processors was -0.9107 and statistically significant at the 1% level. Evaluating the negative of this value of λ as between 0 and 1 indicates a very high degree of oligopoly on behalf of dairy retailers towards consumers. Since under the DOLS estimator, ϕ is significantly

different than 0 and not less than 1 and λ is between 0 and 1, the researcher prioritised the DOLS results, as under the FMOLS methodology the coefficient of oligopoly is not empirically negative.

As a general outcome of the milk second stage results, the expectations of this study were confirmed, especially in terms of the DOLS results.

There is a very high degree of oligopoly power of the retailers towards the consumers and a high degree of oligopsony of the retailers towards processors. This data can be useful for regulators and the CMA, since it may draw their attention towards the business practices of the UK milk industry. To date, there has been limited intervention from the relevant authorities towards the dairy processors and retailers. Due to the high contribution of milk and generally dairy products to the UK's GDP, this pivotal consumer sector should receive the utmost protection from the relevant State and the independent authorities. The potential abuse of the retailer's market power can create a loss in consumer surplus and a deadweight loss to society. As such, the microeconomic objective of competitive prices may be directly affected by the existence of market power. The same occurs for any oligopsonistic power of the retailers towards their providers.

Applying FMOLS to the road fuels chain, this thesis provided evidence that the market power parameter of retailers towards providers was statistically significant at the 1% level and was between 0 and 1. The estimated coefficient was 0.3350 indicating some degree of oligopsony power. The market power parameter of retailers towards consumers was statistically significant at the 1% level. The coefficient of oligopoly was -0.060 and if the negative of this value was evaluated, λ as between 0 and 1, indicated oligopolistic power. In the case that FMOLS considered the estimations that include the recession dummy, the market power of retailers towards their providers was 3.4796, the use of hypothesis testing established it as significantly different than 0 at 1%, but not significantly greater than 0. The estimated Z statistic was -4.42 and the critical value -2.34. Evidence of oligopsony power of the retailers was therefore provided. This study also provides evidence for oligopoly power of retailers since the coefficient of oligopoly was 0.0270 at the 1% level.

Using DOLS, this study concluded that market power parameter of retailers towards providers was 0.0001 and not statistically significant. Market power of retailers towards the consumers was statistically significant at 1% but the degree of oligopoly power was very limited.

Evaluating the findings of the DOLS methodology that considered the financial recession dummy for 2008-2014, the market power parameter of the retailers towards the consumers was 8.21. Since this value is greater than 1, the researcher undertook hypothesis testing with a null that $d_2 > 1$. The Z-statistic was 8.97 and greater than the critical value of -2.34 in absolute terms. Therefore, the null hypothesis was rejected. The parameter of ϕ was statistically different than zero but greater than 1.

The market power parameter of retailers towards the consumers was -0.3934. This was statistically significant at 1% level and if the negative of this value evaluated λ as between 0 and 1, indicated oligopolistic market power.

The estimation of the market power for the UK road fuels sector has received limited attention in the academic literature and limited intervention exists on behalf of relevant authorities. The potential abuse of market power on behalf of retailers and the exercise of collusive practises can directly affect the microeconomic objective of competitive prices. Therefore, the results of this thesis may assist policymakers and to draw attention to a sector with potential for abuse of oligopolistic power. In terms of competition law, this affords an evidential basis for legal intervention.

In conclusion, this thesis provided estimates that the market power parameter of electricity retailers towards the providers is statistically significant at the 1% level, with a coefficient of 0.6357, estimated under the FMOLS methodology. ϕ was therefore between 0 and 1. In the case that a dummy for recession of 2008-2014 was included in the analysis, the estimate of ϕ , 0.1195 remained significant at the 1% level. Oligopsony power therefore exists but to a lower degree.

Using the DOLS methodology, the market power parameter of retailers towards providers was statistically significant at the 1% level with a coefficient of 0.6709, and when the recession dummy was included, a coefficient of 0.6540. ϕ was therefore between 0 and 1, confirming a significant degree of oligopsonistic market power exists. As far as the electricity supply chain is concerned, the market power of retailers towards consumers is statistically insignificant. This finding endorses the correct use of the price cap introduced by Ofgem in 2019 which regulates retail electricity prices in the UK. The present study can therefore demonstrate the efficacy of this regulatory measure to Ofgem. While the high market concentration of the electricity retailers affords the opportunity to exploit market power, it is clear that the price cap

mechanism is offsetting this potential in the sector. The fact that UK consumers also enjoy a choice of electricity suppliers may also limit the retailer market power. The retailers, however, do exert market power over providers since the Big Six are the main electricity sellers with a high market share, and therefore the main buyers of wholesale electricity.

Moving on to the second question examined by this thesis, this section offers summative remarks on the estimation of the cost pass through of an input cost shock to the wholesale price, and the cost pass through of the wholesale cost to the retail price.

Following Nakamura and Zerom (2010), the present thesis employed a standard cost pass through distributed lag regression to elucidate the cost pass through mechanism for the UK dairy, road fuels, and electricity sectors. Degrees of short run and long run pass through were estimated for a change of the input cost to the wholesale price and a change of the wholesale price to the retail price. Potential heteroskedasticity and serial correlation was considered using Newey West standard errors. In the context of the relationship of wholesale to retail prices, instrumental variables methodology were used to account with potential attenuation bias caused by the fact that wholesalers face other costs than price.

In terms of the input to wholesale, the logs specification indicated a cost pass through of 0.2253% in the short run. As such, the cost pass through was incomplete. In the long run a 1% change in the input price (increase) drove a 0.3528% increase in the wholesale price, indicating an incomplete cost pass through. Similar findings were obtained from the levels specification with degrees of pass through 0.2229 in the short run and 0.4370 in the long run.

In the long run, a 1-unit change in the input price was followed by a 0.4370-unit change in the wholesale price. Under the levels specification, the pass through in the long run was incomplete but more complete than the logs specification.

In terms of the wholesale cost change to retail price relationship, this thesis provided evidence that the cost pass through of a change in the wholesale costs to the retail price was 0.2635 under the logs specification and 0.4128 under the levels specification. Therefore, under the logs specification the pass through was incomplete: a 1% change (increase) in the wholesale cost increased the retail price by 0.2635%. Under the levels specification the pass through was incomplete: a 1-unit change (increase) in the wholesale cost increased the retail price by 0.4128 units. The pass through was therefore incomplete but higher. These were results of the IV methodology. Based on the standard cost pass through regressions, similar findings were

established. For the logs specification in the short run, a 1% change (increase) in wholesale costs changes (increases) the retail price by 0.15701%. For the levels specification, a one-unit change in the wholesale price was followed by 0.5052 units change in the retail price.

The pass through of a change in wholesale costs to retail costs was therefore generally incomplete, but under the levels specification much more complete. In terms of asymmetries this thesis did not provide sufficient evidence to establish rockets and feathers from the input cost to the wholesale price or from the wholesale cost to the retail price.

Estimation of the degree of cost pass through is scarce for the UK dairy sector. This thesis provides grounds for further research as the findings of incomplete cost pass through could be an indication of market power abuse, or as Guo and Gisse (2019) purport, an indication of no full internalisation of costs by the processors (in the case of input cost shock to the wholesale price mechanism), or of wholesale costs by the retailers (in the case of wholesale cost shocks to the retail price mechanism). The above incomplete cost pass through findings agrees with the findings of the literature on general food supply chain such as Leibtag et al. (2007) and Nakamura and Zerom (2010). While the UK competition authorities have notably intervened at the early stage of the chain, and specifically the role of cooperatives, no such intervention has taken place at the later stages of the chain relevant to processors and retailers despite the high market concentration indicators. Thus, the present estimation of the cost pass through rates afford an insightful perspective into current market competition.

Concluding the cost pass through analysis for the road fuels sector and as far as the input to wholesale is concerned, the logs specification indicated a cost pass through of 0.3202% in the short run. Therefore, the cost pass through was incomplete. In the long run a 1% change in the input price (increase) drove a 0.6852% increase in the wholesale price indicating an incomplete pass through. Similar findings were obtained from the levels specification with degrees of pass through 0.23584 in the short run and 0.6020 in the long run.

In the long run a 1-unit change in the input price was followed by a 0.6020 unit change in the wholesale price. Under both levels specification and logs specification, more than half of the change in the input cost was passed through to the retail cost.

Looking at the wholesale cost change to retail price relationship, this thesis provided evidence that the cost pass through of a change in the wholesale costs to the retail price was 0.3033 under the logs specification and 0.3794 under the levels specification. Therefore, under the logs

specification the pass through was incomplete; a 1% change (increase) in the wholesale cost increases the retail price by 0.3033%. Under the levels specification the pass through was incomplete: a 1-unit change (increase) in the wholesale cost increases the retail price by 0.3794 units.

The pass through was therefore incomplete but higher. These were the results of the IV methodology. Based on the standard cost pass through regressions, similar findings were established. For the logs specification in the short run, a 1% change (increase) in wholesale costs changes (increases) the retail price by 0.3414%. For the level's specification, a one-unit change in the wholesale price was followed by 0.3577 units change in the retail price. The pass through of a change in wholesale costs to retail costs was thus incomplete but under the levels specification much more complete. The same occurs in the long run where the pass through remains incomplete. In terms of asymmetries this thesis provided evidence of asymmetric price transmission, since the input cost change was transmitted faster to the wholesale price than an input cost decrease. Wholesale cost increase was also transmitted faster to the retail price than a wholesale cost decrease.

The above finding of asymmetric price transmission contradict the findings of Bermingham and O'Brien (2011) and Pesaresi et al. (2014), which do not provide enough evidence for APT for UK road fuels. However, the empirical results do resonate with earlier studies such as those of Bacon (1991) and Manning (1991). As such, this thesis could be useful to competition authorities such as the CMA, in turning their attention towards the road fuels sector for potential asymmetries with potential welfare implications which are detrimental for consumers and society.

Based on Charalambous & Clerides (2020), asymmetric adjustment comprises evidence of collusion between distributors and gas stations. Asymmetric price transmission can also be an indicator of poorly functioning markets. As the rockets and feathers phenomenon and high road fuel prices have the potential to engender social tension and political pressure, detecting and addressing this phenomenon is crucial to policymakers. Adverse social economic and political consequences may be minimised if timely investigations and interventions by the relevant authorities take place.

Concluding the cost pass through analysis for electricity, and as far as the input to wholesale is concerned, the logs specification indicated a cost pass through of 0.3006% in the short run.

Therefore, the cost pass through was incomplete. In the long run a 1% change in the input price (increase) drove a 0.5327% increase in the wholesale price, indicating an incomplete pass through. Similar findings were obtained from the levels specification with degrees of pass through 0.1414 in the short run and 0.3193 in the long run.

In the long run a 1-unit change in the input price was followed by a 0.5327-unit change in the wholesale price. Under logs specification, more than half of the change in the input cost was passed through to the wholesale price. Under levels specification the pass through remains incomplete and occurs at a lower extent.

Looking at the wholesale cost change to retail price relationship, this thesis provided evidence that the cost pass through of a change in the wholesale costs to the retail price is 0.0521 under the logs specification, and 0.0702 under the levels specification. Therefore, under the logs specification the pass through was incomplete: a 1% change (increase) in the wholesale cost increases the retail price by 0.0521%. Under the levels specification the pass through was incomplete, a 1-unit change (increase) in the wholesale cost increases the retail price by 0.0702 units. The pass through was therefore incomplete but higher. These were results of the IV methodology. Based on the standard cost pass through regressions, similar findings were established. For the logs specification in the short run, a 1% change (increase) in wholesale costs changes (increases) the retail price by 0.0016%. For the levels specification, a one-unit change in the wholesale price was followed by 0.0197 units change in the retail price. The pass through of a change in wholesale costs to retail costs was therefore generally incomplete but under the levels specification much more complete. The same occurs in the long run, as the pass through is still incomplete.

It is highlighted that the estimated degree of pass through of a change in wholesale costs to retail prices is incomplete and occurs at a very low extent. This a finding of both IV and standard cost pass through regressions. The present study does not provide enough evidence of asymmetric price transmission within the UK electricity supply chain.

The findings of this thesis contest those as Guo and Gissey (2019) and Guo and Gissey (2021), that established complete cost pass through of fuel costs to wholesale prices.

The impact of these input cost shocks on domestic electricity prices and the consumers is of crucial importance. Complete cost pass through indicates the possibility of competitive markets whilst incomplete cost pass through indicates potential existence of imperfection in the market

and incomplete internalisation of costs by wholesalers (in the case of input cost change to wholesale price) and by retailers in the case of wholesale cost change to the retail price.

The present results illuminate the pass-through mechanism in the UK electricity sector, using the distributed lag model methodology with updated UK data: a method which, to the best of this author's knowledge, has not been formerly applied to the UK.

Evidence of incomplete pass through can be useful to policymakers assessing the effect that a regulation imposed on an input price has on the wholesale price, or the effect that a regulation imposed on the wholesale cost has on the retail cost.

Lastly it is important to highlight that apart from policy contributions, in terms of empirical contributions this thesis uses a new methodology, for the estimation of demand, supply and production within the market power literature. Within a setting of cointegration demand supply and production relationships, this author asserts that the use of the FMOLS and DOLS estimators are the most appropriate. These methods consider cointegration, endogeneity and serial correlation. A vast number of studies exist estimating market power in the supply chain, however for the specific products these studies are rare; especially for milk and road fuels. What is more is that the literature on the estimation of the degree of market power in the specific supply chains for the country of UK is even rarer.

In terms of cost pass through no empirical study has used the distributed lag methodology for the cost pass through of input to wholesale price and wholesale price to retail price. This holds for the three sectors under study. Moreover, this thesis estimates the pass through from the input price to the wholesale price and from the wholesale price to the retail price contradicting a vast amount of studies that estimate cost pass through for the whole value chain rather than looking at individual parts.

APPENDICES

APPENDIX A:

Table A1. Description of Variables Milk First Stage

Variable	Variable description	Unit/Base Year	Source
Quantity demanded	Manufacture of Dairy products	Base Year 2013=100	ONS Source dataset: Index of production time series DIOP Series: K25B
Retail Price	Price to retailers Dairy and Cheese products	Base Year 2015=100	ONS Source dataset: Producer price inflation time series MM22 Series: JU37
Price of complements	Price of complements, Processed Tea and Coffee	Base Year 2015=100	ONS Source dataset: Producer price inflation time series MM22 Series: JU4D
Income	Real Household Disposable Income at chained volume measures (reference year 2016): SA	Million Pounds	ONS Source dataset: UK Economic account time series Series: DG2R
Upstream Supply price	Milk Farm gate price	Euro per kg	Eurostat
Upstream Supply	Supply of Raw Milk Delivered to Dairies	Thousand tonnes	Department for Business Energy and Industrial Strategy
Input price1	Input: Prepared Feed for Animals	Base year 2015=100	ONS Source dataset: Producer price inflation time series MM22 Series: JU4V
Input price2	Labour Cost per Hour ⁶⁴	Base year 2000=100	ONS Source dataset: Index of labour cost per hour series: ILCH Series: MWSS
Capital	Capital Input	Million pounds	ONS
Labour	Labour Input	Number of workers	ONS Source dataset: Employee Jobs by Industry- Manufacture of food products JOBS03

⁶⁴ This is provided from 2000Q1. Therefore this thesis uses percentage change figures for the whole economy to give data from 1996Q1 to 1999Q4.

Table A2. Description of Variables Milk Second Stage

Variable	Variable description	Unit	Source
Quantity demanded	Quantity demanded by consumers Food Milk; cheese and eggs	Million pounds	ONS Source dataset: Consumer trend time series (CT) Series: CCFI
Retail Price	Retail Price of Milk Products	Base year 1987=100	ONS Source dataset: Consumer price inflation time series MM23 Series: DOAR
Price of complements	Price of complements Retail Price Index of Bread	Base year 1987=100	ONS Source dataset: Consumer price inflation time series MM23 Series: DOAA
Income	Gross Domestic Product	Million pounds	ONS Source dataset: UK Economic Accounts Time Series (UKEA)
Upstream Supply Price	Supply Price of Input Dairy & Cheese Products	Base year 2015=100	ONS Source dataset: Producer price inflation time series MM22 Series: JU37
Upstream Supply	Supply of Input: Manufacture of Dairy products	Base year 2013=100	ONS Source dataset: Index of production time series DIOP Series: K25B
Input price1	Inputs for Manufacture of Dairy Products	Base year 2015=100	ONS Source dataset: Producer price inflation time series PPI Series:MC3X
Input price2	Labour Cost per Hour	Base year 2000=100	ONS Source dataset: Index of labour cost per hour series: ILCH ILCH_C1 Manufacturing - Food Products, Beverages and Tobacco. ⁶⁵
Capital	Capital Input	Million pounds	ONS ⁶⁶
Labour	Labour Input	Number of workers	ONS Source dataset: UK Workforce Jobs SA: G Wholesale & retail trade (thousands) - Labour Market Statistics time series LMS Series: JWS3.

⁶⁵ This does not start until 2000Q1. This thesis uses percentage change figures for whole economy to give data from 1996Q1 to 1999Q4

⁶⁶ Sources are described in Appendix A5

Table A3: Description of Variables Petroleum Products

Variable	Variable description	Unit	Source
Quantity demanded	Quantity Demanded by the Consumers Deliveries of Petroleum Products for Inland Consumption (motor spirit)	Thousand tonnes	Department for Business Energy and Industrial Strategy Table 3.13. Oil and oil products.
Retail Price	Price of Vehicle Fuels and Lubricants CPI Index	Base year 2015=100	ONS Source Dataset: Consumer price inflation time series MM23 Series: DK C4
Price of Complements	Price of Complements (Price of motor vehicles)	Base year 1987=100	ONS Source Dataset: Consumer price inflation time series MM23 Series: DOCS
Income	Gross Value Added - Monthly (Index 1dp) : CVM SA	Base year 2018=100	ONS Source Dataset: Monthly GDP time series MGDG Series: ECY2
Upstream Supply Price	Supply Price of Input (Wholesale price of refined petroleum products)	Base year 2015=100	ONS Source Dataset: Producer price inflation series MM22, Series: K37X
Upstream Supply	Quantity Upstream Supplied (refinery output of petroleum products)	Thousand tonnes	Department for Business Energy and Industrial Strategy Refinery throughput and output of petroleum products Table 3.12
Input price1	Price of Inputs: Inputs for Manufacture of Coke and Refined Petroleum Products '	Base year 2015=100	ONS Source dataset: Producer price inflation time series Series: MM22
Input price2	RPI: Price of Coal	Base year 1987=100	ONS Source Dataset: Consumer price inflation time series Series: MM23
Capital	Capital Input	Million pounds	ONS ⁶⁷
Labour	Labour Input	No of workers	ONS

⁶⁷ A full description of capital sources is provided in appendix A, Table A5.

Table A4: Description of Variables Electricity

Variable	Variable description	Unit	Source
Quantity demanded	Sales of Electricity to Domestic Consumers	TWh	Department for business energy and industrial strategy Energy Trends: Electricity, Table 5.5.
Retail Price	Retail price for domestic consumers	Base year 2015=100	Department for business energy and industrial strategy Consumer prices indices: Fuel components monthly figures, Table 2.1.3
Price of complements	Price of Complements RPI: Household Electrical Appliances	Base year 1987=100	ONS Source dataset: Consumer price Inflation time series MM23 Series: DOCC
Income	Gross Value Added - Monthly CVM SA	Base year 2018=100	ONS Source dataset: Monthly GDP Time Series MGDGP Series: ECY2
Upstream Supply Price ⁶⁸	Supply Price of Input, Wholesale Prices of Electricity	UK pounds per MWh	Institution of Civil Engineers
Upstream Supply	Quantity Upstream Supplied Electricity Available	TWh	Department for Business Energy and Industrial Strategy Energy Trends: Electricity, Table 5.5
Input price1	Inputs for Electricity Production and Distribution	Base year 2015=100	ONS Source dataset: Producer price inflation time series MM22 Series: MC4B
Input price2	Gas, RPI: Fuel & Light: gas	Base year 1987=100	ONS Source dataset: Consumer price inflation time series MM23 Series: DOBY
Capital	Capital Input		ONS ⁶⁹
Labour	Labour Input	Number of Workers	ONS Employee Jobs by Industry-Electricity Gas Steam and Air-Conditioning Supply JOBS03 LFS.

⁶⁸ For electricity wholesale prices, data is available from the Institution of Civil Engineers. However due to high volatility between the wholesale price and the gas price which is used as an input, in the estimation of the upstream supply of electricity, the domestic retail price indices are used as a proxy for the wholesale price. In case the wholesale prices are used, very low R2 is provided as well as problematic insignificant estimates.

⁶⁹ Sources are described in detail in Table A5.

Table A5: Sources Description for Capital for the three chains

Milk First Stage- a combination of sources from ONS Annual capital business survey is used.

The Annual Business survey from ONS, gives Total Net Capital Expenditure (TNCE) for Manufacture of dairy products, 10 Manufacture of food products, 11 Manufacture of beverages and 12 Manufacture of tobacco products, for the period 2008-2018. Priv Sect: Manufacture of food, drink and tobacco: Total Asset: £m: CVM: NSA, from DXNV dataset of ONS, has total net capital expenditure for the period 1995 to 2007 for 15.5 Manufacture of dairy products, 15 Manufacture of food products and beverages and 16 Manufacture of the tobacco products. 10.5/15.5 is around 9.7% of food, drink and tobacco. This percent is used to give an estimate of the net capital stock of dairy products for 1995 to 2018. Net capital stock (£bn): S.1: TOTAL: Ind CA Food/Bevs/Tobacco: CP (MI3P) and Net capital stock (£bn): S.1: TOTAL: Ind CA Food/Bevs/Tobacco: CVM (MK5V), 1995-2018, are obtained from Capital Consumption (£m): S.1311: IPP: Ind TOTAL: CP, from ONS, the source dataset of which, is Capital stock and fixed capital consumption time series CAPSTK. The first is divided by the second to get a deflator; 2016=100. The change in Capital is approximately equal to gross fixed capital formation (GFCF). Seasonal pattern for food, drink and tobacco CVM can be found in GFCF from ONS, series DS4R. The seasonal pattern is used to distribute the change in Capital. 1997 is used and change is added to Capital to give quarterly capital.

Milk Second Stage-a combination of sources from ONS Annual capital business survey is used.

Net capital stock figures can be found for Retail trade, except of motor vehicles and motorcycles. Annual data for 1995 to 2018 and current prices from the ONS Annual Business Survey. Annual business survey gives Total Net Capital Expenditure (TNCE) 2008 to 2018 for division 47 and the group 47.1. Retail sale in non-specialised stores (group 47.1 is mainly supermarkets, but also McColl's, etc. and some independent retailers). Annual business survey from the ONS, gives TNCE 1995 to 2007 for retail trade, except of motor vehicles and motorcycles, repair of personal and household goods. The average percent of 47.1 to 47 (53%) is used, to give estimates of 47.1 for 1995 to 2007. Then the average percent of 47.1 to 47 (53%) is used, to give an estimate of the net capital stock (K) of 47.1 for 1995 to 2018. Gross and net capital stock by asset and industry provide Net capital stock (£bn): S.1: TOTAL: Ind G Wholesale/retail: CP (MIJ6) and Net capital stock (£bn): S.1: TOTAL: Ind G Wholesale/retail: CVM (MKS7). The first is divided by the second to get a deflator for estimate one, 2016=100. The change in K is approximately equal to gross fixed capital formation (GFCF). Seasonal pattern for GFCF can be found in Total Gross Fixed Capital Formation CVM NSA £m npqr from the ONS. The seasonal pattern is used to distribute the change in Capital. 1995 is used and the change is added to Capital to give quarterly values of Capital.

Electricity- a combination of sources from ONS Annual capital business survey is used.

For capital input a combination of sources has been used. Total Net Capital Expenditure (TNCE) from the Annual Business survey of the ONS is used from 2008 to 2018, for the distribution of electricity. This class includes operation of distribution systems (i.e., consisting of lines, poles, meters, and wiring) which convey electric power received from the generation facility or the transmission system to the final consumer. TNCE is also used for the Trade of electricity. This class includes sale of electricity to the user; activities of electric power brokers or agents that arrange the sale of electricity via power distribution systems operated by others; operation of electricity and transmission capacity exchanges for electric power. Average percent of 35.13 and 35.14 to D; (D: Electricity, Gas, Steam and Air Conditioning Supply (Index): CVM from ONS GDP first quarterly estimated time series); (48.7%) is used to give an estimate of the net capital stock (K) of 35.13 and 35.14. The Net capital stock (£bn): S.1: TOTAL: Ind D Electric/gas: CP (MIC5) and Net capital stock (£bn): S.1: TOTAL: Ind D Electric/gas: CVM (MKL6) from gross and net capital stock by asset and industry from ONS, is used to obtain a deflator. The first is divided by the second, to get a deflator, 2016=100. Electricity, gas, steam and air conditioning supply gross value added (ECY7) is used from Electricity, gas, steam and air conditioning supply (Index 1dp); CVM SA from the Monthly gross domestic product: time series (MGDP) to distribute quarterly figures.

Table A6: Description of Variables for Estimation of Cost Pass Through Milk Products

	Description of variable	Unit	Data Source
Input price	Price of Input Farm Gate Price	Base year 2010=100	Eurostat
Wholesale price	Wholesale Price Dairy and Cheese products	Base year 2010=100	ONS Source dataset: Producer price inflation time series MM22 Series: JU37
Retail price	Retail Price Milk products	Base year 2015=100	ONS Source dataset: Consumer Price Inflation time series MM23 Series: DOAR

Regressions are undertaken for both logs and levels specifications.

Table A7: Description of Variables for Estimation of Cost Pass Through Petroleum (Road fuels)

Abbreviation	Description of variable	Unit	Data source
Input price	Price of input: brent spot prices ⁷⁰	Base year 2010=100	EIA
Wholesale price	Wholesale price of refined petroleum products	Base year 2010=100	ONS Source dataset: Producer price inflation series MM22, Series: K37X
Retail price	Retail price of vehicle fuels and lubricants	Base year 2015=100	ONS Source dataset: Consumer price Inflation time series MM23 Series: DK C4

Regressions are undertaken for both logs and levels specifications.

Table A8: Description of Variables for Estimation of Cost Pass Through for Electricity

	Description of variable	Unit	Data source
Input price	Price of input Brent spot prices ⁷¹	Base year 2010	EIA
Wholesale price	Wholesale price	Base year 2010	Institution of Civil Engineers
Retail price	Retail price of Electricity to Domestic Consumers	Base year 2010	Department of Energy Business and Industrial Strategy 2.1.3 Consumer Price Index, Fuel components, monthly United Kingdom

Regressions are undertaken for both logs and levels specifications

⁷⁰ Since cost pass through regressions are also estimated in levels, this thesis creates an index for the brent spot price of crude oil, to make sure the interpretations are more interpretable. It can be harder to compare an index with the brent spot prices in Euros.

⁷¹ Since levels cost pass through regressions are also estimated in levels, this thesis creates an index for the brent spot price of crude oil, to make sure the interpretations are more interpretable. It can be harder to compare an index which represents the data for wholesale and retail prices, with the brent spot prices in Euros. For electricity natural gas prices for EIA have also been used.

APPENDIX B: ADF AND PP RESULTS

Table B1: ADF Results for Milk First Stage⁷²

Variables	Trend	Levels	First Differences
		Mac-Kinnon approximate P-value for Z(t)	Mac-Kinnon approximate P-value for Z(t)
Quantity demanded		0.0507*	0.005***
Retail Price	t	0.8251	0.000***
Price of complements		0.8194	0.000***
Income		0.4695	0.000***
Upstream Supply Price		0.4695	0.000***
Upstream Supply		0.9440	0.000***
Input price1	t	0.0398**	0.005***
Input price2	t	0.7227	0.004***
Capital	t	0.4339	0.000***
Labour	t	0.5059	0.000***
lnAlnN1	t	0.2439	0.001***
lnRlnRs	t	0.5259	0.001***

The above table shows the ADF tests in levels and in first differences for milk first stage. t indicates that a trend has been included in the test. All the variables are in natural logarithms.

***Stationary at the 1% level $p < 0.01$ **Stationary at the 5% level $p < 0.05$

Table B2: ADF Results for Milk Second Stage

Variables	Trend	Levels	First Differences
		Mac Kinnon approximate P value for Z(t)	Mac Kinnon approximate P value for Z(t)
Quantity demanded		0.0030***	0.000***
Retail price		0.8965	0.000***
Price of substitutes	t	0.9086	0.000***
Income	t	0.4695	0.000***
Upstream supply price	t	0.1445	0.000***
Upstream supply		0.6915	0.005***
Input price1	t	0.4926	0.021***
Input price2	t	0.9040	0.001***
Capital	t	0.7090	0.004***
Labour		0.0395**	0.001***
lnAlnN1	t	0.5763	0.001***
lnRlnRs	t	0.5645	0.001***

The above table shows the ADF tests in levels and in first differences for milk first stage. t indicates that a trend has been included stage in the test. All the variables are in natural logarithms.

***Stationary at the 1% level $p < 0.01$ **Stationary at the 5% level $p < 0.05$

⁷² Stationarity tests have been undertaken for the three constructed market power variables included in the market power regression, establishing they are a mixture of I(0) and I(1).

Table B3: ADF Results for Petroleum (Road fuels)

Variable	Trend	Levels	First Differences
		MacKinnon approximate P- value for Z(t)	MacKinnon approximate P- value for Z(t)
Quantity demanded		0.7757	0.000***
Retail price	t	0.5561	0.000***
Price of Complements		0.2565	0.000***
Income	t	0.7104	0.000***
Upstream Supply price	t	0.5343	0.000***
Upstream Supply		0.2305	0.000***
Input price1		0.7319	0.000***
Input price2	t	0.8261	0.000***
Capital	t	0.3368	0.000***
Labour	t	0.2358	0.000***
lnAlnN1	t	0.5961	0.000***
lnRlnRs	t	0.1596	0.000***

The above table shows the ADF results for road fuels variables. t indicates that a trend has been included in the test. In the case of 1st differences, no trend is observed. The number of lags is chosen based on the Akaike Information Criterion. All the variables are in natural logarithms. lnAlnN1 represents the interaction term between the natural logarithm of upstream supply and the natural logarithm of Input price1. lnRlnRs represents the interaction term between retail price and price of complements.

***Stationary at the 1% level $p < 0.01$ **Stationary at the 5% level $p < 0.05$.

If the p-value is greater than 0.10, the variable is non-stationary.

Table B4: ADF Results for Electricity

Variables	Trend	Levels	First Differences
		Mac Kinnon Approximate P- value for Z(t)	Mac Kinnon Approximate P-Value for Z(t)
Quantity demanded		0.0000***	0.000***
Retail price	t	0.7102	0.000***
Price of complements		0.1536	0.000***
Income	t	0.7104	0.000***
Upstream Supply price	t	0.0530*	0.000***
Upstream Supply	t	0.0000***	0.000***
Input price1	t	0.9263	0.000***
Input price2	t	0.9349	0.000***
Capital Input	t	0.4013	0.000***
Labour Input	t	0.0144**	0.000***
lnAlnN1		0.1112	0.000***
lnRlnRs	t	0.0853	0.000***

The above table shows the ADF results for road fuels variables. t indicates that a trend has been included in the test. In the case of 1st differences, no trend is observed. The number of lags is chosen based on the Akaike Information Criterion. All the variables are in natural logarithms. .lnAlnN1 represents the interaction term between the natural logarithm of upstream supply and the natural logarithm of Input price1. lnRlnRs represents the interaction term between Retail price and Price of complements.

***Stationary at the 1% level $p < 0.01$ **Stationary at the 5% level $p < 0.05$.

If the p-value is greater than 0.10, the variable is non-stationary.

Philips-Perron Test for Stationarity

Table B5: PP Results for Milk First Stage

Variables	Levels	First Differences	
	Trend	Mac Kinnon Approximate P-value for Z(t)	Mac Kinnon Approximate P-value for Z(t)
Quantity demanded		0.0000***	0.000***
Retail price	t	0.9298	0.000***
Price of complements	t	0.8215	0.000***
Income	t	0.0685*	0.000***
Upstream supply price		0.0145**	0.000***
Upstream supply		0.000***	0.000***
Input Price1	t	0.4311	0.001***
Input Price2	t	0.0911*	0.000***
Capital	t	0.9447	0.003***
Labour		0.5547	0.000***
lnAlnN1	t	0.2810	0.000***
lnRlnRs	t	0.6302	0.000***

The above table shows the PP results for milk first stage variables. t indicates that a trend has been included in the test. In the case of 1st differences, a trend is observed. The number of lags is chosen based on the Akaike Information Criterion. lnAlnN1 represents the interaction term between the natural logarithm of upstream supply and the natural logarithm of input price1. lnRlnRs represents the interaction term between retail price and price of complements.

All the variables are in natural logarithms.

***Stationary at the 1% level p<0.01 **Stationary at the 5% level p<0.05.

If p-value is greater than 0.10, the variable is non-stationary.

Table B6: PP Results for Milk Second Stage

Variables	Levels	Mac Kinnon approximate P- value for Z(t)	First Differences
	Trend		Mac Kinnon approximate P- value for Z(t)
Quantity demanded		0.0009***	0.009***
Retail price	t	0.8401	0.000***
Price of complements	t	0.8548	0.000***
Income	t	0.7881	0.000***
Wholesale price	t	0.3142	0.000***
Upstream Supply		0.0326**	0.033***
Input price1	t	0.3439	0.000***
Input price2	t	0.5918	0.000***
Capital	t	0.2679	0.000***
Labour		0.2169	0.000***
lnAlnN1	t	0.5117	0.000***
lnRlnRs	t	0.7136	0.000***

The above table shows the PP results for milk first stage variables. t indicates that a trend has been included in the test. In the case of 1st differences, a trend is observed. The number of lags is chosen based on the Akaike Information Criterion. lnAlnN1 represents the interaction term between the natural logarithm of upstream supply and the natural logarithm of input price1. lnRlnRs represents the interaction term between retail price and price of complements.

All the variables are in natural logarithms.

***Stationary at the 1% level $p < 0.01$ **Stationary at the 5% level $p < 0.05$.

If p-value is greater than 0.10, the variable is non-stationary.

Table B7: PP Results for Road Fuels

Variable	Levels	First Differences	
	Trend	MacKinnon Approximate P- Value for Z(t)	MacKinnon Approximate P- Value for Z(t)
Quantity demanded		0.5831	0.000***
Retail Price		0.6271	0.000***
Price of Substitutes		0.3640	0.000***
Income	t	0.7321	0.000***
Upstream Supply Price	t	0.5611	0.000***
Upstream Supply		0.0192**	0.000***
Input price1	t	0.6881	0.000***
Input price2	t	0.9464	0.000***
Capital	t	0.3368	0.000***
Labour	t	0.2358	0.000***
lnAlnN1	t	0.5883	0.000***
lnRlnRs	t	0.5093	0.000***

The above table shows the PP results for petroleum variables. t indicates that a trend has been included in the test. In the case of 1st differences, no trend is observed. The number of lags is chosen based on the Akaike Information Criterion. All the variables are in natural logarithms.

***Stationary at the 1% level $p < 0.01$ **Stationary at the 5% level $p < 0.05$.

If p-value is greater than 0.10, the variable is non-stationary.

Table B8: PP Results for Electricity

Variable	Trend	Levels	First Differences
		MacKinnon Approximate P- value for Z(t)	MacKinnon Approximate P- value for Z(t)
Quantity demanded		0.0000***	0.000***
Retail price	t	0.8675	0.000***
Price of complements		0.1932	0.000***
Income	t	0.7521	0.000***
Upstream Supply Price	t	0.0505*	0.000***
Upstream supply	t	0.0000***	0.000***
Input price1	t	0.9356	0.000***
Input price2	t	0.9772	0.000***
Capital	t	0.0742*	0.000***
Labour	t	0.0110**	0.000***
lnAlnN1		0.1699	0.000***
lnRlnRs	t	0.0862*	0.000***

The above table shows the PP results for electricity variables. t indicates that a trend has been included in the test. All the variables are in natural logarithms. lnAlnN1 represents the interaction term between the natural logarithm of upstream supply and the natural logarithm of Input price1. lnRlnRs represents the interaction term between retail price and price of complements.

***Stationary at the 1% level $p < 0.01$ **Stationary at the 5% level $p < 0.05$. If p-value is greater than 0.10, the variable is non-stationary.

Table B9. ADF results for Milk Cost Pass Through Variables in levels

	Levels	First Differences
Variable	Mackinnon approximate p-value for Z(t)	Mackinnon approximate p-value for Z(t)
Input price	0.0413	0.000***
Wholesale price	0.0966*	0.000***
Retail price	0.4353	0.000***

The number of lags is chosen based on the Akaike Information Criterion. A trend is included in the case that an upward trend established. The above variables are in natural logarithms. ***Stationary at 1% level $p < 0.01$

*Stationary at 10% level $p < 0.10$

Table B10. ADF results for Milk Cost Pass Through Variables in logs

	Levels	First Differences
	Mackinnon approximate p- value for Z(t)	Mackinnon approximate p- value for Z(t)
Input price	0.4995	0.003***
Wholesale price	0.8251	0.003***
Retail price	0.8965	0.000***

Number of lags is chosen based on the Akaike Information Criterion. A trend is included in the case that it is established. ***Stationary at 1% level $p < 0.01$.

Table B11. ADF Results for Petroleum Road Fuels Cost Pass Through Variables in Logs

	Levels	First Differences
	Mackinnon approximate P- value for Z(t)	Mackinnon approximate P-value for Z(t)
Input Price	0.5659	0.000***
Wholesale price	0.5343	0.000***
Retail Price	0.4800	0.000***

Number of lags is chosen based on the AIC Criterion. *** Stationary at the 1% level.

Table B12. ADF Results for Petroleum Road Fuels Cost Pass Through Variables in Levels

	Levels	First Differences
	Mackinnon Approximate p-value for Z(t)	Mackinnon Approximate p-value for Z(t)
Input price	0.1747	0.000
Wholesale price	0.0275*	0.000
Retail price	0.0945	0.000

Number of lags is chosen based on the Akaike Information Criterion. They can be provided upon request. A trend is also included in the case that it is graphically established. ***Stationary at 1% level
Stationary at 10% level

Table B13. ADF Results for Electricity Cost Pass Through Variables in logs

	Levels	First Differences
	Mackinnon	Mackinnon
	Approximate p-Value for Z(t)	Approximate p-Value for Z(t)
Input price	0.2918	0.000***
Wholesale price	0.3895	0.000***
Retail price	0.6543	0.000***

The number of lags is chosen based on the Akaike information criterion. They can be provided upon request. ***Stationary at 1% level

*Stationary at 10% level

Table B14. ADF Results for Electricity Cost Pass Through Variables in Levels

	Levels	First Differences
	Mackinnon approximate p- value for Z(t)	Mackinnon approximate p- value for Z(t)
Input price	0.1249	0.000***
Wholesale price	0.0727*	0.001***
Retail price	0.6768	0.000***

Number of lags is chosen based on the Akaike information criterion. They can be provided upon request. The above variables are in natural logarithms.

***Stationary at 1% level $p < 0.1$.

*Stationary at 10% level $p < 0.10$.

Appendix C: COINTEGRATION RESULTS

Table C1: Johansen Cointegration Test for Demand Function-Milk First stage

Lags:10			
Maximum rank (r)	Trace statistic	5% critical value	1% critical value
0	176.7718	87.31	96.58
1	115.1537	62.99	70.05
2	71.2011	42.44	48.45
3	11.7681	25.32	30.45
4	10.7681	12.25	16.26

Table C2: ARDL Cointegration Test for Supply Function-Milk First Stage

H0:no level relationship								F= 4.098
N=96								T=-3.846
Kripfganz and Schneider (2018) critical values and approximate P-value								
	10%		5%		1%		P-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	2.417	3.668	2.875	4.258	3.905	5.564	0.007	0.061
t	-2.475	-3.547	-2.804	-3.921	-3.452	-4.641	0.009	0.107

Table C3: Johansen Cointegration Test for Production Function-Milk First Stage

Lags: 6			
Maximum rank	Trace statistic	5% critical value	1% critical value
0	91.6821	62.99	70.05
1	37.7471	42.44	48.05
2	11.8953	25.32	30.45
3	5.5531	12.25	16.26

Table C4: Johansen Cointegration test for Market power Variables-Milk First Stage ⁷³

Lags=8			
Maximum rank(r)	Trace statistic	5% critical value	1% critical value
0	51.8971	42.44	48.45
1	21.3560	25.32	30.45
2	6.9331	12.25	16.26
3	4.9221	11.23	12.32

Table C5: ARDL Cointegration Test for Demand Function-Milk Second Stage

H0: no level relationship								F=7.961
N=96								T=-6.264
Kripfganz and Schneider (2018) critical values and approximate p-value								
	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	2.449	3.648	2.907	4.224	3.930	5.490	0.000	0.000
t	-2.504	-3.585	-2.827	-3.950	-3.463	-4.651	0.000	0.000

⁷³Table C4, reports the cointegration results for the market power regression for milk first stage for the three variables constructed under FMOLS. This thesis also undertakes similar cointegration tests for the market power variables constructed using the DOLS methodology. The findings confirm the existence of cointegrating relationship, therefore are not reported in detail.

Table C6: Johansen Test for Supply Function-Milk Second Stage

Lags: 4			
Maximum rank(r)	Trace statistic	5% critical value	1% critical value
0	95.6938	87.31	96.58
1	53.8383*	62.99	70.05
2	26.2376	42.44	48.45
3	13.1694	25.32	30.45
4	3.9225	12.25	16.26

Table C7: ARDL Cointegration Test for Production Function-Milk Second Stage⁷⁴

H0: no level relationship							F=3.918	
N=88							T=-3.814	
Kripfganz and Schneider (2018) critical values and approximate p-value								
	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	2.781	3.846	3.322	4.485	4.532	5.878	0.023	0.093
t	-2.561	-3.437	-2.874	-3.780	-3.488	-4.438	0.004	0.046

Table C8: Johansen Cointegration Test for Market Power Regression-Milk Second Stage⁷⁵

Lags: 8			
Maximum rank (r)	Trace statistic	5% critical value	1% critical value
0	45.79	42.44	48.45
1	19.25	25.32	30.45
2	5.16	12.25	16.26
3	4.13	13.25	17.26

Table C9: Johansen Cointegration Test for Demand Function -Road Fuels

Lags: 2			
Maximum rank(r)	Trace statistic	5% critical value	1% critical value
0	142.9813	87.31	96.58
1	73.2905	62.99	70.05
2	32.1505	42.44	48.45
3	14.6112	25.32	30.45
4	5.3023	12.25	16.26

Table C10: Johansen Cointegration Test for Supply Function-Road Fuels

Lags: 3			
Maximum rank(r)	Trace statistic	5% critical value	1% critical value
0	132.4967	87.31	96.58
1	84.8071	62.99	70.05
2	44.1288	42.44	48.45
3	14.6180	25.32	30.45
4	1.8725	12.25	16.26

⁷⁴ For confirmation purposes, this thesis tests for cointegration in the Cobb-Douglas Production Function using the Johansen Procedure. For the null hypothesis of 1 cointegrating relationship the trace statistic is less than both the 5% critical value and 1% critical value, 42.44 and 48.45 correspondingly and therefore one cannot reject the hypothesis of 1 cointegrating relationships.

⁷⁵ Table C8, reports the cointegration results for the market power regression for milk second stage for the three variables constructed under FMOLS. This thesis also undertakes similar cointegration tests for the market power variables constructed using the DOLS methodology the findings confirm the existence of cointegrating relationship, therefore are not reported in detail.

Table C11: Johansen Cointegration Test for Production Function Road Fuels

Lags=2			
Maximum rank(r)	Trace statistic	5% critical value	1% critical value
0	113.9653	62.99	70.05
1	54.0255	42.44	48.45
2	13.1484	25.32	30.45
3	5.3360	12.25	16.26

Table C12: ARDL Test for Market Power Regression Road Fuels using FMOLS⁷⁶

H0: no level relationship								F=8.683
N=228								T=-4.164
Kripfganz and Schneider (2018) critical values and approximate p-value								
	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	3.183	4.137	3.825	4.862	5.241	6.428	0.000	0.001
t	-2.564	-3.217	-2.865	-3.539	-3.449	-4.150	0.001	0.010

Table C13: Supply Function of Electricity Cointegration Test

H0:no level relationship								F=4.682
N=178								T=-2.782
Kripfganz and Schneider (2018) critical values and approximate p-value								
	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	2.473	3.557	2.908	4.075	3.854	5.176	0.000	0.000
T	-2.559	-3.652	-2.863	-3.896	-3.454	-4.618	0.000	0.000

Table C14: Cobb Douglas Production Function of Electricity Cointegration Test

H0:no level relationship								F=36.081
N=243								T=-10.161
Kripfganz and Schneider (2018) critical values and approximate p-value								
	10%		5%		1%		p-value	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	2.724	3.785	3.237	4.387	4.362	5.678	0.000	0.000
t	-2.550	-3.409	-2.854	-3.740	-3.446	-4.367	0.000	0.000

Table C15: Johansen Cointegration test for Market power Electricity Variables⁷⁷

Lags=2			
Maximum rank	Trace Statistic	5% critical value	1% critical value
0	101.1367	42.44	48.45
1	40.9731	25.32	30.45
2	40.9731	25.32	30.45
3	3.1081	12.25	16.26

⁷⁶ Table C12, reports the cointegration results for the market power regression for road fuels for the three variables constructed under FMOLS. This thesis undertakes cointegration tests for the three market power regression variables that are obtained based on DOLS and for the three market power regression variables that are obtained using FMOLS and include the recession dummy. The results exhibit cointegration.

⁷⁷ Table C15, reports the cointegration results for the market power regression for electricity for the three variables constructed under FMOLS. This thesis also undertakes similar cointegration tests for the variables Oligopoly and Oligopsony constructed using the DOLS methodology. The findings confirm the existence of cointegrating relationship, therefore are not reported in detail.

APPENDIX D: MARKET POWER RESULTS

Table D1: Demand Function Milk First Stage

	Lags	Lags
	2	1
Quantity demanded	FMOLS	DOLS
Retail Price	-7.1101*** (1.5851)	-13.8879*** (3.2756)
Income	-1.8262*** (0.4144)	-0.1949* (0.1030)
Price of Complements	-5.7942*** (1.5391)	-10.6868*** (3.1184)
lnRlnRs	1.4181*** (0.3440)	2.7434*** (0.6996)
Linear	0.0126*** (0.0032)	
Constant	56.0821*** (8.3506)	61.7756*** (14.6999)
Adj R2	0.69	0.67
N	96	96

The above table shows the estimated FMOLS and DOLS coefficients for demand function of the milk first stage. lnRlnRs represents the interaction term between Retail Price and Price of complements. The number of lags is chosen based on the Akaike Information Criterion and the standard errors are in parentheses. N is the number of observations. In the case the linear trend is not affecting the results and is not significant it is not reported. All the variables are in natural logarithms

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.10$

Table D2: Supply function Milk First Stage

	Lags	Lags
	1	1
Upstream supply price	FMOLS	DOLS
Upstream supply	136.6312*** (3.3272)	-4.5181 (5.3181)
Input price1	225.7005 (5.9138)	-9.6777 (11.8840)
Input price2	0.2723*** (0.0634)	0.4214*** (0.1397)
lnAlnN1	-27.6109*** (0.7239)	1.3225 (1.4495)
Linear		-0.0126***
Constant	-114.7741	(0.0003)
Adj R2	0.69	0.68
N	96	96

The above table shows the estimated FMOLS and DOLS coefficients for the supply function of the milk first stage, therefore the supply towards the processors. lnAlnN1 represents the interaction term between Input price1 and upstream supply. The number of lags is chosen based on the Akaike Information Criterion and the standard errors are in parentheses. N is the number of observations. In the case the linear trend is not affecting the results and is not significant it is not reported. All the variables are in natural logarithms.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.10$

**Table D3: Production Function Milk
First Stage**

	Lags	Lags
	1	1
	FMOLS	DOLS
Quantity produced	1.7144*** (0.3478)	2.3408*** (0.4068)
Capital	-0.0648 (0.2410)	-0.2091 (-0.2375)
Labour	(0.4346) (0.1241)	0.4815*** (0.1138)
Linear	0.0041*** (0.0009)	0.0048*** (0.0008)
Constant	-9.6789 (2.8087)	-13.459*** (2.7534)
Adj R2	0.4899	0.75
N	96	96

The above table shows the estimated FMOLS and DOLS coefficients for the production function of the milk first stage. The number of lags is chosen based on the Akaike Information Criterion and the standard errors are in parentheses.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.10$

Table D4. Market power

Regression for Milk First Stage		
	Lags	Lags
	4	1
	FMOLS	DOLS
Oligopsony	0.0176***	-0.2895*** (0.0317)
Oligopoly	0.1952	-0.2856* (0.1102)
Cons	-0.3754	-13.6197*** (0.8031)
Adj R2	0.23	0.87
N	96	96

The above table shows the estimated FMOLS and DOLS coefficients for the market power regression of the milk first stage. The number of lags is opted based on the Akaike Information Criterion and the standard errors are in parentheses.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.1$

Market Power Results Milk Second Stage

Table D5: Demand Function Milk Second Stage

	Lags	Lags
	1	4
	FMOLS	DOLS
Quantity demanded		
Retail Price	-5.7765*** (1.1241)	-3.2421*** (0.5627)
Income	3.3412*** (0.7229)	2.0089*** (0.3624)
Price of	-8.4766*** (1.9553)	-4.3786*** (0.9769)
Complements	1.4684*** (0.1730)	0.8169*** (0.0851)
lnRlnRs	-0.2719*** (0.0009)	0.0001*** (7.9e-0.6)
Linear	0.0001*** (8.71e-0.6)	108.1946*** (43.4312)
Quadratic	41.7734*** (11.4999)	0.0170*** (0.0007)
Constant	0.88	0.47
Adj R2		
N	96	96

The above table shows the estimated FMOLS and DOLS coefficients for the demand function of the milk second stage. lnRlnRs represents the interaction term between price and price of complements. The number of lags is chosen based on the Akaike Information Criterion and the standard errors are in parentheses.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.1$

Table D6: Supply Function Milk Second Stage

	Lags	Lags
	2	3
Upstream	FMOLS	DOLS
Supply Price		
Upstream	20.6168***	-5.1601
Supply	(2.0348)	(4.1895)
Input price1	19.8553***	-3.9233
	(1.9848)	(4.9331)
Input price2	0.4071***	-0.1140
	(0.0594)	(0.1456)
lnAlnN1	-4.3799***	1.0769
	(0.4461)	(0.9097)
Constant	-90.8160***	24.1308
	(19.3456)	(18.8261)
Adj R2	0.22	0.99
N	96	96

The above table shows the FMOLS and the DOLS coefficients for the estimated demand function of the milk second stage. The number of lags is opted on the basis of the Akaike information criterion and the standard errors are in parentheses. lnAlnN1 represents the interaction term between upstream supply and Input price1.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.10$

Table D7. Production Function Milk Second Stage

	Lags	Lags
	1	2
Quantity produced	FMOLS	DOLS
Upstream Supply	-0.2576 (0.0526)	-0.0942* (0.0487)
Capital	-0.1291**** (0.0289)	-0.9571*** (0.0358)
Labour	0.7018*** (0.3451)	0.6591** (0.0035)
Constant	3.3811 (2.8652)	3.6791 (2.6493)
Adj R2	0.26	0.95
N	96	96

The above table shows the estimated FMOLS and DOLS coefficients for the production function of the milk second stage. The number of lags is chosen using the AIC. In the case a linear trend is included it is statistically insignificant not altering the results therefore it is not reported. Standard errors are included in parentheses. All the variables are in natural logarithms.

***Statistically significant at 5% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

**Table D8. Market Power Regression for Milk
Second Stage**

	Lags	Lags
	4	4
	FMOLS	DOLS
Oligopsony	1.3111*** (0.3475)	-1.0884*** (0.1684)
Oligopoly	0.6527*** (0.1550)	-0.9107*** (0.0256)
Constant	5.6717*** (3.2217)	-55.8901*** (14.2497)
Linear	253.3354* (142.0857)	-0.9795*** (0.1103)
Adj R2	0.51	0.97
N	96	96

The above table shows the estimated market power parameters for the milk second stage. The coefficient of oligopsony represents the market power parameter of the retailers towards the processors and the coefficient of oligopoly represents the market power parameter of the retailers towards the consumers. The number of lags is chosen based on the Akaike Information Criterion and the standard errors are in parentheses. All the variables are in natural logarithms.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table D9. Demand Function for Road Fuels

	Lags	Lags
	3	3
Quantity demanded	FMOLS	DOLS
Retail price	-9.5407** (3.8269)	-16.1376*** (1.8583)
Income	-1.1295*** (0.2258)	-0.9184*** (0.1147)
Price of Complements	-8.3463** (3.5595)	-14.3294*** (0.1146)
lnRlnRs	1.9897** (0.8278)	3.4052*** (0.4029)
Cons	52.3867*** (16.2807)	79.3796 (7.7135)
Adj R2	0.87	0.92
N	228	228

The above table shows the estimated FMOLS and DOLS coefficients of the demand function of road fuels. The number of lags is chosen using the Akaike Information Criterion. Standard errors are included in parentheses. lnRlnRs represents the interaction term between retail price and price of complements.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table D10: Supply Function for Road Fuels

	Lags 0	Lags 0	Lags 3	Lags 1
Upstream Supply Price	FMOLS	FMOLS with recession dummy	DOLS	DOLS with recession dummy
Upstream	0.5008*	0.3764	0.4506*	0.4844
Supply	(0.2737)	(0.5678)	(0.2478)	(0.4249)
Input	1.8024***	1.3717**	1.5094***	1.7276**
price1	(0.5229)	(1.3265)	(0.4504)	(0.7843)
Input	0.0781***	0.1208***	-0.0767**	0.0743*
price2	(0.0251)	(0.0345)	(0.0308)	(0.0396)
lnAlnN1	-0.1083*	-0.0563	-0.0729	-0.0955
	(0.0603)	(0.0587)	(0.0521)	(0.0905)
Recession		-0.0374***		-0.0342***
		(0.0121)		(0.0124)
Linear			0.0009***	
			(0.0001)	
Constant	-4.2754*	-3.5732	-2.8954	-4.2449
	(-2.4399)	(-4.5267)	(2.1955)	(3.8430)
Adj R2	0.99	0.98	0.99	0.99
N	228	228	228	228

The above table, indicates the estimated FMOLS and DOLS coefficients for the Supply function of road fuels. lnAlnN1 represents the interaction term between Upstream Supply and Input price1. The results of the estimations that include a dummy for the recession period 2008-2014 are also included. Number of lags is chosen based on the Akaike Information Criterion. Standard errors are in parentheses. All the variables are in natural logarithms.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table D11. Production Function for Road Fuels⁷⁸

	Lags 1	Lags 2	Lags	Lags
Quantity produced	FMOLS	FMOLS with recession dummy	DOLS	DOLS with recession dummy
Upstream supply	0.2164*** (0.0478)	0.2902*** (0.0021)	0.2787** (0.1365)	-0.0386* (0.0245)
Capital	0.1909*** (0.0821)	0.6475*** (0.0025)	0.2334** (0.1289)	0.2209 (0.3208))
Labour	0.2973*** (0.0690)	-0.2782* (0.0245)	-0.2590 (0.1807)	0.0702 (0.1115)
Linear	-0.0033*** (0.0003)	-0.0566*** (0.002)	-0.0036*** (0.002)	-1.387 (1.456)
Constant	8.17568*** (1.0481)	11.4667*** (4.6325)	6.9716*** (2.5377)	6.8700*** (2.5467)
Adj R2	0.94	0.90	0.95	0.95
N	228	228	228	228

The above table indicates the FMOLS and DOLS coefficients of the production function of road fuels. In the case the linear trend is statistically significant it is included in the table. Number of lags are chosen using the Akaike Information Criterion. Standard errors are included in parenthesis. All the variables are in natural logarithms.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

⁷⁸ In the case of Petroleum products (road fuels) this thesis also estimates the translog production function following Perekhozhuk and Gluben (2017), the coefficients of which are mostly insignificant and can be characterised by a high degree of multicollinearity. Therefore, this thesis does not base its analysis for market power on that function.

Table D12. Market Power Regression for Road Fuels

	Lags	Lags	Lags	Lags
	1 FMOLS	1 FMOLS with recession dummy	1 DOLS	1 DOLS with recession dummy
Oligopsony	0.3350*** (0.0259)	3.4796*** ⁷⁹ (0.0390)	0.0001 (2.3958)	8.2100*** ⁸⁰ (0.5997)
Oligopoly	-0.0600*** (0.0126)	-0.0270* (0.0015)	3.02e ^{-0.9} *** (1.06e ^{-0.9})	-0.3934*** (0.0606)
Cons	-97.7445*** (2.7426)	-12.003*** (0.6432)	0.001 (5.8615)	-70.27 (7.8300)
Adj R2	0.96	0.96	0.64	0.65
N	228	228	228	228

The above table shows the FMOLS and DOLS estimated market power parameters. It also includes the estimations that consider the dummy variable for the recession period 2008-2014. The coefficient of Oligopsony indicates the market power parameter of retailers towards their providers and the coefficient of Oligopoly indicates the market power parameters of retailers towards the consumers. The number of lags is chosen based on the Akaike Information Criterion and the standard errors are in parentheses.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

⁷⁹ Since when including the recession dummy, the coefficient for market power of retailers towards providers is 3.4796, this thesis performs a hypothesis test for the significance of the coefficient with a null of $d_1 > 1$. The Z statistic is 2.83 and the critical value at 1% is -2.34. Therefore, since the statistic is greater than the critical value one can reject the null that the coefficient is greater than 1 at the 1% level.

⁸⁰ Since when including the recession dummy, the coefficient for market power of providers towards the retailers, is 8.21, this thesis performs a hypothesis test for the significance of the coefficient with a null of $d_2 > 1$. The Z statistic is 0.65 and the critical value at 1% is -2.34. The statistic is greater than the critical value and one can reject the null hypothesis that the coefficient is greater than 1 at the 1% level.

Market power results for electricity

Table D13. Demand Function for Electricity

	Lags	Lags	Lags
	0	1	1
Quantity demanded	FMOLS	DOLS	DOLS with recession dummy
Retail price	-8.3174*** (1.5543)	-4.9961 (3.9853)	-6.0517*** (2.1798)
Income	-0.2818 (0.8143)	-0.3512 (0.4552)	-0.1691 (0.2422)
Price of complements	-8.8407*** (1.565)	-5.5524 (3.9882)	-6.4081*** (2.1784)
lnRlnRs	1.8594*** (0.3602)	1.1049 (0.9209)	1.3378*** (0.5031)
Recession			1.2967*** (0.0605)
Constant	43.0358*** (7.1939)	28.8391 (18.1591)	31.8497 (9.9061)
Adj R2	0.066	0.068	0.72
N	243	243	243

The above table includes the FMOLS and DOLS estimations of the electricity demand function. The FMOLS estimation that takes into consideration the recession dummy is included. The number of lags is chosen using the Akaike Information Criterion.

Standard errors are in parentheses.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.10$

Table D14: Supply Function for Electricity

	Lags 0	Lags 4	Lags 1
Upstream Supply Price	FMOLS	FMOLS with recession dummy	DOLS
Upstream Supply	3.4308** (1.2510)	4.0179*** (1.0200)	1.3411 (0.5247)
Input price1	2.4674* (0.9887)	2.4763*** (0.8174)	1.1390*** (0.4171)
Input price2	0.5858*** (0.1599)	0.5851*** (0.1324)	0.8314*** (0.0363)
lnAlnN1	-0.7433*** (0.2905)	-0.8160*** (0.2378)	-0.3613** (0.1212)
Recession		0.1033** (0.0442)	
Constant	-10.3380** (4.3660)	-11.4900*** (3.6044)	-4.2299** (1.7895)
Adj R2	0.99	0.76	0.97
N	243	243	243

The above table indicates the supply function of Electricity. lnAlnN1 represents the interaction term between the upstream supply and the input price 1.

The number of lags is chosen using AIC.

***Statistically significant at 1% level. $P < 0.01$. ** Statistically significant at 5% level. $p < 0.05$

*Statistically significant at 10% level. $p < 0.10$.

Table D15: Production Function for Electricity

	Lags 4	Lags 3
Quantity demanded	FMOLS	DOLS
Upstream supply price	1.4805*** (0.0393)	1.8481*** (0.1074)
Capital	0.0502* (0.0281)	0.1077*** (0.0328)
Labour	-0.0301 (0.0252)	-0.0017 (0.0255)
Cons	-3.1434*** (0.2785)	-5.0563*** (0.5916)
Adj R2	0.89	0.95
N	243	243

All the variables are in natural logarithms. The above table shows the estimated FMOLS and DOLS electricity production function. The number of lags is chosen using the Akaike Information Criterion.

***Statistically significant at 1% $p < 0.01$

** Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.10$

Table D16: Market Power Regression for Electricity

	Lags 3	Lags 3	Lags 4	Lags 1
	FMOLS	FMOLS with recession in supply	DOLS	DOLS with recession in supply
Oligopsony	0.6357*** (0.1144)	0.1195*** (0.0383)	0.6709*** (0.0248)	0.6540*** (0.0239)
Oligopoly	0.0003 (0.0010)	-0.0001 (0.0002)	0.0022* (0.0013)	-0.0001 (0.0003)
Cons	-58.5951*** (2.6256)	-31.542*** (2.9089)	-20.9698*** (1.0690)	-22.3393*** (0.7770)
Adj R2	0.54	0.90	0.78	0.77
N	243	243	243	243

The above table includes the FMOLS and DOLS estimations of the market power parameters. The results of the estimations that consider supply with recession dummy are included. The number of lags is chosen based on the Akaike Information Criterion. All the variables are in natural logarithms.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

APPENDIX E: COST PASS THROUGH RESULTS

Milk Cost Pass Through Results ⁸¹

Table E1. Input to Wholesale Price Cost Pass Through Milk

	Logs Specification	Levels Specification
	Lags 1	Lags 10
	Coefficient	Coefficient
ΔWholesale price		
ΔInput price	0.2253*** (0.0498)	0.2229*** (0.0538)
ΔInput price_t-1	0.1275*** (0.0443)	0.1142*** (0.0317)
Constant	-0.0036 (0.0077)	0.7651 (-0.4200)
Long run pass through	0.3528*** (0.0814)	0.4370*** (0.0430)
N	96	96

The above table includes the standard cost pass through estimation results for the effect of a change in the input price to the wholesale price of the dairy products. All Newey west standard errors are included in parentheses. Results are presented for the logs specification and the levels specification.

N indicates the number of observations. t-1 is the first lagged value.

***Statistically significant at 1% level $p < 0.01$.

**Statistically significant at 5% level $p < 0.05$.

*Statistically significant at 10% level $p < 0.10$.

⁸¹ All the following regressions regarding milk and dairy products as well as road fuels and electricity, are also estimated with the inclusion of a dummy variable for the financial recession 2008-2014. A dummy variable is equal to 1 during the recession and 0 for the rest of the period. This is an addition to the methodology used by Nakamura and Zerom (2010) since the period under investigation is longer and it would be wise to account for structural breaks such as this. “A structural break is when a time series abruptly changes over time. This change could involve a change in mean or a change in the other parameters of the process that produce the series.” (Stata.com 2013) By including the dummy, this thesis considers the potential effects that the recession might have had on the model. The dummy variable in the regressions seems to be statistically insignificant, therefore the study does not proceed to further investigation of the issue.

Table E2. Wholesale to Retail Cost Pass Through IV Milk⁸²

	Logs specification	Levels specification
	Lags 4	Lags 10
	Coefficient	Coefficient
Δ Retail price		
Δ Wholesale price	0.2635*** (0.0859)	0.4128*** (0.1484)
Constant	0.0029 (0.004)	0.5396 (0.7277)
N	96	96
	Logs	Levels
Underidentification test	14.424	12.495
LM statistic		
Chi Sq. P-value	0.0252**	0.0518
Overidentification test	9.1980	9.3890
Chi Sq. P-value	0.1014	0.0945*
C Statistic-exogeneity	0.0220	0.0080
orthogonality of main instrument dlnI		
Chi Sq. P-value	0.8810	0.9268
Instruments: dI, L1dI, L2dI, L3dI, L4dI, L5dI, L6dI		
The above table includes the IV cost pass through estimation results for a change effect in the wholesale price to the retail price of dairy products. Results are also presented for the logs specification and the levels specification. N indicates the number of observations.		
***Statistically significant at 1% level $p < 0.01$		
** Statistically significant at 5% level $p < 0.05$		
*Statistically significant at 10% level $p < 0.10$		

⁸² In the case lagged values of the wholesale price are included in the estimation, the lagged values are statistically insignificant therefore this thesis does not give any report on long run pass through from the IV estimation. C-statistic is checked for all the instruments. For reporting purposes, this thesis reports the C-statistic for the first instrument.

Table E3. Wholesale to Retail Price Cost Pass Through Milk

	Logs Specification	Levels Specification
	Lags 6	Lags 10
	Coefficient	Coefficient
ΔRetail price		
ΔWholesale price	0.1570* (0.0857)	0.5052*** (0.2953)
ΔWholesale price_t-1	0.0707 (0.0826)	0.2196 (0.1217)
Constant	0.0360 (0.0039)	0.8626 (0.8959)
Long run pass through	0.0707*** (0.0826)	0.2196*** (0.1217)
N	96	96

The above table includes the standard cost pass through estimation results for a change effect in the wholesale price to the retail price of dairy products. Newey West Standard Errors are also included in parentheses. Results are also presented for the logs specification and the levels specification. N indicates the number of observations. t-1 is the first lagged value.

***Statistically significant at 1% level $p < 0.01$

** Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table E4. Asymmetries in the Milk Supply Chain Milk

	Logs Specification Input to Wholesale	Logs Specification Wholesale to Retail
	Lags 10 Coefficient	Lags 10 Coefficient
Positive change in input price/wholesale price	0.7635** (0.3010)	-0.4296 (0.9026)
Positive change in input price/wholesale price	0.2505 (0.1575)	1.7496*** (0.5478)
Δ Input Price _{t-1} / Δ WholesalePricet-1	0.1047*** (0.0204)	0.1391* (0.0725)
Constant	-0.0017 (0.0037)	0.0039 (0.0024)
N	96	96

The dependent variable is the change in the wholesale price in the first specification and the change in the retail price in the second specification. Newey West standard errors are included in parentheses. For the first specification, a positive change in the input price is used as an independent variable and a negative change in the input price. For the second specification a positive change in the wholesale price is used as an independent variable and a negative change in the wholesale price.⁸³ The first lagged value of the change in input is included in the input to wholesale specification and the first lagged value of the change in wholesale price is included in the wholesale to retail specification. Results are presented for the logs specification of input to wholesale price and for the logs specification of wholesale to retail price. In the case that more lagged values of the change in wholesale prices are included, they are statistically insignificant not altering the results and are therefore not reported. _{t-1} indicates the first lagged value. N indicates the number of observations.

***Statistically significant at 1% level

**Statistically significant at 5% level

*Statistically significant at 10% level

⁸³ The positive change represents a positive percentage increase in the price and the negative change represents a negative percentage increase in the price variable.

Petroleum Cost Pass Through Results

Table E5. Input to Wholesale Price Cost Pass Through Road Fuels

	Logs Specification	Levels Specification
	Lags 10	Lags 10
	Coefficient	Coefficient
ΔWholesale price		
ΔInput price	0.3202*** (0.0244)	0.3584*** (0.0303)
ΔInput price_t-1	0.2780*** (0.0284)	0.2436*** (0.0289)
ΔInput price_t-2	0.0870*** (0.0326)	
Constant	-0.0033 (0.0030)	-0.5283 (0.6425)
Long run pass through	0.6852*** (0.0462)	0.6020*** (0.0621)
N	228	228

The above table shows the input to wholesale pass through results For road fuels. The number of lags is chosen based on the Akaike Information Criterion.

*** Statistically significant at 1% level. $P < 0.01$.

Statistically significant At 5% level. $P < 0.05$.

Statistically significant at 10% level. $p < 0.10$.

Table E6. Wholesale to Retail Price IV Road Fuels

	Logs Specification	Levels Specification
	Coefficient	Coefficient
ΔRetail price		
ΔWholesale price	0.3033*** (0.0741)	0.3794*** (0.0732)
Constant	-0.0020 (0.0401)	-0.1982 (0.3764)
N	228	228

	Logs	Levels
Underidentification test LM statistic	9.503	8.666
Chi Sq. P-value	0.0086***	0.0131**
Overidentification test	0.145	0.035
Chi Sq. P-Value	0.7032	0.8516
C-statistic-exogeneity	0.145	0.035
orthogonality of main instrument dI		
Chi Sq. P-value	0.7032	0.8516

Instruments: L2dI,L3dI

The above table includes the IV estimation results for the effect of a change of wholesale price of petroleum products to the retail price of road fuels. Robust standard errors are included in parentheses. The table also includes the corresponding p-value underidentification, overidentification and exogeneity tests. Instruments used, are the second lagged value and the third lagged value of change in input price. These are represented by L2dI and L3dI. The change of the natural logarithm of the input price is used in the logs specification.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table E7. Wholesale to Retail Price Cost Pass Through for Road Fuels

	Logs Specification	Levels Specification
	Lags 10 Coefficient	Lags 10 Coefficient
ΔRetail price		
ΔWholesale price	0.3414*** (0.0287)	0.3577*** (0.0384)
ΔWholesale price_t-1	-0.0351*** (0.1699)	0.1111*** (0.0210)
ΔWholesale price_t-2	0.0914*** (0.0238)	
Constant	0.0009 (0.0035)	-0.0817 (0.3269)
Long run pass through	0.3984*** (0.0230)	0.4688*** (0.0288)
N	228	228

The above table includes the standard cost pass through results for the effect of a change in wholesale price of petroleum products to the retail price. Newey West standard errors are included in parentheses. Results are presented for the logs specification and the levels specification. For the second specification only one lagged value of change in the wholesale price is reported. _t-1 indicates the first lagged value and _t-2 the second. N is the number of observations.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table E8. Asymmetries for Road Fuels Supply Chain

Input to wholesale		Wholesale to retail	
	Lags 10		Lags 10
Δ Wholesale Price	Coefficient	Δ Retail Price	Coefficient
Positive change in input price	0.0339*** (0.0033)	Positive change in wholesale price	0.0156*** (0.0029)
Negative change in input price	-0.0139*** (0.0055)	Negative change in wholesale price	-0.0133*** (0.0028)
Δ Input price_t-1	0.3389*** (0.0234)	Δ Wholesale price_t-1	-0.0701*** (0.3240)
Δ Input price_t-2	0.1146 (0.0312)	Δ Wholesale price_t-2	0.2227*** (0.3646)
Δ Input price_t-3		Δ Wholesale price_t-3	-0.0339 (0.2937)
Δ Input price_t-4		Δ Wholesale price_t-4	-0.0654*** (0.2087)
Constant	0.0116 (0.0035)	Constant	-0.0015 (0.0024)
N	228	N	228

The dependent variable is the change in the wholesale price in the first specification and the change in the retail price in the second specification. Newey West standard errors are included in parentheses. The first three lagged values of the change in input are included in the input to wholesale specification and the first four lagged values of the change in wholesale price are included in the wholesale to retail specification. Results are presented for the log specification of input to wholesale price and for the logs specification of wholesale to retail price. In the case that more lagged values of the change in wholesale prices are included, they are statistically insignificant not altering the results and are therefore not reported. _t-1 indicates the first lagged value. N indicates the number of observations.

***Statistically significant at 1% level $p < 0.01$.

**Statistically significant at 5% level $p < 0.05$.

*Statistically significant at 10% level $p < 0.1$.

Electricity cost pass through results

Table E9. Δ Input price to Wholesale Price Cost Pass Through Electricity

	Logs Specification	Levels Specification
	Lags 6	Lags 10
	Coefficient	Coefficient
ΔWholesale price		
Δ Input price	0.3006*** (0.1183)	0.1414* (-0.0494)
Δ Input price_t-1	-0.1154 (0.1178)	0.1779 (0.0643)
Δ Input price_t-2	0.2321** (0.1161)	0.1779** (0.0710)
Constant	-0.0252 (0.0356)	-0.8525 (1.7015)
Long run pass through	0.5327*** (0.1209)	0.3193*** (0.1087)
N	178	178

The above table shows the standard cost pass through regression of a change in the price of input (Brent spot prices) to the wholesale price of electricity. Newey West standard errors are included in parentheses. Two lagged values are included for the logs specification and two lagged values for the levels specification. Results are presented for the logs specification and for the levels specification. In the case that more lagged values of the cost are included they are statistically insignificant not altering the results and are therefore not reported. _t-1 indicates the first lagged value and _t2 the second. N is the number of observations.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

*Statistically significant at 10% $p < 0.10$

**Table E10. Δ Input price to Wholesale price–
using Natural Gas as the Input ,
cost pass through**

	Logs Specification	Levels Specification
	Lags 10	Lags 10
	Coefficient	Coefficient
ΔWholesale price		
Δ Input price	0.1909** (0.0831)	0.0700 (0.0494)
Δ Input price_t-1	-0.0401 (0.0744)	-0.0221 (0.0277)
Δ Input price_t-2	0.0225 (0.1160)	0.0443 (0.0507)
Δ Input price_t-3	0.2287** (0.1198)	0.1569*** (0.0320)
Δ Input price_t-4	-0.0401 (0.0843)	-0.0124 (0.0276)
Δ Input price_t-5	0.2137* (0.0833)	0.0616** (0.2837)
Constant	0.0089 (0.0073)	-0.2866 (0.3954)
Long run pass through	0.6333*** (0.1668)	0.2185*** (0.0402)
N	178	178

The above table shows the standard cost pass through regression of a change in the price of input (natural gas price) to the wholesale price of electricity. Newey West standard errors are included in parentheses. Five lagged values are included for the logs specification and five lagged values for the levels specification. Results are presented for the logs specification and for the levels specification. In the case that more lagged values of the cost are included they are statistically insignificant not altering the results and are therefore not reported. The five lagged values are indicated by _t-1 - _t-5. N is the number of observations.

***Statistically significant at 1% $p < 0.01$

**Statistically significant at 5% $p < 0.05$

***Statistically significant at 10% $p < 0.10$

Table E11: Δ Wholesale to Retail Price IV Electricity

	Logs Specification	Levels Specification
	Lags 10 Coefficient	Lags 10 Coefficient
ΔRetail price		
Δ Wholesale price	0.0520** (0.0254)	0.0702** (0.0318)
Constant	0.0127*** (0.0053)	1.1044* (0.6330)

	Logs Specification	Levels Specification
Underidentification test LM statistic	12.230	15.194
Chi Sq. P-value	0.0933*	0.0336**
Overidentification test	0.3810	11.1460
Chi Sq. P-value	0.1532	0.0840*
C-Statistic-exogeneity Orthogonality of main instrument dI	0.6570	0.0466
Chi Sq. P-value	0.1981	0.4949
Instruments: dI and L1dI L2dI L3dI L4dI L5dI L6dI		

The above table includes the IV estimation results for the effect of a change of the wholesale price of electricity to the retail price. Robust standard errors are included in parentheses. The table also includes the corresponding p-value for under-identification, over-identification and exogeneity tests. Instruments are the change in input price Brent spot prices and six lagged values. These are represented by dI, L1dI L2I L3dI L4dI L5dI L6dI. For the logs specification the log of this change is used.

***Statistically significant at 1% level. $p < 0.01$

**Statistically significant at 5% level. $p < 0.05$

*Statistically significant at 10% level. $p < 0.10$

**Table E12: Δ Wholesale Price to Retail Price
Cost Pass Through Electricity**

	Logs Specification	Levels Specification
	Lags 10	Lags 10
	Coefficient	Coefficient
ΔRetail price		
Δ Wholesale price	0.0016 (0.0111)	0.0197 (0.0314)
Δ Wholesale price_t-1	-0.0004 (0.0106)	0.0027 (0.0229)
Δ Wholesale price_t-2	0.0024 (0.0095)	0.0113 (0.0216)
Δ Wholesale price_t-3	0.0199* (0.0075)	0.0430* (0.0175)_
Δ Wholesale price_t-4	0.0277*** (0.0127)	0.0491** (0.0246)
Δ Wholesale price_t-5	0.0288* (0.0118)	0.0664** (0.0298)
Δ Wholesale price_t-6		0.0495** (0.0241)
Constant	0.0049 (0.0013)	0.4697*** (0.1310)
Long run pass through	0.0910*** (0.0189)	0.1410*** (0.0697)
N	178	178

The above table includes the standard cost pass through results for the effect of a change in wholesale price of electricity to the retail price. Newey West standard errors are included in parentheses. Results are presented for the logs specification and the levels specification. For the sixth lagged value of the first specification, the value is insignificant not altering results and is not reported. _t-1 to _t-6 indicate the first six lagged values. N is the number of observations.

***Statistically significant at 1% level $p < 0.01$

**Statistically significant at 5% level $p < 0.05$

*Statistically significant at 10% level $p < 0.10$

Table E13: Asymmetries Electricity ΔInput to Wholesale Price

	Logs Specifications Brent Spot prices	Logs Specifications Natural Gas Input Prices
	Lags	Lags
	1	1
	Coefficient	Coefficient
ΔWholesale price		
Positive change in input price	0.2423 (1.1287)	-0.0239 (0.0244)
Negative change in input price	1.6719*** (0.6359)	-0.0566** (0.0276)
ΔInput Price_t-1	-0.1708 (0.1240)	-0.0567 (0.0788)
ΔInput Price_t-2		0.0253 (0.1193)
ΔInput Price_t-3		0.2264** (0.1214)
ΔInput Price_t-4		0.0552 (0.0891)
ΔInput Price_t-5 ⁸⁴	0.1875* (0.1103)	-0.1996 (0.0857)
Constant	0.0166 (0.0153)	0.0490 (0.0238)
N	178	178

The dependent variable is the change in the wholesale price in the first specification and the change in the wholesale price in the second specification. The table shows the standard cost pass through regression of a change in the wholesale price on two variables that represent the percentage change in the input price in the case of a positive change in the input price and the percentage change in the input price in the case of a negative change. Newey West standard errors are included in parentheses. Results are presented for the logs specification of input (brent spot) to wholesale price and for the logs specification of input (natural gas) to retail price. In the case that more lagged values of the change in wholesale prices are included, they are statistically insignificant not altering the results and are therefore not reported. The five lagged values are indicated by _t-1 - _t-5. N indicates the number of observations.

***Statistically significant at 1% level

**Statistically significant at 5% level

*Statistically significant at 10% level

⁸⁴ In the case of brent spot prices the second, third and fourth lagged values are statistically insignificant with very high p-values and are omitted from the table.

Table E14: Asymmetries Electricity Δ Wholesale to Retail

	Lags
	1
	Coefficient
ΔRetail price	
Positive change in wholesale price	-0.0934*** (0.0418)
Negative change in wholesale price	0.0404 (0.0696)
Δ Wholesale price_t-1	-0.0031 (0.0127)
Δ Wholesale price_t-2	0.0019 (0.0102)
Δ Wholesale price_t-3	0.0193** (0.0083)
Δ Wholesale price_t-4	0.0317** (0.0149)
Δ Wholesale price_t-5	0.0321** (0.0128)
Constant	0.0100*** (0.0054)

The dependent variable is the change in the retail price.

The table shows the standard cost pass through regression of a change in the wholesale price on two variables that represent the percentage change in the wholesale price in the case of a positive change in the wholesale price and the percentage change in the wholesale price in the case of a negative change. Newey West standard errors are included in parentheses. Results are presented for the logs specification of wholesale to retail price.

In the case that more lagged values of the change in wholesale prices are included, they are statistically insignificant not altering the results and are therefore not reported.

The five lagged values are indicated by _t-1 - _t-5.

N indicates the number of observations.

***Statistically significant at 1% level

**Statistically significant at 5% level

*Statistically significant at 10% level

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