Cointegration between the structure of copper futures prices and Brexit

Abstract

In copper futures trading, 'contango' (or 'forwardation') is the condition in which the futures price enjoys a premium over the spot price on the London Metal Exchange at the close of the second ring and 'backwardation' the contrary. That spread or difference between the two prices is affected by fundamentals such as supply and demand as well as by political, social, environmental and macroeconomic risks, hereafter grouped under the term 'financialisation factors'. Based on analysis of variations in the BUKHI50P stock index that monitors the impact of Brexit on UK companies, this study shows that in the context of a market shortage, Brexit-related macroeconomics and their effect on local companies are cointegrated with the structure of copper futures prices. Guidelines are also provided for traders on when to short- and when to long-sell to capitalise on the structure of copper futures prices under simultaneous market shortage and adverse macroeconomic circumstances.

Keywords:

Brexit; commodities; structure of copper futures prices; cointegration; contango; backwardation

1. Introduction

Commodity markets are used by investors as financial markets to diversify their exposure to securities (Aepli et al. 2017). So-called fundamentals and their effects on commodity prices are strictly associated with the law of supply and demand and investor bullish (positive) or bearish (negative) sentiment. Financialisation, in contrast, defined here to mean the growing market involvement of investment funds and other interest groups, is related to their tendency to buy or sell shares in keeping with what is most beneficial for their respective positions. The outcome is a situation in which players' actual positions are difficult to determine and a market sensitive to international trading, international finance and trading technology, all of which are contended by Valiante (2015) to drive physical trading.

A market's local (microeconomic) impact, the conditions that specifically affect a given security, the effect of geopolitical and global (macro-) economic indicators, fundamentals and financial factors vary with the market cycle. The extent of such effects differs in bull and bear markets as well as when there is an excess or shortage of supply or demand. The greater or lesser impact of financialisation and market fundamentals was explored by Paraschiv et al. (2015), who identified situations in which commodity prices would be driven by the former and structural breaks by the latter. Figuerola-Ferreti et al. (2015), in turn, found periods of mild volatility to be associated with financial bubbles and others when prices were driven by tight physical markets.

Commodity market contracts, generally traded on futures markets and formalised on exchanges are primarily used to hedge price exposure, with a mere 1 % subsequently materialising as physical movements of goods to or from warehouses. Kleinman (2013) noted that in the London Metal Exchange's (LME) prompt date system, which envisages different contract durations, some terms are more liquid than others and positions can be hedged in advance of the purchase or sale date contracted.

In non-ferrous LME markets such as copper, timing is a major issue due to its high price and volume of futures trading. Three-month transactions are the most liquid and the ones to which most LME contracts are referenced by traders and brokers (Otto, 2011). Against that backdrop, a term of 3 months may be adopted as the reference for the structure of copper futures prices, defined as the differences between the 3-month futures and spot prices. When the forward price is higher (difference >0), the result is known as contango and when the spot or cash price is higher, backwardation.

Where there is a physical shortage of a commodity on the near-term market, the situation is generally termed 'normal backwardation'. One review of backwardation not strictly attributable to physical shortage found that the prevalence of 'speculator' over producer / consumer behaviour had a significant effect on the futures price curve of some commodities (ap Gwilym et al. 2019). The perception of physical shortage may be induced by high market demand, supply problems affecting a specific player or production cutbacks intended to force prices upward (Go and Lau, 2017). Contango, in contrast, is generally associated either with a balanced market or sufficient availability or reserves to ensure short- and medium-term supply.

Contango and backwardation are likewise deemed to be a reaction to investor demand, in turn heavily impacted by producers/manufactures and traders who attempt to deviate these trends in favour of their own positions. In a bear market, for instance, financial investors may tend to sell their commodity market positions to lower the cash or spot price to beneath the forward value, whereas producers/manufacturers who seek to prevent the price from dropping may buy those positions to neutralise that effect (raising the price and generating backwardation). A third type of player may also be present, however, such as traders in need of backwardation because they hold a contract with a near-term maturity or simply seek a dominant strategic position. Such actors would conclude more short-term contracts or even buy at the spot price in an attempt to induce backwardation.

The commodity studied here, copper, is a metal heavily traded worldwide with a direct effect not only on the economic environment in Chile, the world's number one producer, where interest and currency exchange rates are affected by the demand for copper (Pedersen, 2019), but also on the Peruvian, Mexican, Congolese and Zambian economies. Copper is not alone as such an influential commodity; Cashin et al. (2004) detected co-movements between 44 commodities and exporting countries' economic indicators.

Park and Lim (2018) showed that forward prices cannot be predicted by spot prices alone, contending that they may be impacted by financialisation factors, the inference being that contango and backwardation are also induced by such factors. That has informed the present attempt to identify possible correlations, co-movements or contagion between the structure of copper futures prices and macroeconomic events such as Brexit.

As mining is characterised by short numbers of large-scale transactions which must be optimised, the findings may prove to be of particular interest to the industry for they would provide traders with better insight into when to capitalise on the structure of copper futures prices.

This research makes a number of contributions to the state of the art:

- identification of the effects of macroeconomic events, and not merely the spot price, on the structure of copper futures prices as has been observed for other commodities such as gold or oil (Akbar et al. 2019; Kagraoka 2016);
- use of BUKHI50P, CBOE's alternative index to analyse the effect of Brexit-related events;
- determination of how macroeconomic events may modify the cost of carry (CoC) as theorised by Watkins and McAleer (2002), affecting price volatility and risk, particularly in a context of shortage of supply such as studied here, with a copper market deficit due to predictions of higher global demand than global output and when the leading exchanges' (LME, SHFE and COMEX) warehouses stood at historical lows;
- comparison of financialisation in the copper and other non-ferrous metal markets such as aluminium, zinc, tin and lead.

The remaining five sections into which this article is divided are: literature review in section 2; range and methodology in section 3; description of results and analytical review in section 4; discussion in section 5; and policy recommendations by way of conclusions in section 6.

2. Literature review

2.1. Co-movement

Co-movements involving macroeconomic variables and commodity prices have been observed for metals such as gold, silver, platinum and palladium (Batten et al. 2010), although some of those metals are less dependent than others on global macroeconomic indicators such as GDP and real interest rates (Chen 2010). Such relationships have been identified not only in metals or hard commodities, but also in soft commodities, whose price has been shown to be cointegrated with S&P 500 returns, more obviously in volatile environments such as financial crises (Creti et al. 2013). The price of copper has been linked to China's economic activity and the returns on its stocks (Guo 2018). Co-movements between prices and macroeconomic variables have also been found in freight markets (Lim et al. 2019).

Macroeconomic events could either attenuate or exacerbate two Watkins et McAleer´s 2002 theories regarding the relationship between metal spot prices and the nearest maturity date prices: Price volatility and risk.

Backwardation has traditionally been associated with a physical shortage of the commodity at issue, whether attributable to actual market availability or geopolitical issues. In a study of the (soft commodity) soya bean market Lambrechts and Muganiwa (2019) observed shortage and low warehouse levels to concur with speculative forward purchases to guarantee supply. That is consistent with the theory of normal backwardation extensively studied by Benbachir and Lembarki (2018) applied to the near-term oil price curve as well as by Ames et al. (2020) to the long-term curve for that commodity. The two theories, backwardation and storage, were combined in a model developed by Ekeland et al. (2019).

The literature review of co-movements also revealed reports of significant bidirectional Granger causality among the world's three leading metal futures markets, the Shanghai Futures Exchange (SHFE), London Metal Exchange (LME) and New York Commodities Exchange (COMEX) (Rutledge et al. 2013). At this time, however, backwardation cannot be as readily associated with shortage due to the prevalence of financialisation.

2.2. Brexit

The substantial impact of Brexit on the world economy can be attributed to the United Kingdom's position as a major actor in the European Union and a world power. On 27 June 2016, the start date for Brexit, David Cameron confirmed that the people of the United Kingdom had voted to leave the European Union, triggering a series of worldwide economic events. Despite the short time lapsing in the interim, the literature includes many studies of the effect of that outcome on financial markets.

Gu and Hibbert (2018) found that highly volatile stocks were more sensitive to Brexit than those exhibiting greater price stability. Bohdalová and Greguš (2017), using the EPUCCEUM, EPUCUK and EPUCBREX indices, ruled out any association between Brexit and FTSE 100 volatility. In contrast, Davies and Studnicka (2018) observed that the worst daily post-referendum results were posted not only by companies highly exposed to the UK and the EU, but also by businesses reliant on imported intermediates. Breinlich et al. (2018) reported that stocks and sterling were both adversely affected when expectations around changes in UK-EU trading arrangements (tariffs and non-tariff barriers) were updated. Alkhatib and Harasheh (2018) observed an impact on ETFs and Nasir and Morgan (2018) on sterling. Škrinjarić (2019), obtained mixed results for the effect of Brexit-related events on the abnormal cumulative return series in Central and Eastern European (CEE) and South and Eastern European (SEE) securities markets, but observed a significant impact on the respective volatility series. Dao et al. (2019) proved that the Brexit vote had a sizeable effect on Forex, the world's largest financial market, in light of the correlation between intraday values and the transmission of volatility to certain currencies. An analysis authored by Shaikh (2018) of the major implicit volatility indices in the Eurozone, Asia-Pacific, Africa, Canada and the US revealed positive abnormal returns and cumulative positive abnormal returns for the volatility index, along with negative returns for stocks, in most global equity markets.

Brexit was also observed to have a heavier adverse impact in countries with a high debt/GDP ratio, including Greece, Ireland, Italy, Portugal and Spain (Burdekin et al., 2018), and on companies with high domestic as opposed to international revenues (Oehler et al., 2017).

Post-Brexit European financial markets tended to be negatively correlated in the long run (Bashir et al. 2019). In addition, volatility contagion was observed in 43 emerging countries' stock exchanges following on the June 2016 referendum (Aristeidis and Elias, 2018).

3. Data and Methodology

3.1. Data

The copper price data for this study were sourced from the contracts used by the London Metal Exchange[1] to establish the price structure upon official daily close of the second ring which included 1042 price observations in the sessions held between 31/12/2015 and 27/12/2019. The Chicago Board Options Exchange's (CBOE) BUKHI50P[2] stock index that monitors the performance of the 50 UK companies most severely impacted by Brexit (those with the highest proportion of earnings in sterling), was the basis for determining the effect of Brexit events. Those events (listed in Appendix I), in turn, were drawn from the UK Parliament's House of Commons Library (2019)[3].

3.1.1. Structure of copper futures prices

The LME, an HKEX (Hong Kong Exchange Group, Hong Kong Exchanges and Clearing Market[4]) company, is the benchmark exchange for the international market price of non-ferrous metals (copper, zinc, aluminium, lead, tin and nickel), precious metals, the NASAAC (North American Special Aluminium Alloy Contract[5]), cobalt and molybdenum. Its system is used by all market participants to formulate and monitor prices and arrange for physical delivery via a global network of warehouses.

The structure of copper futures prices is defined as the difference between the London Metal Exchange's cash price and the 3-month forward price (the most liquid, according to Otto 2011) at official second ring closing, the latter constituting both the reference price for physical trading and the official market price. In this context:

$$copper\ price\ structure = copper\ price_{3\ months} - copper\ price_{spot}$$

$$copper\ price\ structure\ > 0\ \rightarrow contango$$

$$copper\ price\ structure < 0\ \rightarrow backwardation$$

3.1.2. Copper market fundamentals

Copper market fundamentals show that physical supply and demand were fairly well balanced in 2016 to 2019, although balance on this market induces substantial industry concern around the possibility of a copper shortage generating a situation akin to market deficit.

Copper availability is determined by three sub-markets: refined product (mining) output, scrap (circular economy) output and warehouse inventories.

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1 see www.lme.com
2 see www.cboe.com/indexeurope/brexit
3 see www.hansard.parliament.uk/commons/2016-06-27/debates/1606275000001/OutcomeOfTheEU Referendum
4 see www.hkex.com.hk/?sc_lang=en
5 see www.lme.com/en-GB/Metals/Non-ferrous/NASAAC#tabIndex=0

According to the International Copper Study Group's (ICSG) Copper Factbook 2018[6], copper consumption on the refined product market has been consistently higher than production since 2010 (Figure 1).

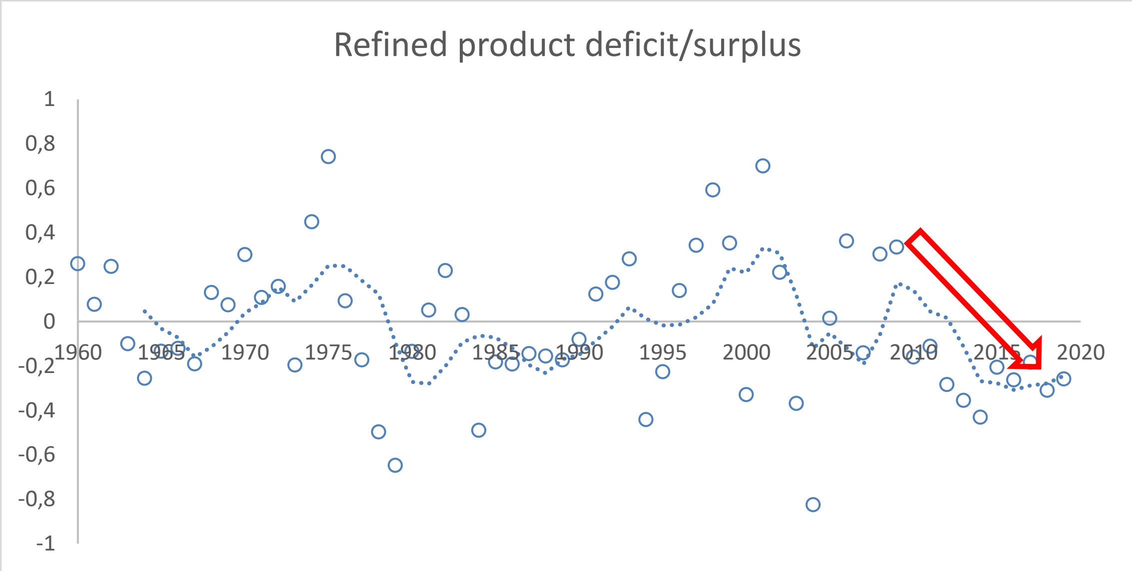

Fig. 1. Refined product deficit (-) or surplus (+) (source: formulated by the authors from ICSG Copper Factbook 2018 and Economist Intelligence Unit N.A. data)

Consumption on scrap markets has held fairly steady for years (Figure 2), for despite the growing demand for recycled materials, greater industry efficiency has lowered the amount of scrap generated in the manufacture of all products. As a result, neither availability nor consumption has risen exponentially. That notwithstanding, recycling is one of the major factors in copper supply, as explained by Gómez et al. (2017).

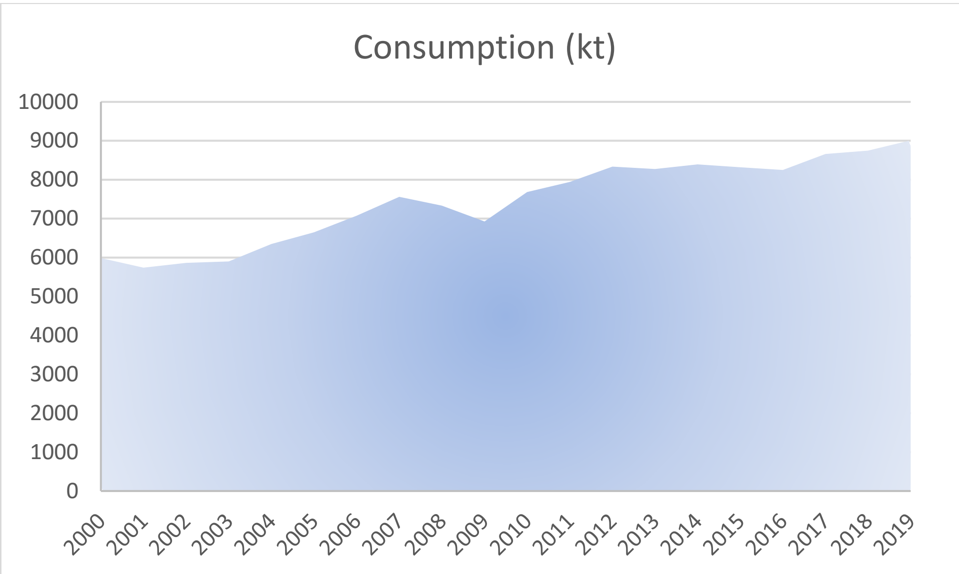

Fig. 2. Total scrap consumption (thousands of metric tonnes) (source: formulated by the authors from ISRI[7] and ICSG data)

[6] see www.icsg.org/
[7] see www.isri.org

Warehouse inventories have declined significantly since 2016, to 25 % of the peak volume recorded in the period studied (Figure 3).

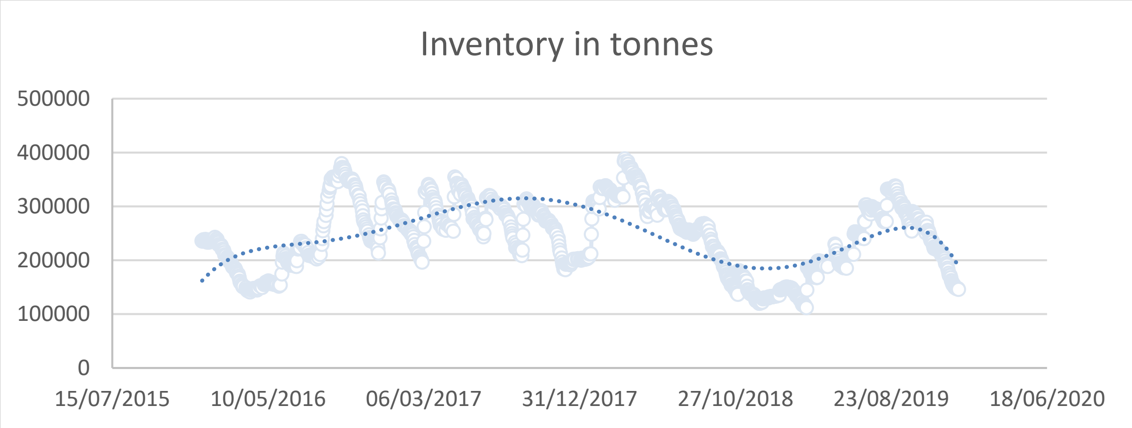

Fig. 3. Copper inventory in LME warehouses

Figure 4, in turn, graphs the gradual decline in copper stocks as well as the progressive decrease in warehouse inventories (associated with specific customer demand) characteristic of shortage. That was attendant upon abrupt large-scale inflows resulting from speculation by major players with short positions in an attempt to keep prices from rising too far.

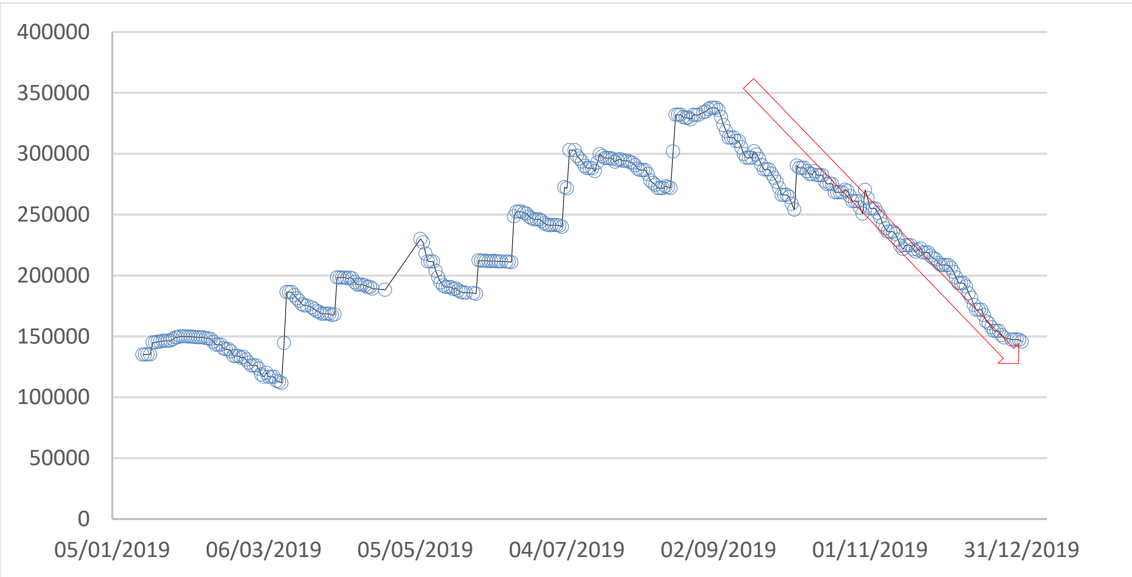

Fig. 4. Copper stocks in LME warehouses (metric tonnes) in 2019

On the grounds of the information about the three sources of supply cited (refined product and scrap output, warehouse inventories), market supply and demand in the period were well balanced or exhibited a deficit, prompting fears of shortage.

An alternative approach to measuring copper shortage consists in the long-term netting of physical market positions and financialisation. Further to the LME's Committee of Traders Report (COTR) on the activity of LME members and their clients, that calculation revealed a net market shortage. The report analysed (Quandl[8] database) both physical market (producer / merchant / processor / user) and financial market (money managers: primarily institutional investors) positions. A comparison of the two attested to a global historic net shortage of physical positions and a surplus of financial positions, due essentially to overbuying to keep the commodity price as high as possible (Figure 5).

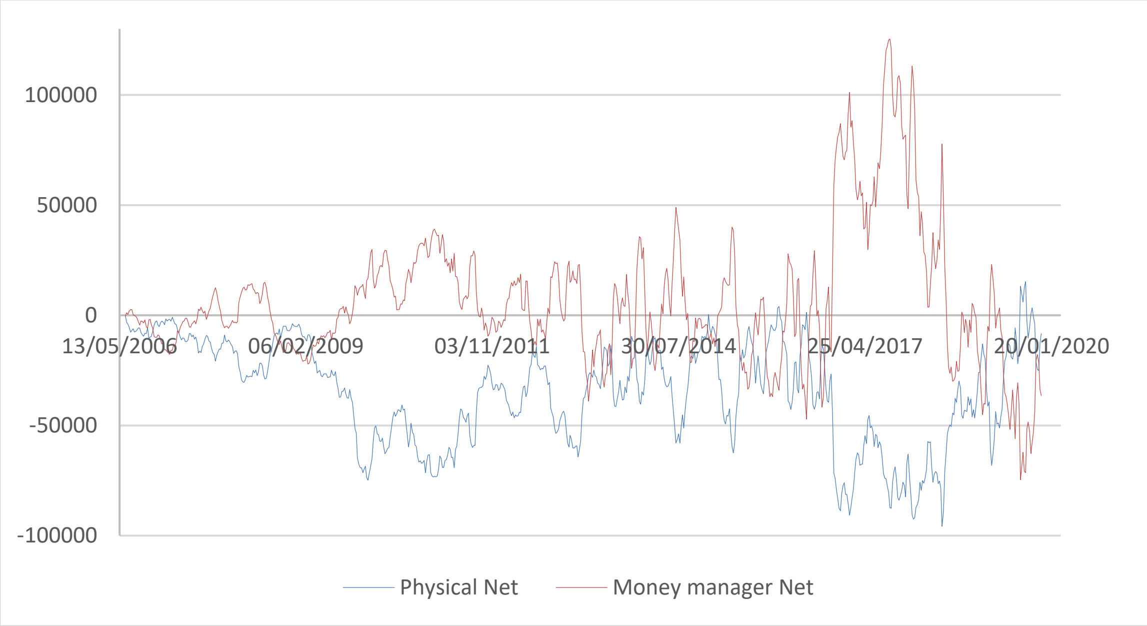

Fig. 5. Physical and financial positions in copper on the LME by number of lots (Quandl)

An analysis of the overall position of the commodity based on all elements addressed in the report (including physical and speculative swaps and other transactions not cited in the foregoing) showed a deficit in the worldwide market in the period studied (Figure 6).

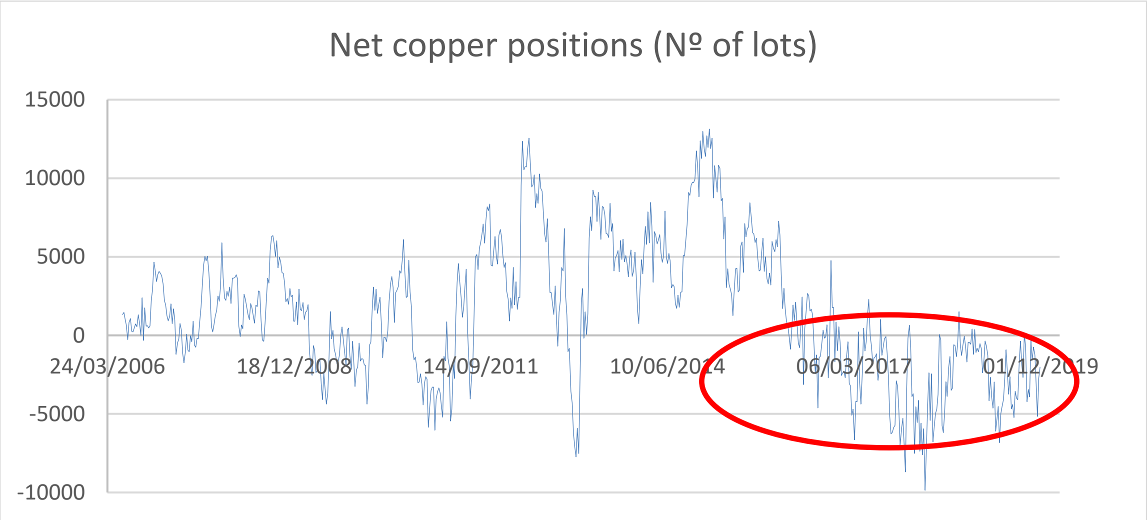

Fig. 6. LME. Net copper positions in number of lots (Quandl).

[8] see www.quandl.com

3.1.3. Copper market financialisation

The LME's Commitment of Traders Report[9] was analysed to compare LME copper market financialisation to that of other LME non-ferrous metal markets, including aluminium, zinc and lead.

The number of lots held by each type of financial actor extracted from all the reports for the period was then multiplied by the metal price in the respective session. That exercise showed copper to be the major non-ferrous metal traded by value (Table 1).

Table 1. Financial institutions' holdings of LME metals by value

	Lot	Total Zn	Total Sn	Total Pb	Total AH	Total Cu
Investment firms or credit institutions	Long	164 670.98	13 153	95 226.83	710 566.22	258 192.84
	Short	137 691.60	9 814	74 858.49	521 487.79	231 266.00
Investment funds	Long	22 080.37	488	5 595	44 967.28	15 549.99
	Short	31 978.55	486	8 291	79 168.28	23 707.99
Other financial institutions	Long	52 837.87	1 723	51	124 930.71	41 445.68
	Short	36 474.93	1 269	83	94 559.98	31 115.88
All in	SUM	445 734.3	26 933	184 105.32	1 575 680.26	601 278.38
LME official price on 15/04/2020	Per mt	$1 909	$15 340	$1 664	$1 470	$5 055
All-in price ($)	Per mt	$850 683 912	$413 152 220	$306 351 252	$2 315 462 142	$3 039 161 572

3.1.4. BUKHI50P Index

The CBOE's (Cboe Global Markets) Europe Equities BUKHI50P index was used to analyse the effect of Brexit events on the copper market. That reference, a barometer of the impact of Brexit on local companies whose economic performance is determined by their business in the UK, is based on earnings geography. The BUKHI50P index comprises the companies in the Cboe 100 UK index of the country's largest companies by market capitalisation deriving the highest portions of their revenues from the UK on a specific date, in this case 15/07/2019 (Appendix II).

Correlations between Brexit events and the BUKHI50P index values were sought separately for three periods: 2016-2017; 2018; and 2019.

Brexit events were consequently observed here to be closely correlated to changes in BUKHI50P index trends. That contrasts with findings reported by Bohdalová and Greguš (2017) based on the EPUCBREX, which ruled out any association between Brexit and FTSE 100 volatility. Yao and Memon (2019), however, observed the referendum to have a post-Brexit positive impact on that index.

3.2. Methodology

Granger causality theory (Granger 1969), was used to analyse the relationship between these two non-stationary time series, i.e., the structure of copper futures prices and the BUKHI50P index

[9]https://www.lme.com/Market-Data/Reports-and-data/Commitments-of-traders#tabIndex=0

These series used $(y_t)_{t=1}^{N}$ are defined below:

- Structure of copper futures prices, $(y_t)_{t=1}^{N}$: $(stru_t)_{t=31-12-2015}^{27-12-2019}$ (Equation 1a)
- BUKHI50P (CBOE), $(z_t)_{t=1}^{N}$: $(BUK_t)_{t=31-12-2015}^{27-12-2019}$ (Equation 1b)

The series $\mathrm{stru_t}$ and $\mathrm{BUK_t}$ are non-stationary (mean and variance are not constant, and the covariance between any two points depends only on the distance between them but not on their specific locations in time, Tsay, 2010) (see Figure 7).

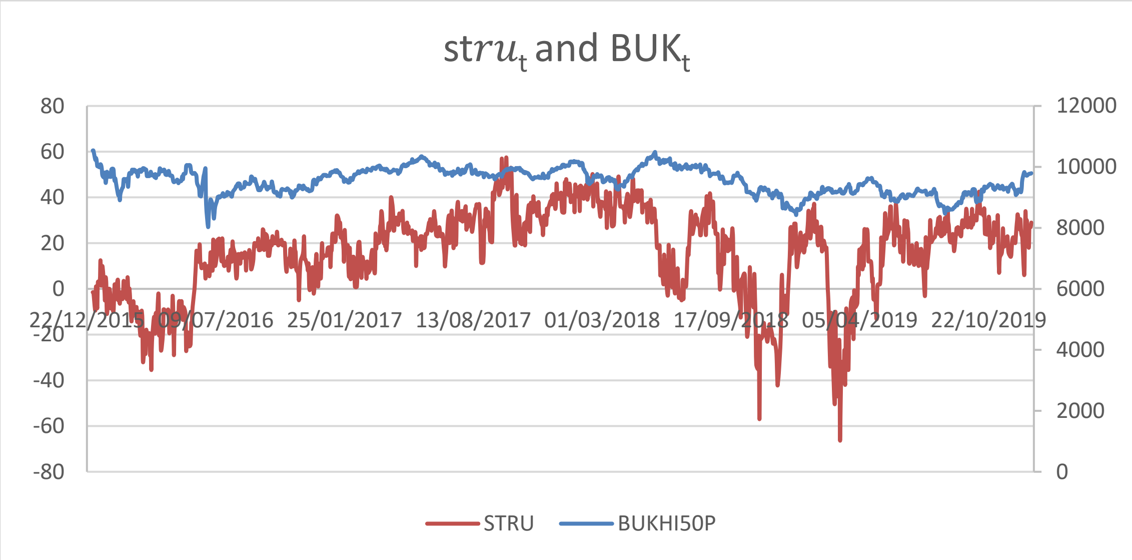

Fig. 7 $stru_t$ and $\mathrm{BUK_t}$ over the time period studied

A number of tests are in place to verify time series stationarity: those where the stationarity of the series is the null hypothesis H0, such as KPSS (Kwiatkowski et al. 1992), used by Chen and Pun 2019 (who found it to be more effective in bootstrap-based time series), the Leybourne tests and McCabe tests (Leybourne and McCabe 1994) used in Otero and Smith (2012). In contrast, in other approaches, the null hypothesis assumes non-stationarity such as the Dickey-Fuller test (Dickey and Fuller 1979), the Phillips-Perron test (Phillips and Perron, 1988), the DF-Generalized Least Square tests (Elliot et al. 1996). The number of lags complies the Bayesian Information Criterion (BIC), as suggested by Yao (1988), and the Akaike information criterion (AIC), Akaike (1974) and extended in Bai and Perron (2003); Other processes could have been used to determine the optimum number of lags like referred in Ng and Perron (2001).

According to the Bayesian Information Criterion (BIC), as suggested by Yao (1988), and the Akaike information criterion (AIC), Akaike (1974) and extended in Bai and Perron (2003), the number of lags proposed as standard by the software has been certified; Other processes could have been used to determine the optimum number of lags like referred in Ng and Perron (2001).

The augmented Dickey-Fuller (ADF) tests have been recently deployed by de Souza et al. (2019) and Khalfaoui et al. (2019).

In the case of non-stationary result, Box-Cox transformations (Box and Cox 1964), a family of power transformations, can be performed (as in Habib, 2018) to look for the stationary of the series and going on with the stationary tests. This transformation is one of the most widely used methods for transforming the curves for non-normal variables into a normal shape. It is deemed ‘best practice’, for other procedures are not based on specific patterns but randomly iterated until they yield the best normalisation (Osborne 2010).

Such transformations cannot be applied to negative values because they may involve logarithms. As the objective here was to find co-movements (trend curves) rather than to pair data, the structure of copper futures prices was assigned a fixed value to elude the presence of negative values.

After this transformation in keeping with the above procedures, the resulting series had to be tested for stationarity; where affirmative (running again ADF tests) they would be deemed to be integrated of order 1, denoted I(1).

Even if we have used integer integration, most tests in fact fail to reject the null of a unit root (Abbritti et al., 2016). Unit root methods have been extended, so, in the last years to the case of fractional integration (Gil-Alana and Robinson, 1997). In fact, many authors have shown that the classical unit root methods have lower power if the true data are fractionally integrated, see, e.g., Diebold and Rudebusch (1991); Hassler and Wolters (1994), Lee and Schmidt (1996).

Thereafter, a unit root of the same order as the transformed series (here order 1 I(1) for BUKHI50P and stru) has been then calculated, using the Engle and Granger (1987) causality-based cointegration tests. In the case where fractional integration would be applied, cointegration could be also extended to the same fractional idea like in recent years, see, e.g., Robinson and Marinucci (2003), Robinson and Yajima (2002) or more recently to the fractional CVAR, FCVAR approach of Johansen (2008) and Johansen and Nielsen (2010, 2012).

Based on Engle and Granger causality cointegration, the autoregressive vectors (VAR) can be calculated and for instance the basis for the Trace test and λ_{max} using Johansen’s approximation (1988) to find at least one cointegration relationship between the two series.

Engle and Granger cointegration tests were conducted to estimate the two equations shown below from the two series of data transformed using OLS (ordinary least squares):

$$stru_t = \alpha_0 + \alpha_1\, stru_{t-1} + \cdots + \alpha_1\, stru_{t-l} + \beta_1\, stru_{t-1} + \cdots + \beta_1\, BUK_{t-l} + \varepsilon_t,$$

$$BUK_t = \alpha_0 + \alpha_1\, BUK_{t-1} + \cdots + \alpha_1\, BUK_{t-l} + \beta_1\, BUK_{t-1} + \cdots + \beta_1\, stru_{t-l} + u_t$$

where: $stru_t$ and BUK_t are the time series for which cointegration was to be determined, l the number of delays used, α and β the parameters to be studied and ε_t and u_t the errors or random disturbance, which are normally uncorrelated.

Briefly, if $\beta_l = \beta_l = 0$ there is no inter-series causation whereas if $\beta_l \neq \beta_l \neq 0$ the two are co-integrated as defined by Granger.

The Johansen approximation yields α and β as the vectors:

$\alpha = |p,r|$ and $\beta = |m,r|$

where r is the number of cointegrating vectors and p and m are the series vector components.

Examples of the current use of the Granger model can be found in Eross et al. (2019), who applied the methodology to study a highly topical subject, bitcoins, and in Qadan (2019) and Rutledge et al. (2013) in analyses of the same market environment as explored here. Other authors adopting a similar approach include Hossain and Mitra (2017), Alam (2017), Hadi et al. (2019), Dong (2017), Chalmers et al. (2019) and Samsi et al. (2019).

4. Results

4.1. Relationship between Brexit-related events and the structure of copper futures prices

This descriptive study shows four clearly distinct phases in strut and BUKt joint movements. This 4-period selection has been specified based on the authors´ experience on the copper market, strongly linked with different behaviours of the contango and backwardation periods in the studied time-frame, intense backwardation followed by an incremental contango, a stable contango and finally falling into a series of ups and down alternating contango and backwardation (see Fig. 8). This descriptive study could be also improved through standard structural breaks tests like those of Bai and Perron (2003) introduced in the methodology.

Consequently the characteristics of the four periods are:

Phase 1: consistently high BUKHI50P values were observed, attendant upon intense backwardation across the period due to the copper market shortage and the absence of adverse Brexit-related news.

Phase 2: change from backwardation to contango in conjunction with stabilisation of the BUKHI50P index

Phase 3: consistent contagion with the decline in BUKHI50P and change to backwardation with the rise in the index

Phase 4: variable ups and downs in both indices and backwardation consistently appearing with improvements in BUKHI50P

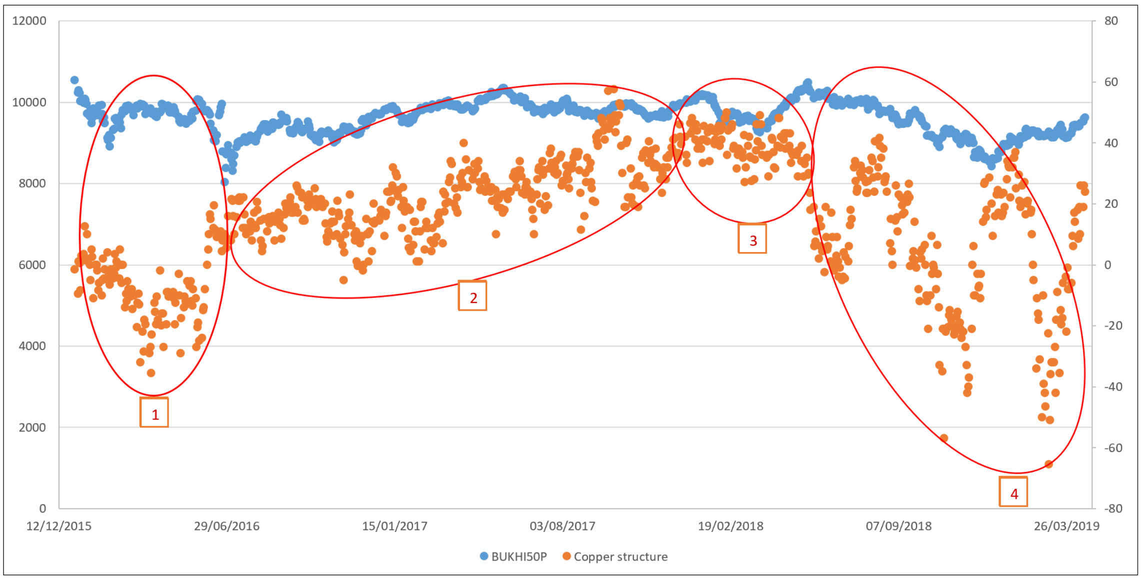

Fig. 8. Structure of copper futures prices in USD and BUKHI50P index values (source: authors' formulation)

A joint analysis of the *stru* and *BUK* series showed Brexit events to impact both in the whole range studied.

- Brexit-related events induced changes in the BUKHI50P index, which is based on the stock market value of the UK companies with highest exposure to the domestic economy and consequently to the country's political situation.
- When warehouse inventories are low in a context of output shortfalls, the structure of copper futures prices may be impacted by any geopolitical event able to prompt short-term shortage, which would favour backwardation or narrow the contango.

The graphs in Figures 9 to 11 illustrate the short-term changes in the copper price curve induced by Brexit events (text in red, list in Table 2). All the events favouring the United Kingdom's exit from the European Union raised political uncertainty and with it the perceived risk of shortage.

Table 2. Most prominent Brexit-related events by period analysed

	Date	Brexit event
2016-2017	22/02/2016	The Prime Minister announces the EU referendum date – 23 June 2016.
	03/10/2016	In her Party Conference speech, Theresa May announces a 'Great Repeal Bill' and confirms Article 50 will be triggered before the end of March 2017.
	16/03/2017	The European Union (Notification of Withdrawal) Act receives Royal Assent.
	29/03/2017	The Prime Minister triggers Article 50 of the Treaty on European Union.
	30/03/2017	The Government publish the Great Repeal Bill White Paper
	08/06/2017	The outcome of the general is a hung Parliament, with the Conservatives win of a simple majority enabling Theresa May to form a Government.
2018	16/05/2018	The European Union (Withdrawal) Bill passes House of Lords stages with ensuing parliamentary ping pong.
	23/08/2018	The Government publish the first series of technical notices providing guidance on how to prepare for a no-deal Brexit.
	19/09/2018	EU leaders hold an informal summit in Salzburg.
	14/11/2018	The Withdrawal Agreement is passed and published.
	15/11/2018	Brexit Secretary resigns as Secretary of State for Exiting the European Union and is replaced by Stephen Barclay the following day.
2019	15/01/2019	The Prime Minister loses the 'Meaningful Vote' and the Leader of the Opposition tables a motion of no confidence in the Government.
	16/01/2019	The Prime Minister wins a vote of confidence in the Government.
	29/03/2019	The Prime Minister loses 'Meaningful Vote 3'.
	01/04/2019	On the second day of indicative votes, all four options are defeated.
	02/04/2019	The Prime Minister announces she will seek a further extension to the Article 50 process and offers to meet with the Leader of the Opposition to finalise a deal that will win the support of MPs.
	30/10/2019	The Government table the Early Parliamentary General Election Bill, setting the 12 December as the date for a general election. The Bill passes all its Commons stages.

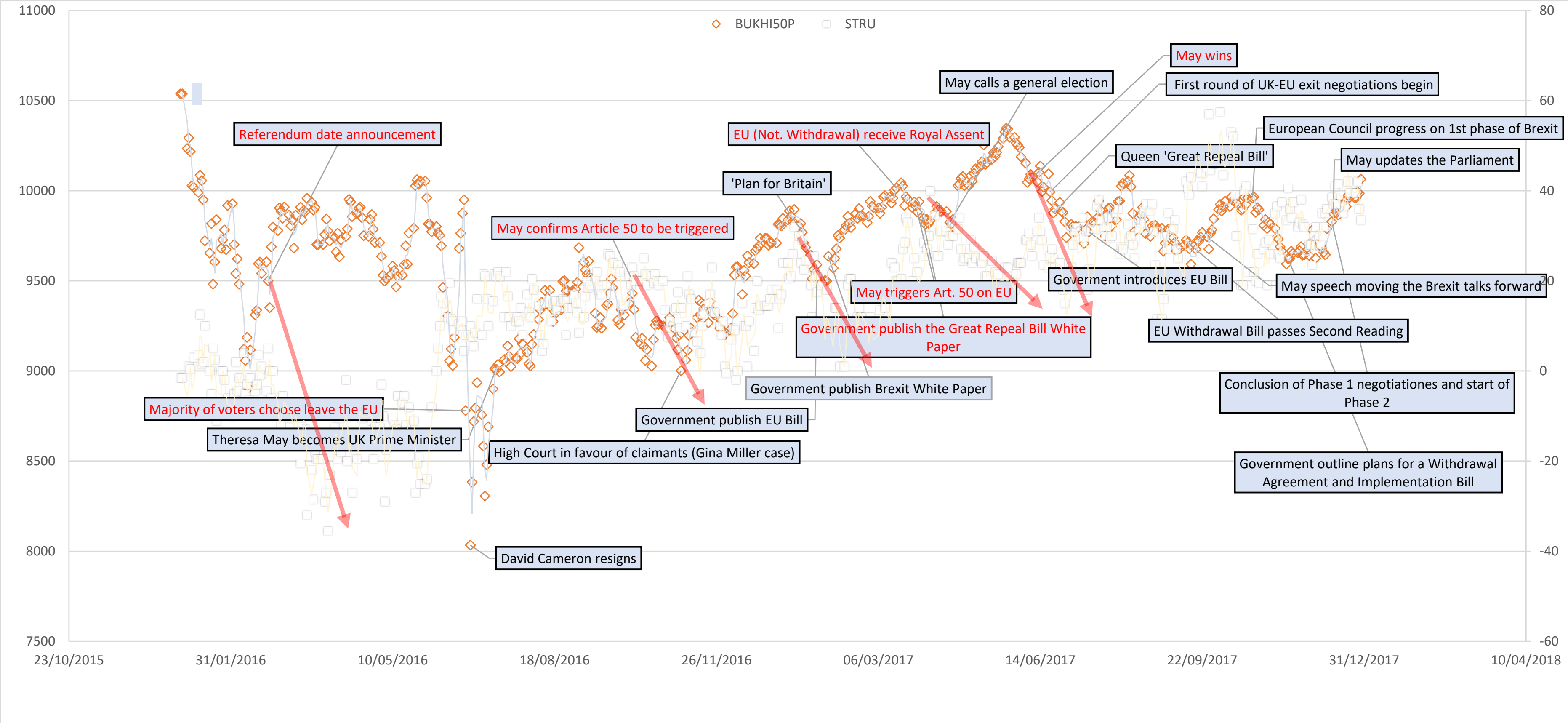

Fig. 9. Variations in the structure of copper futures prices and BUKHI50P in the wake of Brexit-related events (2016-2017)

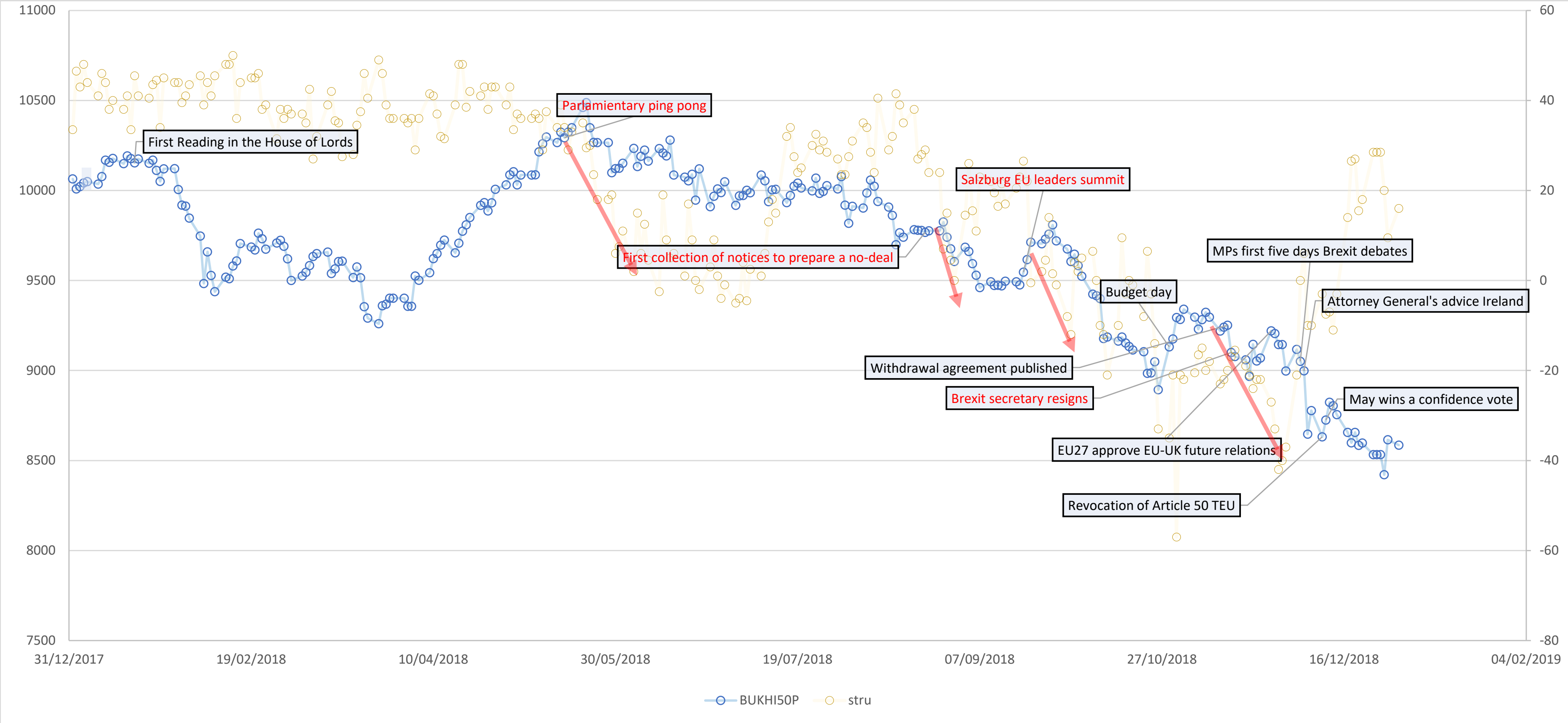

Fig. 10. Variations in the structure of copper futures prices and BUKHI50P in the wake of Brexit-related events (2018)

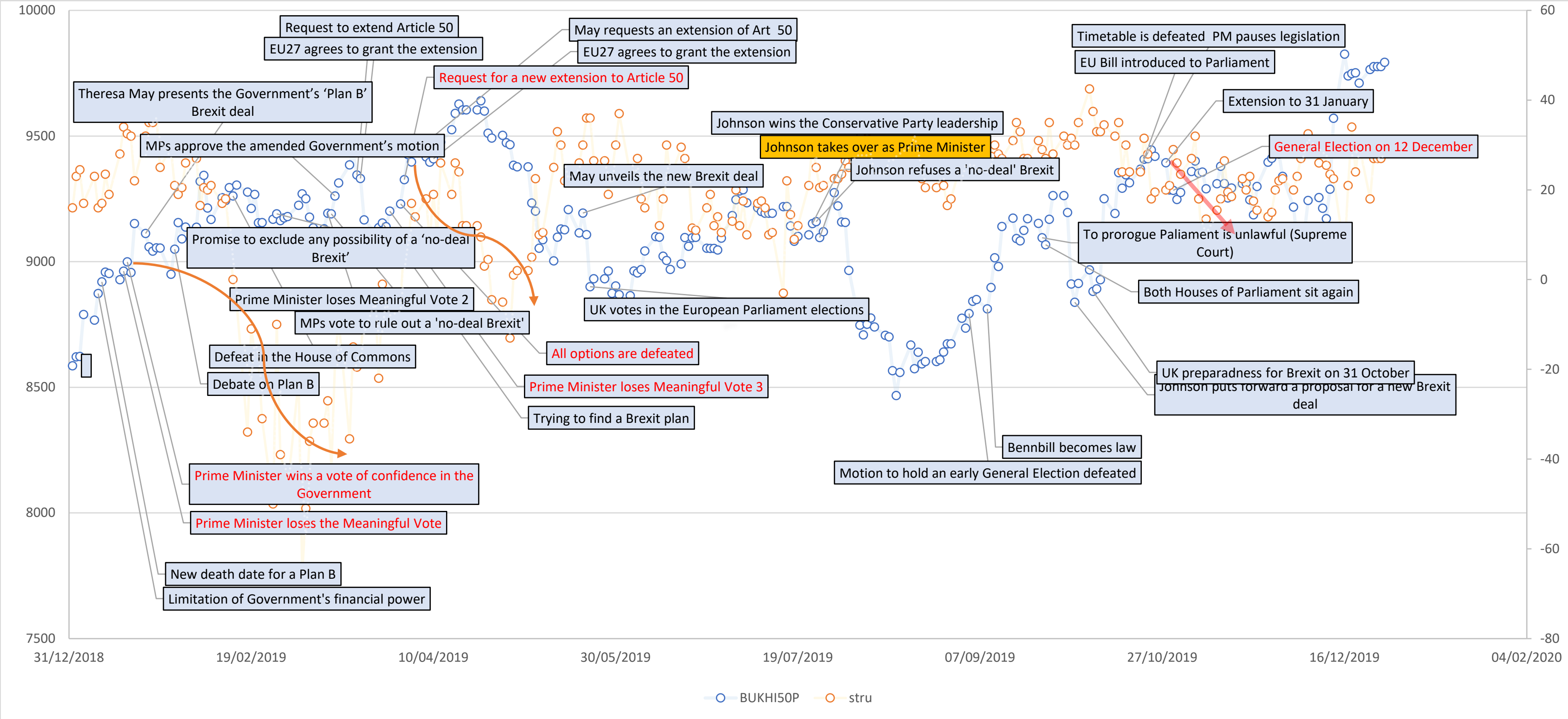

Fig. 11. Variations in the structure of copper futures prices and BUKHI50P in the wake of Brexit-related events (2019)

BUKHI50P - structure of copper futures prices causality test

Applying Box-Cox transformation to λ values of ½ and λ_{max} to analyse $stru_t$ and BUK_t series stationarity yielded similar results.

Table 3. ADF p-value for $stru_t$ and BUK_t

			Augmented Dickey-Fuller		
	Period	Transformed serie (through Box-Cox)	Significance	Significance using λ = ½	Significance using λmax
BUK_t	2016-2019	I(0)	7%*		
	2016-2017	I(0)	4%**		
	2018	I(0)	87%		
	2019	I(0)	65%		
	2016-2019	I(1)		**7%***	7%*
	2018	I(1)		88%	82%
	2019	I(1)		64%	68%
$stru_t$	2016-2019	I(0)	5%**		
	2016-2017	I(0)	1%***		
	2018	I(0)	40%		
	2019	I(0)	21%		
	2016-2019	I(1)		**4%****	6%*
	2018	I(1)		39%	37%
	2019	I(1)		20%	22%

Notes: *** rejection of the null hypothesis at the 1% significance level
** rejection of the null hypothesis at the 5% significance level
* rejection of the null hypothesis at the 10% significance level

The augmented Dickey-Fuller tests for the period as a whole showed stationarity at 5 % significance for $stru_t$ and at 7 % for BUK_t.

Box-Cox transformations applied to the two series also verified Dickey-Fuller stationarity, with 4 % significance for $stru_t$ and 7 % for BUK_t when a λ value of ½ was used. With λ_{max}, 6 % significance was observed for $stru_t$ and 7 % for BUK_t.

The analysis by period (2016-2017, 2018 and 2019) revealed stationarity for the 2016-2017 series, but for neither the 2018 nor the 2019 series (with or without transformation). Given that discrepancy in stationarity, comparing periods in pursuit of differences in patterns was deemed futile.

Focusing on the whole range 2016-2019, Box-Cox transformation with λ=½ yielded the data with the best p-values arriving to two stationary series of order 1, I(1), where the statistical parameters are listed in Tables 4 and 5.

Table 4. ADF test for *BUK* stationary series after Box-Cox transformation with λ =½

Descriptive statistics	
Variable	*BUK*
Observations	1042
Obs. with lost data	0
Obs. without lost data	1042
Minimum	8034.46

Dickey-Fuller (ADF stationarity) / k: 10 / *BUK*):	
Tau (observed value)	-3.241
Tau (critical value)	-3.394
p-value (one-sided)	0.074
alpha (α)	0.1

Maximum	10537.3
Average	9545.39
Standard deviation	420.142

H_0: There is a unit root for the series.
H_a: There is no unit root for the series. The series is stationary

The *p*-value as calculated is lower than significance level α=0.1. Null hypothesis H_0 must be rejected and alternative hypothesis Ha accepted.

Table 5, ADF test for *stru* stationary series after Box-Cox transformation with λ =½

Descriptive statistics

Variable	*stru*
Observations	1042
Obs. with lost data	0
Obs. without lost data	1042
Minimum	-65.5
Maximum	57.5
Mean	16.545
Standard deviation	18.974

Dickey-Fuller (ADF stationarity) / k: 10 / *stru*):

Tau (observed value)	-3.417
Tau (critical value)	-3.394
p-value (one-sided)	0.048
alpha (α)	0.05

H_0: There is a unit root for the series.
H_a: There is no unit root for the series. The series is stationary.

The *p*-value as calculated is lower than significance level α=0.1. Null hypothesis H_0 must be rejected and alternative hypothesis Ha accepted.

As the two series found to be of the same order, they were tested for cointegration. Applying AIC criteria delivered a *VAR* order of 5 (Table 6).

Table 6. *VAR* order calculations for series *stru* and *BUK*

Descriptive statistics

Variable	*BUK* Box-Cox	Box-Cox stru + 70
Observations	1042	1042
Obs. with lost data	0	0
Obs. without lost data	1042	1042
Minimum	177.27	2.243
Maximum	203.303	20.583
Mean	193.353	16.472
Standard deviation	4.32	2.23

VAR order Significance level (%): 5

Number of temporary lags	AIC	HQ	BIC	FPE
1	-0.244	-0.237	-0.225	0.783
2	-0.362	-0.348	-0.324	0.696
3	-0.39	-0.368	-0.333	0.677
4	-0.395	-0.366	-0.319	0.673
5	**-0.418**	-0.382	-0.323	0.658

AIC-estimated *VAR* order = 5.

The λ_{max} and trace tests revealed at least one cointegration relationship at a significance level of 5 % (Table 7).

Table 7. Results of λ_{max} and trace tests for *BUK* and *stru* time series

H_0 (Number of cointegrating equations)	Eigenvalue	λ_{max}	Critical value	p-value
None	0.017	17.255	11.225	0.004
At most 1	0	0.011	4.13	0.931

Further to the λ_{max} test there is 1 cointegration relationship at a significance level of 0.05.

Trace test				
H_0 (Number of cointegrating equations)	Eigenvalue	Trace	Critical value	p-value
None	0.017	17.266	12.321	0.007
At most 1	0	0.011	4.13	0.931

Further to the **trace** test there is 1 cointegration relation at a significance level of 0.05.

The values of fitting coefficients α and β for the cointegrating equations are given in Table 8.

Table 8. Fitting coefficients for the cointegrating equations

Fitting coefficient α:		
BUK BC	-0.067	-0.003
BC stru + 70	0.097	-0.001

Fitting coefficient β:		
BUK BC	0.041	0.002
BC stru + 70	-0.477	0.033

The findings showed that the time series associated with the BUKHI50P (*BUK*) stock index was cointegrated with the structure of copper futures prices (*stru*) at a 5 % level of significance in the period studied: 31/12/2015 to 27/12/2019. The inference is that Brexit, a major macroeconomic event, had a significant effect on the structure of copper futures prices in a tight marketplace. That information may prove useful to agents trading lots whose size is linked to the immediate market cycle, such as mining companies that engage in high-volume transactions impacted by developments not strictly related to the demand for copper.

That the performance of companies with high exposure to Brexit is cointegrated with variations in the structure of copper futures prices implies a close relationship between the two series. Monitoring Brexit events may consequently provide good insight into the behaviour of the structure of copper futures prices in a tight market.

4.2. BUKHI50P and the price structure for other metals

The robustness of the present results was tested by applying the procedure described for copper to less financialised metals (as discussed in the section on data) such as aluminium (Al), lead (Pb), tin (Sn) and zinc (Zn).

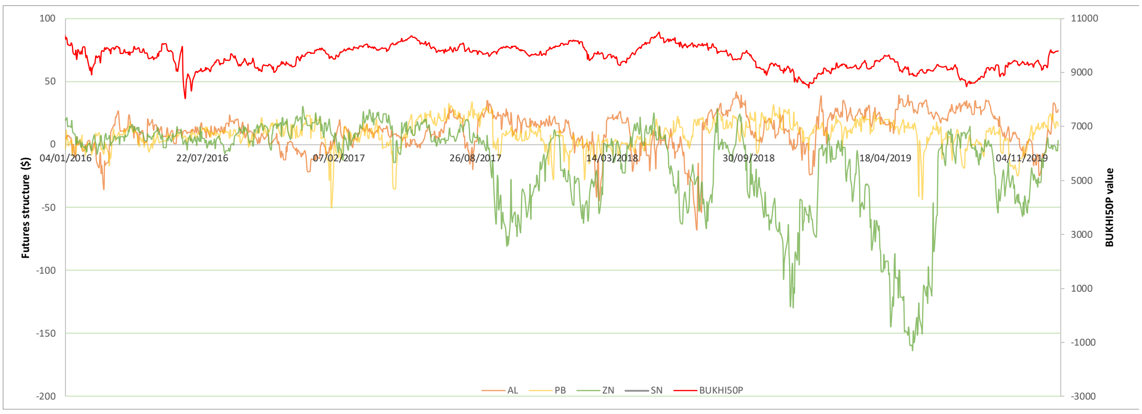

Fig. 12. Al, Pb, Zn, Sn price structures and BUKHI50P index value

The series for three of the four metals, Al, Pb and Sn, were found to be stationary (further to ADF) in the period studied, in which their price structures were determined to the same criterion as described for copper. The results exhibited a much better level of significance, with no need for transformation, than observed for BUKHI50P and Zn (Figure 12). The two non-stationary series, BUKHI50P and Zn, were transformed using the values of λ found with ADF and the levels of significance shown in Table 9.

Table 9. Calculation of Al, P, Sn, Zn and BUKHI50P time series stationarity

Variable/Period		Transformed serie (through Box-Cox)	Significance (DAF)
BUK_t		I(0)	7%*
		I(1)	7%*
$stru_t$	Al	I(0)	1%***
	Pb	I(0)	1%***
	Sn	I(0)	1%***
	Zn	I(0)	5%*
		I(1)	5%*

The Engle and Granger cointegration findings for the Zn price structure and BUKHI50P after one transformation are given in Table 10, finding no cointegration.

Table 10. Cointegration values for the Zn and BUKHI50P series

H0 (Number of cointegrating equations)	Eigenvalue	λ_{max}	Critical value	p-value
None	0.009	9.578	11.225	0.096
At most 1	0.000	0.126	4.130	0.770

Further to the $\boldsymbol{\lambda_{max}}$ test there is no cointegration relationship at a significance level of 0.05.

H0 (Number of cointegrating equations)	Eigenvalue	Trace	Critical value	p-value
None	0.009	9.704	12.321	0.132
At most 1	0.000	0.126	4.130	0.770

Further to the **trace** test there is no cointegration relationship at a significance level of 0.05.

5.- Discussion

In the context of the influence of macroeconomic events on commodity prices, the present findings confirm the existence of a relationship between Brexit and the structure of copper futures prices, measured on the grounds of BUKHI50P data.

Commodity financialisation has been addressed in the literature, with authors such as Batten et al. (2010), Chen (2010) and Creti et al. (2013) associating volatility with macroeconomic movements. Whereas those authors included copper as part of a general study, others such as Guo (2018) explored volatility and Shao et al. (2013) and Guzmán and Silva (2018) the variation in price for that metal separately.

The present analysis adopts a different approach. Rather than volatility or price, often the object of commodity market research based on the S&P 500, the U.S. Dollar Index or similar, it explores the dependence of the structure of copper futures prices, along with contango and backwardation, on worldwide economic developments and more specifically on Brexit, one of the most impactful economic developments in recent history.

Despite that difference in approach, however, the analysis was based on the same methodology, namely Granger causality, and the same copper market environment as applied by other authors (Guzmán and Silva 2018).

6.- Conclusions and Policies

Behaviour patterns differ substantially among the various types of copper market actors. The present study is intended to provide guidance to players conducting small numbers of large-scale transactions, such as mining firms, seeking to optimise their trading. It consequently focuses on fluctuations in the structure of copper futures prices (contango and backwardation) as a physical market driver. The decision to engage in a cash or a 3 month forward transaction may be informed by which is believed to deliver higher value. This paper aims to support decision-making based not only on fundamentals such as supply and demand but also on macroeconomic events such as Brexit in a tight market or one on the brink of shortage.

Our contribution has proven that the evolution of companies with high exposure to Brexit is cointegrated with variations in the structure of copper futures prices. The conclusion drawn is that just as Brexit-related events imply a weakening of the UK economy, they have a detrimental effect on the structure of copper futures prices.

Given that the structure of copper futures prices is defined by the difference between the LME spot price and the 3-month forward price, in a context such as the current one, of shortage of supply, Brexit-related events that may be perceived as negative geopolitical impacts will lead to short-term stockouts, which would lower copper futures prices relative to spot prices. The outcome is, thus, a rise in the copper spot relative to its forward price (narrower contango or advent of backwardation).

As Brexit events generate a negative impact on the structure of copper futures prices, these events (whose importance perceived by the market is immediately observed in it), should induce bidders (miners and metal holders) to carry out operations according to a price-structure oriented strategy instead of prompt or long term due dates strategies.

Watkins and McAleer (2002) identified a number of elements that affect the relationship between a commodity's cash and its future value. One they cited is 'price volatility and risk'. In that context, the effect of Brexit-associated events on the structure of copper futures prices addressed in this article may merit further analysis as an element that raises or lowers volatility and risk.

Another line of study might be the impact of other macroeconomic events not only on the structure of copper futures prices but also on those of less financialised metals, either in periods of shortage or of lower market stress.

Additionally, one more relevant issue to be addressed in future research would be to analyse other sub-periods to the descriptive-based ones, since the moment of each break is not known. A suitable methodology can be the Robinson (1994) tests, as in Gil-Alana (2002).

Finally, the study of volatility is a topic of the utmost importance and being able to provide solutions to reduce or manage volatility in the market would be an important contribution, which we would like to work on next.

References

Abbritti, M., Gil-Alana, L. A., Lovcha, Y., & Moreno, A. (2016). Term structure persistence. *Jnl of Financial Econometrics*, *14*(2), 331-352.

Aepli, M.D., Fuss, R., Henriksen, T.E.S., & Paraschiv, F., 2017. Modeling the multivariate dynamic dependence structure of commodity futures portfolios. Journal of Commodity Markets*, 6*, 66-87. doi:10.1016/j.jcomm.2017.05.002

Akaike, H. (1974). A new look at the statistical model identification. *IEEE transactions on automatic control*, *19*(6), 716-723.

Akbar, M., Iqbal, F., & Noor, F., 2019. Bayesian analysis of dynamic linkages among gold price, stock prices, exchange rate and interest rate in Pakistan. Resources Policy, 62, 154-164. doi:10.1016/j.resourpol.2019.03.003

Alam, N., 2017. Analysis of the impact of select macroeconomic variables on the Indian stock market: A heteroscedastic cointegration approach. Business and Economic Horizons, 13(1), 119. doi:10.15208/beh.2017.09

Alkhatib, A., & Harasheh, M., 2018. Performance of Exchange Traded Funds during the Brexit referendum: An event study. International Journal of Financial Studies, 6(3), 64.

Ames, M., Bagnarosa, G., Matsui, T., Peters, G. W., & Shevchenko, P. V. (2020). Which risk factors drive oil futures price curves? Energy Economics, 87 doi:10.1016/j.eneco.2020.104676

ap Gwilym, R., Ebrahim, M. S., El Alaoui, A. O., Rahman, H., & Taamouti, A., 2019. Financial frictions and the futures pricing puzzle. Economic Modelling, <xocs:first xmlns:xocs=""/>. doi:10.1016/j.econmod.2019.08.009

Aristeidis, S., & Elias, K., 2018. Empirical analysis of market reactions to the UK's referendum results – how strong will Brexit be? Journal of International Financial Markets, Institutions & Money, 53, 263-286. doi:10.1016/j.intfin.2017.12.003

Bai, J., & Perron, P. (2003). Computation and analysis of multiple structural change models. *Journal of applied econometrics*, *18*(1), 1-22.

Bashir, U., Zebende, G.F., Yu, Y., Hussain, M., Ali, A., & Abbas, G., 2019. Differential market reactions to pre and post Brexit referendum. Physica A: Statistical Mechanics and its Applications, 515, 151-158.

Batten, J.A., Ciner, C., & Lucey, B.M., 2010. The macroeconomic determinants of volatility in precious metals markets. Resources Policy, 35(2), 65-71. doi:10.1016/j.resourpol.2009.12.002

Benbachir, D., & Lembarki, S. (2018). Price dynamics of crude oil in the short and long term. International Journal of Economics and Financial Issues, 8(5), 103-114.

Bohdalova, M., & Gregus, M., 2017. Impact of uncertainty on European market indices quantile regression approach. CBU International Conference Proceedings 2017: Innovations in Science and Education, 5, 57-61. doi:10.12955/cbup.v5.902

Box, G., & Cox, D., 1964. An analysis of transformations. Journal of the Royal Statistical Society Series B-Statistical Methodology, 26(2), 211-252.

Breinlich, H., Leromain, E., Novy, D., Sampson, T., & Usman, A., 2018. The Economic Effects of Brexit: Evidence from the Stock Market. Fiscal Studies, 39(4), 581-623.

Burdekin, R.C., Hughson, E., & Gu, J., 2018. A first look at Brexit and global equity markets. Applied Economics Letters, 25(2), 136-140.

Cashin, P., Céspedes, L.F., & Sahay, R., 2004. Commodity currencies and the real exchange rate. Journal of Development Economics, 75(1), 239-268. doi:10.1016/j.jdeveco.2003.08.005

CBOE, Chicago Board Options Exchange, www.cboe.com

Chalmers, N., Revoredo-Giha, C., & Jumbe, C., 2019. Measuring the degree of integration in the dairy products market in Malawi. Social Sciences, 8(2) doi:10.3390/socsci8020066

Chen, M., 2010. Understanding world metals prices—Returns, volatility and diversification. Resources Policy, 35(3), 127-140. doi:10.1016/j.resourpol.2010.01.001

Chen, Y., & Pun, C.S., 2019. A bootstrap-based KPSS test for functional time series. Journal of Multivariate Analysis, 174 doi:10.1016/j.jmva.2019.104535

CME, Commodity Exchange Inc., www.cmegroup.com

Creti, A., Joëts, M., & Mignon, V., 2013. On the links between stock and commodity markets' volatility. Energy Economics, 37, 16-28. doi:10.1016/j.eneco.2013.01.005

Dao, T. M., McGroarty, F., & Urquhart, A., 2019. The Brexit vote and currency markets. Journal of International Financial Markets Institutions & Money, 59, 153-164. doi:10.1016/j.intfin.2018.11.004

Davies, R.B., & Studnicka, Z., 2018. The heterogeneous impact of Brexit: Early indications from the FTSE. European Economic Review, 110, 1-17. doi:10.1016/j.euroecorev.2018.08.003

de Souza Ramser, C.A., Souza, A.M., Souza, F.M., da Veiga, C.P., & da Silva, W.V., 2019. The importance of principal components in studying mineral prices using vector autoregressive models: Evidence from the Brazilian economy. Resources Policy, 62, 9-21. doi:10.1016/j.resourpol.2019.03.001

Dickey, D., & Fuller, W., 1979. Distribution of the estimators for autoregressive time-series with a unit root. Journal of the American Statistical Association, 74(366), 427-431. doi:10.2307/2286348

Diebold, F. S., and G. D. Rudebusch (1991) On the Power of Dickey-Fuller Tests against Fractional Alternatives, Economics Letters35, 155-160.

Dong, F., 2017. Testing the Marshall-Lerner condition between the U.S. and other G7 member countries. North American Journal of Economics and Finance, 40, 30-40. doi:10.1016/j.najef.2017.01.003

Ekeland, I., Lautier, D., & Villeneuve, B. (2019). Hedging pressure and speculation in commodity markets. Economic Theory, 68(1), 83-123. doi:10.1007/s00199-018-1115-y

Elliot, G., Rothenberg, T.J. & Stock, J.H. (1996), Efficient tests for an autoregressive unit root, Econometrica 64, 813-836.

Engle, R., & Granger, C., 1987. Cointegration and error correction - representation, estimation, and testing. Econometrica, 55(2), 251-276. doi:10.2307/1913236

Eross, A., McGroarty, F., Urquhart, A., & Wolfe, S., 2019. The intraday dynamics of bitcoin. Research in International Business and Finance, 49, 71-81. doi:10.1016/j.ribaf.2019.01.008

Figuerola-Ferretti, I., Gilbert, C. L., & Mccrorie, J. R. (2015). Testing for mild explosivity and bubbles in LME Non-Ferrous metals prices. *Journal of Time Series Analysis, 36*(5), 763-782. doi:10.1111/jtsa.12121

Gil-Alana, L. A. (2002). Structural breaks and fractional integration in the US output and unemployment rate. *Economics Letters*, *77*(1), 79-84.

Gil-Alana, L. A., & Robinson, P. M. (1997). Testing of unit root and other nonstationary hypotheses in macroeconomic time series. *Journal of Econometrics*, *80*(2), 241-268.

Go, Y., & Lau, W., 2017. Investor demand, market efficiency and spot-futures relation: Further evidence from crude palm oil. Resources Policy, 53, 135-146. doi:10.1016/j.resourpol.2017.06.009

Gómez, F., Guzmán, J.I., & Tilton, J.E., 2007. Copper recycling and scrap availability. Resources Policy, 32(4), 183-190. doi:10.1016/j.resourpol.2007.08.002

Granger, C., 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica, 37(3), 424-438. doi:10.2307/1912791

Gu, C. & Hibbert, A.M., 2018. Expectations and Financial Markets: Lessons from Brexit. Available at SSRN: https://ssrn.com/abstract=2874646 or http://dx.doi.org/10.2139/ssrn.2874646

Guo, J., 2018. Co-movement of international copper prices, china's economic activity, and stock returns: Structural breaks and volatility dynamics. Global Finance Journal, 36, 62-77. doi:10.1016/j.gfj.2018.01.001

Guzmán, J., & Silva, E., 2018. Copper price determination: Fundamentals versus non-fundamentals. Mineral Economics, 31(3), 283-300. doi:10.1007/s13563-017-0130-y

Habib, B.A., Sayed, S., & Elsayed, G.M., 2018. Enhanced transdermal delivery of ondansetron using nanovesicular systems: Fabrication, characterization, optimization and ex-vivo permeation study box-cox transformation practical example. European Journal of Pharmaceutical Sciences, 115, 352-361. doi:10.1016/j.ejps.2018.01.044

Hadi, A.R.A., Yap, E.T.H., & Zainudin, Z., 2019. The effects of relative strength of USD and overnight policy rate on performance of Malaysian stock market--evidence from 1980 through 2015.(U.S. dollar)(report). Contemporary Economics, 13(2), 175. doi:10.5709/ce.1897-9254.306

Hassler, U., & Wolters, J. (1994). On the power of unit root tests against fractional alternatives. *Economics letters*, *45*(1), 1-5.

HKEX, Hong Kong Exchanges and Clearing Market, www.hkex.com.hk/?sc_lang=en

Hossain, M.S., & Mitra, R., 2017. The determinants of price inflation in the united states: A multivariate dynamic cointegration and causal analysis.(report)(abstract). Journal of Developing Areas, 51(1), 153. doi:10.1353/jda.2017.0009

ICSG, International Copper Study Group. Copper Factbook 2018 www.icsg.org/

Johansen, S. (2008). A representation theory for a class of vector autoregressive models for fractional processes. *Econometric Theory*, 651-676.

Johansen, S., & Nielsen, M. Ø. (2010). Likelihood inference for a nonstationary fractional autoregressive model. *Journal of Econometrics*, *158*(1), 51-66.

Johansen, S., & Nielsen, M. Ø. (2012). Likelihood inference for a fractionally cointegrated vector autoregressive model. *Econometrica*, *80*(6), 2667-2732.

Johansen, S., 1988. Statistical-analysis of cointegration vectors. Journal of Economic Dynamics & Control, 12(2-3), 231-254. doi:10.1016/0165-1889(88)90041-3

Kagraoka, Y., 2016. Common dynamic factors in driving commodity prices: Implications of a generalized dynamic factor model. Economic Modelling, 52, 609-617. doi:10.1016/j.econmod.2015.10.005

Khalfaoui, R., Sarwar, S., & Tiwari, A.K., 2019. Analysing volatility spillover between the oil market and the stock market in oil-importing and oil-exporting countries: Implications on portfolio management. Resources Policy, 62, 22-32. doi:10.1016/j.resourpol.2019.03.004

Kleinman, G., 2013. Trading commodities and financial futures: A step-by-step guide to mastering the markets, fourth edition (4th ed.) FT Press. 4 The Futures Primer

Kwiatkowski, D., Phillips, P. C., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of econometrics*, *54*(1-3), 159-178.

Lambrechts, H., & Muganiwa, K., 2019. The impact of convenience yield on soybean futures contracts trading on safex. Management Dynamics, 28(1), 4-16.

Lee, D., & Schmidt, P. (1996). On the power of the KPSS test of stationarity against fractionally-integrated alternatives. *Journal of econometrics*, *73*(1), 285-302.

Leybourne, S.J., & Mccabe, B.P.M., 1994. A consistent test for a unit root. Journal of Business & Economic Statistics, 12(2), 157-166. doi:10.2307/1391480

Lim, K.G., Nomikos, N.K., & Yap, N., 2019. Understanding the fundamentals of freight markets volatility. Transportation Research Part E, 130, 1-15. doi:10.1016/j.tre.2019.08.003

LME, London Metal Exchange, www.lme.com

Nasir, M.A., & Morgan, J., 2018. Pre-Brexit: The EU referendum as an illustration of the effects of uncertainty on the Sterling exchange rate. Journal of Economic Studies, 45(5), 910-921.

Ng, S., & Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power. *Econometrica*, *69*(6), 1519-1554.

Oehler, A., Horn, M., & Wendt, S., 2017. Brexit: Short-term stock price effects and the impact of firm-level internationalization. Finance Research Letters, 22, 175-181.

Osborne, J.W., 2010. Improving your data transformations: Applying the box-cox transformation. Practical Assessment, Research & Evaluation, 15(12).

Otero, J., & Smith, J., 2012. Response surface models for the Leybourne unit root tests and lag order dependence. Computational Statistics, 27(3), 473-486. doi:10.1007/s00180-011-0268-y

Otto, S.W., 2011. A Speculative Efficiency Analysis of the London Metal Exchange in a Multi-Contract Framework. International Journal of Economics and Finance 3: 3–16.

Paraschiv, F., Mudry, P., & Andries, A.M., 2015. Stress-testing for portfolios of commodity futures. Economic Modelling, 50, 9-18. doi:10.1016/j.econmod.2015.06.005

Park, J., & Lim, B., 2018. Testing efficiency of the London Metal Exchange: New evidence. International Journal of Financial Studies, 6(1), 32. doi:10.3390/ijfs6010032

Pedersen, M., 2019. The impact of commodity price shocks in a copper-rich economy: the case of Chile. Empirical Economics, 57(4), 1291-1318

Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335-346.

Qadan, M. (2019). Risk appetite and the prices of precious metals. Resources Policy, 62, 136-153. doi:10.1016/j.resourpol.2019.03.007

Robinson, P. M. (1994). Efficient tests of nonstationary hypotheses. *Journal of the american statistical association*, *89*(428), 1420-1437.

Robinson, P. M., & Yajima, Y. (2002). Determination of cointegrating rank in fractional systems. *Journal of Econometrics*, *106*(2), 217-241.

Robinson, P.M. and Marinucci, D. (2003). Semiparametric frequency domain analysis of fractional cointegration, in P.M. Robinson eds., Time Series with Long Memory, Oxford.

Rutledge, R., Karim, K., & Wang, R., 2013. International copper futures market price linkage and information transmission: Empirical evidence from the primary world copper markets. Journal of International Business Research, 12(1), 113-131.

Samsi, S.M., Cheok, C.K., & Yusof, Z., 2019. Financial crisis, stock market and economic growth: Evidence from ASEAN-5. Journal of Southeast Asian Economies, 36(1), 37. doi:10.1355/ae36-1e

Shaikh, I., 2018. The Brexit and investors' fear. Ekonomski pregled, 69 (4), 396-422. Retrieved from https://hrcak.srce.hr/205514

SHFE, Shanghai Futures Exchange, www.shfe.com.cn/en

Shao, L., Zhu, X., Huang, J., & LI, H., 2013. Empirical study of speculation roles in international copper price bubble formation. *Transactions of Nonferrous Metals Society of China, 23*(8), 2475-2482. doi:10.1016/S1003-6326(13)62757-0

Škrinjarić, T., 2019. Stock market reactions to Brexit: Case of selected CEE and SEE stock markets. International Journal of Financial Studies, 7(1), 7.

Tsay, R. S. (2010). *Analysis of financial time series* (3rd edition. ed.). Hoboken, NJ: Hoboken, NJ : Wiley.

Valiante, D., 2015. Three narratives on the changing face of global commodities market structure. Kredit Und Kapital, 48(2), 243-308. doi:10.3790/ccm.48.2.243

Watkins, C., & McAleer, M. (2002). Cointegration analysis of metals futures. *Mathematics and computers in simulation*, *59*(1-3), 207-221.

Yao, H., & Memon, B.A., 2019. Network topology of FTSE 100 index companies: From the perspective of Brexit. Physica A-Statistical Mechanics and its Applications, 523, 1248-1262. doi:10.1016/j.physa.2019.04.106

Yao, Y. C. (1988). Estimating the number of change-points via Schwarz'criterion. *Statistics & Probability Letters*, *6*(3), 181-189.

Appendix I

Date	Key event
17/12/2015	The European Union Referendum Act providing for a referendum on the UK's future membership of the EU receives Royal Assent.
22/02/2016	The Prime Minister announces the EU referendum date – 23 June 2016.
23/06/2016	The UK referendum on membership in the EU results in a majority vote in favour of exit (51.9% versus 48.1% of voters).
24/06/2016	Prime Minister David Cameron announces his intention to resign.
13/07/2016	Theresa May becomes the new UK Prime Minister.
03/10/2016	In her Party Conference speech, Theresa May announces a 'Great Repeal Bill' and confirms Article 50 will be triggered before the end of March 2017.
03/11/2016	The High Court rules in favour of the claimants in the Gina Miller case. The Government announce they will appeal the decision.
17/01/2017	The Prime Minister delivers her Lancaster House speech, setting out the

	Government's 'Plan for Britain' and the priorities that the UK will use to negotiate Brexit.
24/01/2017	The Supreme Court rejects the Government's appeal of the Gina Miller case.
26/01/2017	The Government publish European Union (Notification of Withdrawal) Bill.
02/02/2017	The Government publish the Brexit White Paper, formally setting out the strategy for the UK to leave the EU.
16/03/2017	The European Union (Notification of Withdrawal) Act receives Royal Assent.
29/03/2017	The Prime Minister triggers Article 50 of the Treaty on European Union.
30/03/2017	The Government publish the Great Repeal Bill White Paper
18/04/2017	The Prime Minister calls a General Election for 8 June 2017.
08/06/2017	The General election results in a hung Parliament, the Conservatives' win of a simple majority enable Theresa May to form a Government.
19/06/2017	The first round of UK-EU exit negotiations begin.
21/06/2017	The Queen's Speech at the State Opening of Parliament includes a reference to the 'Great Repeal Bill'.
13/07/2017	The Government introduce the European Union (Withdrawal) Bill, commonly referred to as the 'Great Repeal Bill'.
12/09/2017	The EU Withdrawal Bill passes Second Reading in the House of Commons.
22/09/2017	The Prime Minister delivers her key Brexit speech in Florence, setting out the UK's position on moving the Brexit talks forward.
20/10/2017	The European Council hold a meeting to assess progress on the first phase of Brexit negotiations.
13/11/2017	The Government outline plans for a Withdrawal Agreement and Implementation Bill.
08/12/2017	The UK and EU publish a Joint Report on progress made during Phase 1 of negotiations. This concludes Phase 1 of negotiations and both sides move to Phase 2.
11/12/2017	The Prime Minister updates Parliament on Brexit negotiations.
18/01/2018	The European Union (Withdrawal) Bill has its First Reading in the House of Lords.
02/03/2018	The Prime Minister gives a speech at Mansion House on the UK's future economic partnership with the European Union
14/03/2018	European Parliament endorses a resolution laying out a possible association agreement framework for future EU-UK relations after Brexit.
19/03/2018	The amended Draft Withdrawal Agreement is published.
16/05/2018	The European Union (Withdrawal) Bill passes House of Lords stages with ensuing parliamentary ping pong.
26/06/2018	The European Union (Withdrawal) Bill receives Royal Assent and becomes an Act of Parliament: the European Union (Withdrawal) Act.
06/07/2018	The Cabinet meets at Chequers to agree a collective position for the future Brexit negotiations with the EU.
09/07/2018	David Davis resigns as Secretary of State for Exiting the European Union and is replaced by Dominic Raab.
24/07/2018	The Government publish the White Paper on future UK-EU relations.
23/08/2018	The Government publish the first collection of technical notices providing guidance on how to prepare for a no-deal Brexit.
19/09/2018	EU leaders hold an informal summit in Salzburg.
29/10/2018	The last budget before the UK leaves the EU is passed on Budget Day.
14/11/2018	The Withdrawal Agreement is passed and published.
15/11/2018	The Brexit Secretary resigns as Secretary of State for Exiting the European Union and is replaced by Stephen Barclay the following day.
26/11/2018	At a special meeting of the European Council, EU27 leaders endorse the Withdrawal Agreement and approve the political declaration on future EU-UK relations.
04/12/2018	MPs begin the first of five days of Brexit debates, leading up to the 'Meaningful Vote' on 11 December.
05/12/2018	The Government publish the Attorney General's legal advice to Cabinet on the Protocol to the Withdrawal Agreement on Ireland and Northern Ireland.
10/12/2018	The CJEU rules on the Wightman case, finding unilateral revocation of Article 50 TEU to be a sovereign right for any Member State. The Prime Minister pulls the

	final vote on her Brexit deal planned for the next day.
11/12/2018	Theresa May wins a vote of confidence in her leadership of the Conservative Party.
08/01/2019	In the Report Stage and Third Reading of Finance (No. 3) Billthe Prime Minister is defeated, with MPs approving an amendment that would limit the Government's financial powers in the event of a no-deal Brexit.
09/01/2019	As five days of Brexit debates begin – leading to a 'Meaningful Vote' on 15 January – an amendment to the business motion is passed, giving the Prime Minister only three days, as opposed to the original 21, to present a 'Plan B' Brexit plan if she loses meaningful vote.
15/01/2019	The Prime Minister loses the 'Meaningful Vote' and the Leader of the Opposition tables a motion of no confidence in the Government.
16/01/2019	The Prime Minister wins a vote of confidence in the Government.
21/01/2019	Theresa May presents the government's 'Plan B' Brexit deal.
29/01/2019	MPs debate the Prime Minister's 'Plan B' deal, which is then approved following two amendments.
14/02/2019	The Government's Brexit plan suffers a defeat in the House of Commons.
26/02/2019	The Prime Minister promises MPs a vote on ruling out a no-deal Brexit or delaying Brexit if she loses the second 'Meaningful Vote' next month
12/03/2019	The Prime Minister loses 'Meaningful Vote 2'.
13/03/2019	In a defeat for the Prime Minister, MPs vote to rule out a 'no-deal Brexit'.
14/03/2019	MPs approve the amended Government's motion, instructing the Government to seek permission from the EU to extend Article 50.
20/03/2019	The Prime Minister writes to European Council President Donald Tusk, asking to extend Article 50 until 30 June 2019.
21/03/2019	Following a meeting of the European Council, EU27 leaders agree to grant an extension comprising two possible dates: 22 May 2019, should the Withdrawal Agreement gain approval from MPs next week; or 12 April 2019, should the Withdrawal Agreement not be approved by the House of Commons.
27/03/2019	Commons debates and votes on eight indicative votes, in an attempt to find a Brexit plan that wins the support of the majority of MPs. All options are defeated.
29/03/2019	The Prime Minister loses 'Meaningful Vote 3'.
01/04/2019	In the second day of indicative votes, all four of the selected options are defeated.
02/04/2019	The Prime Minister announces she will seek a further extension to the Article 50 process and offers to meet with the Leader of the Opposition to finalise a deal that will win the support of MPs.
05/04/2019	Theresa May formally writes to Donald Tusk, requesting a further extension to the Article 50 process to the end of June 2019.
10/04/2019	The European Council meets. The UK and EU27 agree to extend Article 50 until 31 October 2019.
21/05/2019	The Prime Minister unveils her new Brexit deal.
23/05/2019	The UK votes in the European Parliament elections.
23/07/2019	Boris Johnson wins the Conservative Party leadership race.
24/07/2019	Boris Johnson formally takes over as Prime Minister.
25/07/2019	Prime Minister Johnson makes a statement in the House of Commons and commits to the October date for Brexit and – while hoping for a renegotiation of the Withdrawal Agreement – refuses to rule out the possibility of a 'no-deal' Brexit.
04/09/2019	With the Commons passing Hilary Benn's European Union (Withdrawal) (No. 6) Bill, the Prime Minister moves to hold an early General Election. The motion is defeated.
09/09/2019	The Benn bill becomes law: the European Union (Withdrawal) (No. 2) Act 2019 and parliament prorogues
24/09/2019	The Supreme Court unanimously rules that the decision to prorogue Parliament was unlawful. The Speaker of the House of Commons announces that the House will sit again the next day.
25/09/2019	Both Houses of Parliament sit again.
03/10/2019	The Prime Minister delivers a statement to Commons outlining the Government's proposals for a new Brexit deal.
08/10/2019	The Government publish the No-Deal Readiness Report, detailing the UK's preparedness ahead of Brexit on 31 October.

19/10/2019	At a rare Saturday sitting of Parliament the Prime Minister presents his new Brexit deal, but is defeated when the Letwin amendment is passed. The PM later writes to Donald Tusk, in accordance with the Benn Act, to ask for a Brexit extension.
21/10/2019	The European Union (Withdrawal Agreement) Bill is introduced to Parliament.
22/10/2019	The EU (Withdrawal Agreement) Bill passes its second reading, but the programme motion setting out the timetable is defeated. The PM pauses the legislation.
28/10/2019	EU Ambassadors agree to a Brexit extension to 31 January 2020. The Prime Minister confirms the UK's agreement to this extension.
30/10/2019	The Government table the Early Parliamentary General Election Bill, which sets the date for a general election on 12 December. The Bill passes its Commons stages.

Appendix II

Companies conforming BUKHI50P, Brexit CBOE High 50

Code	Name
IIIl	3i Group
ADMl	Admiral Group
ABFl	Associated British Foods
AUTOl	Auto Trader Group
AVl	Aviva
BAl	BAE Systems
BARCl	Barclays
BDEVl	Barratt Developments
BKGl	Berkeley Group Holdings
BPl	BP
BLNDl	British Land Co /The
BTl	BT Group
CNAl	Centrica
DCCl	DCC
DLGl	Direct Line Insurance Group
EXPNl	Experian
FLTRl	Flutter Entertainment
HLl	Hargreaves Lansdown
IAGl	International Consolidated Airlines Group SA
ITVl	ITV
SBRYl	J Sainsbury
JDl	JD Sports Fashion
JMATl	Johnson Matthey
JEl	Just Eat
KGFl	Kingfisher

Code	Name
LANDl	Land Securities Group
LGENl	Legal & General Group
LLOYl	Lloyds Banking Group
LSEl	London Stock Exchange Group
MKSl	Marks & Spencer Group
NGl	National Grid
NXTl	Next
OCDOl	Ocado Group
PSNl	Persimmon
PHNXl	Phoenix Group Holdings
RMVl	Rightmove
RBSl	Royal Bank of Scotland Group
SGEl	Sage Group /The
SDRl	Schroders
SGROl	Segro
SVTl	Severn Trent
SSEl	SSE
STJl	St James's Place
SLAl	Standard Life Aberdeen
TWl	Taylor Wimpey
TSCOl	Tesco
TUIl	TUI AG
UUl	United Utilities Group
WTBl	Whitbread
MRWl	Wm Morrison Supermarkets