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Analysis on Causality between Speculation and Futures Prices of Non-ferrous Metals

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Abstract

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The environment of international commodity markets such as metals and energy, including non-ferrous metals, has undergone substantial changes in the 21st century. The financialization of commodity market was obvious and this led financial investors step into commodity markets such as non-ferrous metals. The commodity has become a very attractive asset class to financial investors. The London Metal Exchange (LME) is the central exchange across the globe for non-ferrous metals and provides commodity trade of options and futures. This thesis analyzes the impact of speculative positions on futures prices of major non-ferrous metals using a time series analysis model to determine the impact of the financialization trend over the international commodity price.

There are many studies that analyze the impact of speculation on the price of non-

ferrous metal futures. However, only few studies have conducted analysis on the minor non-ferrous metals including the six major non-ferrous metals on the London Metal Exchange (LME). Previous studies analyzing the impact of speculative transactions in the LME market have covered some or all of the six major non-ferrous metals including Copper, Lead, Nickel, Zinc, Aluminium High, and Tin. However, there are two types of non-ferrous metals that can be analyzed in LME, Aluminium Alloy and North American Special Aluminium Alloy Contract (NASAC). Therefore, this thesis analyzes total 8 metals including six major non-ferrous metals and two Aluminium Alloys to analyze the impact of speculative transactions in the current LME non-ferrous futures market on futures prices.

This paper examined the effects of speculative transactions on futures prices of 8 non-ferrous metals traded in LME through the Ganger-causality analysis. For the analysis, the structural long-term time series analysis model, Vector Error Correction Model (VECM) and Vector Autoregressive (VAR), were used.

Based on the Commission of Traders Report (COTR) provided by LME, this study used the position of non-commercial traders on the non-ferrous metals futures market as a variable representing speculative trading. The futures price of each non-ferrous metal was used as a variable by the closing price of the LME. Previous studies mainly used VAR models to analyze the impact of speculation on futures prices, where the use of the VECM model is more appropriate for long-term equilibrium analysis if there is a cointegration relationship between variables. Thus, this study used VAR and VECM models to analyze the existence and causal relationship between speculation and futures prices according to the form of data by confirming cointegration.

First, the weekly basis analysis examined the causal relationship between the futures price and speculative positions. Cointegration test were not testable for all 7 non-ferrous metals, except Zinc. As a result of the analysis, cointegration is only found Zinc and it confirms that speculative position and futures prices in a bilateral causal relationship in long and short-term. The remaining 7 non-ferrous metals were analyzed through VAR models and they confirmed that futures prices cause speculative position in the short-term except for NASAAC.

Secondly, the causal relationship between speculative position and futures prices was analyzed on monthly basis. First of all, cointegration between speculative position and futures prices was identified in Copper, Aluminium Alloy and NASAAC. Based on the analysis, the futures price in the short-term on Copper and NASAAC caused speculative position, but no causal relationship between variables was confirmed in Aluminium Alloy. All other 5 non-ferrous metals showed different causal relationships. Lead was the only one confirmed that speculative position causes futures prices in single direction.

A weekly or monthly analysis of all 8 non-ferrous metals on the LME confirmed that futures prices cause speculative positions. Among them, non-ferrous metals that have a causal relationship in both directions between futures prices and speculative position are Aluminium, Copper, Zinc, and Aluminium Alloy. Most of these non-ferrous metals tend to have relatively high trading volume. However, Lead shows conflicting causal relationships in the weekly and monthly analysis.

The implications of this study are as follows: It is necessary to recognize that LME's transactions of non-ferrous metals are a place where commercial and speculative traders simultaneously form prices and positions differently for each nonferrous metal depending on the nature of market environment. This thesis analyzes the causal relationship between futures prices and speculative position in each non-ferrous metal to provide insight to investors decision-making and strategy. Unlike previous studies, this study identified whether speculation exists in the long-term through cointegration. This provides implications such that it is possible to provide investors with appropriate strategies of speculation and hedging considering the characteristics of each non-ferrous metal.

Keywords: Speculation; Cointegration; Granger-causality; LME; Non-ferrous Metal
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Chapter 1. Introduction

1.1. Research Background and Purpose

Speculation is defined as the actions of purchasing or selling goods with re-sale or re-purchase at later dates where the motivation behind is at the expectation of changes in prices in the future to gain relative returns but not coming from gaining returns by using them (Kaldor, 1939). Since the tulip mania in the 1630s, as financial crisis has been considered attribution of speculation such as financial crisis of 2008 in housing and derivative securities, there has been a number of studies that examine the effects of speculation on financial markets.

The market environment of commodity trading has undergone substantial changes over the last century. As commodity markets are financialized, commodity has become an extremely attractive asset class for investors. Commodity futures markets are amplified by an emerging popularity of index related financial products, which is often associated with the increased trading activities in the markets (Tang and Xiong, 2012). The controversy is whether commodity price is distorted by the financialized commodity market. During 2000s, prices of commodities showed the rapid rise and the number of financial investors trading in commodity futures market increased, which let observers question whether the market is destabilized (Cheng and Xiong, 2014).

Although commodities are the essential substances in the earliest production stage for producers and consumers, they are traded as financial assets in futures market. As both commercial and non-commercial traders participate in the market, traders take short or long positions to hedge or speculate the market prices. There has been a number of research conducting analysis of speculative effect over futures price of various commodities such as agriculture, gold, oil on different exchange markets. Buyuksahin et al. (2009) argued that the oil price rises as non-commercial traders increase their investment in financial commodity products. Moreover, there is a statistically significant relationship identified between index trading and agriculture commodity price (Gilbert, 2010). On the other hand, there are relatively small number of studies examining the speculation effects on the London Metal Exchanges (LME) market.

Most studies examining the effects of speculation in futures market employed official data such as Commitments of Traders (COT) issued by the exchanges. The COT provides a detailed position information by various types of traders who take positions in a specific commodity.

The purpose of this thesis is to examine speculation on the LME non-ferrous metal futures market by analyzing data from the Commitment of Traders Report (COTR) and futures prices. This thesis conducts cointegration test and Granger-causality test to identify a statistically significant relationship between non-commercial traders' position and futures prices of the LME market analyzing the period from October 2015 to December 2020.

This thesis aims to identify the causal relationship between the futures price and non-commercial trader's position with the following hypothesis:

Hypothesis 1: The futures price and non-commercial trader's position is cointegrated.

Hypothesis 2: There is a bilateral causal relationship between the futures price and non-commercial trader's position.

1.2. Theoretical Background

Before diving into the discussion of the effects of speculation on commodity price and volatility, it is important to understand how the financialized commodity market attracts investors to decide their capital investment in the market. Therefore, this chapter presents traditional speculation theory first by listing the pre-requisites of speculation. Second, economic demonstration of speculation in futures market which interprets investors behavior by prices in the market is examined. Lastly the role of speculation in the market is presented.

1.2.1. Pre-requisites of Speculation

Traditional theory of speculation views that speculative activity evens out fluctuations in price coming from changes in the mechanism of demand and supply since the assumption behind the theory is that speculators have better foresight so that they step in the market as buyers when there is oversupply by moderating the price-fall. They also step in the market when there is a deficiency of supply while moderating the price-rise as sellers (Kaldor, 1939). However, the argument implies that speculative activity can influence the magnitude of the price-change but not the direction of the price-change since the proportion of it is relatively small compared to the total and there is underlying non-speculative factors in the market (Keynes, 1936).

Speculators endures the bearing of value risks and try to exclude predictable risks which can diminish their chance of gaining from their foresight regarding changes in value. Therefore, the commodity futures market has developed a high standard of contract with perfection, liquidity, and security in order to fulfill the obligations of contracts, which attracts speculators to step in the market (Blau, 1944).

Kaldor (1939) defines two main conditions that must be satisfied to be economic objects of speculative activity, which are the existence of a perfect or semi-perfect market and low carrying cost. The presuppose of these two conditions is that the good is fully standardized, article of general demand, durable and valuable proportionally.

The first two presupposes support the first condition of speculation, which are indispensable for any goods to develop a perfect market in exchange. The last two provide low carrying cost by ensuring durability of goods generating less wastage and less cost of storage, respectively.

1.2.2. Economic of Speculation in Futures Market

Commodity market mostly consists of the cash and futures market where the cash market is to purchase or sale commodities or securities while receiving goods at the point of purchase or sale and the futures market is an auction to buy and sell forward contracts for delivery on a specific maturity date.

Trades in the cash market and the futures market might be either spot or forward transactions. Therefore, there will be four different forms of price quotations for the markets developed futures trading for standard grade of a commodity (Blau, 1944):

(*I*) *Cash spot price, the price ruling in the cash market for spot delivery*;

(*II*) *Cash forward price, the price ruling in the cash market for deferred delivery*;

(*III*) *Future spot price, the price ruling in the futures market for spot transaction*;

(*IV*) *Futures forward price, the price ruling in the cash market for forward transaction*

The trading system in futures market shows that prices of cash and futures market move together. Since the effects of hedging in the market neutralize price risks in the cash market with opposite risk assumption in the futures market, the effectiveness of hedging shall be impaired to extent to which the movements of cash and futures prices diverge for speculators. With the assumption above, if futures forward prices were higher than cash forward prices at any time then arbitrage could be made with a profit by buying forward in the cash market and selling forward in the futures market simultaneously. When the maturity date of forward contract arrives, contractor fulfills the futures contract by delivering the commodities bought for deferred delivery in the cash market.

On the other hand, if cash prices were higher than futures prices, arbitrageurs who holds maturing buying contracts in the futures market demand the actual delivery and re-sell the commodities in the cash market at any time rather than liquidate their position by selling futures since they find it feasible.

In the following, the relation of cash and futures prices in the market is described to refer to the close link of the series of futures prices with the parallel series of cash prices in the market. Considering the relation of cash and futures prices in the market, the relation shall be written in algebraical form denoting interest cost by i, carrying cost by c and the marginal risk premium by r such that

$$EP - CP = i + c + r$$

$$FP - CP = i + c$$

$$Hence\ FP = EP - r$$

where EP, CP and FP is expected price, cash price and futures price, respectively. In the theory of the forward market by Keynes (1930), backwardation is defined as the negative carrying cost should equal the sum of interest and risk premium if there is no speculation, i.e. $EP = CP$, then $-c = i + r$, which implies $FP = CP - r$. In this case, a hedger is willing to bear a risk premium by expose themselves of price risk, while a speculator is willing to enter the futures market if they see the expectation of gaining premiums. Hence, the current future or forward price must decrease below the expected future price by the amount of the risk premium since hedgers take short position in futures and speculators take long position predominately (Johnson, 1960).

1.3. Literature Review

The studies analyzing the LME market is mainly focused on discussing the market efficiency by analyzing the relationship between the cash and futures market, the behavior of metal prices by conducting price modelling or forecasting and the speculation effects on the market. Most studies analyzing the LME market focus on non-ferrous metals since it is the most important centre of cash and futures trading in the main industrially-used non-ferrous metal whereas other metals traded in the LME market are relatively new material compared to the base metals. After Keynes invested in Tin in the LME market during 1920s as a speculator, there have been a number of studies analyzing his outcomes and the effects of speculation in other metals on the LME market over time (Chambers, Dimson & Foo, 2015). Furthermore, there are a number of researches noting the industrial metal sector has gone financialized in general. The industrial metals can give us signals of general financial status in markets by revealing returns in equity markets (Jacobsen et al., 2016). As a growing co-movement between industrial metals and equity markets is identified as early as 2003 and this co-movement spreads to all commodity classes and becomes unambiguously stronger with the global financial crisis in 2008 (Delatte and Lopez, 2013).

1.3.1. Pricing of Metals

The LME offers opportunities to invest in several non-ferrous metals, such as Aluminium, Aluminium Alloy, Copper, Lead, NASAAC, Nickel, Tin and Zinc. All these metals are important in industrial sectors. The price volatility of these industrial metals has attracted attention within the industry. Furthermore, non-ferrous metals have recently been attractive assets to investors and speculators. Therefore, non-ferrous metals have become major financial commodities and attracted researcher to analyze their pricing.

Most previous research estimated price functions of cash price and futures price of metal commodities implemented ARIMA to forecast their forward price levels (Lasheras et al., 2015; Dooley et al., 2005; Liu et al., 2020; Kriechbaumer et al., 2014). Lasheras et al. (2015) and Liu et al. (2020) conducted several estimations to find the best fit for price forecasting by comparing their performance such as Neural Network (NN) and concluded NN shows better performance in forecasting the cash price of Copper from COMEX and futures price of Zinc, Copper and Aluminium from the LME.

On the other hand, there is no conclusive evidence identified that a superior forecasting model providing better performance in the different analysis period on the cash and futures prices of Lead and Zinc from the LME (Dooley et al., 2005). As a price discovery function may be identified in periods of low volatility or small previous spreads (Beckmann et al., 2013), the performance and presence of price functions may differ depending on the periods analyzed. Liu et al. (2014) estimated and confirmed the presence of correlation of price jumps and price-volatility of Copper and Aluminium on the Yangtze Non-ferrous Metals Market for cash transaction and on the Shanghai Futures Exchange (SHFE) for futures.

Beckmann et al. (2013) and Dooley et al. (2005) confirmed that there is cointegration relationship between the cash price and futures price on the LME during different time periods for Aluminium, Nickel, Zinc and Copper, which may provide insights that the pricing models of the cash and futures for most non-ferrous metals on the LME can be simplified into single functions.

Table 1. Summary of Literature Review (Estimation of Metal Pricing)

Author(s)	Data	Methodology	Variables	Major Findings
Liu et al. (2014)	Time series (2003 - 2011)	Stochastic Model (Volatility)	- Spot price of Copper & Aluminium from the Yangtze Non-ferrous Metals Market - Futures price of Copper & Aluminium from the SHFE	In-sample estimation confirms the presence of correlation of price jumps and price-volatility.
Beckmann et al. (2013)	Time series (1991.01 - 2011.10)	Regression (Fama)	- Spot price of Aluminium, Nickel, Zinc and Copper from the LME - Futures price of Aluminium, Nickel, Zinc and Copper from the LME	A price discovery function can in most cases only be identified in periods of low volatility or small previous spreads
Lasheras et al. (2015)	Time series (2002.01 - 2014.01)	ARIMA, NN (Elman)	- Spot price of Copper from the COMEX	NN model shows better performance in forecasting the spot price level.

Author(s)	Data	Methodology	Variables	Major Findings
Dooley et al. (2005)	Time series (1988.11 - 1999.12)	ARIMA	- Spot price of Lead and Zinc from the LME - Futures price of Lead and Zinc from the LME	There is no conclusive evidence that a superior forecasting model dominates the performance
Liu et al. (2020)	Time series (2006.06 - 2019.03)	ARIMA, NN (LSTM)	- Futures price of Zinc, Copper & Aluminium from the LME	NN model shows better performance in forecasting the futures price level.
Kriechbaumer et al. (2014)	Time series (1960.01 - 2012.04)	ARIMA (Wavelet)	- Price of Aluminium, Copper, Lead and Zinc	Wavelet transform improves the performance of ARIMA model for price forecasting

1.3.2. Speculation

As the commodities become an attractive financial asset, speculators participate the markets to make profits, which bring questions to market if there is efficiency from the speculative activities. Agyei-Ampomah et al. (2014) analyzed risk-free asset properties in Copper against sovereign bond adverse events. Metals are often considered as assets with less risk during financial turmoil and non-ferrous metals used to be considered as a hedging product. However, the increased trade in metal markets raised the price volatility (Watkins and McAleer, 2006; Watkins and McAleer, 2008). As there is more demand in speculative trade, the analysis and prediction of prices are gone challenging as well as price driven by changes in industrial production.

Through the earlier research that analyzed the price volatility of non-ferrous metals on the LME over the period from 1972 to 1995, the clear evidence is found that: (i) the intense speculation in the market from 1993 to 1995 increased the price volatility; (ii) there is cyclicity in the price level; (iii) the price volatility should analyzed by decomposition of long-run and short-run components due to different broad factors such as speculative trade and fundamental influence (Brunetti and Gilbert, 1995; Davutyan and Roberts, 1994; McMillan and Speight, 2001).

Roberts (2009) analyzed the cyclicality of metal prices but could not conclude the metal prices follow random walk demonstrating some cyclicality since the cycle are not fully predictable. Watkins and McAleer (2008) forecasted the price volatility with daily returns on the metal futures prices using the AR(1) and GARCH (1,1) model with data from 1976 to 2006 for Aluminium and Copper. The results showed that the time-varying nature of volatility while the performance of forecasting was weaken during the shocks in 1987. Lien and Yang (2008) investigated Shanghai Futures Exchange (SHFE) to identify different hedging strategies on futures of Aluminium and Copper. The results showed that markets behave differently according to the basis, positive or negative. Todorova (2015) analyzed the dynamics of realized volatility on the LME non-ferrous metals over the period from 2004 to 2012 and highlighted an increasing importance of short-term volatility components and superior forecasting ability of a simple HAR model.

The increased interest in commodity markets in general, and particularly in non-ferrous metals, derived the markets greatly relevant for market effects such as spillover effects, portfolio strategy and contango. Li and Zhang (2013) and Hua and Chen (2007) examined SFHE and LME market, specifically for Copper and Aluminium, and found linkages between them while the LME was highly dominant. However, Li and Zhang (2013) showed that the LME is slowly fading against the SFHE. Aruga and Managi (2011) found that there is little linkage between Copper and Brass. Sensoy et al. (2015) analyzed convergence effect in the base industrial metals and Singhal and Ghosh (2016) analyzed linkage between the base metals and the Indian equity indices but provided a limited results.

Chevallier and Ielpo (2013) and Todorova et al. (2014) discussed that there is a number of research on volatility spillover in agricultural, energy and precious metals commodities but not much on industrial metals. Diebold and Yilmaz (2009, 2012) found little evidence of spillovers between Aluminium, Copper, Lead, Nickel, and Zinc futures on the LME. Todorova et al. (2014) found that there are multi-direction spillovers between cash to futures price volatility over Aluminium and within metals.

There has been an interesting controversy within observers on commodity markets questioning the role of speculators (Brunetti et al. 2015). However, it is hard to conclude there is a consensus on the speculative impact on commodity futures markets. There are several researchers found that speculative transactions had a statistically significant impact on future price (Singleton, 2014; Buyuksahin and Robe, 2009; Buyuksahin et al, 2009; Gilbert, 2010) while some researchers found opposite results (Buyuksahin and Harris , 2011; Sanders et al., 2010; Irwin and Sanders, 2012).

Singleton (2014) found that the intermediate-term growth rate of index position and spread position showed the greatest speculative impact in oil future markets. Moreover, he found that a specific trading position held by hedge fund in spread is associated with the term structure of oil futures price. Buyuksahin et al. (2009) showed an evidence of causality between oil price and non-commercial traders. The result showed that the increase in the number of non-commercial traders in the oil market caused the increase in concurrent oil price during 2000 - 2008. Buyuksahin and Robe (2009) provided an evidence of co-movements between energy and equity in energy market while showing the impact of equity providers in the market gone weakened during financial turmoil. Gilbert (2010) conducted Granger-causality analysis to find the huge investment in index-based products in agricultural futures markets transmits the rapid food price increase between 2007 and 2008.

Buyuksahin and Harris (2011) highlighted the role of speculators as oil futures price peaked in July 2008. Park and Lim (2018) examined the efficiency of the LME market and found the LME market inefficient. They conducted Granger-causality test to analyze the relationship between metal price and the trader's position in the LME futures market. Moreover, they showed with weak evidence but there is causality relationship between the speculator's position changes and oil price changes. Irwin and Sanders (2012) conducted Granger-causality test but could not find significant causality relationships between returns or volatility with the trader's positions in crude oil and in natural gas. Brunetti and Buyuksahin (2009) also conducted Granger-causality test to find a statistical relationship between swap dealers' positions and returns or volatility in crude oil, natural gas, and corn futures but the result was not statistically significant. Sanders et al. (2010) showed evidence that there is no relationship between the speculation and the returns in agricultural futures markets using COT data.

Park (2018) showed that the volatility spillover between oil and base metals with strong 1% significant level. His findings could provide strategic hedge and investment decisions in oil and LME futures market. Due to wrong assumption that the commodity markets had grown, Park and Lim (2018) conclude that the LME market was inefficient. This could imply that the LME futures market has potentially give excess returns, and so forth, more speculators are attracted to the LME market. Park (2019) investigated the canceled warrants in the LME market to explain the effects in the metal prices. He conclude that canceled warrants was important because it could be fundamentals and non-fundamentals factor explaining the price in the market. Within the metals with large transactions, the price tends to rise when the canceled warrants rises.

Arouri et al. (2011) conducted cointegration approach to examine the efficiency of speculation of the Aluminium futures in the LME. They found that futures price was cointegrated with spot price. Ferretti and Gilbert (2008) found that the price volatilities of Aluminium and Copper have long memory process due to speculative transactions.

Canarella and Pollard (1986) examined market efficiency of four base metals including Copper, Lead, Zinc, and Tin from 1975 to 1983. They utilized OLS model on non-overlapping data, while an autoregressive moving average (ARMA) process was applied to in overlapping data. The null hypothesis of market efficiency was not statistically rejected, which implies that the futures price is unbiased predictor of the future spot price. Hence, the long-term profit of speculation in the LME market is hard to succeed due to market efficiency.

There are several researches examining the Efficient Market Hypothesis (EMH) on the LME market. Gross (1988) examined EMH for Copper and Aluminium from 1983 to 1984. He found that there is a semi-strong EMH for those two metals.

MacDonald and Taylor (1988) conducted cointegration test for the data from 1976 to 1987. They found that there is EMH for Copper and Lead but not in Tin and Zinc.

Kenourgios and Samitas (2004) also conducted cointegration test for the 3-month and 15-month maturities of Copper futures contracts from 1989 to 2000. They found that there is no EMH in Copper. Using same approach, Arouri et al. (2011) showed that there is EMH for Aluminium futures for long-term and short-term.

Otto (2011) analyzed the EMH of the LME using 3-month and 15-month futures prices from 1991 to 2008 with the monthly average second ring price data. For the 3-month contracts, he found that there is EMH for all base metals except for Aluminium. He argued that Aluminium is the most liquid contract on the LME, and so forth, the EMH could not be captured. For the 15-month contracts, there is no EMH except for Lead and Tin.

Chinn and Coibion (2014) investigated the unbiasedness of futures prices in

Aluminium, Copper, Lead, Nickel, and Tin from 1997. They found that the futures prices implied a strong rejection of the null hypothesis of unbiasedness.

There is no consensus about the efficiency of speculation of the LME. Some studies have pointed incorrect econometric methodologies (Otto, 2011). Most studies used monthly data have pointed that they cannot appropriately capture the arbitrage in the trading. In particular, there has been discussion regarding how average data may lead to spurious results (Gross, 1988) .

Table 2. Summary of Literature Review (Speculation)

Author(s)	Data	Methodology	Variables	Major Findings
Otto (2011)	Time series (1991.07 - 2008.03)	ARMA	- Futures price of six base metals from the LME - Cash price of six base metals from the LME	There is speculative efficiency for 3-month & 15-month Aluminium futures and the 3-month Lead futures. The efficiency of speculation after 2000 decreases significantly.
Leone et al. (2019)	Time series (2007.01 - 2016.12)	VECM	- Gxgrwpsp Index of Chicago Board of Trade - Open interest of agriculture futures	No evidence that traders position taken in the market affects futures price.

Author(s)	Data	Methodology	Variables	Major Findings
Brunetti et al. (2011)	Time series (2005.01 - 2009.03)	VAR	- Open interest of crude oil & natural gas from NYME - Cron & eMini-Dow from CBOT, EuroDollars from CME	Speculators(swap dealer, index trader) position changes do not Lead the price changes, but rather Lead to reduce market volatility.
Park (2019)	Time series (2014.08 - 2017.07)	VAR	- Open interest of LME base six metals - Futures prices of the LME base six metals	Producers position changes do not affect price changes. Price changes Lead the position changes of speculators for all metals.

Author(s)	Data	Methodology	Variables	Major Findings
Agyei-Ampomah et al. (2014)	Time series (2008.08 - 2014.03)	VAR	- Futures price of Copper - Sovereign bond adverse events	Found that there is a safe haven status during the financial crisis in Copper futures.
Watkins and McAleer (2006)	Time series (1982.10 - 2006.07)	AR	- Futures price of Copper from the LME - Volatility of Copper futures price	Non-ferrous metals viewed as hedging products in the market, The increased activity in metals consequently increased the volatility on the markets.
Watkins and McAleer (2008)	Time series (1976.01 - 2006.07)	GARCH	- Futures price and volatility of Aluminium from the LME	Financial crisis weakens the estimation model performance.

Author(s)	Data	Methodology	Variables	Major Findings
Brunetti and Gilbert (1995)	Time series (1972 - 1995)	GARCH -	Futures prices of the LME base six metals	Metals price volatility is stationary, High volatility is associated in particular with periods of tight demand, most clearly 1973-74 and 1987-90. This is particularly clear in Aluminium and Nickel.
Davutyan and Roberts (1994)	Time series (1988.01 - 1994.01)	GARCH -	Futures prices of the LME base six metals	The futures price of six base metals is stationary. Price volatility is associated with the demand.
McMillan and Speight (2001)	Time series (1994.01 - 1999.12)	ARMA -	Futures prices of the LME base six metals	No statistically significant speculation identified in the periods for all metals.

Author(s)	Data	Methodology	Variables	Major Findings
Roberts (2009)	Time series (1947.01 - 2007.12)	GARCH -	Futures prices of the LME base six metals	The future price is not fully predictable but found that there is regularity and cyclicality demonstrated by random walk.
Lien and Yang (2008)	Time series (2000.01 - 2007.12)	VAR -	Futures prices of Copper and Aluminium from the SHFE and demand	The basis has asymmetric effects such that the markets behave differently when the basis is positive or negative
Todorova (2015)	Time series (2004.01 - 2012.09)	HAR -	Futures prices of the LME base six metals	Analysis period highlighted an increasing importance of short-term volatility components and superior forecasting ability of a simple HAR model

Author(s)	Data	Methodology	Variables	Major Findings
Li and Zhang (2013)	Time series (2003.01 - 2012.12)	VAR -	Futures prices of Copper and Aluminium from the SHFE and the LME	Found significant bivariate linkages between the SHFE and the LME, but with the LME greatly dominant
Aruga and Managi (2011)	Time series (1991.10 - 2008.10)	VAR -	Futures prices of Copper and Aluminium from the SHFE and the LME	Only found little linkage for Copper between SHFE and LME
Sensoy et al. (2015)	Time series (2000.01 - 2007.08)	VECM -	Futures prices of six base metals and precious metals	Found coordination and convergence in base metals and precious metals

Author(s)	Data	Methodology	Variables	Major Findings
Chevallier and Ielpo (2013)	Time series (2003.09 - 2011.11)	VAR	- Futures prices of six base metals	Found high frequency spillovers between the metals
Todorova et al. (2014)	Time series (2007.04 - 2013.05)	VECM	- Open interest of crude oil & natural gas - Futures prices from NYME	Found cointegration relationship between the open interest and the futures price, which means there is speculation in the market
Diebold and Yilmaz (2009)	Time series (2001.01 - 2007.12)	ARIMA	- Futures price of agriculture commodities from CBOT	No statistically significant speculation identified in the periods

Author(s)	Data	Methodology	Variables	Major Findings
Buyuksahin et al. (2009)	Time series (2002.08 - 2008.10)	VAR	- Trade volume, futures and cash price of six base metals from the LME	Granger causality identified between the trade volume and the futures price in most metals
Gilbert (2010)	Time series (2006.04 - 2010.03)	VAR	- Trade volume of six base metals from the LME - Futures and cash price of six base metals from the LME	Significant single causality of prcie over the trade volume identified.
Buyuksahin and Harris (2011)	Time series (2004.03 - 2009.12)	VAR	- Open interest of commodities on the CBOT & NYME	Various causality direction identified in the commodities

Author(s)	Data	Methodology	Variables	Major Findings
Sanders et al. (2010)	Time series (1999.01 - 2006.12)	VAR -	Futures price of crude oil from NYME	Found statistically significant causal links between daily returns or volatility in the crude oil.
Irwin and Sanders (2012)	Time series (2001.09 - 2010.12)	VAR -	Futures price of crude oil and natural gas from NYME	Found no statistically significant causal links between daily returns or volatility in the crude oil, and even natural gas futures markets and the positions for two large sample energy exchange-traded index funds using a Granger causality test.

Author(s)	Data	Methodology	Variables	Major Findings
Park (2018)	Time series (2014.10 - 2018.03)	VAR	- Cancelled warrants of LME base six metals - Trade Volume of oil futures	Found the evidence of volatility transmission between oil and base metals was strong
Arouri et al. (2011)	Time series (2007.03 - 2010.10)	VECM	- Futures price of six base metals from the LME - Cash price of six base metals from the LME	Futures Aluminium prices were found to be cointegrated with spot prices and they were the biased estimators of future spot prices
Ferretti and Gilbert (2008)	Time series (2000.01 - 2007.12)	VAR	- Futures price of six base metals from the LME, Trade volume	Aluminium and Copper volatilities follow statistically long memory process, which were caused by speculative traders

Author(s)	Data	Methodology	Variables	Major Findings
Canarella and Pollard (1986)	Time series (1975.01 - 1983.12)	ARMA	- Cash and futures price of Copper, Lead, Zinc and Tin from the LME	Found that the hypothesis of market efficiency was not statistically rejected. The futures prices were unbiased predictors of the respective future spot prices. Any strategy designed to enhance the long-term profitability of trading LME futures may not succeed as long as the market is efficient.
Gross (1988)	Time series (1979.01 - 1987.12)	ARIMA	Cash and futures price of Copper and Aluminium from the LME	Semi-strong EMH could not be rejected for both base metals

Author(s)	Data	Methodology		Variables	Major Findings
Kenourgios and Samitas (2004)	Time series (1989 - 2000)	VECM	-	Cash and futures price of six base metals from the LME	Copper market is not efficient
Chinn and Coibion (2014)	Time series (2008.01 - 2012.12)	VAR	-	Futures price of various commodities from various markets	The futures prices of precious and base metals implied a strong rejection of the null hypothesis of unbiasedness, while the futures prices in the energy and agricultural markets were consistent with unbiasedness

Chapter 2. Data and Methodology

This chapter describes the methodology and data used in the analysis. In Section 1, the data used in the empirical analysis of the thesis is described. In Section 2, methodologies including unit-root test, cointegration test, Vector Error Correction Model (VECM) and Vector Autoregressive (VAR) used in the thesis are explained first and other methodologies used in references such as ARMA and GARCH are described. The Johansen cointegration test is to identify cointegration relationship between the futures prices and non-commercial trader's position of non-ferrous metals traded in the LME market. The VECM and VAR is conducted for estimation of models to identify Granger-causality.

2.1. Data

This thesis uses weekly COTR (Commitments of traders' reports) data issued by LME from Aug 2018 to Dec 2020 and daily COTR data from Oct 2015 to Aug 2018. The COTR includes the trading positions taken by various types of non-commercial traders such as money manager, broker, dealer and index trader as well as commercial traders such as producer, merchant and user. LME started providing COTR on a weekly basis from Aug 2014, however, data from Aug 2014 to Oct 2015 is unavailable from the report open to the public. The daily data is converted to a weekly basis to expand analysis period of weekly basis. For monthly basis analysis, the average of weekly data each month is taken. These data are used to compute net futures positions. The futures prices for all non-ferrous metals including Aluminium, Aluminium Alloy, Zinc, Nickel, Tin, Copper, Lead, NASAAC are closing price of contracts expiring in 3 months obtained from Metalmetre, a licensed distributor of LME, over the same period. For monthly basis analysis, the average of weekly closing prices is taken as a price variable.

Closing futures data on non-ferrous metal contracts offered by the LME to examine data for Aluminium, Aluminium Alloy, Copper, Lead, Nickel, Tin and Zinc. These metals represent the most important non-ferrous metals in industrial use, where Aluminium is the mostly used one, while the second and the third highest usages are for Copper and Zinc (Boulamanti and Moya, 2016).

The basic statistics of 8 non-ferrous metals including Aluminium, Aluminium Alloy, Copper, Lead, NASAAC, Nickel, Tin and Zinc are as follows:

Variable		Obs.	Mean	Std. Dev.	Min	Max
Aluminium Alloy	Level Variable	272	-9.353	120.360	-313.000	329.000
	1st diff. Variable	271	-0.576	43.657	-138.000	136.000
Aluminium	Level Variable	272	173144.210	28303.006	84363.640	238874.000
	1st diff. Variable	271	201.385	13260.372	-104808.360	54034.000
Copper	Level Variable	272	43971.559	18417.792	4084.000	81682.000
	1st diff. Variable	271	75.856	6611.450	-25568.580	25737.000
NASAAC	Level Variable	272	942.860	1051.847	-516.000	3844.000
	1st diff. Variable	271	-4.269	145.357	-655.000	622.000
Nickel	Level Variable	272	22723.097	12822.729	-12822.000	45558.030
	1st diff. Variable	271	61.396	4729.318	-20516.360	33456.000
Lead	Level Variable	272	25426.245	7608.850	8890.200	44734.000
	1st diff. Variable	271	-7.160	2911.231	-26443.090	9573.000
Tin	Level Variable	272	2310.586	708.211	671.000	3938.000
	1st diff. Variable	271	-3.568	337.450	-1358.000	1759.640
Zinc	Level Variable	272	58668.584	19041.714	22815.000	94433.000
	1st diff. Variable	271	135.272	5537.694	-54759.090	14866.960

Table 3. Basic Statistics Summary of Weekly Position Variables

The most traded non-ferrous metal in futures market is Aluminium and Zinc and Copper follow afterward. The least traded metals are all types of Aluminium Alloy including NASAAC as described in Table 4. The negative value in Table 4 stands for selling of futures, which means the net position toward short position. The positive value is buying of futures, the net position toward long position.

Variable		Obs	Mean	Std. Dev.	Min	Max
Aluminium Alloy	Level Variable	272	1546.129	206.824	1150.000	1970.000
	1st diff. Variable	271	0.001	0.026	-0.129	0.108
Aluminium	Level Variable	272	1836.612	222.407	1459.500	2587.000
	1st diff. Variable	271	0.001	0.030	-0.147	0.170
Copper	Level Variable	272	5919.603	787.821	4352.000	7914.000
	1st diff. Variable	271	0.002	0.027	-0.131	0.144
NASAAC	Level Variable	272	1590.715	284.048	1015.000	2065.000
	1st diff. Variable	271	0.001	0.026	-0.106	0.104
Nickel	Level Variable	272	12107.169	2344.895	7750.000	18005.000
	1st diff. Variable	271	0.003	0.039	-0.113	0.157
Lead	Level Variable	272	2044.116	262.966	1575.000	2652.000
	1st diff. Variable	271	0.001	0.029	-0.090	0.081
Tin	Level Variable	272	18586.257	2036.680	13255.000	21730.000
	1st diff. Variable	271	0.001	0.026	-0.174	0.088
Zinc	Level Variable	272	2507.392	477.557	1461.500	3595.000
	1st diff. Variable	271	0.002	0.033	-0.129	0.081

Table 4. Basic Statistics Summary of Weekly Price Variables

The highest price among 8 non-ferrous metal per metric ton is Tin and Nickel and Copper follow afterward. The lowest price of metals are all types of Aluminium including Aluminium High, Aluminium Alloy and NASAAC. The 1st differentiated variable stands for the changes in price and Lead show the least value of the difference between the maximum and minimum value.

Basic statistics of monthly variables is summarized in Appendix 1 & 2.

2.2. Methodology

Throughout the literature review, there are 4 main methodologies identified to assess speculation in futures, which are Vector Autoregressive (VAR), Vector Error Correction Model (VECM), Autoregressive-Moving-Average Model (ARMA), Generalized AutoRegressive Conditional Heteroskedasticity (GARCH).

In the following, the methodologies (unit-root test, cointegration test, causality test) applied to this thesis are described first and then others are demonstrated to give reasons why they are not used in this thesis.

To analyze causal relationships between time series variables, we need to conduct unit-root test to determine variables are stationary and cointegration test to identify long-term equilibrium relationship between variables. If there is a long-term relationship between the variables, Vector Error Correction Model (VECM) confirms the long and short-term causal relationship. If variables are not in cointegration relationship, Vector Autoregressive Model (VAR) is used to identify the short-term causality between the first differentiated variables.

2.2.1. Unit-root test

To conduct time series analysis, it is assumed that time series variables should satisfy its stability. If the variables are not stationary, there is a validity issue arising in the time series model. There are most commonly used unit-root tests which are Augmented Dicky-Fuller (ADF) test and Phillips-Perron (PP) test (Phillips and Perron, 1988). The ADF test is to determine stationarity of the variables to test unit-root based on the first-order autoregressive model. PP test mitigates weakly dependency of error terms and heteroscedasticity constraints to test stationarity of variables. The null hypothesis states there is a unit-root, which means times series variable is not stationary. If the test statistic is greater than the critical value, the null hypothesis is rejected, and it is referred that the time series is stationary without unit-root.

A unit root test (ADF) involving trends and constant terms is shown in the following formula (1) such that

$$\mathrm{Y_t} = \alpha + \rho Y_{t-1} + \delta t + u_t \qquad (1)$$

If $\rho = 1$, then Y_t follows the unit root process. These unit root tests are classified as follows, depending on the inclusion of time series determinants such as draft and linear trends.

Model	Identification	Constraints
1	Random walk without drift and trend	$\alpha=\delta=0$
2	Random walk without trend	$\delta=0$, default
3	Random walk without drift	$\alpha=0$
4	Random walk with drift and trend	None

Table 5. ADF Test (Augmented Dickey Fuller Test)

The ADF test described in Table 5 is valid if the time series Y_t is well characterized by an AR(1) with white noise errors. However most time series tend to have a more complicated structure so a simple AR(1) model could not capture them. ADF test is referred as the basic autoregressive of unit-root test that accommodates a general ARMA(p, q) model with unknown orders (Said and Dickey, 1984). Null hypothesis of the ADF test is that a time series Y_t is I(1) against the alternative that Y_t is I(0) with assumption that the structure of the data has an ARMA process.

In case of Phillips-Perron's unit root test, Phillips and Perron (1988) developed several unit-root tests for the analysis of time series data, which became popular.

The main difference between the PP test and the ADF test is how they deal with serial correlation and heteroskedasticity in the error terms. Specifically, the PP test ignore any serial correlation in the regression while the ADF test approximates the ARMA structure of the error terms in the regression by using a parametric autoregression.

Under the null hypothesis PP statistics have the same asymptotic distributions of the ADF t-statistic and bias statistics that is normalized. Advantages of the PP test over the ADF test are that the PP test is flexible in general for heteroskedasticity in the error terms and that there is no need to specify a lag length for the test regression.

The test regression for the PP test is

$$\Delta y_t = \beta' D_t + \pi y_{t-1} + u_t$$

where u_t is I(0) and heteroskedastic. The PP test corrects serial correlation and heteroskedasticity in the error terms u_t by modifying the test statistics.

2.2.2. Cointegration test

To conduct cointegration analysis, it is required that each time series variable is non-stationary with the same degree of integration or all should have a common probabilistic trend (Granger, 1996). The estimation can be conducted by Eagle and Granger (1987) method using 2-step cointegration or Johansen (1995) cointegration test using maximum likelihood estimation.

Engle and Granger (1987) cointegration test is based on the residual terms of the regression model such that the residual terms is stationary without unit-root. But there is an issue that the test result might be inconsistent according to the dependent variables. Engle-Granger's two-step method there is a linear combination of x_t and y_t is stationary for some value β and u_t if x_t and y_t are non-stationary and order of integration 1. This can be denoted as

$$y_t - \beta x_t = u_t \qquad (1)$$

where the term u_t is stationary.

If β is known, the ADF and PP test can be run to test their stationarity. However, as β is unknown in most cases, this should be estimated first with ordinary least squares and unit-root test on series of u_t estimated. The second regression should be run with the first differenced variables from the previous regression. The term u_{t-1}, a regressor, would be included.

Therefore, this study conducts Johansen's cointegration test which is based on the maximum likelihood estimation. Unlike the Engle-Granger method, the Johansen test allows us to test more than one cointegrated relationships, but this test is subject to asymptotic properties which requires large samples in general. The results of the test would not give reliability if the sample size is too small. In this case, one should go with Auto Regressive Distributed Lags (ARDL).

Cointegration rank is determined by a test using the trace value representing the sum of the diagonal components of the generalized eigenvalue matrix. In this study, the cointegration test is performed on the null hypothesis such that the cointegration vector is less than or equal to the number of ranks by using trace statistics.

2.2.3. Causality test

As a consequence of the cointegration test, if there is a cointegration and a long-term equilibrium relationship between variables, the Granger causality can be tested through the VECM. If not, the first-order differentiated VAR model can be used to identify the Granger causality.

2.2.3.1. Vector Error Correction Model (VECM)

VECM is a dynamic model that considers cointegration relationships between time series along with short-term dynamics. This includes cointegrated level variables with the lag term of the variables that are differentiated as explanatory variables and all variables are converted into stationary time series as shown in formula (2):

$$\Delta \mathrm{Z_t} = v + \Gamma A' Z_{t-1} + \sum_{i=1}^{p} \Gamma \Delta \mathrm{Z_{t-1}} + \varepsilon_t \qquad (2)$$

where A: cointegration vector, ε_t: white noise, $\Gamma A' Z_{t-1}$: error, Γ: coefficient of error correction.

VECM is a suitable model to consider multivariate time series with unit root having cointegration relationships between the variables. It can be interpreted most appropriately if there are l relationships between the r-dimensional multivariate time series Z_t containing unit root and the rXl matrix that has cointegration vectors as columns is set as A. This model allows the identification of the causality pathway by identifying short-term, long-term and strong causality. The existence of short-term causality here means a statistically significant improvement in the ability of explaining when adding historical variables to account for changes in the dependent variable, and a long-term causal relationship means that the Error Correction Term (ECT) is statistically significant. This means that in the event of an external shock, the change in the dependent variable returns to the long-term balance of the two variables at the rate at which the coefficient of the error correction term is measured.

VECM imposes additional restriction due to the existence of non-stationary but cointegrated data forms. It utilizes the cointegration restriction information into its specifications. The advantage of VECM over VAR is that the resulting VAR from VECM representation has more efficient in coefficient estimation.

2.2.3.1. Vector Autoregressive (VAR)

VAR is a useful model when motion of a single time series is determined not only by its own past values but also by the past values of other time series, it is composed of linear regression equations including all possible variables. The structure of VAR is shown as follows in formula (3):

$$y_t = v + A_1 y_{t-1} + \cdots + A_p y_{t-p} + B_0 x_t + B_1 x_{t-1} + \cdots + B_s x_{t-s} + u_t \qquad (3)$$

where $y_t = (y_{1t}, \ldots, y_{kt})' : K \times 1$ random vector, $E(u_t) = 0, E(u_t u_t') = \sum \;, E(u_t u_t') = 0$ for $t \neq s$

Each equation sets the current observation (endogenous variable) of each variable as a dependent variable and the historical observation (external variable) of itself and other variables as an explanatory variable. Since multiple time differences are taken for the same variables, all regression coefficients may not be statistically significant due to their multicollinearity. However, regression coefficients of VAR models estimated with least square method is typically consistent and efficient.

Most previous articles in this study area have employed Granger causality tests to examine the effect of non-commercial traders on specific commodity market prices (Buyuksahin et al. 2009; Brunetti and Buyuksahin 2009; Gilbert 2010; Buyuksahin and Harris 2011; Irwin and Sanders 2012). The Granger causality test is based on a bivariate VAR (vector autoregressions) representation of stationary time series. The null hypothesis is that “lagged y does not Granger-cause x”, while the alternative hypothesis is that “lagged x causes y”. The null hypothesis will be rejected if the coefficients on the lagged y’s are jointly significantly different from zero. Specification issues arise in relation to the choice of lag length because test results are sensitive to lag selection. To determine the optimal lag to be used in the VAR estimation, this paper employs the AIC (Akaike Information Criterion).

2.2.4. Autoregressive-Moving-Average Model (ARMA)

In the statistical analysis of time series, autoregressive–moving-average (ARMA) models provide a parsimonious description of a weakly stationary stochastic process in terms of two polynomials, one for the autoregression (AR) and the second for the moving average (MA). The general ARMA model was described in the 1951 thesis of Peter Whittle, Hypothesis testing in time series analysis.

Given a time series of data X_t , the ARMA model is a tool for understanding and, perhaps, predicting future values in this series. The AR part involves regressing the variable on its own lagged values. The MA part involves modeling the error term as a linear combination of error terms occurring contemporaneously and at various times in the past. The model is usually referred to as the ARMA(p,q) model where p is the order of the AR part and q is the order of the MA part as below: the notation ARMA(p, q) refers to the model with p autoregressive terms and q moving-average terms. The model contains the AR(p) and MA(q) models such as

$$X_t = c + \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}.$$

where the θ_1, ..., θ_q are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0), and the epsilon white noise error terms.

2.2.5. Generalized AutoRegressive Conditional Heteroskedasticity (GARCH)

Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) is used in analysis of timeseries as a statistical model with serially autocorrelated variance error. The assumption behind GARCH model is that the variance of the error terms follows an ARMA process.

Typically, GARCH model is used in financial sectors to estimate the volatility of returns of market index, stock and bond while the model can be utilized in other types of financial data including macroeconomic data. Financial institutions use the results when determining pricing and judging potentiality of the returns of assets. Moreover, the model can be used to project the returns in the future from current investments to decide in their strategy on asset allocation including risk management and portfolio optimization.

As the GARCH model is used when the variance of the error term is not constant, which means the error term is heteroskedastic. Heteroskedasticity provides the information of the irregular patterns from the error terms or variables.

Fundamentally, the conformity of observations is not a linear pattern when there is heteroskedasticity while they tend to cluster. Hence, the result and forecasts from the model would not be reliable if the model assumes constant variance for the data.

The variance of the error terms in GARCH model vary subject to the average size of the error terms in previous periods. That is, the model has conditional heteroskedasticity. This is because the error terms follow an ARMA pattern and means it is a form of an average of its own past values.

Chapter 3. Empirical Results

This chapter presents result of this analysis with the following order: basic statistics of data used, results of unit-root test, result of cointegration test, result of causality test and summary. This thesis uses weekly COTR data from October 2015 to December 2020, which includes the trading positions of various types of investors, such as a money manager, broker-dealer/index trader, producer/merchant/user, and other reportable parameters.

The previous analysis of speculation effects on LME futures market has focused on specific metal's futures price. This thesis analyzes speculation on the futures prices of all 8 non-ferrous metals in LME futures market. This thesis is re-estimated by extending the period using the analysis method of the existing study from Park (2019) and conduct additional methodology VECM to identify strong evidence of speculation in the market. The analysis tool used in this analysis is STATA 12 package.

3.1. Unit-root Test

In this thesis, unit-root test for the variables is examined by using ADF and PP test. The result of unit-root test of the whole period is as follows:

Metal	Variable	ADF Level Variable	ADF 1st Diff. Variable	PP Level Variable	PP 1st Diff. Variable	Result
Aluminium Alloy	Position	-3.151**	-2.648***	-3.071**	-20.081***	I(0)
	Price	-17.634***	-3.574***	-17.625***	-45.122***	I(0)
Aluminium	Position	-2.617**	-7.1246***	-3.644***	-21.086***	I(0)
	Price	-1.624***	-1.611***	-19.181***	-44.390***	I(0)
Copper	Position	-2.635***	-13.364***	-3.057**	-16.581***	I(0)
	Price	-0.622***	-2.572***	-16.179***	-41.124***	I(0)
NASAAC	Position	-0.221***	-5.565***	-0.796	-17.876***	I(0)
	Price	-1.241***	-1.128***	-16.002***	-44.267***	I(0)
Nickel	Position	-3.264***	-15.011***	-2.767*	-18.602***	I(0)
	Price	-2.119***	-7.202***	-17.669***	-44.904***	I(0)
Lead	Position	-3.917***	-3.984***	-3.232**	-15.690***	I(0)
	Price	-5.632***	-1.223***	-15.637***	-38.0638**	I(0)
Tin	Position	-0.916***	-3.825***	-4.048***	-20.770***	I(0)
	Price	-3.581***	-1.257***	-16.138***	-39.077***	I(0)
Zinc	Position	-2.185	-11.251***	-2.432	-17.110***	I(1)
	Price	-1.287	-10.577***	-1.878	-16.430***	I(1)

Critical value : ADF t-statiscis 1% = -3.430, 5% = -2.860%,

PP t-statistics = 1% = -20.700, 5% = -14.100

Table 6. Result of unit-root test of weekly data

For unit-root test on weekly basis, the result by ADF and PP shows that all non-ferrous metals except for Zinc have stability in position and price in terms of level variables, and so forth, they reject the null hypothesis that the unit-root exists, which indicates that the time series except for Zinc are I(0) variables.

In case of Zinc, there is identified non-stationarity in position and price variables whereas 1st differentiated variables reject the null hypothesis of existence of unit-root, and so forth, it obtains stability as I(1) variable. As two time series are analyzed statistically significant when regressing the relationship between two unrelated time series that share trends. I(1) variables may meet an error in spurious-regression when performing Ordinary Linear Square (OLS), and so forth, Johansen's cointegration and causality test is performed to identify equilibrium relationship between the variables.

		ADF		PP		
Metal	**Variable**	**Level Variable**	**1st Diff. Variable**	**Level Variable**	**1st Diff. Variable**	**Result**
Aluminium Alloy	Position	-2.508	-6.188***	-2.718*	-6.063***	I(1)
	Price	-0.865	-3.514***	-1.486	-3.639***	I(1)
Aluminium	Position	-2.697*	-7.819***	-2.519	-8.124***	I(0)
	Price	-1.552	-6.211***	-1.632	-6.124***	I(1)
Copper	Position	-2.54	-6.37***	-2.567	-6.246***	I(1)
	Price	-0.447	-5.073***	-0.887	-4.952***	I(1)
NASAAC	Position	-0.524	-5.738***	-0.818	-5.767***	I(1)
	Price	-0.649	-3.871***	-1.157	-3.817***	I(1)
Nickel	Position	-2.167	-7.001***	-2.492	-7.01***	I(1)
	Price	-0.753	-5.205***	-1.223	-5.104***	I(1)
Lead	Position	-2.671*	-8.224***	-2.644*	-8.359***	I(0)
	Price	-1.615	-6.277***	-1.754	-6.238***	I(1)
Tin	Position	-3.028**	-7.818***	-3.218**	-7.922***	I(0)
	Price	-1.757	-5.244***	-1.988	-5.17***	I(1)
Zinc	Position	-2.184	-7.396***	-2.237	-7.385***	I(1)
	Price	-1.704	-5.638***	-1.861	-5.59***	I(1)

Critical value : ADF t-statiscis 1% = -3.430, 5% = -2.860%,

PP t-statistics = 1% = -20.700, 5% = -14.100

Table 7. Result of unit-root test of monthly data

From the result of unit-root test for monthly data, position and price variables are identified as I(1) variables in Aluminium Alloy, Copper, NASAAC, Nickel and Zinc whereas Aluminium, Lead and Tin show I(0) variables in position and I(1) variables in price. For I(1) variables, Johansen's cointegration and causality test is conducted. For the rest 3 non-ferrous metals conflicting in variable level and 1st differentiated variables of price are used to identify causal relationships between the position and price change.

3.2. Cointegration Test

This thesis implements cointegration test using Johannsen (1991)'s Maximum Likelihood estimation method. The number of cointegration vectors can be estimated using such as trace statistics, maximum eigenvalue statistics, and so forth, this analysis uses trace statistics to confirm the presence of cointegration vectors. The null hypothesis is that the number of different cointegration vector is less than or equal to r and by increasing the r from zero to the maximum possible value (number of endogenous variables) calculate the likelihood ratio. To obtain the most optimal time lag, Akaike Information Criterion (AIC) is used and the result is as follows in Table 8.:

Variable	Hypothesis	Lags	λ_{trace}	Cointegration
Zinc	$r = 0$	2	24.550	O
Position - Price	$r \leq 1$		6.475***	

Critical value : 5% (r = 0, 15.41 & r = 1, 3.76), 1% (r = 0, 20.04, r = 1, 6.65)

Table 8. Result of Cointegration test of weekly data

From the result of cointegration test for weekly basis, the only metal presenting cointegration relationship between the price and position is Zinc. Zinc show 1% significant rejection level to its null hypothesis statistically while other metals are unavailable to conduct cointegration test due to their I(0) variable.

Variable	**Hypothesis**	**Lags**	λ_{trace}	**Cointegration**
Copper Position - Price	$r = 0$	2	19.591***	O
	$r \leq 1$		1.817**	
Aluminium Alloy Position - Price	$r = 0$	2	16.492***	O
	$r \leq 1$		2.778**	
NASAAC Position - Price	$r = 0$	2	3.375***	O
	$r \leq 1$		0.745***	
Zinc Position - Price	$r = 0$	1	29.658	X
	$r \leq 1$		7.732	
Nickel Position - Price	$r = 0$	2	15.005***	X
	$r \leq 1$		3.462	

Critical value : 5% (r = 0, 15.41 & r = 1, 3.76), 1% (r = 0, 20.04, r = 1, 6.65)

Table 9. Result of Cointegration test of monthly data

There are 5 metals, which are Copper, Aluminium Alloy, Zinc, Nickel and NASAAC, that could run the cointegration since they have I(1) variables in monthly basis analysis.

From the result, Copper, Aluminium Alloy and NASAAC show cointegration relationship between the price and position with 5% significant level for Copper and Aluminium Alloy and 1% for NASAAC.

For the entire analysis period (2015.10 - 2020.12), the results of cointegration test show the null hypothesis for aluimnium Alloy, Copper, NASAAC and Zinc is not rejected that one or fewer cointegration vectors exist since they are lees than 5% threshold of 3.76, and thus confirming that one cointegration vector exists. This means there is long-term relationship between the futures price and trader's position for Aluminium Alloy, cooper, NASAAC and Zinc in the LME market.

Moreover, data form of Nickel allowed to conduct cointegration test, however, there is no evidence of long-term relationship identified between the futures price and position in them.

The result of cointegration test for Zinc in weekly and monthly basis show different outcomes. Zinc is cointegrated in price and position in weekly basis but not in monthly basis. This implies that Zinc's price and position are coupled in shorter terms and changes rapidly.

3.3. Causality Test

The purpose of this thesis is at identifying speculation by examining Granger causality between the futures price and non-commercial trader's position. As we found that there is a cointegration relationship between the price and position in Zinc, Aluminium Alloy, Copper and NASAAC, these 4 metals are estimated by VECM to present long-term equilibrium with causality analysis. Other metals are estimated by VAR to show causality relationship between the price and position in short-term.

3.3.1. Vector Error Correction Model (VECM)

As the price and position of Zinc are cointegrated on weekly basis, the error correction terms using regularized parameters from Johansen's cointegration equation for Zinc is as follows:

From weekly basis analysis,

$$ect_{Zinc}^{Price-Position} = Position_t - 7.208Pirce - 0.426 \qquad (4)$$

Zinc has a bilateral causality between the futures price and position in long-term and short-term. The result of causality test shows that the bilateral causality is statistically significant with 1% hypothesis level.

For monthly basis analysis, as there is no cointegration identified in Zinc and Nickel, the error correction terms using regularized parameters from Johansen's cointegration equation for Aluminium Alloy, Cooper and NASAAC are as follows:

From monthly basis analysis,

$$ect_{Aluminium\ Alloy}^{Price-Position} = Position_t + 0.332Pirce - 496.612 \qquad (5)$$

$$ect_{Copper}^{Price-Position} = Position_t + 0.981Pirce - 50116.42 \qquad (6)$$

$$ect_{NASAAC}^{Price-Position} = Position_t - 9.394Pirce - 12950.73 \qquad (7)$$

The result of causality test presents that there is unilateral relationship from price to position in Copper and NASAAC whereas there is no statistically significant causality identified in Aluminium Alloy. The result of causality test shows that the unilateral causality from price to position is statistically significant with 1% hypothesis level in Copper and NASAAC.

The above error correction coefficient allows us to identify the rate at which deviations from the long-term relationship are gradually corrected partially through short-term adjustments between prices and positions. The coefficients of the causal relationship of long-term, short-term along with strong relationship are summarized in the following table:

Metal	Zinc	Copper	NASAAC	Aluminium Alloy
Basis	Weekly	Monthly	Monthly	Monthly
Long-term	7.270*** (0.007)	1.02 (0.313)	0.09 (0.764)	0.77 (0.380)
	8.56*** (0.003)	0.40 (0.525)	0.24 (0.621)	0.03 (0.860)
Short-term	7.00*** (0.008)	12.29*** (0.000)	14,22*** (0.000)	0.13 (0.715)
	3.00*** (0.008)	0.69 (0.404)	0.05 (0.820)	2.44 (0.118)
Strong	12.27*** (0.002)	13.18*** (0.001)	14.54*** (0.000)	0.80 (0.668)
	12.49*** (0.001)	0.93 (0.628)	0.38 (0.825)	2.600 (0.271)

Table 10. Result of Causality Test using VECM

3.3.2. Vector Autoregressive Model (VAR)

Granger causality tests require variables to be stationary. To test stationarity, this paper employs the ADF unit root test. Table 6 and Table 7 report the unit-root test result. The table 6 confirms that all variables except for Zinc are I(0) in weekly basis analysis, that is, stationary data. Therefore, the VARs were ran in levels, rather than first differencing. The VARs for I(0) can be estimated by a model as follows:

$$y_t = v + A_1 y_{t-1} + \cdots + A_p y_{t-p} + B_0 x_t + B_1 x_{t-1} + \cdots + B_s x_{t-s} + u_t \qquad (9)$$

To run VARs for monthly basis analysis, the price variable is 1^{st} differentiated and conduct VAR estimation with the price level variable as follows:

$$y_{i,t} = a_{i,0} + \sum_{j=1}^{p} \Gamma_{ij} y_{i,t-j} + \sum_{i=1}^{q} \Gamma_{ii} \Delta x_{i,t-i} + \varepsilon_{i,t} \qquad (10)$$

The result of granger causality test is as follows:

Metal	Weekly	Monthly
Aluminium	7.186**(0.028)	6.100 ** (0.047)
	0.563 (0.754)	13.446*** (0.001)
Aluminium Alloy	6.114**(0.047)	
	5.915* (0.052)	
Copper	27.527*** (0.000)	
	7.379** (0.025)	
Lead	9.638*** (0.002)	1.035 (0.309)
	1.158 (0.282)	4.598** (0.032)
NASAAC	0.765 (0.283)	
	0.443 (0.506)	
Nickel	4.562** (0.033)	12.604*** (0.000)
	0.530 (0.467)	0.0232 (0.879)
Tin	4.9419* (0.085)	0.000 (0.979)
	3.242 (0.198)	0.641 (0.423)
Zinc		1.815 (0.178)
		0.002 (0.961)

Table 11. Result of Causality Test using VAR

From the result of weekly basis analysis, except for NASAAC, there is a unilateral directional causality from price to position in short-term identified on 6 metals (Aluminium, Aluimnium Alloy Copper, Lead, Nickel and Tin). Moreover, a bilateral causality in short-term between the price and position found in Copper and Aluminium Alloy.

From the result of monthly analysis, Aluminium showed a bilateral short-term causality between the price and position. Nickel presents a unilateral causality from the price to position, which has the same directional result as of weekly basis analysis. For Lead, there is a unique result came out from the causality test, which is a unilateral direction from the position to price. Other metals including Tin and Zinc, there is no statistically significant causality identified even there is cointegration relationship found between the price and position..

All causality in weekly and monthly basis has 1-2 weeks of lags in VAR estimation. Throughout this analysis, the price in the market dominantly causes investor’s flows into the market.

3.3.3. Summary

The result of Granger causality test through VECM and VAR presents that there is a unilateral causality from the price to position in all 8 non-ferrous metals on the LME market. In Aluminium, Aluminium Alloy, Copper and Zinc, there is a bilateral direction found between the price and position. Only Lead shows that there is a unilateral causality from the position to price among all 8 non-ferrous metals.

An initial hypothesis of existence of cointegration is verified in Zinc, Copper, Aluminium Alloy and NASAAC. This means the futures price and speculator's position is coupled in long-term. In other words, there is speculation in these 4 non-ferrous metals in long-term. However, only Zinc confirms that there is a bilateral causal relationship between the price and position, which supports the second hypothesis. This means there is a strong evidence of speculation on Zinc in long-term.

Furthermore, the second hypothesis is satisfied in Aluminium, Aluminium Alooy and Copper by confirming a bilateral causality. Adding on Zinc, these 4 metals tend to have a higher trading volume in the market.

Chapter 4. Conclusion

The main purpose of this thesis is at identifying the causal movement in the market by speculators in consequence of financial actions taken. By utilizing LME COTR data, Granger causality tests were examined to determine the relationship between the futures price and non-commercial trader's position taken on the LME non-ferrous metal market.

The thesis conducted empirical analysis on how the futures price and speculator's position are associated in the LME non-ferrous metal market from October 2015 to December 2020. For the empirical analysis, the thesis adopted VECM and VAR estimation to utilize Granger causality over existing 8 non-ferrous metals on the LME market.

First, the thesis highlighted there is a cointegration between the futures price and speculator's position that guarantees they are coupled in long-term. The existence of cointegration is verified in Zinc, Copper, Aluminium Alloy and NASAAC. This implies there is a speculation over these 4 contracts, which attracts speculators to step in the market to facilitate their profit. Throughout the Granger causality test over these 4 metals, Zinc showed the best environment for speculators to invest. Zinc is the only metal that is cointegrated between the futures price and speculator's position and the causality relationship between these two factors is bilateral. This means the price affects speculator's decision and speculator's investment affects the price level. Therefore, the market environment on Zinc shows the best fit to speculation.

Second, the thesis provides causal relationship between the futures price and speculator's position over all 8 non-ferrous metals on the LME market. Over all 8 non-ferrous metals, there is a unilateral causality from the futures price to speculator's position identified. This implies that speculators dominantly decide their investment into futures by examining the trend of price movement. However, the unilateral or bilateral directions are not identical over all 8 non-ferrous metals. The market environment for each futures contract has different conditions such as number of players or target profit. This implies that investors shall note that the strategy for each futures contract must be different regarding the characteristics of the market environment.

A clear evidence of speculation is found in Zinc and speculator's investment is followed by the price trend in all non-ferrous metals on the LME market.

For further development of this thesis, it would be appropriate to investigate Lead where there is possibility that trader's position has dominant impact on the price. It is expected that there are some dominantly large companies take position in the market with purpose to drive the price level.

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Abstract (Korean)

비철금속을 포함한 광물과 에너지 등 주요 원자재의 국제시장 거래 환경은 21세기에 들어오면서 상당한 변화를 겪었다. 이 중 특히 원자재시장의 금융화 추세가 가장 확연 하였으며 이로 인하여 비철금속 등 국제시장에서 거래되는 원자재는 금융투자자들에게 매우 매력적인 자산 부류가 되었다. 런던금속거래소(LME)는 세계 최대의 원자재 선물거래소로 세계 비철금속 거래의 중심이다. 본 논문은 원자재시장의 금융화추세가 국제가격에 미치는 영향을 알아보기 위하여 LME 주요 비철금속 거래가격을 대상으로 시계열분석모형을 사용하여 투기 거래의 영향을 분석하였다.

비철금속 선물시장에서의 투기거래(speculation)가 비철금속 선물 가격에 미치는 영향에 대해 분석한 연구는 다수 존재한다. 하지만 런던금속거래소의 주요 6대 비철금속 외 종목을 포함하여 분석한 연구는 찾아보기 힘들다. LME 시장 내 투기 거래의 영향을 분석한 기존 연구들은 주요 6대 비철금속인 구리(Copper), 납(Lead), 니켈(Nickel), 아연(Zinc), 알루미늄(Aluminium High), 주석(Tin) 중 일부 또는 전부를 다루었다. 하지만 LME에서 분석이 가능한 비철금속은 2종, 알루미늄합금(Aluminium Alloy)과 북미특수알루미늄합금(North American Special Aluminium Alloy Contract: NASAAC)이 더 존재한다. 따라서 본 연구에서는 현재 LME 비철금속 선물시장 내 투기성 거래가 선물가격에 미치는 영향을 분석할 수 있는 주요

비철금속 6종과 알루미늄합금 2종을 더하여 총 8종에 대하여 분석하였다.

본 논문은 LME에서 거래된 비철금속 8 종목을 대상으로, 투기거래가 8개 비철금속의 선물가격에 미치는 영향을 인과관계 (Ganger-causality) 분석을 통해 알아보았다. 분석을 위하여 구조적 장기시계열분석모형인 벡터오차수정모형 (Vector Error Correction Model: VECM)과 벡터자기회귀모형 (Vector Autoregressive: VAR)을 활용하였다.

본 연구는 LME에서 제공하는 Commitment of Traders Report (COTR)을 기반으로 비철금속 선물거래 시장의 주 단위 (weekly basis) 비상업적거래자 (non-commercial trader)의 선물에 대한 포지션 (position)을 투기성거래를 대변하는 변수로 이용하였다. 각 비철금속의 선물가격은 LME의 마감가격 (closing price)을 이용하여 변수로 활용하였다. 기존의 연구들은 주로 VAR 모형을 이용하여 투기성 거래가 선물가격에 미치는 영향을 분석하였는데, 변수 간에 공적분(cointegration) 관계가 있는 경우 장기균형관계 분석을 위해 VECM 모형의 활용이 보다 적절하다. 이에 본 연구에서는 공적분 관계 확인 후 자료의 형태에 따라 VAR 및 VECM 모형을 활용하여 투기거래와 선물가격 간 장기균형 존재여부 및 인과관계를 분석하였다.

첫번째 분석으로 주 단위의 투기성거래 포지션과 선물가격 간 인과관계를 분석하였다. 아연을 제외한 7종의 비철금속은 모두 공적분검정이 불가하였다. 분석결과, 아연에서 유일하게 공적분관계가 확인되었고 투기성거래와 선물가격 간 장단기적으로 상호 인과하는 것으로 확인되었다.

나머지 7종의 비철금속은 VAR 모형을 통해 분석하였는데 NASAAC을 제외하고 모두 선물가격이 투기성거래를 단기적으로 인과하는 것이 확인되었다.

두번째로 월 단위의 투기성거래 포지션과 선물가격 간 인과관계를 분석하였다. 우선 구리, 알루미늄합금, 북미특수알루미늄합금에서 투기성거래와 선물가격 간 공적분관계가 확인되었다. 분석결과, 구리와 북미알루미늄합금에서 단기적으로 선물가격이 투기성거래를 인과하였으나 알루미늄합금에서는 변수간 인과관계는 확인되지 않았다. 나머지 5종의 비철금속에서는 모두 상이한 인과관계를 보였는데, 그 중 납은 유일하게 투기성거래가 선물가격을 한 방향으로 인과하는 것이 확인되었다.

LME의 모든 8종의 비철금속에서 주 단위 또는 월 단위 분석결과에서 선물가격이 투기성거래를 인과하는 것이 확인되었다. 그 중 선물가격과 투기성거래 간 양 방향으로 인과관계가 성립되는 비철금속은 알루미늄, 구리, 아연, 알루미늄합금이다. 이 비철금속들은 대부분 상대적으로 거래량이 많은 경향이 있다. 납은 주 단위 분석에서는 선물가격이 투기성 거래를 인과지만 월 단위 분석에서 상반된 인과관계를 보이고 있다.

본 연구가 시사하는 바는 다음과 같다. LME의 비철금속 선물거래는 상업적, 투기적 거래자가 동시에 가격을 형성하는 장소로 거래참여자의 성격에 따라 각 비철금속에서의 가격과 포지션이 다르게 형성됨을 인지할 필요가 있다. 본 연구는 각 비철금속에서의 선물가격과 투기성거래의 인과관계를 분석하여 투자자의 의사결정과 전략에 대한 통찰력을 제공하게

된다. 본연구는 기존의 연구와는 다르게 공적분관계 확인을 통해 투기성이 장기적으로 존재하는지 여부에 대해 확인하였다. 이를 통해 각각의 비철금속의 특징을 고려하여 투자자들의 적절한 투기와 헷징 전략을 제공할 수 있다는 점에서 의의가 있다.

주요어 : Speculation; COTR; Cointegration; Granger-causality; LME; Non-ferrous Metal
학 번 : 2019-21962

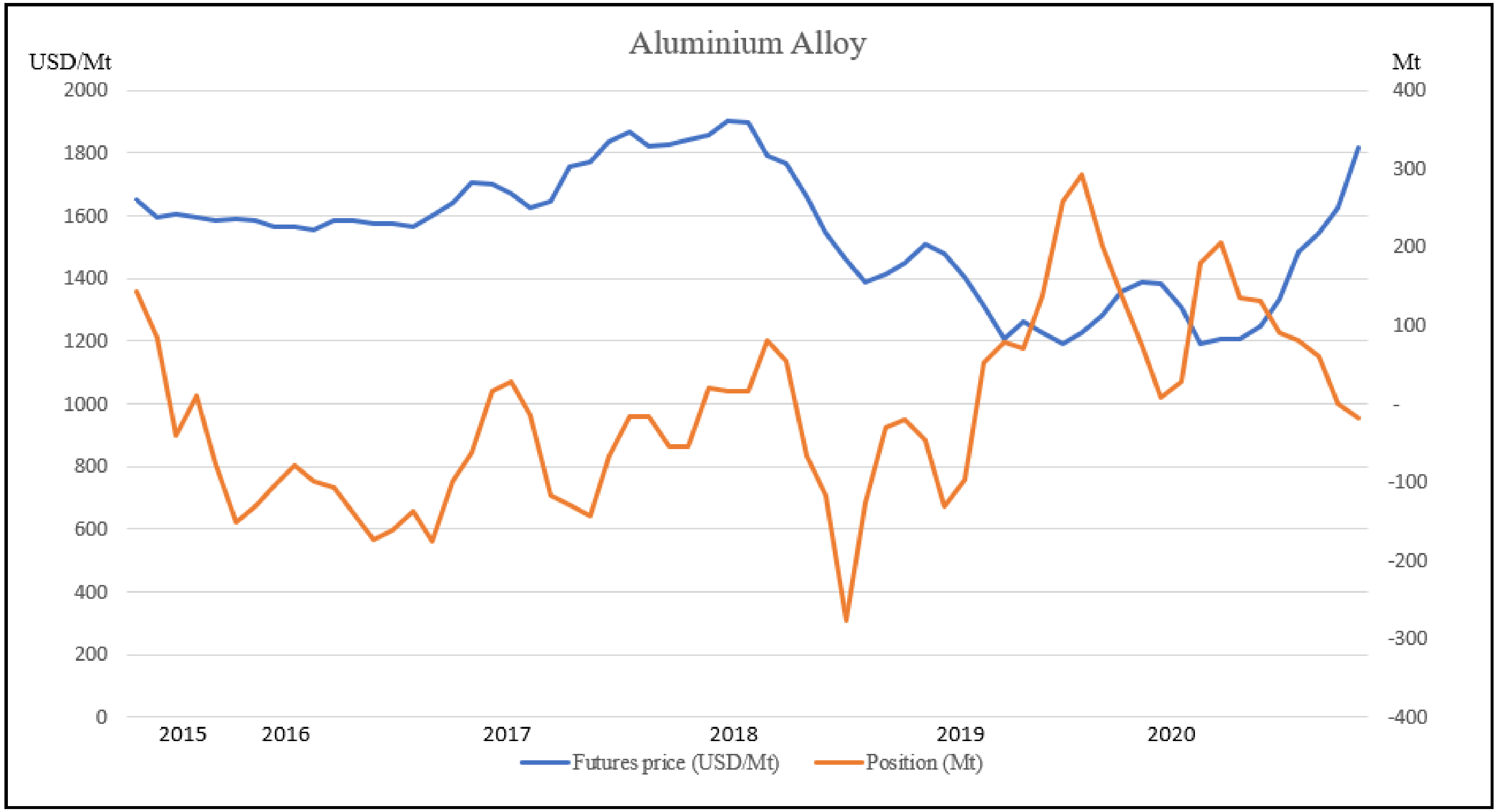
Appendix 1: Basic Statistics Summary of Monthly Position Variables

Position Variable		Obs	Mean	Std. Dev.	Min	Max
Aluminium Alloy	Level Variable	63	-8.975	116.477	-277.000	292.800
	1st diff. Variable	62	-2.587	66.594	-161.000	151.850
Aluminium	Level Variable	63	172959.120	26909.879	116444.520	228481.000
	1st diff. Variable	62	782.395	15968.213	-64884.478	36184.250
Copper	Level Variable	63	43960.794	17682.904	9009.000	74507.600
	1st diff. Variable	62	302.160	11150.479	-23600.772	33242.250
NASAAC	Level Variable	63	950.936	1048.846	-356.800	3657.250
	1st diff. Variable	62	-18.494	232.189	-704.850	605.800
Nickel	Level Variable	63	22718.217	12380.904	-645.000	40240.600
	1st diff. Variable	62	248.234	6842.393	-22068.250	27774.300
Lead	Level Variable	63	25536.845	7335.129	10421.612	42296.250
	1st diff. Variable	62	-42.353	4839.434	-23945.426	8380.630
Tin	Level Variable	63	2319.725	677.085	786.800	3722.000
	1st diff. Variable	62	-12.961	431.753	-964.500	1039.000
Zinc	Level Variable	63	58569.033	18955.962	29509.035	92642.750
	1st diff. Variable	62	596.500	9500.845	-48337.330	15715.000

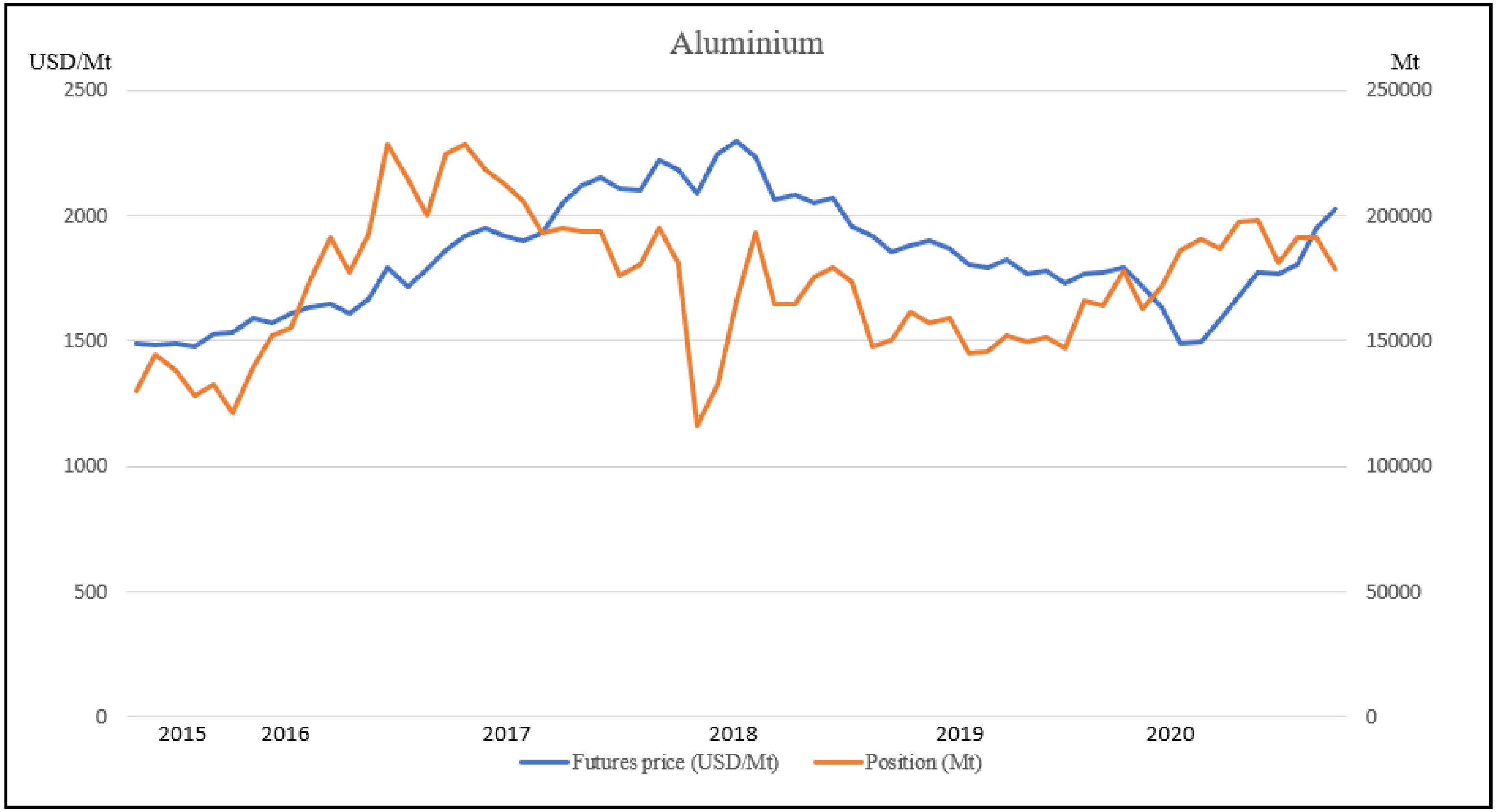
Appendix 2: Basic Statistics Summary of Monthly Price Variables

Price Variable		Obs	Mean	Std. Dev.	Min	Max
Aluminium Alloy	Level Variable	63	1546.687	203.666	1192.500	1901.250
	1st diff. Variable	62	2.695	61.914	-116.750	194.600
Aluminium	Level Variable	63	1834.040	220.871	1480.750	2297.000
	1st diff. Variable	62	8.606	66.992	-169.000	161.550
Copper	Level Variable	63	5910.862	778.697	4443.250	7785.100
	1st diff. Variable	62	41.413	271.853	-756.250	748.475
NASAAC	Level Variable	63	1591.575	281.390	1069.000	1962.500
	1st diff. Variable	62	4.198	73.630	-186.500	174.675
Nickel	Level Variable	63	12081.106	2301.063	8301.250	17483.750
	1st diff. Variable	62	102.884	829.494	-2008.750	1980.750
Lead	Level Variable	63	2042.374	260.858	1622.125	2587.000
	1st diff. Variable	62	4.608	91.135	-260.750	139.500
Tin	Level Variable	63	18567.179	2033.964	13633.750	21533.750
	1st diff. Variable	62	66.700	742.091	-1445.750	1942.500
Zinc	Level Variable	63	2501.128	482.289	1506.250	3541.750
	1st diff. Variable	62	17.302	146.730	-462.375	247.775

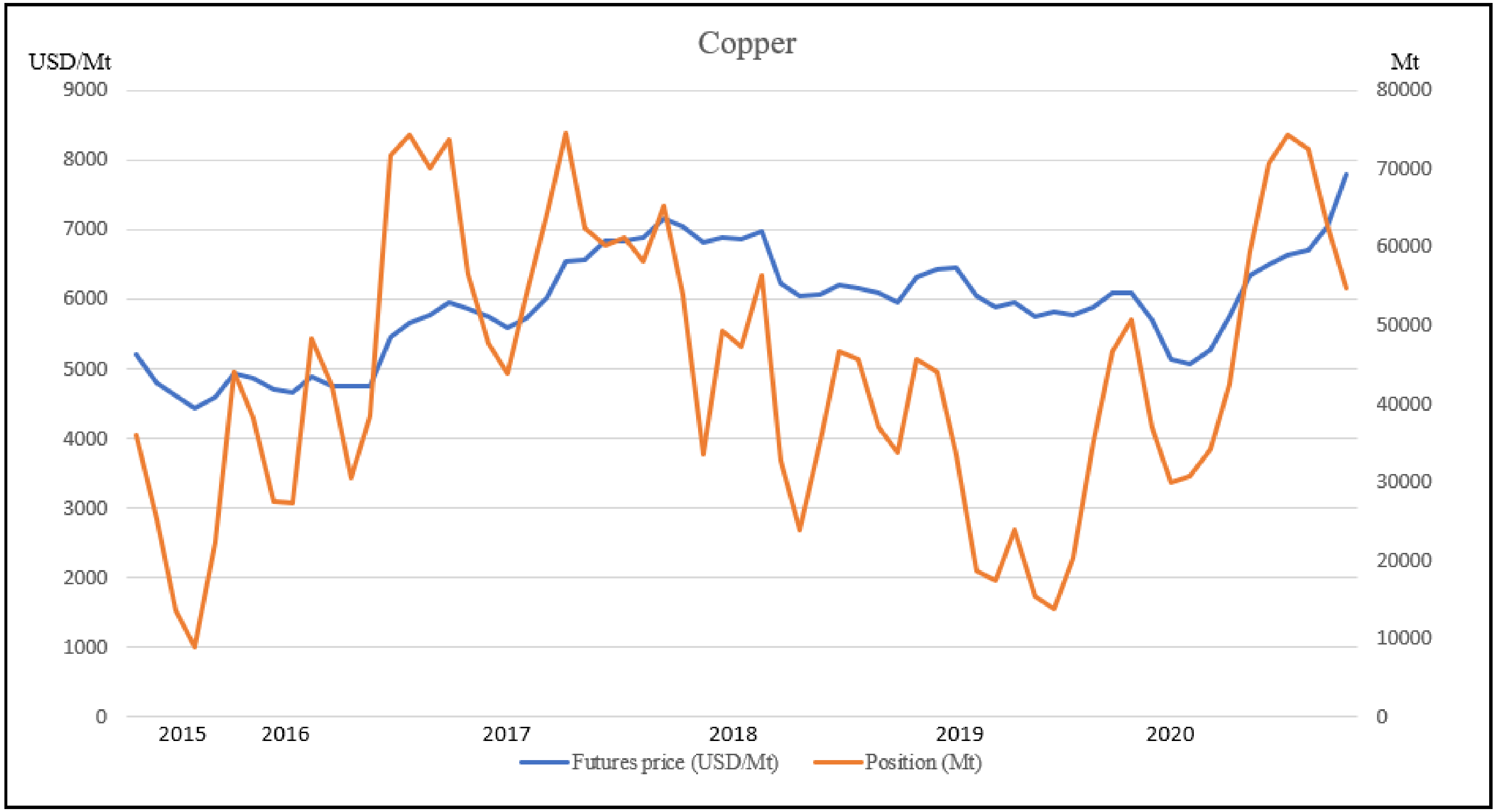
Appendix 3: Futures Price and Speculator's Position of Aluminium Alloy



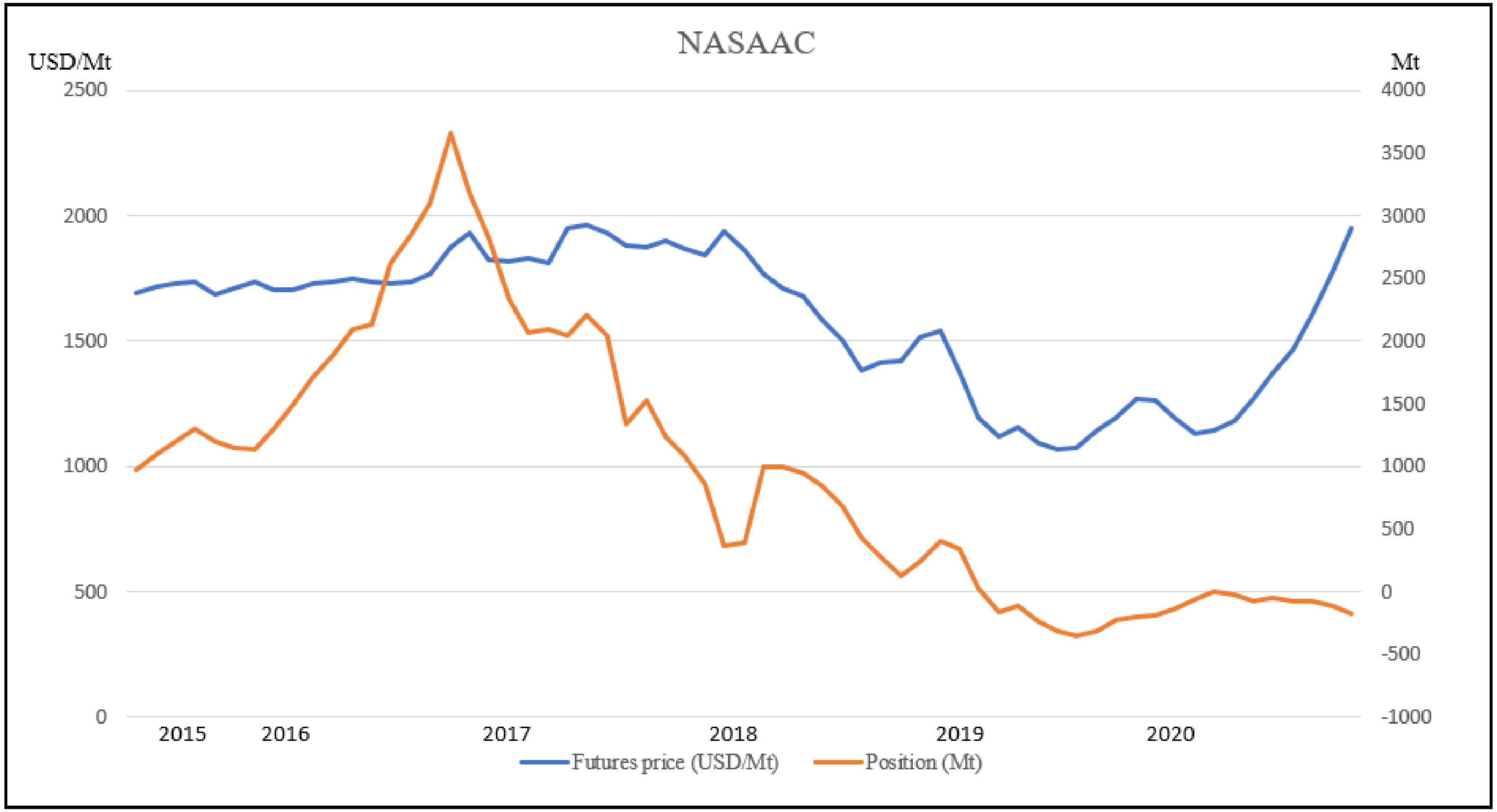
Appendix 4: Futures Price and Speculator's Position of Aluminium



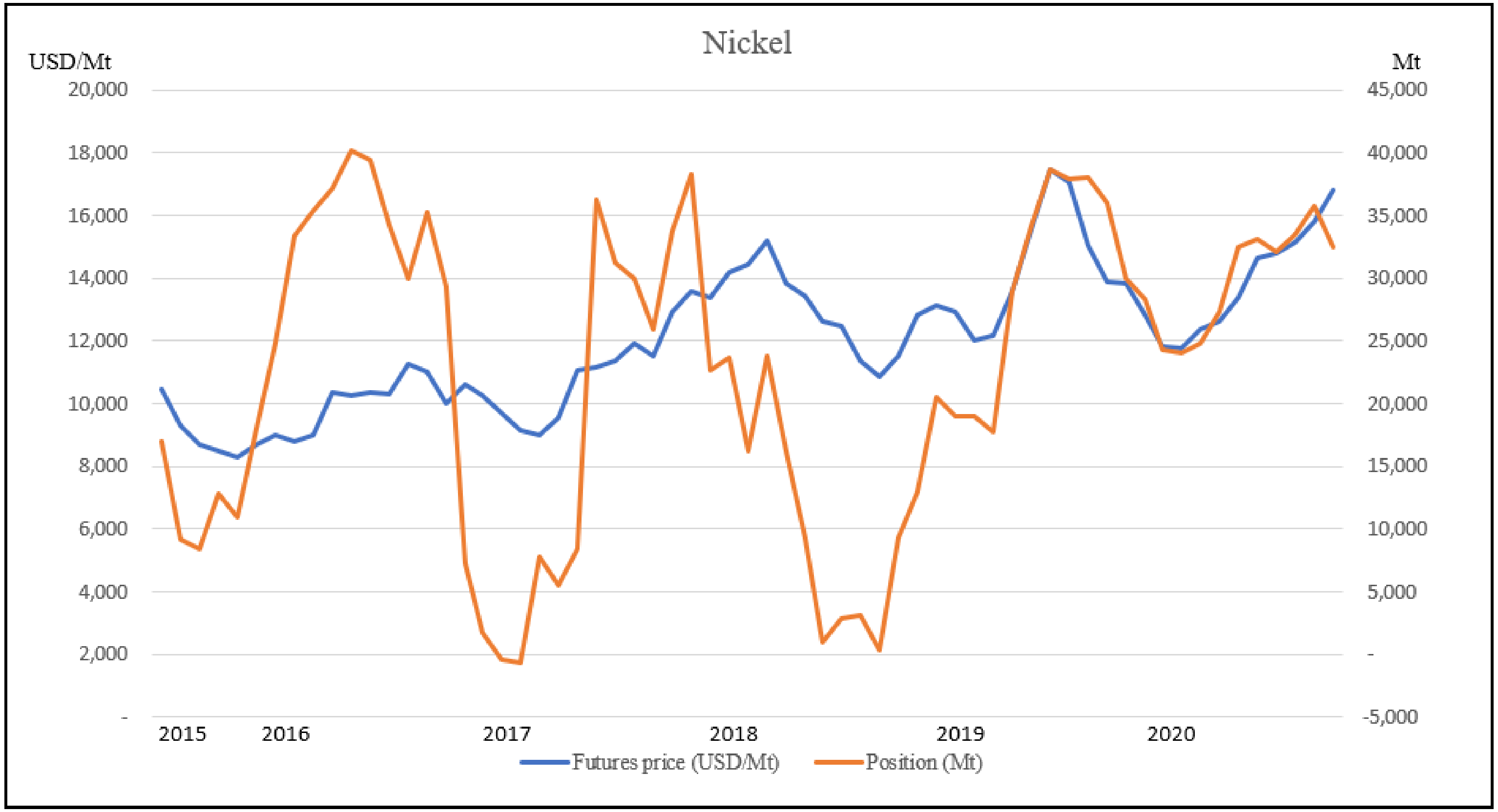
Appendix 5: Futures Price and Speculator's Position of Copper



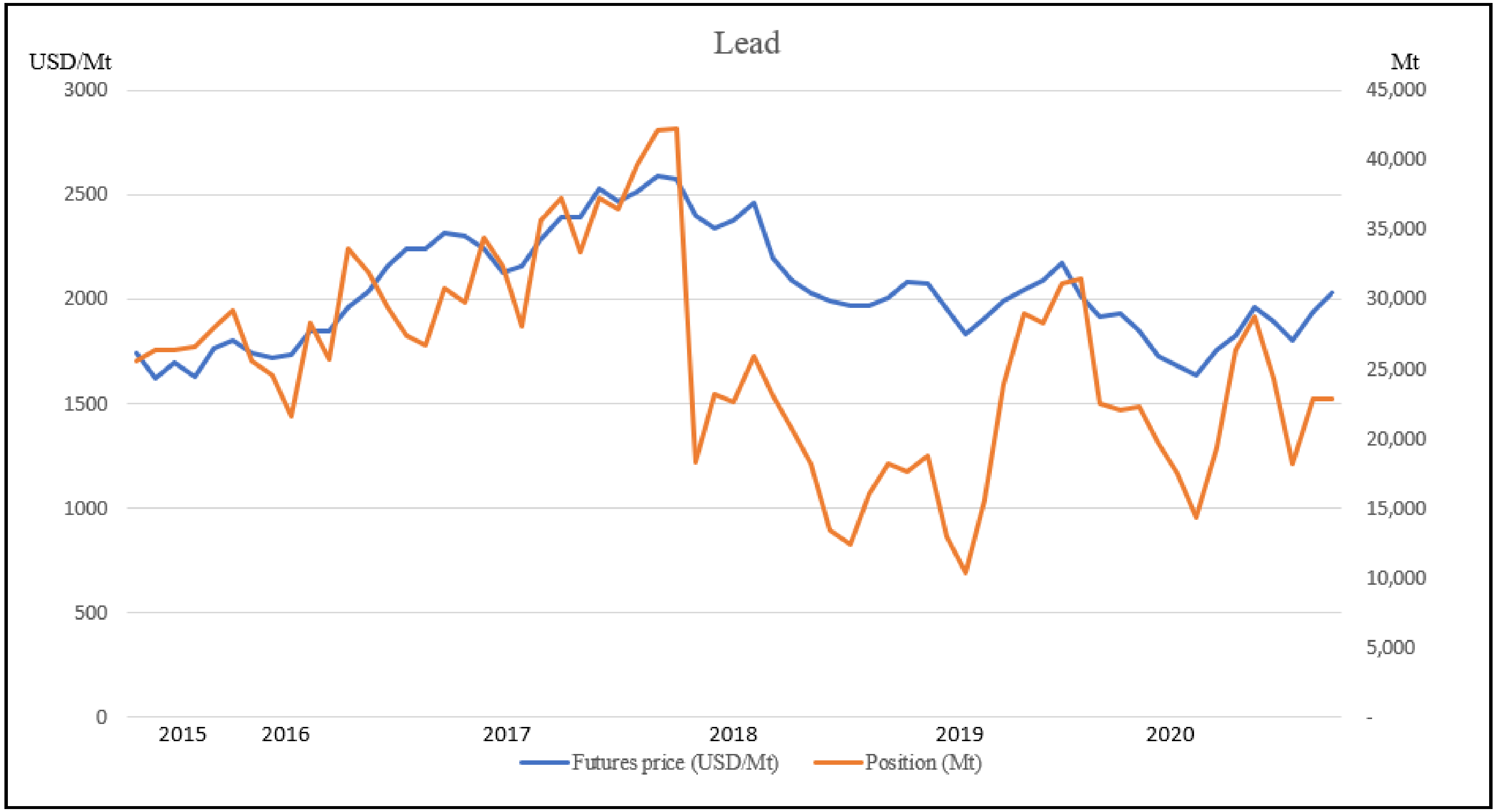
Appendix 6: Futures Price and Speculator's Position of NASAAC



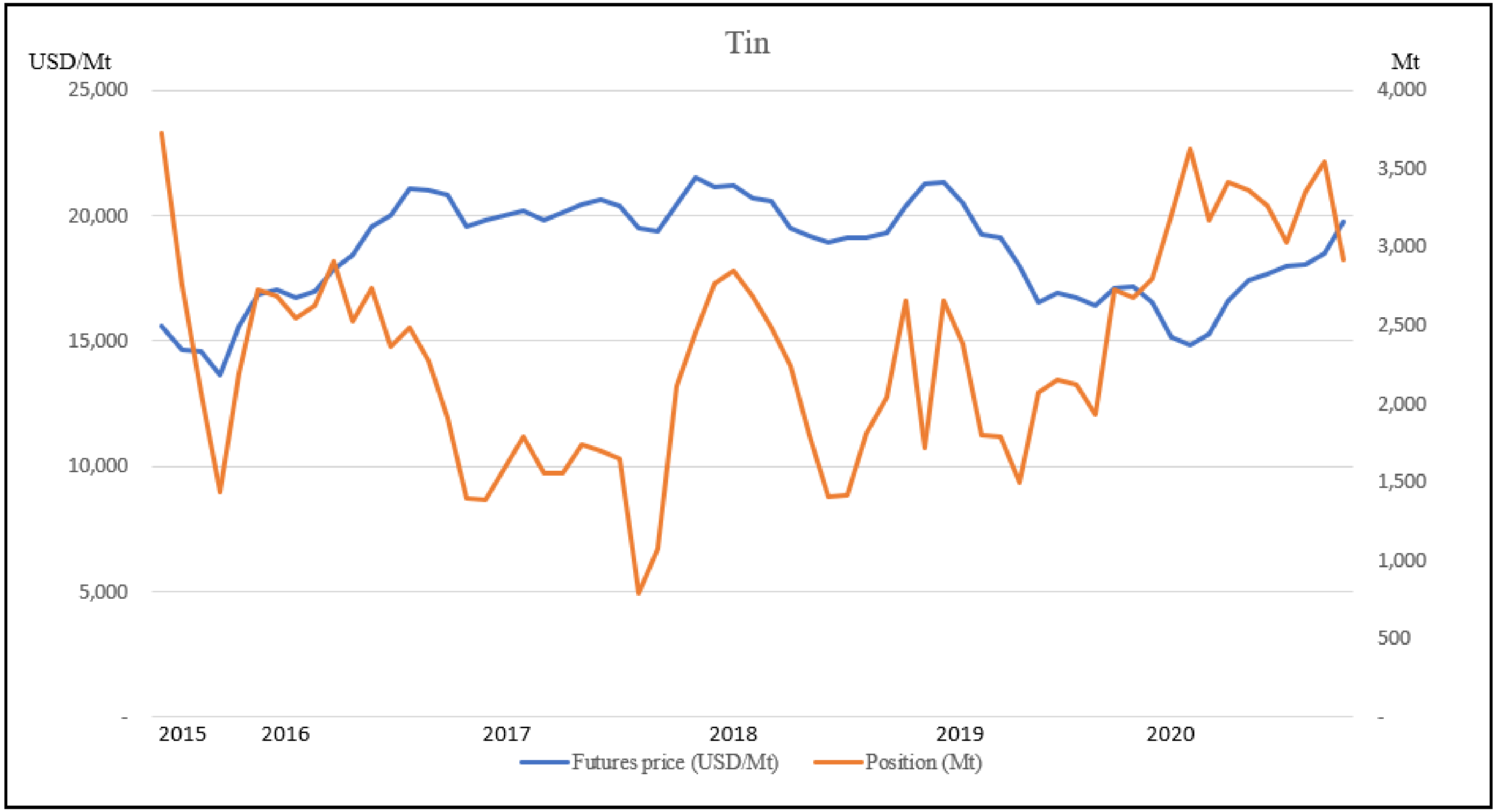
Appendix 7: Futures Price and Speculator's Position of Nickel



Appendix 8: Futures Price and Speculator's Position of Lead



Appendix 9: Futures Price and Speculator's Position of Tin



Appendix 10: Futures Price and Speculator's Position of Zinc