Professional MBA
Automotive Industry

FINDING THE APPROPRIATE CHINESE ECONOMIC INDICATORS TO MODEL COPPER PRICE DEVELOPMENT

A Master's Thesis submitted for the degree of
"Master of Business Administration"

supervised by

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Vienna, 28 March 2016

Affidavit

I, **TOD REES** , hereby declare

1. that I am the sole author of the present Master's Thesis, "FINDING THE APPROPRIATE CHINESE ECONOMIC INDICATORS TO MODEL COPPER PRICE DEVELOPMENT", 56 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 28.03.2016

Signature

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I would first like to say thank you to Julia and Stella for their support while undertaking this study. Additionally, I would like to dearly thank Jenice Tom for assisting with the statistical analysis portion which inevitably greatly helped in bringing about the results of this analysis.

II. Abstract

Copper is an extremely important metal for use in today's industrial society, but it is also known in some circles to be an indicator for economic activity regionally and globally. Additionally, Chinas commodity strength means that copper prices are largely dependent on the economic activity in China. Purchasing professionals have few resources such as those in large trading or commodity houses, therefore an analysis was run using various Chinese economic indicators against the LME copper price using commercially available Chinese economic data from the Trading Economics website.

The research was set up in the following manner:

1. Questionnaire sent by email to 5 copper industry professionals asking them to rank from 1 to 10 the most likely highly correlated Chinese Economic Indicators provided with the LME cash settlement copper price.
2. Multiple regression analysis of the variables against LME cash settlement copper prices and tested for auto-correlation.
3. Time Series analysis whereby auto-regressive (AR), auto-regressive with integrated moving average (ARIMA) and generalized autoregressive conditional heteroskedasticity (GARCH) models were tested
4. Proceed with hypothesis testing to be able to determine the significance of the results

A multiple regression was run using the various dependent economic variables in order to determine the best indicators as well as a time series analysis to attempt to find the best indicators as well as the best model fit. It was discovered in the regression analysis that the Chinese Leading Economic Indicator Index (P-Value: 0.0889), Chinese Manufacturing Purchasing Managers Index (P-Value: 0.0912), Chinese Exports (P-Value: 0.1440) and the USD/CNY Exchange Rate (P-Value: 0.1560) demonstrate the lowest P values (which is the probability that the data we have seen are purely based on chance) with the lowest autocorrelation and thus the best dependent variables against the LME copper prices.

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V. Definitions

1) *Regression*:

The relationship between the values of a variable x and the observed values from y. Regression attempts to predict the value of y with any given change in x. An example of regression is the tipping seen in restaurants. If x is the amount of the bill and y the value of the expected tip, one can surmise that x and y should be correlated and thus y can roughly be predicted from x, the value of the food bill.

2) *Distribution*:

The way in which plots are scattered around a certain value. In modelling, predicted values rarely hit exactly on the predicted value, but the distribution around the predicted value lends significant value to the power of the model. Normal distribution is the most well-known distribution for modelling whereby the plots are symmetrically distributed around the center and 68% of the plots fit within one standard deviation of the mean and 95% of the plots fit within 2 standard deviations of the mean.

3) *Scatterplot*:

To fit plots on an x and y axis whereby one can observe in a visual way how two variables may fit be related. A regression is simply a best-fit line drawn through a scatter plot.

4) *Time Series:*

A series of values which is given over a period of time. The most obvious example of a time series is the stock market. Every day, a new value is determined and continues on into the future as such.

5) *Correlation:*

Represents the relationship between two variables and is normally expressed in either a positive or negative number between -1 and +1. Negative values represent a negative correlation, meaning when one variable increases, the other variable decreases in some shape. Positive values are said to be positively correlated, meaning that when one variable increases, the second variable also increases.

The closer that the values are to -1 and +1, the closer the stronger the respective correlation. A value of zero represents no correlation.

6) Auto Correlation:

Auto-correlation is a phenomenon in time-series analysis, whereby the historical values are correlated with the present values. In a time series with more than 2 plots, autocorrelation is usually present. For example in government finances, a previous year's budget is usually positively correlated to the budget for the coming year. In this sense, government budgets are largely auto-correlated.

7) *ACF:*

Auto-correlation function is a test used to determine if values may be correlated to their previous values.

8) *PACF:*

Partial auto-correlation function is a test used to determine how many lags are significant in the autocorrelation of a given value.

9) *Residuals:*

The errors which are evident when running a best fit line through a scatterplot of points. Residuals help in determining how good the line fits the data. Where the residuals are high, the best fit line may not have much meaning for predictability. Low residuals tell that the line drawn to fit the data may be a good fit to predict future plots.

10) *Durban-Watson score:*

A score which is derived from the Durban-Watson test. The lower the score, or the closer the score moves to 0, the higher probability that auto correlation is present.

11) P Value:

Used in regression to determine the predictability value of a certain dependable variable against the independent variable. A P value of less than 0.10 is considered noteworthy and a P value of less than 0.05 is considered highly significant.

12) *GARCH:*

Stands for generalized autoregressive conditional heteroskedasticity. This time series model is common in the financial modelling community to model price movements of stocks or other commodities.

13) *Multicollinearity:*

Is a situation in a multiple regression whereby the dependent y factors are highly correlated with each other. Usually there is always some sort of multicollinearity in multiple regressions, however elevated multicollinearity can lead to errors in the model.

14) *Stationarity:*

Helps determine if there is a trend in the data or if values in a series have a mean to which they always revert back to.

1. Introduction

a) Background Information on Copper

Base metals are a group of metals which fit well into the definition of metal commodities. Base metals are those metals which can be tarnished or oxidized relatively easily by contact with moisture or with the air and are invaluable to todays industrialized society. These metals are aluminum, copper, nickel, lead, tin and zinc and differ from precious metals in that they are more widespread and used on a much larger industrial scale. And although based purely on tonnage alone, aluminum is considered the most important base metal, copper has a versatility in industrial applications not seen in other metals and thus deserves special focus when contemplating the global economic picture.

Copper is a base metal, and one of the oldest metals used by mankind. It has greatly contributed towards sustaining the society which we've developed today. It has been used throughout civilization in the form of coins and ornaments starting at around 8000 B.C. Copper was also useful in making tools that were important in transforming the Stone Age into civilization. The Bronze Age was an era in human history which brought about rapid development in the way humans shaped the world we know today[1]. Its' characteristics as a good conductor of heat and electricity has made it useful all over the world (Figure 1). It continues to be the metal of choice for mankind in domestic and industrial applications. Just as in ancient times, copper is still used in coinage among the many other uses that have been developed with time. Its attractive alloying features have made the metal an invaluable component when combined with other metals. Additionally, copper's nature to withstand corrosion has ensured that it can also be used in marine environments. These advantages of copper have made it the metal of choice for most domestic and industrial applications are responsible for the rapid rise in the worldwide consumption of copper.

Copper is mined from the earth's crust in many different places around the world. Deposits of the copper metal are grouped depending on how the deposits are formed. The most important of this category are the porphyry deposits that contain igneous intrusions. These deposits are regarded as the most important because

[1] J.M. Coles & A.F. Harding

they provide the larger share of the world's copper. They are found in North and South America. The other deposits that are found within sedimentary rocks provide about 25% of the world's copper and are found in Eastern Europe and Central Africa. [2]

The largest reserves by far are in Chile followed by Peru. This means that much of the world's raw copper concentrates are produced in South America and then to be shipped to other places in the world to further process the concentrated copper. [3]This leaves the whole copper industry somewhat dependent and constantly worrying about the supply of copper should strikes, war or natural disasters hit the region. Although a very liquid market, small disruptions in South America can wreak havoc on the global copper prices.

Materials	Electric resistivity (Ω.m)	IACS (%)
Silver	16.10^{-9}	106,3%
Copper	17.10^{-9}	100%
Gold	22.10^{-9}	77,3%
Aluminium	27.10^{-9}	63%
Magnesium	46.10^{-9}	37%
Bronze	50.10^{-9}	34%
Zinc	60.10^{-9}	28,3%
Nickel	70.10^{-9}	24,3%
Brass	70.10^{-9}	24,3%
Iron	104.10^{-9}	16,3%
Tin	142.10^{-9}	12%
Lead	207.10^{-9}	8,2%
Nichrome	1000.10^{-9}	1,7%

Figure 1: Electrical Conductivity of the Main Metals

China's unanticipated growth over the last 30 years, coupled with the gradual strengthening of the RMB's purchasing power has seen the price of copper remain considerably high in comparison to other metals which are used for conductors such as aluminum.

The chemical symbol of Copper is Cu with an atomic number of 29, which places copper in the same group of precious metals as silver and gold. All metals in this group are highly conductive, meaning that electrical current is easily transmitted

[2] Harald U. Sverdrup, Kristin Vala Ragnarsdottir, Deniz Koca. Koca
[3] Antonio Alonso-Ayuso, Felipe Carvallo, et al.

through these mediums. The most conductive material in the world is silver, however due to silvers' much higher price and only slightly better conductivity, the metal of choice for many electrical applications is copper (Figure 1).

When copper is not used, the usual conductive alternative is aluminum, also due to its relatively good conductivity, but also much lighter weight. Aluminum conductors are therefore an important part of the automotive industries' attempt to produce lighter, and thus more fuel efficient vehicles.

Because of this relationship with other precious metals silver and gold, copper is often referred to as a semi-precious metal. Copper is ductile and malleable therefore is a good candidate for drawing into thin wire or also rolled down to thinner diameters.

The main applications of copper are in electrical conductors as well as tubing for plumbing in construction. Due to its overall and universal application use in construction, industry and electrical purposes, copper has historically been a very good bellwether for economic activity.[4]

b) Significance of China in commodities and metals

Research studying copper consumption from 1980 to 2010 reveals a rather interesting trend. In an emerging economy such as that of China, the consumption rose rapidly through that period but declined in the industrialized nations. At the beginning of the 21st century, the U.S.A. was the highest consumer of copper in consuming a record 17% of the world's pure refined copper. However, China's consumption rose above that of the U.S. and became the world's biggest consumer of refined copper shortly afterwards. Also, up until 2000, the U.S. was the world's largest producer of copper only to be overtaken by Chile in the years to come. The Chinese economy went through an economic boom in this time frame which in turn increased the demand for more refined copper.

China consumes a wide range of commodities including copper on a scale never before seen in recorded history. As a percentage of the worldwide consumption,

[4] Hao Yang, Lihong Lin

China accounted for 45% of the global copper consumption in 2014[5]. The nation's rapid economic growth has allowed the overall global demand levels of commodities to rise over the past five years. Chinas consumption of raw materials, given its stage of economic development, has been disproportionately high in comparison to other countries; however given that over 1.3 billion people call China home, this should not come as a surprise. This strategic and very important position taken by China has had huge implications for the global trade patterns of various commodities and has led a commodity fueled recovery from the depths of the 2008-2009 financial crisis.[6]

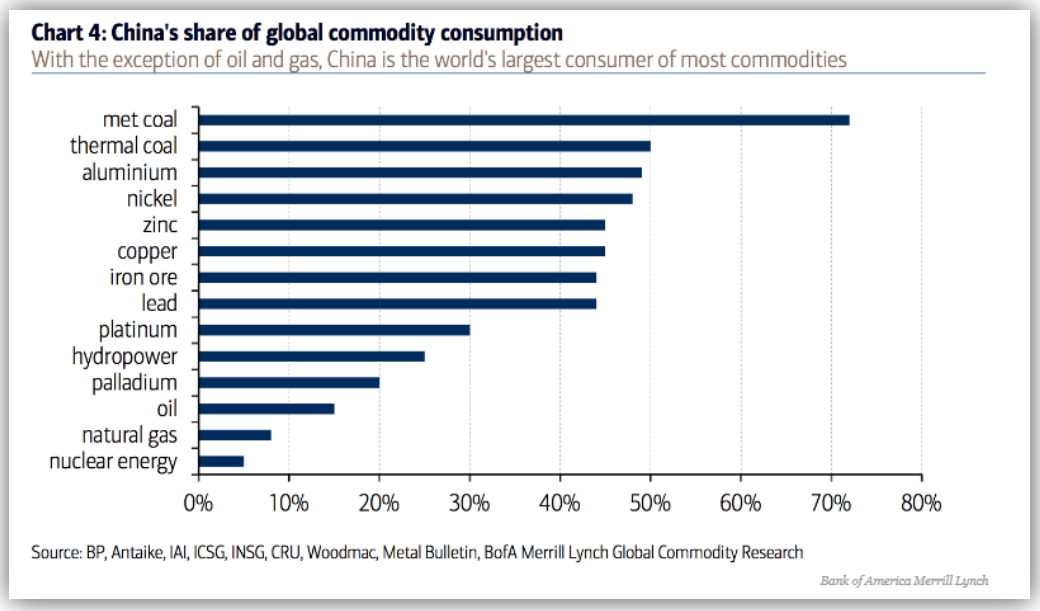

Figure 2: Chart 4 - China's share of global commodity consumption

In the world of base metals, the economic influence and effect that China has is felt way beyond their own national borders. The demand and supply of copper have always been of greater significance to investors. Not only does its reputation predict the shape of the global economy, but also acts as a stimulant to its general growth. The ability of the metal to conduct both heat and electricity make it a common feature in virtually all industries such as construction, electronics, and power, to name a few. Even the products made from copper can be found anywhere on the globe. From the chips found in computers to wires used in motor vehicles and airplanes, copper reigns supreme among a large collection of useful metals. As

[5] Kentaka Arugaa, Shunsuke Managia
[6] Lino Briguglio, Stephen Piccinino

such, it has evolved to become a strong indicator of an economy's health in any part of the globe.[7]

At any one time when the demand is high and it is during economic booming periods, more copper is being used in various industries and-other factors being constant-the price of copper is bound to rise as a result. It has attracted accolades such as "Dr.Copper" with time due to its ability, real or imagined, to predict economic growth. According to Klotz, Lin & Hsu[8], history has affirmed the high correlation between the prices of the metal and the overall growth of per capita. On a general point of view that has been observed in history, a rise in copper prices indicates a strong demand and a rising global economy's strength.

Additionally, the prices of copper, China's economy and world trade have been historically thought to be strongly correlated. China is responsible for almost 50% of the world's metal demand such that every time its economy goes through a period of slower growth, the respective global stock market usually also dwindles accordingly. Copper has been found to have wider industrial applications than other metals such

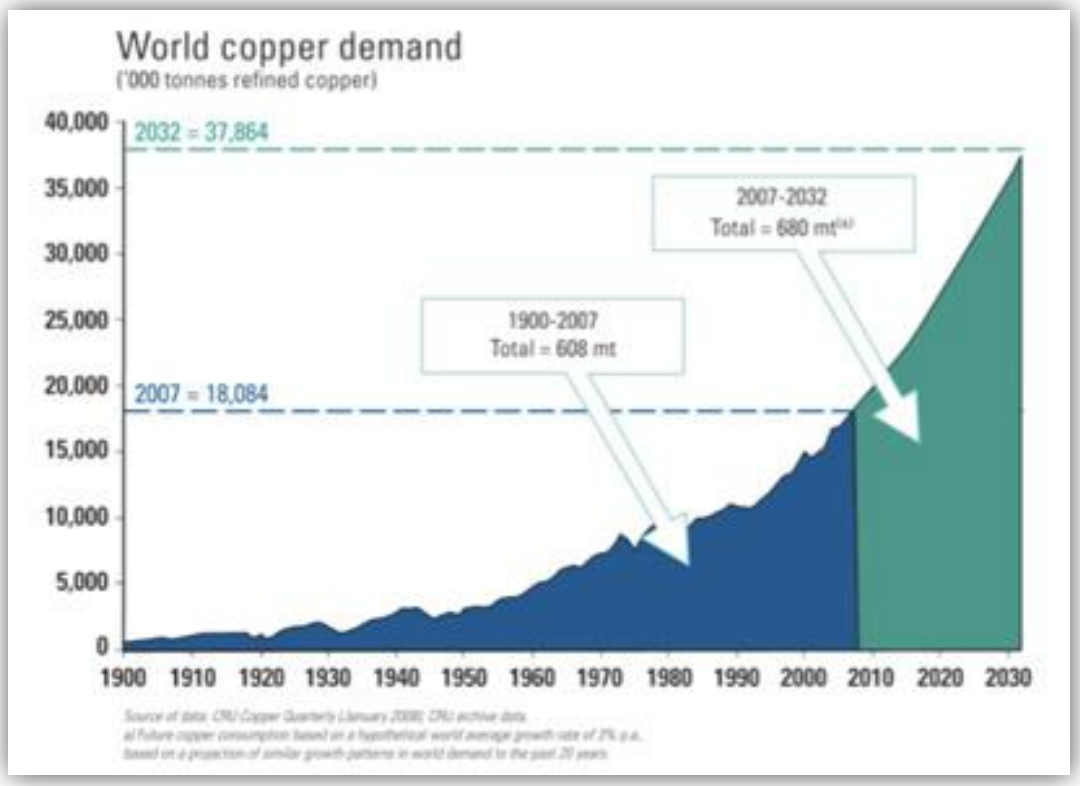

Figure 3: World Copper Demand

[7] Garnaut, R
[8] Klotz, P., Lin, T. C., & Hsu, S. H

as silver or gold. This translates into its vast application in an industrialized economy such as China as it is critical for infrastructure growth. Case in point of the high correlation between China's growth and the copper demand can be traced back to 2011 when the copper prices were at an all-time high of $10.100/ to. This was caused by the rampant demand in China resulting in a rapid expansion of the economy. However, as soon as China's demand slowed, the copper prices also responded in the same direction from the waning industrial usage of the copper.

Within the past century, the industrial demand for copper has risen to over 20 million metric tons from an initial 500,000 metric tons. Some indications point to the fact that with a continually rising world population, the resulting demand for copper will rise exponentially to demand levels never seen before. This rise will most likely lead to the search for new mines, processing plant facilities and expansion of the current structures to accommodate the demand. Farooki & Kaplinsky[9] establish that the developing nations are using copper as a stimulant for civilization as well as their in their push for improving the living standards. China's demand for copper amounts to approximately 22 million metric tons as the world's 2nd largest economy.

The outlook for copper is focused greatly on the Chinese economy as it has been a general reflection of global economic and industrial growth. Between 1980 and 2010, the yearly rate of growth was recorded at 9.8%. As indicated in the World Copper Demand chart (Figure 2), the consumption of copper is expected to grow as a result of the overall global economic growth by 2030. In particular, it is projected that by 2030 the copper demanded by China will be more than double that required in 2007. China has several factors that have been identified to be of great significance in spurring copper consumption. According to Sverdrup, Ragnarsdottir & Koca[10], the urban population is projected to hit over 1.1. billion people in China by 2025 and over 220 cities will have over a million people in China. This rapid increase in urban population in China will be accompanied by a demand for houses and transit systems.

Approximately 6 million houses and 180 transit systems are predicted to be developed by 2025 due to the massive increase in urban population. This means that copper will be required to facilitate the development of the infrastructure. At the

[9] Farooki & Kaplinsky
[10] Raphael Paschkea, Marcel Prokopczuk

same time, the world copper demand is projected to hit 680 million metric tons as a result of the massive population pressure and demand for infrastructure across the globe.

In 2015, copper fell to its lowest point in six years on the London Metal Exchange. Within the same period, the nation's manufacturing Purchasing Manufacturers Index declined to 50 as the number of business orders also declined. The manufacturers cut down their levels of production meaning that China was slowing down rather than experiencing a recession. A downward pressure on the nation's economy was to follow as the growth in infrastructure expenditure picked up at a slower rate. During the 2nd quarter of 2015, the demand for copper contracted as compared to the same point in time in 2014. During this time, the growth in the economy was recorded to be at an annual rate of 7%, thus beating a 6.8% consensus.[11]

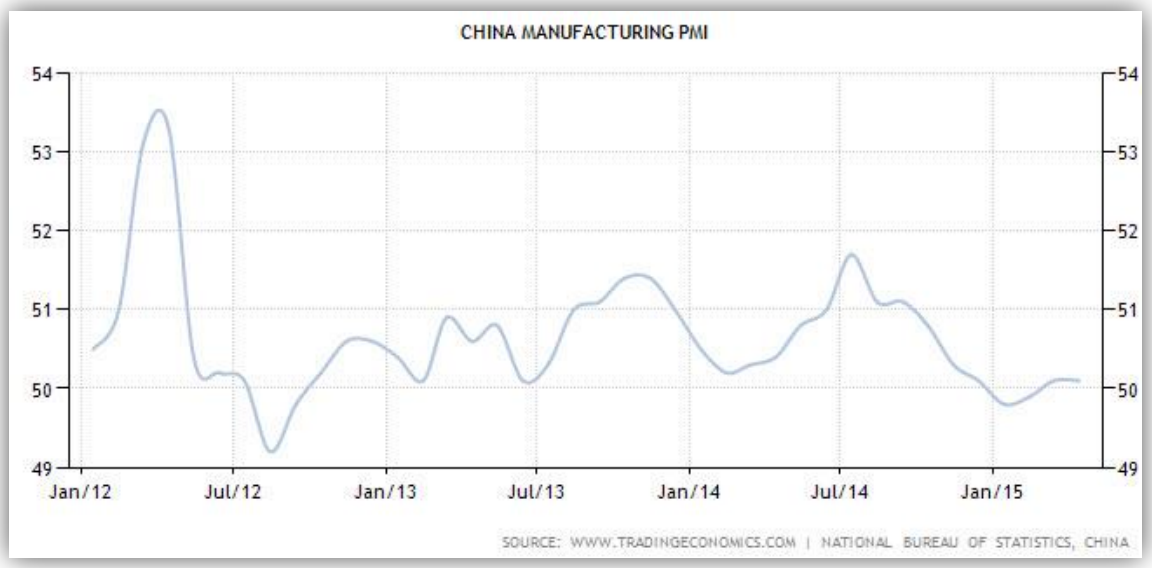

Figure 4: China Manufacturing PMI

The above chart on China's manufacturing PMI can be used to indicate either an economic contraction or expansion. Running from 2012, the PMI data indicates various levels of economic contract or expansion

Depending on the data points, readings above 50 show an accompanying economic contraction while readings above 50 indicate economic expansion. As illustrated, the PMI indicates a decline of manufacturing since 2012 and a recovering period

[11] Perry Sadorsky

between the three years. The 1st quarter of 2015 proved to be a sharp contrast to the previous year when the economy was catapulted by the demand of copper in the nation. This proves that there is a strong correlation between China's economic activity and the copper prices/ demand. As the demand for copper grows, the price will eventually rise, and the level of industrial activity will follow suit to cause the economy to expand. The copper prices are influenced by various economic forces. In March 2014, the copper prices were adversely affected by the collapse of China's Chaon Solar from its failure to find its footing in the corporate bonds sector. The liquidity of the copper market was also put into question later in June 2014 when fraudulent practices involving the China's port of Qingdao brought to light the copper shipments used as collateral. Point f goes into more detail on this and other schemes used.

As it has been observed in China, the production of copper is more of a capital-intensive venture. However, the copper refinery process is more of an energy-intensive process. These processes indicate that they can have a very large influence on the copper prices. However, the demand from the larger Asia region accounts for a larger proportion of the consumed copper. Other developments in the global economy have also shown to be of strong influence on the copper prices. Trends in the EU, US and Chinese GDP and the global trade also play a massive role in determining the overall copper prices. The influence emanating from China acts as a key factor as it is one of the largest consumers and producers of global copper. It is estimated that China produces around 33% of the global pure copper. It is these statistics that link China's economic growth patterns to the copper prices. The correlation between the global economy and the trends in copper prices has always been a strong predictor of a strong correlation between the two variables. According to Garnaut, the consumption and production of copper around the world ensures that global trade is always on its high demand. Therefore, a decline in copper prices would be explained by falling demand, and ultimately a decrease in the global trade. It is from this perspective that the copper prices act as strong indicators of the trade volumes around the globe.

The worldwide demand and supply of copper are one of the aspects that are of great importance due to the rise in demand. As the developing nations join the global market, the demand for copper is expected to rise. However, the supply of copper supply is considered sufficient and not at risk of being disrupted because it is

not exclusive to one region in the world. China is, however, taking considerable steps to ensure that the impact of the copper supply disruption is not too high and is within manageable levels.[12] Scientists are studying the future copper deposits together with their concentrations in the Earth's crust. They are then using that data to assess any potential for undiscovered deposits. This is after reports emerged that there is enough copper in the ground that remains to be discovered. In the U.S.A. alone, over 200 million tons of copper ore were estimated to have been undiscovered leading up to the 21st century. At the same time, the recycling plants have stepped up to ensure that used copper, or also known as secondary copper, is also recycled more efficiently or further reprocessed without the loss of the vital features and properties which for most purposes is conductivity. More assessments have also been conducted to help in understanding the interactions between the environment and the copper availability in a bid to ensure that the world has adequate copper supplies in the future.

c) Influence of China on Copper Prices

Copper prices have been effective as a barometer of the global economy. Therefore, businesses and as a result, the economy, will always be concerned whenever copper prices fall. In November 2015, the copper prices fell to their lowest point in six years to record a price of $4500 for every ton. Some analysts came up with evaluations of the market and suggested that an economic recession was imminent because the recorded decline in copper prices reflected the same decline recorded during the global financial crisis. The collapse in prices was linked directly to the Chinese economy whose demand for copper had declined. It is not to take away the fact that China's consumption of copper has risen rapidly in the past few decades from the respective economic boom. China consumes more copper than any other nation in the world, but the slow pace of the Chinese economy since 2010 meant that copper demand was lower than previously. During this period, the Chinese economy recorded a slowdown by expanding by only 6.9% in the third quarter of 2015. In response, China attempted to restructure its economy so that consumer demand would stimulate further economic growth. The strategy was to move away from manufacturing to a driver of growth and limit the sector's tendency to gobble the metal.

[12] Paresh Kumar Narayan, Ruipeng Liu

Copper has a huge impact on the global economy since it is a key for major infrastructure projects. When the copper market goes through periods of volatility, the global economy is bound to react in kind. The decline in copper prices has a direct effect on the mining companies whose stocks start piling up. The fall in copper prices spreads to other commodities within the economy, raising concerns that the slowdown could spread to the energy market.[13] Right after the price of copper was recorded to be at its lowest point in 2015, the World Bank reported that the slowdown in China's economy would reduce the growth of the global economy. The slowdown would limit the growth in infrastructure while the world economy fell short of the estimated 3.4%.

The graph below indicates the level of GDP in China between 1992 and 2015 versus the copper prices. It is evident that a rise in copper prices is followed closely by a

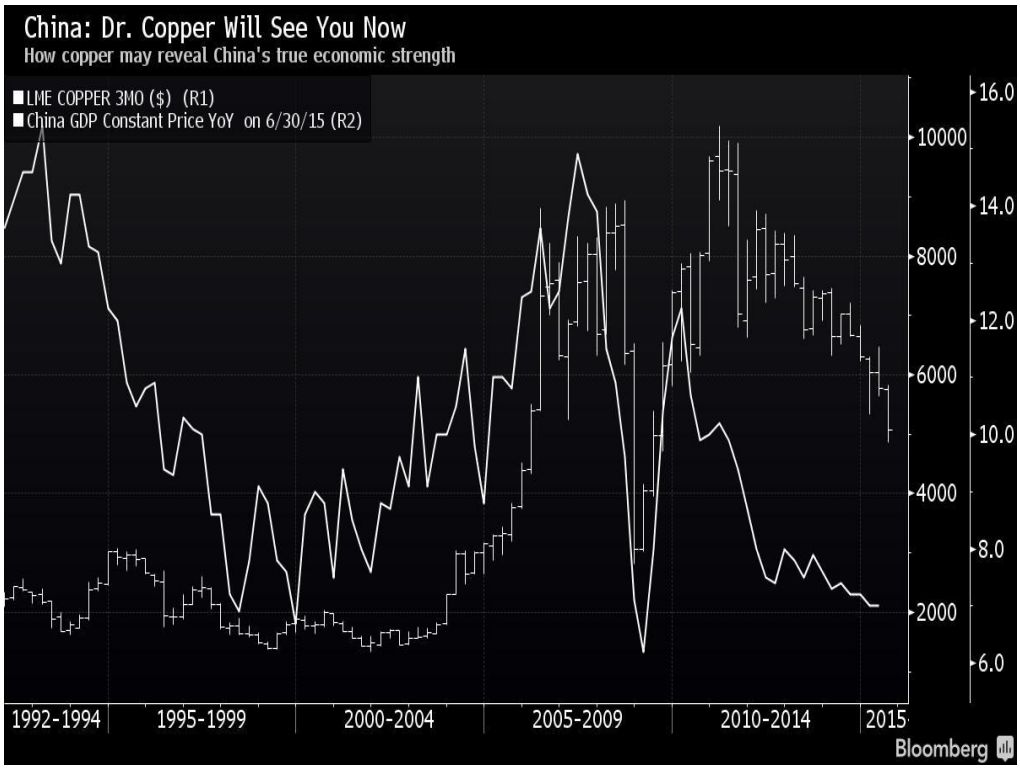

Figure 5: Divide Copper Price by 1000 to find strength of Chinese Economy

[13] "Energy Use in the Copper Industry" Princeton University

corresponding increase in China's GDP. At the same time, a drop in the copper prices leads to a slowdown in the strength of the economy. When copper is listed at $5000 per ton, the corresponding growth in the economy is about 5%. The global economy's strength can also be determined by evaluating the copper prices. The ability of the copper prices to indicate the direction of the economy has come under scrutiny lately, but history confirms that it is as useful as ever in gauging the strength of the world economy. Recent Copper market derivatives enabling speculators and traders into the market have fueled some thoughts that the copper prices are not anymore driven by economic fundamentals, but rather by speculators attempting to make quick profits in daily or hourly trading.

Its status is more so made relevant through China's reflection of the economy as its services become significant aspects of GDP. As indicated by the graph above, there is such a strong correlation between China's GDP and the copper prices that the nation's real growth can be assessed through the division of the copper prices by a thousand. Although it is an unapproved "rule of the thumb", the calculation has been used in approximating China's rate of growth. This estimate approximation of China's economy confirms that copper really has a Ph.D. in economics in its strength to point out the direction of the global economy. From the basic economic law of demand, an increase in the demand for copper causes the prices also to increase to reveal a bulging global economy.

On the other hand, a fall in copper prices indicates that the demand is sluggish, and may be an indication of an economic slowdown. According to Roache[14], the correlation between copper prices and the overall global economic growth is at a significant 0.5, which is above the moderate level. Therefore, clear-cut strategies have to be developed to capture the real market situation in the metals area in an attempt to anticipate the swings in the market, especially potential massive drops in prices. The influence of copper prices on the global economic growth can be made stronger by listing the expansion in China's economy versus the real data corrected by statistical reports.

d) China and the Global Consumption and Production of Copper

[14] Roache, S. K.

The Chinese economy is statistically the largest consumer of copper in the world. This is particularly interesting since China does not have the large-scale copper deposits within its territory such as Peru or Chile, let alone smelting facilities to meet its ever-increasing demand. Chile has copper in abundance as a result of its history in volcanic activities. It hosts 60% of the world's largest mines such as the Escondida mine that is estimated to account for almost 55 of the copper supplied around the world. This means that Chile is of critical importance to the global economy alongside China. Over the years, China has continually relied on international suppliers and exporters for both primary and secondary forms of copper[15]. The recent and unprecedented phase of large-scale industrialization in this country has led to its emergence as a key player in global copper market as a dominant importer. As of 2014, 18.2% of China's total copper consumption has come from imports, and only 1.8% of the revenue in this branch has come from exporting copper products.[16]

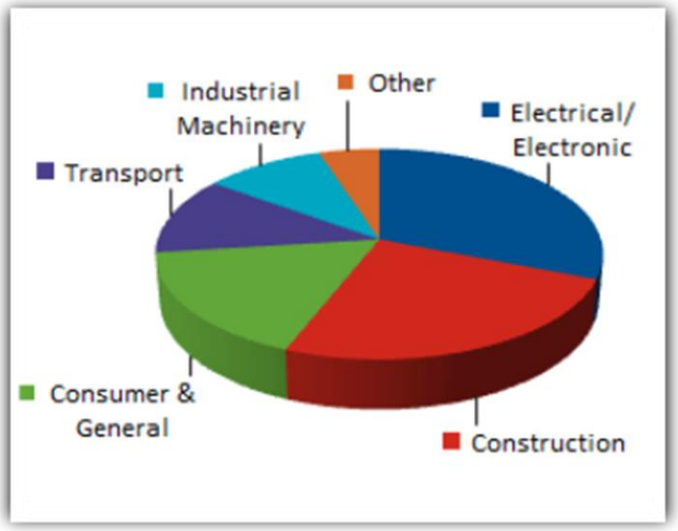

Figure 6: Global Industrial consumption of copper 2011

The Chinese appetite for copper is not surprising. This can be linked to the key pillars of economic development which are principally centered on the manufacture of electronics and machinery, transportation technologies and a rapid rate of urbanization and construction. All of which are produced on a massive scale in China and all of these sectors have an intensive rate of copper usage. The growth of the Chinese consumers is projected to have a huge impact on the demand for copper as domestic consumption is also predicted to rise at an even higher pace than the overall GDP. As the number of consumers increase, the demand for products such as cars and electronics also rises. In fact, China projects a target of 60-65% in the

[15] Rutledge, R. W., Karim, K., & Wang, R
[16] Ibis World - Copper Smelting Market Research Report

urbanization rate in the next 40 years. This urban growth will push the demand for copper to higher heights than experienced at the moment.

Taking these factors into consideration, a shift in the demand and supply structure of copper within China would have profound effects on copper stock and copper prices as a result. Over the years, copper producing countries (e.g., Chile, Peru and Zambia) have experienced a financial boom mainly due to the consistent consumption by China. This consumption has in many ways prevented a further collapse in economic activity after the global recession in 2008-2010. Work done by Briguglio and Piccinino (cited earlier), have shown that East Asian economies were more resilient to the global downturn due to a higher Growth With Resilience (GWR) index number than other emerging and developed economies. Despite the economic downturn in the past decade, China's demand for copper as a vital raw material for manufacturing and production remained persistent, and one could say helped pull the rest of the world out of recession.

China’s role in the supply-demand balance of copper is now non-debatable. Figure 7 shows the worldwide consumption of copper in percentage and the large share which is attributed to the Chinese demand.

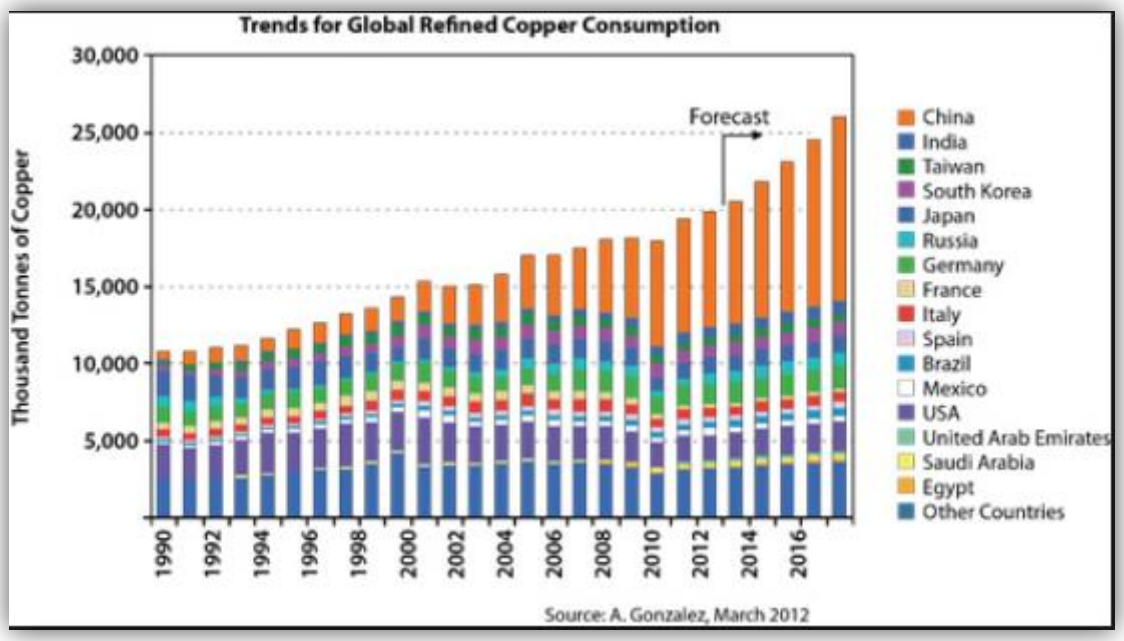

Figure 7: Trends for global refined copper consumption

Recently, China has actively advocated recycling of copper and copper based alloys in line with its sustainability plans. China's 12th 5-year plan (2011-2016) focuses on sustainability, clean energy, and efficiency, which takes direct aim at the unfettered growth which has been underway for nearly 30 years (Figure 8). As the government supports more sustainability projects, doors should open for the development of wind and solar energy, which are industries which also demand intensive quantities of copper for their production.[17]

[17] "China's 12th Five-Year Plan: Overview." KPMG Advisory China (Ltd)

China's 12th Five-Year Plan: Seven Priority Industries	
1	**New energy** • Nuclear, wind and solar power
2	**Energy conservation and environmental protection** • Energy reduction targets
3	**Biotechnology** • Drugs and medical devices
4	**New materials** • Rare earths and high-end semiconductors
5	**New IT** • Broadband networks, internet security infrastructure, network convergence
6	**High-end equipment manufacturing** • Aerospace and telecom equipment
7	**Clean energy vehicles**

Figure 8: China's 12th Five-Year Plan: Overview

At the same time, China is advocating the increased recycling of metals such as copper, which in turn could also affect the supply / demand equilibrium in the primary copper market. China has also taken a notable interest in the economic empowerment of copper producing countries, especially in Africa. This has mostly been in the form of trading partnerships and business ties to aid the exchange of goods for currency between the different parties.

e) Possible drivers of Copper Prices

Copper has been used as a currency for many centuries. Being one of the oldest metals, it has remained as the key metal in the industrial sector. It acts as a financial instrument for traders who use it as a speculative measure. It follows that copper prices have key drivers that lead active traders in today's economy to speculate against. One of the major drivers of copper prices is the invention and integration of new substitutes. In certain applications in the industrial sector, the technology has advanced to ensure that copper can be replaced by cheaper metals. In the energy sector, copper is partly being substituted by aluminum in coating the power cables. It is also emerging that aluminum is being used increasingly in automobile radiators. Roles that were known to be best suited for copper traditionally are now being

replaced by other cheaper and in the case of aluminum, lighter metals. The availability of substitutes has a direct downward pressure on copper prices.

The prevalence of substitutes in the manufacturing sector is a major concern for the future trend in copper prices. The higher the availability of the substitutes, the higher the pressure will be directed on copper which ultimately will make it even cheaper. Reports from China indicate that China has enough supply of aluminum even when it has to import a large share of copper. At the same time, copper is far more expensive than aluminum, thus making it an attractive option due to the price difference. The Financial Times is quoted as stating,

> *"An increased rate of substitution to aluminum alloy, from copper, is highly likely … the China price of copper is 3.4 times that of aluminum (and substitution becomes profitable at a ratio of 2.5/1),"* [18]

However, China still prefers copper to aluminum although it is predicted that almost 250,000 tons of copper demand could be lost in 2016 when aluminum is used in the grid infrastructure project that is currently underway.

Market demand has a massive influence on copper prices as outlined earlier. As the demand for copper rises around the world, it is expected that the price levels will change to accommodate the change. Consumer demand is projected to cause a shift in the level of services needed in sectors such as housing and construction. China's economy being a major consumer of copper may act as a determinant to copper prices. Therefore, if the Chinese economy slows down, the demand for copper could be affected as former demanding sectors use less of copper. However, new investments and developments that raise the demand of copper are likely to stimulate growth in the economy and cause a rise in copper prices. In various economies, copper prices have been known to be volatile as prices react to different push and pull factors. Supply disruptions have also been mentioned as having a major influence on global copper prices.

Since China and Chile account for the world's largest copper producers and/or refiners, disruptions and/or shortages can have a huge impact on the prices of

[18] Matich, Teresa

copper. South America holds a huge bearing on copper prices as it forms a large proportion of the copper supplied across the world. However, China's copper inventory is kept under scrutiny not to fall under the required minimum by several stakeholders. Since the Chinese economy is the largest consumer of copper, it has to take note of the inventory levels regularly. Companies such as Teck Resources and BHP iliton are tasked with keeping tabs on copper inventory. The graph below (Figure 9) indicates a run of two years copper inventory. It can be observed that towards the latter part of 2015 the copper inventory holds steady for a month. A decline can be noticed as one month graduates into another in the case below taken over the two years. Falling inventory could either mean that the supply in the market is low in the market when demand is taken into account. When there is an excess supply, copper inventories rise in the nations' warehouses. These demand and supply variations play a lead role in influencing the prices of copper.[19]

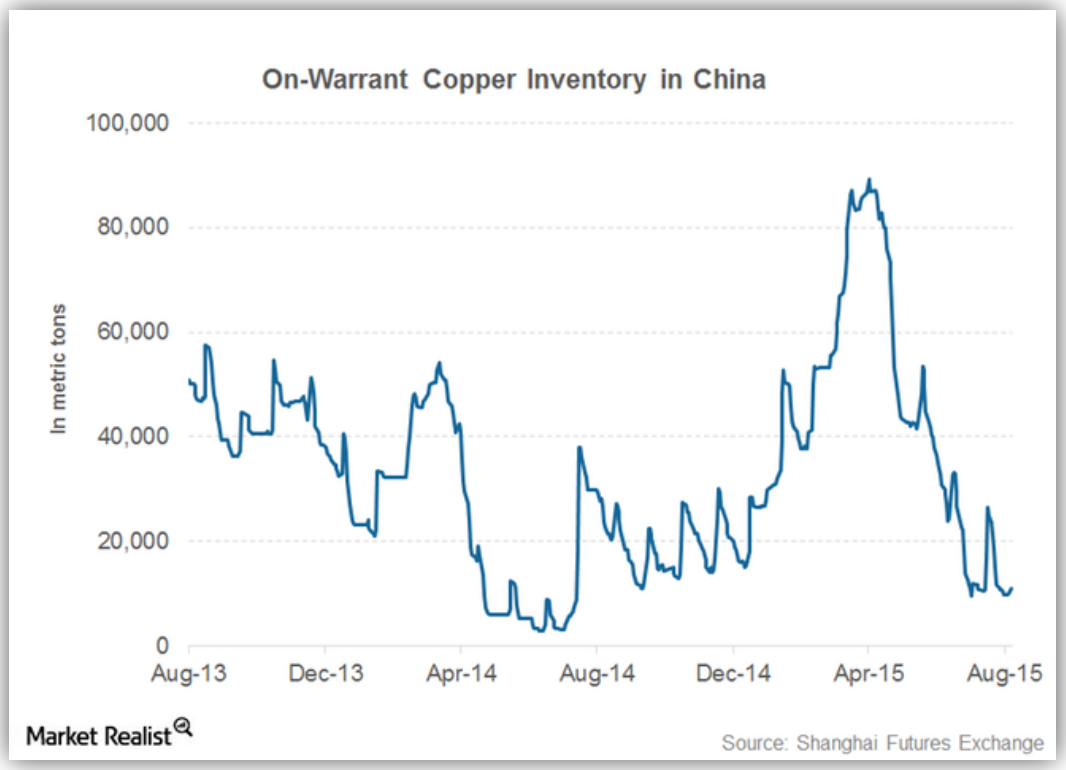

Figure 9: On Warrant Copper Inventory in China

f) Other possible drivers

[19] Fama, E.F., French, K.R

There are other possible factors which have not been spoken about for years, but have come to light in the last 2-3 years. This is the topic of the copper carry trade and the distortions in the copper market it can produce. The copper carry trade has resulted in what many players in the market see as a distortion in the amount of copper actually consumed and used in production in China. A quick explanation of the carry trade had been outlined by Bloomberg in the fall of 2015 below:

> "*The impact of the Chinese metal carry trade is in the distortion of the true underlying copper demand, and a buildup in the metal's inventory, strictly for collateral in financing. China accounts for 46% of global copper demand, according to the Word Bureau of Metals Statistics. One question analysts must ask: What if it's just 35%? The potential stopping of this trade, and normalization of the distorted demand, will provide understanding of China's true copper needs and their potential growth."*[20]

The copper carry trade is a huge unknown in the markets and it is thought that the unwinding of this trade could bring markets a level of turbulence which has rarely been seen. The basics of this trade are that copper is ultimately imported into China using a low interest credit facility from Chinese Bank. The trader in this case, would then use the copper as collateral to borrow US Dollars at a low interest rate. They would use these US dollars to then invest in higher yielding currencies and pocket the profit. Yet one other trade which is made is to finance full cargoes of copper with a letter of credit, then discounting these L/Cs at non-official shadow banks which then generates cash for investments in other high yielding areas such as real estate. [21]

Therefore, while such trades are performed, imported copper sits in a warehouse and is not used in production. If this is the case, distortions in the copper market may come about since it would be difficult to discern in the statistics which copper is being used for production and which for financing other activities.

It is said that this trade is as of fall 2015 has started to unwind, since there were many losing positions on this trade due to the appreciation of the Chinese Yuan in August of 2015 and additionally due to the reduced real estate projects GDP growth

[20] Hoffman, Kenneth and Gilmartin, Sean
[21] "The pH Report". International EChem

of Chinas economy is moving from investment-induced growth to consumption-induced growth. Another possible cause for copper price movements may well be the energy prices. As mentioned earlier, copper mining and production is an energy intensive process. Smelting the copper alone accounts for 40% of the total energy costs of the copper production which includes transportation and beneficiation of the copper ore.

The correlation of oil and copper prices has been studied for many years and the link is clear. The below figure demonstrates the correlation.

Figure 10: Correlation of Various Factors

A correlation over the last 15 years between the price of Brent oil and copper as published by ABN AMRO Economics is seen above as a whopping 0.94, which

means only 0.06 points off from being perfectly correlated (Figure 10). Some argue that this relationship has decreased in the past few years; however, a strong correlation would still be present even today[22]. Below is a chart of the oil vs. copper price since 2006 and the correlation is also striking.

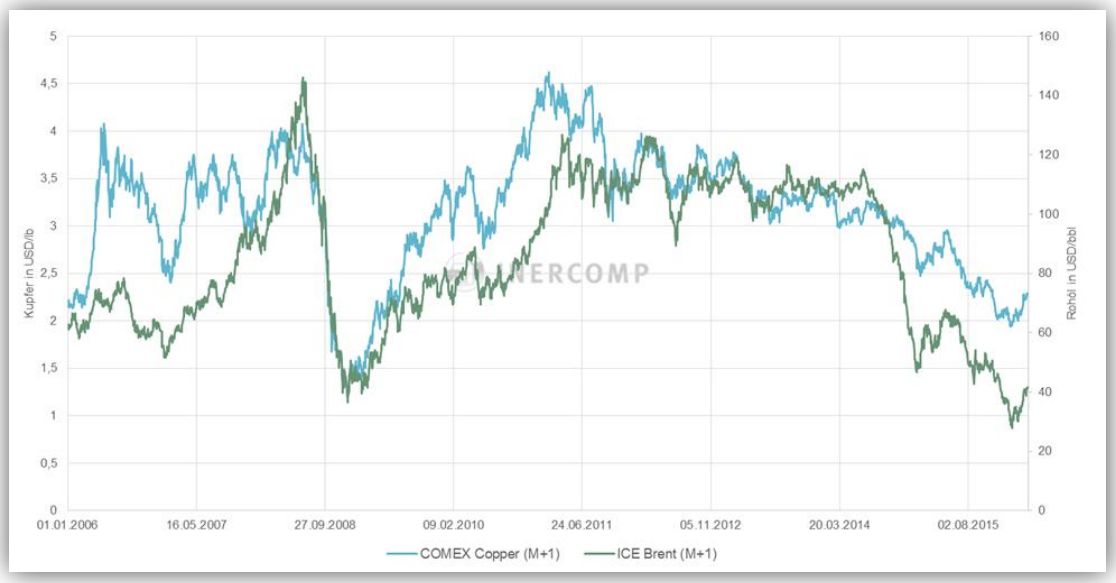

Figure 11: Brent Oil vs. COMEX copper prices

[22] Cortazar, G., Eterovic, F.

2. Importance of copper prices for purchasing professionals

Purchasing professionals in the metals area have a need to attempt to anticipate the swings in the market or at least in the most basic sense, understand the potential drivers for the movement in the copper price. Considering in the last 10 years that the global economy has experienced massive volatility in prices, such knowledge could be vital to a buyer. In the past few years, metals price volatility has played a massive role in the purchasing activities of many organizations. In a procurement department for a typical manufacturer, the potential price swings on the metal side can be much greater than those in services, or other production direct or indirect materials. For example, a cable manufacturer in Europe would account for copper around 60% of their direct material spend directly on copper.

Any establishment that purchases metals for industrial and domestic consumers form an important part of the national economy. Not only does the trade of metals provide a constant supply for the industries, but it also provides jobs and revenue for the economy. Economic analysts value the metal services in an economy because they represent tangible commodities that maintain their intrinsic value. They argue that metals balance a country's portfolios so that even when the economy is going through a deflationary period, parts of the portfolio maintain their value. Critics of modeling metal prices state that just like any other investment, it is not worth over-investing as the stock portfolio would lead to an imbalance. Not only are the metal prices volatile, but they also offer limited returns. The fear is that an over-investment would lead to a fall in commodity prices. In 2012, the Chinese data for copper prices indicated that the industrial production had fallen from the projected rate of over 9.7%. The nation had at this time over-invested in copper, and the fear was that it would send waves of deflation across the globe as the falling commodity prices began the chain reaction. Metal prices offered a reflection of the economy's health. However, metals provide a good defensive strategy in an economy during an unattractive investment period. At this point, copper provides the most popular base metal that an economy can trade in because compared to the hefty prices that gold fetches, copper prices offer a drastic difference in the prices they fetch. As a base metal, copper has a variety of applications in many industries. Therefore, modeling its prices in an economy becomes an attractive option.

Although metal prices provide reliable data that can be used to confidently predict the outline of an economy, they may be subject to various supply challenges. Rogue traders and new inventions can have a massive effect on metal prices with oil being the only exception in the category of precious commodities used across the world. China imports copper as a financial speculation strategy and as the purchasing professionals they have been in the past, they are able to add value and increase the functionality of the traded metals. Shocks to the Chinese aggregate activities have an extended impact on the price of metals.

Metal prices are largely dependent on the general consumer demand in an economy. As such, being the industrial inputs of many sectors, copper will tend to peak and fall in demand as the requirements dictate. In the face of declining production, copper prices will most likely decline and cause economic challenges in the long run. In 2010, China engaged in a spending spree buying metals to saturate their metal market. This response occurred when the copper prices were low in anticipation of a looming rebound in the metals market. The production and demand for copper have always been linked with having a symmetrical relationship. As their demand rises, the production also increases until there is equilibrium.

The demand for metals in an economy can be a strong predictor of the economic status. Variations in demand signals reflect either business confidence or a sign of fear in the market.

Therefore, introducing a way that purchasing professionals may go about their copper buying decisions would be a topic of interest for those purchasing metals and in particular copper.

3. Analysis

The London Metal Exchange

The London Metal Exchange, also known as the LME, is the premier metals market used to establish copper prices in Europe.

According to their website, the LME states the following:

> *"The London Metal Exchange is the world centre for the trading of industrial metals – more than three quarters of all non-ferrous metal futures business is transacted on our platforms. In 2015 this equated to:*
>
> - *$12 trillion notional*
> - *4 billion tonnes*
> - *170 million lots*
>
> *A member of HKEx Group, the LME brings together participants from the physical industry and the financial community to create a robust and regulated market where there is always a buyer and a seller, where there is always a price and where there is always the opportunity to transfer or take on risk – 24 hours a day.*
>
> *Investors value the LME as a vibrant futures exchange but also for its close links to industry. The possibility of physical delivery via the world-wide network of LME-approved warehouses makes it the perfect hedging venue for industry and provides a reference price they trust.*
>
> *The Exchange provides producers and consumers of metal with a physical market of last resort and, most importantly of all, with the ability to hedge against the risk of rising and falling world metal prices.*
>
> *It's what we've been doing since 1877."* [23]

In addition to the LME, two other markets help the global metals industry converge on prices, the Commodity Exchange, Inc.(COMEX) and the Shanghai Futures Exchange (SHFE). Prices of these 3 exchanges influence the global copper price as well as influence each other at different times during the trading day. The LME is based in London, therefore copper price settlement is done on this exchange during the European business day.

[23] London Metal Exchange 2015

The LME is geared in effect for the producers and end users of copper, whereby the opportunity to physically hedge risk is available. Derivatives and speculation are also present, however on a smaller scale than the COMEX. The COMEX offers less opportunity to physically hedge positions as a purchaser in a production company, however the main business is the derivatives which are available. In this sense, one can say that the LME is more end-user friendly and the COMEX is more trader friendly.

The Chinese economic data

The data used in this analysis was taken from the Trading Economics website[24]. The trading economics website is a site which is available to all people globally and offers free data for most all countries worldwide. Much economic data can be extracted for free from this website and paying members are able to export the data to an excel sheet whereby higher powered analyses may be performed. The following economic indicators or indexes were chosen on a subjective basis, but on a basis whereby the author believed there may be a good correlation with copper prices:

Industrial production:

The industrial production index measures the industrial production output of businesses in the industrial sector in China. These include businesses in manufacturing, mining and utilities. The index started in 1990 and is reported by the National Bureau of Statistics of China. The values are reported in percent change over the previous month. Therefore, negative values indicate industrial production contraction and positive values indicate industrial production growth. It is expected that as the services sector in China begins to take more share of the Chinese economy, that industrial production growth shall follow suit and decrease over time accordingly. Chart of industrial production in figure 15a

[24] Trading Economics 2015. *China.*

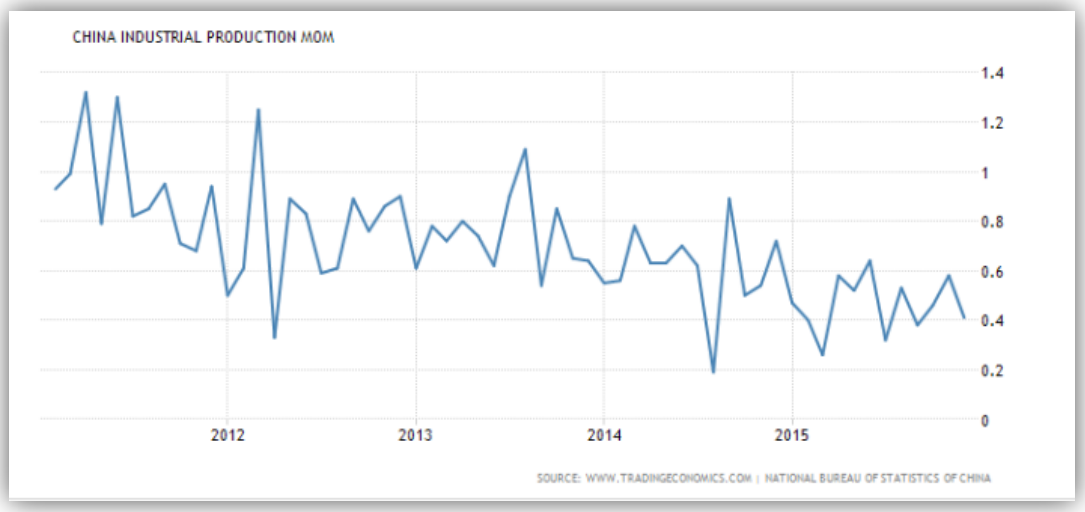

Figure 12: China Industrial Production MoM

Possible Importance

As industrial production increases or decreases, so should in theory also the copper consumption. If this is the case, it should have a direct correlation with LME cash copper prices.

USD-RMB Exchange Rate:

The USD-RMB is the USD-CNY spot exchange rate. This is differentiated from the offshore rate of USD-CNH, which is traded in Hong Kong, and is generally traded at higher RMB values than the USD-CNY due to the CNH market being more liquid. Although still highly pegged to the USD by the Chinese Authorities, slight movements are now allowed and these small deviations allow analysis of the copper price development. The exchange rate is reported on a daily basis; however, for purposes of this work, monthly averages were used for direct comparison purposes.

Figure 13: Chinese Yuan / US Dollar

Possible Importance

Many people these days believe that due to the arbitrage and derivative trading nature of copper, as well as its use as collateral in the carry trade which is now fading. The possible importance of the currency rate could be larger than imagined.

Manufacturing Purchasing Managers Index (PMI):

The Manufacturing PMI is reported by the National Bureau of Statistics on a monthly basis and measures the strength of manufacturing in China. Data is obtained by means of a survey of private sector companies. The whole index is based on 5 indices which contain various weighting: Employment as 20%, Output as 25%, New Orders as 30 %, Suppliers Delivery Times as 15% and Goods held on stock as 10 %. A reading of over 50 indicates manufacturing expansion and lower than 50 indicates manufacturing contraction.

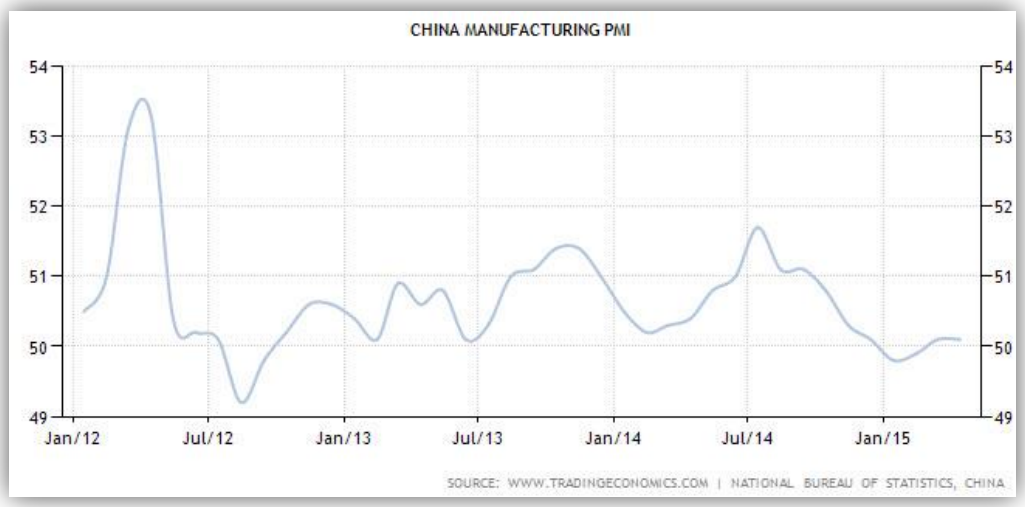

Figure 14: China Manufacturing PMI

Possible Importance

This index is believed to be one of the strongest indices for reflecting economic activity especially in the industrial sector. As such, the manufacturing PMI should demonstrate a high correlation to copper prices.

Chinese Exports

These statistics are available from 1983 until 2015 and are reported by the General Administration of Customs. From 1983 until 2015, the average export amount has been USD52 billion per month over the last 23 years and 176,3 billion in April 2015.

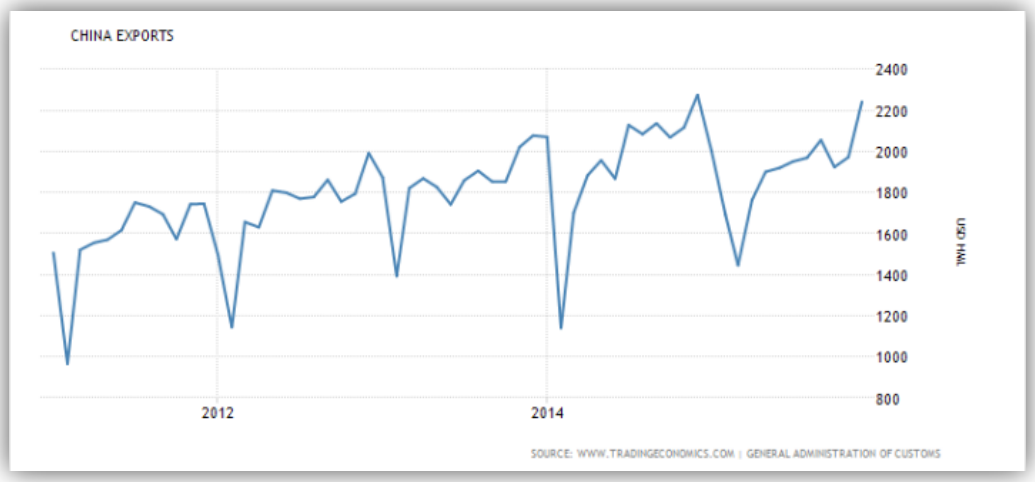

Figure 15: China Exports

Possible Importance

Chinese exports more products and electronics than any other country in the world, therefore it may also be assumed that the exports index should loosely associated with copper prices.

Chinese Producer Prices

The Producer Prices index measures wholesale goods and services price changes sold by manufacturers and producers. The index is reported by the National Bureau of Statistics of China.

Possible Importance

A measurement of prices between businesses is usually always a good signal of economic activity, and therefore could be correlated to copper prices.

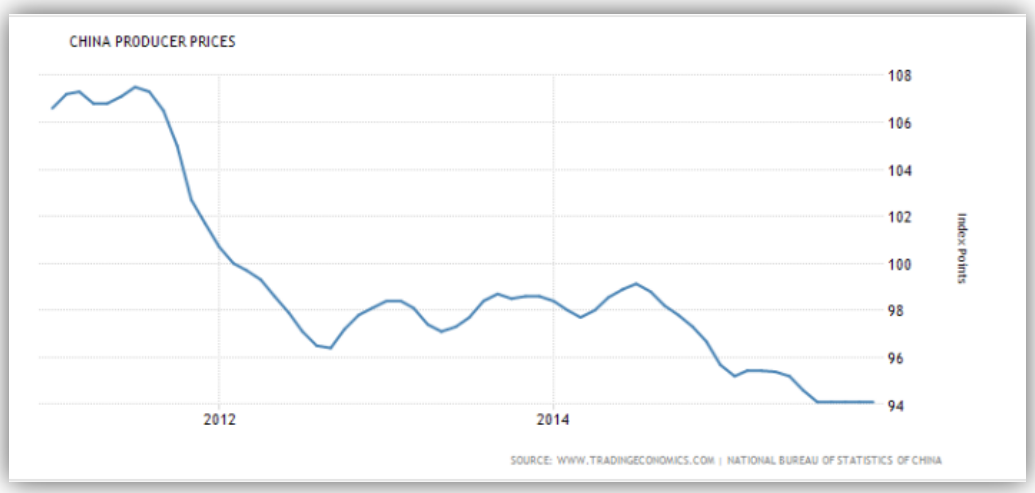

Figure 16: China Producer Prices

Chinese Import Prices

Import prices measure the price change of goods and services which were purchased by Chinese companies from foreign individuals or entities. Chinese Import Prices are reported by the National Bureau of Statistics of China.

Figure 17: China Import Prices

Possible Importance

Copper ore is imported mostly from South America, meaning that copper prices should also partly explain variations in this index. One should expect that correlations are high between these two variables.

Chinese month over month Inflation

This indicator is reported by the National Bureau of Statistics in China and indicates the month over month change in inflation in China.

Possible importance: Inflation may be related to the copper prices in the sense that most all consumer electronic goods contain copper in the form of wiring as well as construction building. The movements in inflation may be positively correlated with the LME copper prices

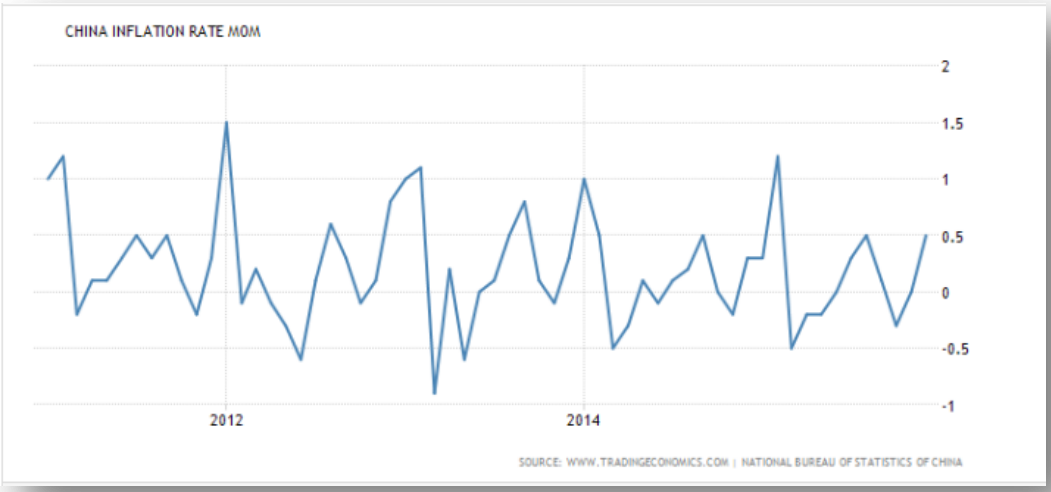

Figure 18: China Inflation Rate MoM

Chinese Leading Economic Index

The leading index is reported by the National Bureau of Statistics of China and comprises 8 indicators which reflect the various points of Chinese economic activity which include: Investments in new projects, industrial production, the real estate development leading index, M2 money supply in circulation, consumer expectations

index, logistics index, Mainland Chinese Hang Seng circulation index and the national debt interest rate spread. The index is based on 100 points as the baseline level.

Figure 19: China Leading Economic Index

Possible Importance:

The Leading economic index is a more widespread economic index taking into account many broad measures of the economy. The relationship to copper could be a strong one if the Leading indicators index properly reflects the economic climate in China.

China New Orders

New Order is a Chinese index which measures the number of new orders Chinese businesses accept per month.

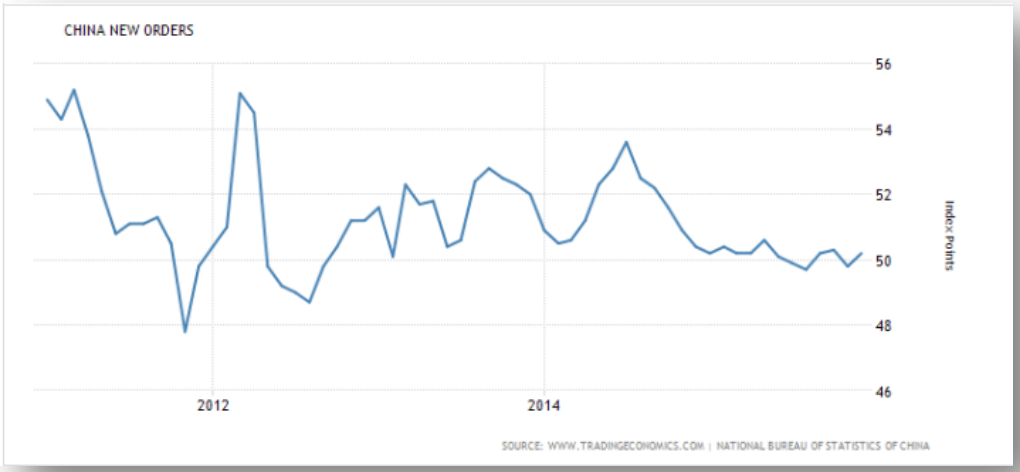

Figure 20: China New Orders

Possible Importance

New orders generally directly reflect the business climate in China. Due to this fact, it could be well correlated with copper prices.

Chinese Consumer Price Index (CPI)

The consumer price index in China measures the amount retail customers in China will pay for a pre-selected basket of household goods. This is differentiated from inflation rate in that this focuses solely on the retail customers and certain goods.

Possible Importance:

The CPI is a measure of the end customer prices for most all retail goods. This index usually excludes highly volatile measures such as gas. Since copper is found in all electronics and most all consumer goods, the CPI measure could be seen as correlated to the LME copper cash settlement price.

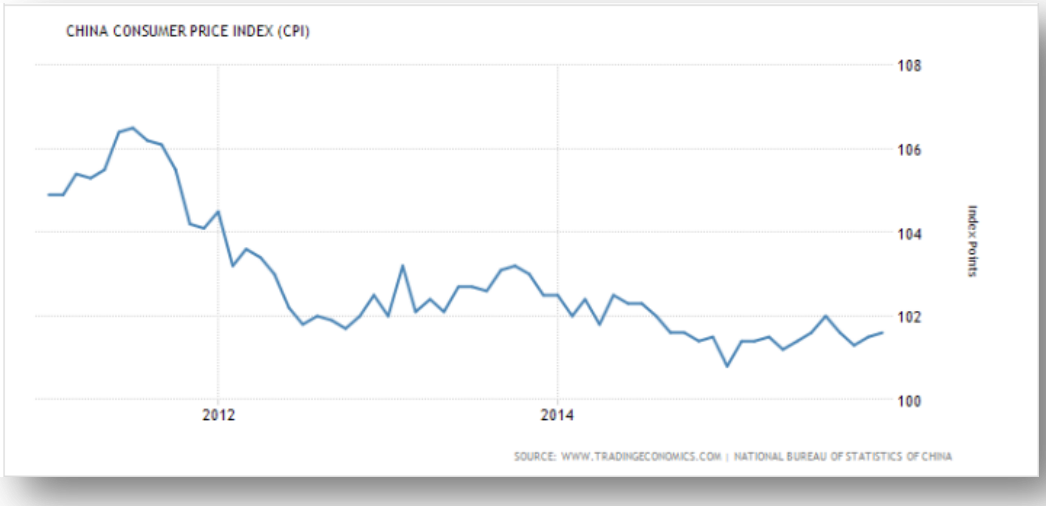

Figure 21: China Consumer Price Index (CPI)

4. Research Methodology

a) Copper industry insider survey

In order to obtain a better idea of the possible most important factors in the relationship between copper price development and the economy of China, a survey was sent out in May 2015 to 5 copper industry insiders in Europe. The insiders were asked to choose which top five Chinese economic factors may be the most valuable predicting copper price development.

The following indicators were generally chosen as the most likely to correlate with LME copper average cash settlement prices:

1) *Industrial Production - 4 Votes*
2) *Copper Inventories – 4 Votes*
3) *USD-RMB exchange rate – 3 Votes*
4) *Manufacturing Purchasing Managers Index (PMI) – 3 Votes*
5) *Consumer Price Index (CPI) – 2 Votes*

All data, including the average cash settlement and the indicators were downloaded from the Trading Economics website. The values indicated in the data are the monthly average for each specified period. The time frame chosen for the data set was January 2010 until April 2015. Some data, such as the leading indicators index, did not exist until a later time period, and other data does not fully run until April 2015 as a result of the reporting period and to some indicators only being reported in quarterly intervals instead of monthly intervals.

In the following analysis, data downloaded from the website Trading Economics the above-mentioned indicators in conjunction with the LME copper settlement prices in order to analyze the development of copper prices in comparison to China's economic data.

The analysis has been performed based on the LME cash settlement copper prices from January 2010 to April 2015, recorded monthly.

These results are divided into the following sections: general trends, the regression model, time series- auto regression model, GARCH Model followed by a summary.

Additional note: Copper inventories were included in the survey and received many votes as a good indicator, however, the data available was quite limited, therefore copper inventories were excluded from the analysis. Once a reliable data source becomes available, a proper analysis shall be conducted.

5. Hypothesis

The Industrial Purchasing Manufacturers Index indicator in China will show the single greatest correlation to LME copper cash settlement prices of all chosen Chinese economic factors due the enormous amount of copper used in manufacturing organizations in China and a multiple regression model including all of the manufacturing economic data shall be the best multi-variable model for LME copper cash settlement prices.

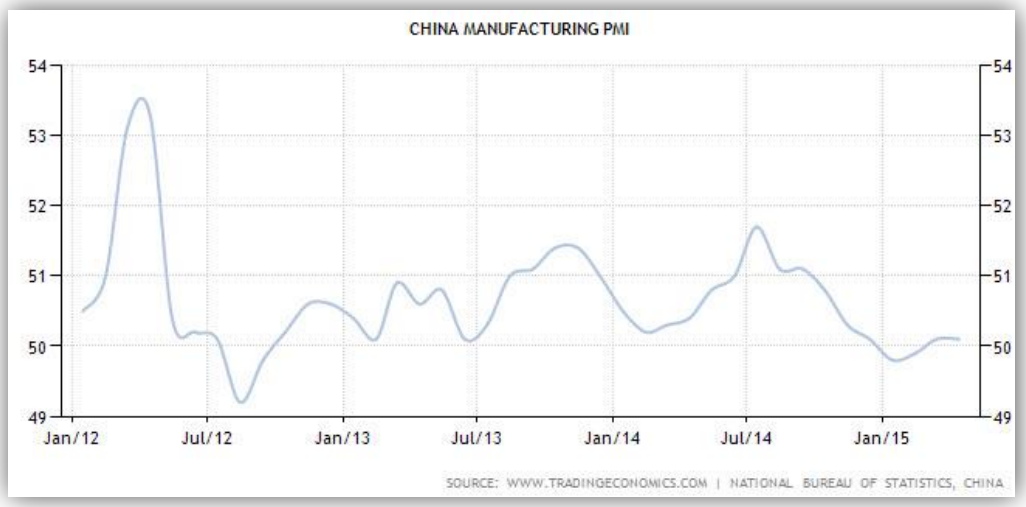

Figure 22: China Manuafacturing PMI

6. Results

General Trends in the data

It was observed that copper prices in China have steadily declined over the period of analysis, as observed in Figure 21. Price changes are not volatile and tend to be stable over time while staying around mean. They tend to have a slightly negative tilt, but not far from 0, as noticed in Figure 22. This may be a result from smoothing of the monthly data. For the purpose of predicting future price trends, this analysis used the multiple regression model based on variables found in the dataset and an autoregressive model based on a similar distribution. A mixed model to predict prices may be the best approach to predicting future prices in this instance.

A simple scatterplot matrix is plotted to observe some simple correlations between the LME cash settlement prices with each other. A quick view of the data may prove that the Leading Indicators Index may have some explanatory power, and there may be some multicollinearity. This does not show any autocorrelation with time, but it is likely that some may be present.

Figure 21 uses a scatterplot matrix depiction to illustrate average cash settlement over time in absolute terms, which has shown steady decline over time. The relative change in average cash settlement values is depicted in Figure 22. It is observed that the second plot shows mean close to 0. This means that despite variation, the variation in average settlement prices tends to stabilize each other over time.

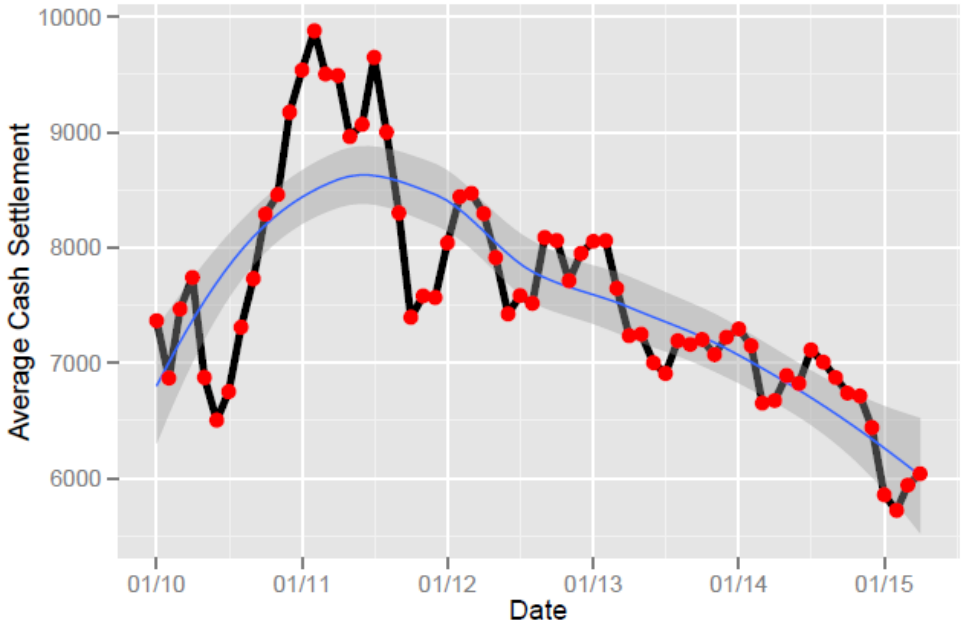

Figure 23: Average cash settlement variation with time, when the mean of prices is 7595

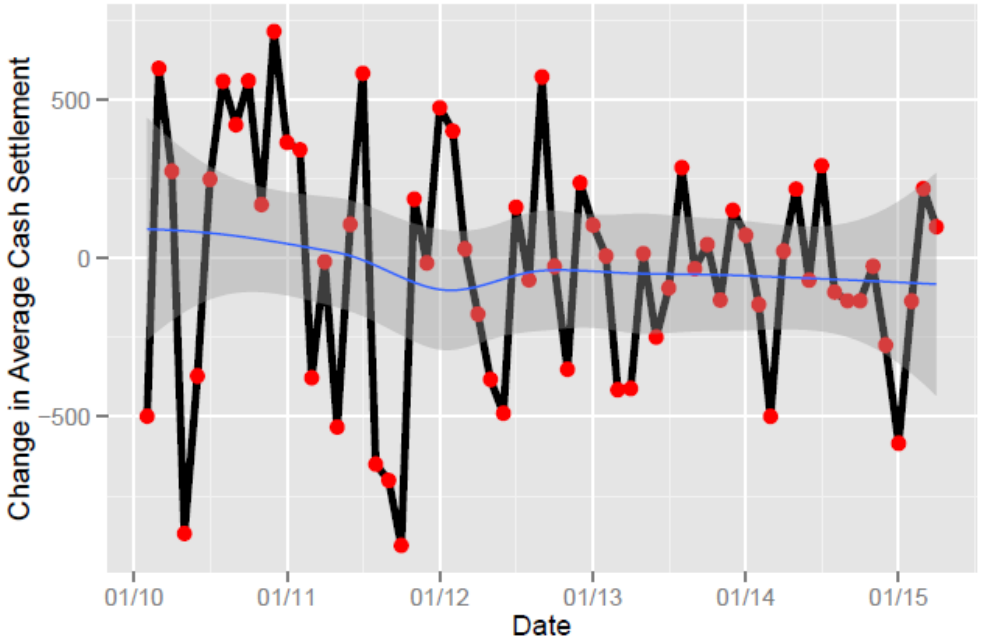

Figure 24: Variation in average cash settlement variation with time, when the mean of prices is 21.0731746

Regression model

The first step of the regression model was to regress all of the variables against the LME average cash settlement. The LME is the “dependent” variable or y, and the

Chinese economic data shall act as the “independent” variables or the x values. In this sense, the formula shall be observed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon$$

In the above formula, n shall be the number of variables, Beta(0) is the y intercept or constant, and E is the error term (can also be thought of as the residuals).

The observations are divided into 2 sets- training and testing. A smaller subset of the total observations is then used to train the data and then model against the remaining set of observations to test for predictive power or goodness of fit. For the modeling purposes, the last 12 observations were held out to evaluate the performance of the model. The rest is used for training purposes.

Table 1: Coefficients used for regression model

	Estimate	Standard Error
(Intercept)	-3.545e+04	2.954e+04
China.Manufacturing.PMI	6.503e+02	3.343e+02
China.Exports	-2.535e-01	4.548e-01
USD.RMB	1.855e+03	9.975e+02
China.Producer.Prices	9.403e+01	1.862e+02
China.Import.Prices	1.133e+01	3.656e+01
China.Imports	3.309e-01	8.130e-01
China.Industrial.Production	1.488e+02	1.055e+02
China.Inflation.Rate.MoM	3.249e+02	1.530e+02
China.Leading.Indicators.Index	3.925e+02	1.879e+02

China.New.Orders	-2.379e+02	1.832e+02
China.CPI	-3.023e+02	1.955e+02

Table 2: t values and P values for the multiple regression

	t value	Pr(>|t|)
(Intercept)	-1.200e+00	2.475e-01
China.Manufacturing.PMI	1.945e+00	6.950e-02
China.Exports	-5.574e-01	5.850e-01
USD.RMB	1.860e+00	8.140e-02
China.Producer.Prices	5.050e-01	6.205e-01
China.Import.Prices	3.098e-01	7.607e-01
China.Imports	4.070e-01	6.894e-01
China.Industrial.Production	1.409e+00	1.778e-01
China.Inflation.Rate.MoM	2.123e+00	4.970e-02
China.Leading.Indicators.Index	2.088e+00	5.310e-02
China.New.Orders	-1.298e+00	2.126e-01
China.CPI	-1.546e+00	1.416e-01

As a result of the multiple regression modeling performed using all of the Chinese economic data points against the LME cash settlement prices, it was observed that the adjusted R-squared is relatively high (0.7014675). However, multicollinearity of the independent variables is the likely culprit.

Checking residuals for autocorrelation

Durbin Watson test is used to check if there is auto-correlation present in the time series over a lagged period. Time series plots regarding price developments usually always show some levels of positive auto-correlation. The formula is as:

$$d = \frac{\sum (\hat{e}_t - \hat{e}_{t-1})^2}{\sum \hat{e}_t^{\,2}}$$

Using the Durbin-Watson test, the score came out as 1.2991735. This combined with a low p-value of 0.006, allows the assumption that some levels of autocorrelation are present. It would also be quite obvious to many that the data is highly autocorrelated since the data represents the same information which are copper prices.

The analysis will then be run using 1st order differencing, which essentially takes the difference between consecutive observations, essentially modeling price change movements and monthly changes between variables.

Table 3: Coefficients used for checking residuals for autocorrelation

	Estimate	Standard Error
(Intercept)	-3.545e+04	2.954e+04
China.Manufacturing.PMI	6.503e+02	3.343e+02
China.Exports	-2.535e-01	4.548e-01
USD.RMB	1.855e+03	9.975e+02
China.Producer.Prices	9.403e+01	1.862e+02
China.Import.Prices	1.133e+01	3.656e+01
China.Imports	3.309e-01	8.130e-01
China.Industrial.Production	1.488e+02	1.055e+02
China.Inflation.Rate.MoM	3.249e+02	1.530e+02

China.Leading.Indicators.Index	3.925e+02	1.879e+02
China.New.Orders	-2.379e+02	1.832e+02
China.CPI	-3.023e+02	1.955e+02

Table 4: t values and P values for the multiple regression

	t value	Pr(>|t|)
(Intercept)	-1.200e+00	2.475e-01
China.Manufacturing.PMI	1.945e+00	6.950e-02
China.Exports	-5.574e-01	5.850e-01
USD.RMB	1.860e+00	8.140e-02
China.Producer.Prices	5.050e-01	6.205e-01
China.Import.Prices	3.098e-01	7.607e-01
China.Imports	4.070e-01	6.894e-01
China.Industrial.Production	1.409e+00	1.778e-01
China.Inflation.Rate.MoM	2.123e+00	4.970e-02
China.Leading.Indicators.Index	2.088e+00	5.310e-02
China.New.Orders	-1.298e+00	2.126e-01
China.CPI	-1.546e+00	1.416e-01

As a result, it was observed that the adjusted R-squared was much lower at 0.7014675, but likely more reliable. The Durbin-Watson test score of 1.9631601 and p-value 0.78 shows little autocorrelation. Figure 25 represents the adjusted R-squared for the 1st order model.

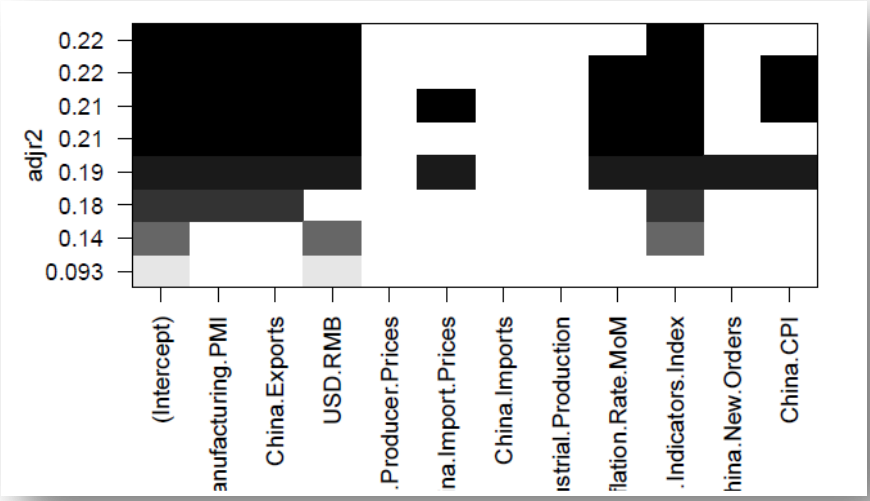

Figure 25: Adjusted R^2 for 1st order Model

Running a best fit analysis, a model with some predictability could have been found.

Table 5: Coefficients used for best fits analysis

	Estimate	Standard Error
(Intercept)	-40.4647	46.6644
China.Manufacturing.PMI	104.8026	59.3329
China.Exports	-0.2566	0.1694
USD.RMB	-2231.0780	1518.8549
China.Leading.Indicators.Index	284.2855	159.7259

Table 6: t values and P values for the multiple regression

	t value	Pr (>|t|)
(Intercept)	-0.8671	0.3952
China.Manufacturing.PMI	1.7663	0.0912
China.Exports	-1.5149	0.1440

USD.RMB	-1.4689	0.1560
China.Leading.Indicators.Index	1.7798	0.0889

The adjusted R-squared with this multiple regression model is 0.2204494. The explanatory capabilities of this model are limited. This model may be fitting to a factor of the direction of price changes, but not the magnitude. Table 5 and 6 depict the coefficients of Best- fits model. As observed, the numbers of variables that are statistically signification and have low auto-correlation are the two indicators:

"Manufacturing PMI and Leading Economic Index"

Evaluating the model

In evaluating the model, it was observed that no collinearity was present with the remaining variables.

```
China.Manufacturing.PMI                 China.Exports
               1.077509                      1.112036
               USD.RMB China.Leading.Indicators.Index
               1.060227                      1.019395

China.Manufacturing.PMI                 China.Exports
                 FALSE                         FALSE
               USD.RMB China.Leading.Indicators.Index
                 FALSE                         FALSE
```

Figure 26: Collinearity of the remaining variables

Evaluating the fit and predictive ability

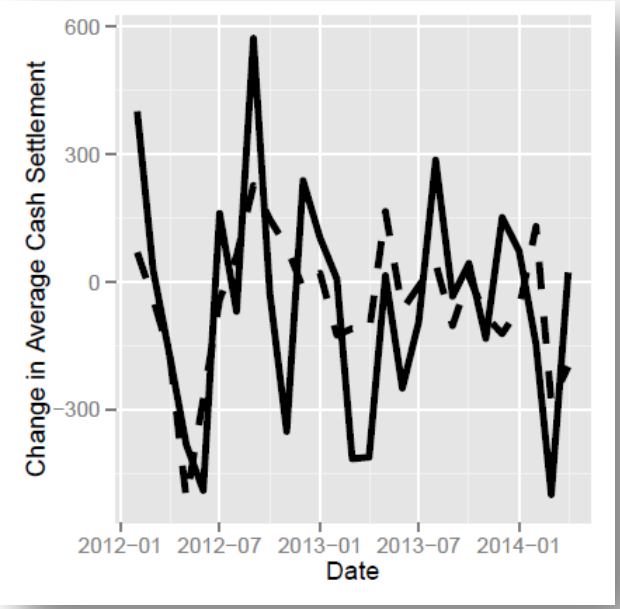

Figure 27: Half-yearly variation in change in average cash settlement

The dotted lines are the fitted and predicted values respectively. The model's accuracy during the training period is choppy at best, but when observing the holdout sample, it seems to be directionally correct.

The next attempts will utilize various autoregressive models in an attempt to gain more accuracy and precision in forecasting the data.

Time Series - Autoregressive models

Time-series models attempt to predict the future prices movements by assessing the current and past volatility in the series, and then proposing a most likely model to predict the next price movements.

These models incorporate the time element, which is present in the data. For a few of these auto regression models, stationarity must also be tested, which signifies a measure of stability, particularly around a mean.

The first two models used are the auto-regressive (AR) and the auto-regressive with integrated moving averages (ARIMA).

The formulas are as follows:

AR-

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

This above formula represents the variable X(t) as a constant (c) + the formula parameters + white noise represented as E. This is considered a basic stochastic model as it incorporates the general trend of the past points of the data plus white noise (random variables).

ARIMA-

$$\left(1 - \sum_{i=1}^{p} \phi_i L^i\right) (1 - L)^d X_t = \delta + \left(1 + \sum_{i=1}^{q} \theta_i L^i\right) \varepsilon_t$$

The above model can be broken down into the Ø portion, which represents the auto-regressive part of the equation, the θ portion, which represents the moving average part and the (1-L)^d part which represents the polynomial factoring or the "integrated" part of the ARIMA model.

Given some research done on these models, daily or weekly data is preferred since smoothing occurs with the reduction in frequency on these time series.

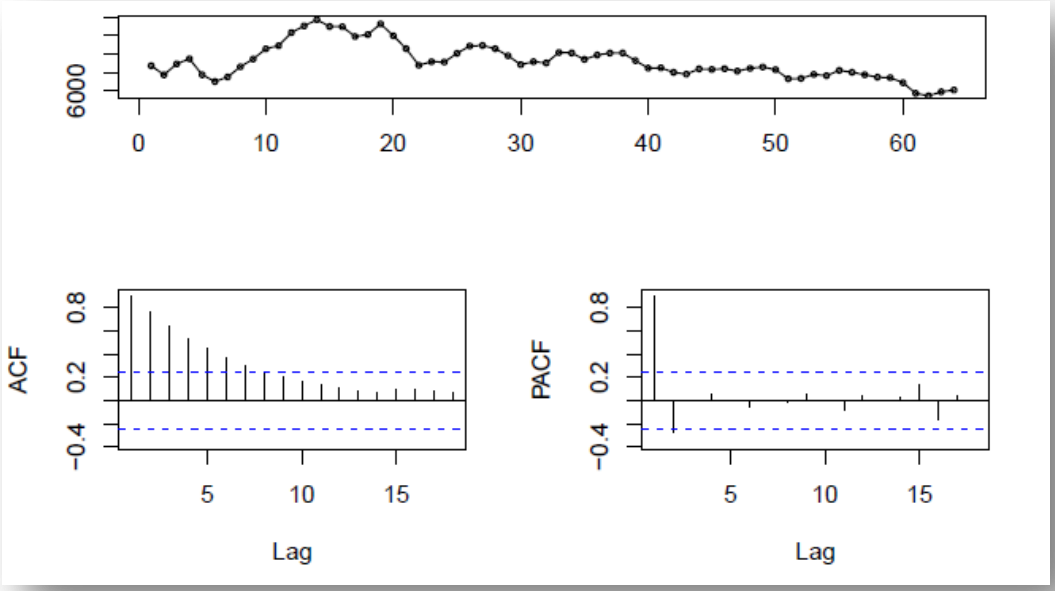

Figure 28: Average cash settlement

There seems to be an interesting decay in the residuals of the ACF (auto-correlation function) plot that implies some autocorrelation with time. Another test called PACF also confirms a trend. The PACF test implies that there is one time lag value of significance. First order differencing is used once again for this analysis and model.

```
 KPSS Test for Trend Stationarity

data:  copper_Settlement_diff
KPSS Trend = 0.042058, Truncation lag parameter = 1, p-value = 0.1
```

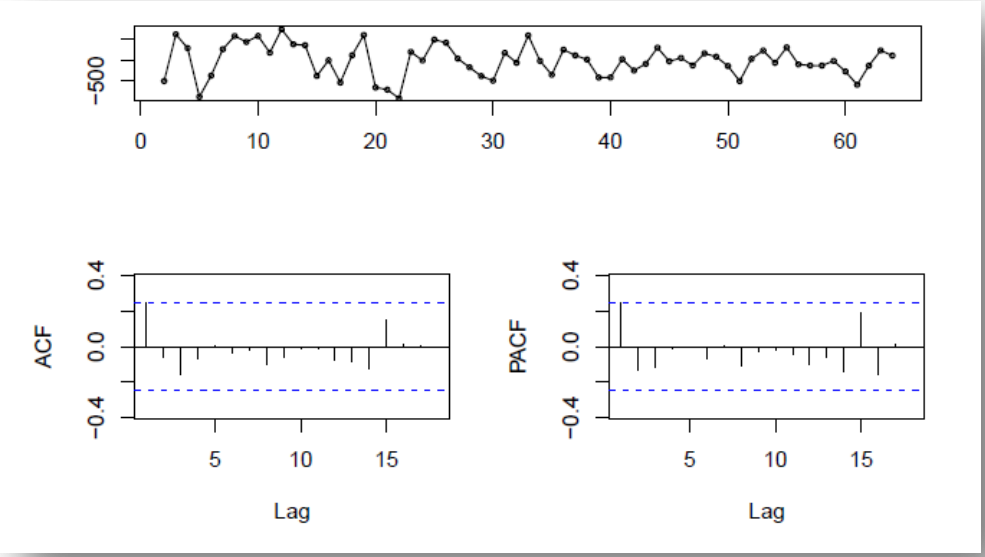

Figure 29: Average cash settlement

A plot of a univariate model, an autoregressive model (AR) and an autoregressive integrated moving average (ARIMA) are generated based on this model and is depicted in below in Figure 28.

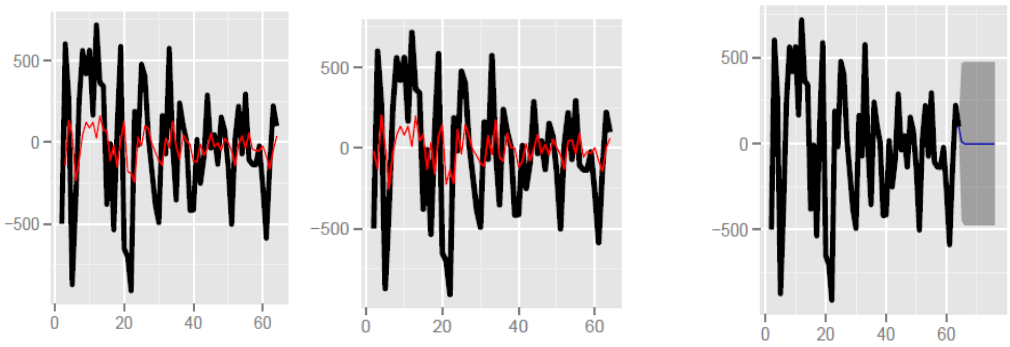

Figure 30: Plot of an (AR) and an autoregressive integrated moving average (ARIMA) and univariate an autoregressive model

The red line in Figure 28 is the predicted change and the black line is the actual change. This model appears to follow the direction of the prediction, but can't seem to capture the magnitude. This forecasting method doesn't seem to capture the price levels either. Perhaps another model would be best suited for this prediction.

Generalized Autoregressive Conditional Heteroskedasticity (GARCH)

GARCH and specifically GARCH (1,1) is another autoregressive model which is used quite often for the modelling of price development behaviors in commodities as well as stocks and bonds. The GARCH (1,1) formula first introduced by Taylor in 1986[25] states:

$$\sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2$$

This formula goes on the premises that negative values in the past of a time series (in this case the price of a commodity) increase the volatility of returns in the future.

This model is used on many thick-tailed distributions (such as financial returns) and where volatility has some clustering, and in order to model the autocorrelation pattern when there seems to be some relationship in the magnitude of the change. By observing the distribution of price changes, it appears to show a normal distribution. Running the test for normality confirms normality exists. Squaring the residuals and then plotting them demonstrated the clustering of the volatility as shown in Figure 29.

[25] Taylor, S.J

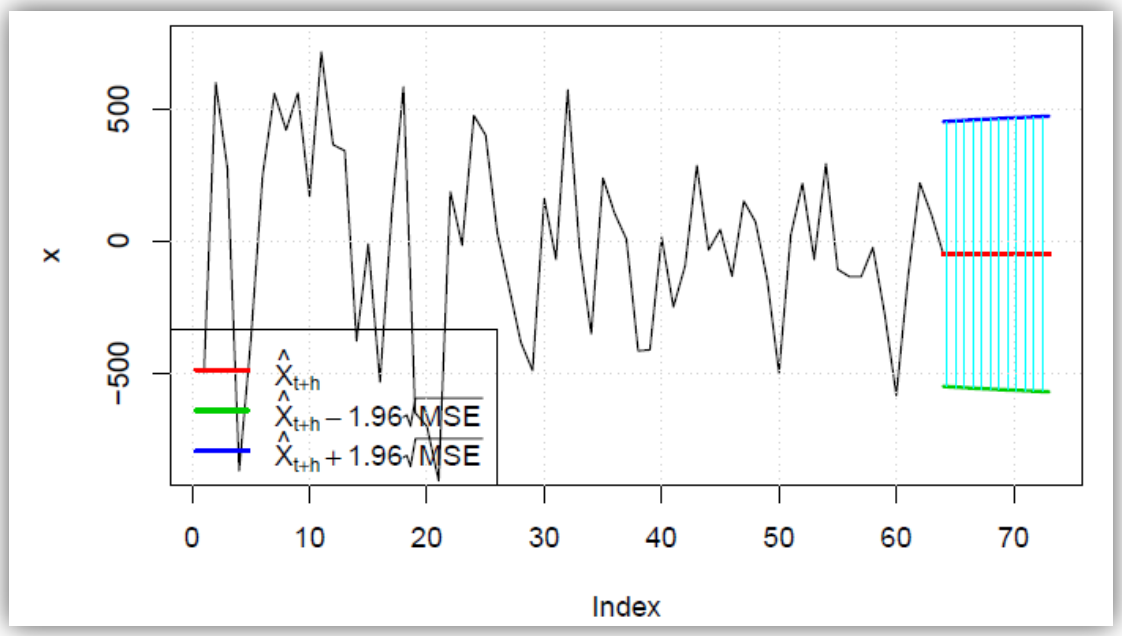

Figure 31; Variation in GARCH

	meanForecast	meanError	standardDeviation	lowerInterval	upperInterval
1	-48.70751	255.4592	255.4592	-549.3983	451.9832
2	-48.70751	256.8884	256.8884	-552.1995	454.7845
3	-48.70751	258.2394	258.2394	-554.8475	457.4325
4	-48.70751	259.5170	259.5170	-557.3515	459.9365
5	-48.70751	260.7255	260.7255	-559.7200	462.3050
6	-48.70751	261.8688	261.8688	-561.9610	464.5460
7	-48.70751	262.9509	262.9509	-564.0819	466.6669
8	-48.70751	263.9753	263.9753	-566.0896	468.6746
9	-48.70751	264.9452	264.9452	-567.9906	470.5756
10	-48.70751	265.8638	265.8638	-569.7910	472.3759

Figure 32: Prediction with confidence intervals

The dataset appears to be limiting the predictive nature of the GARCH and its long term effectiveness. Given these limitations, bootstrapping (random data re-sampling) may be useful to simulate data given that it is normally distributed. Figure 31 highlights the negative direction of the sample in the future forecasting using the GARCH (1,1) model.

7. Conclusion

The analysis of various models for analyzing and modelling the copper price data in conjunction with Chinese economic data was performed using various models. By comparing the results of the different models, it was discovered that for the purpose of predicting the next 12 months of copper price development, the best fit is the regression model using the following change in variables (in order of significance):

1. Leading Economic Index – Available on: (http://www.tradingeconomics.com/china/leading-economic-index)
2. Manufacturing Purchasing Managers Index – Available on: (http://www.tradingeconomics.com/china/manufacturing-pmi
3. Chinese Exports – Available on: (http://www.tradingeconomics.com/china/exports)
4. USD / RMB exchange rate – Available on: (http://www.tradingeconomics.com/china/currency)

This means that the best predictor for the change in copper prices from economic data is the „Leading Economic Index“ which is published by the Trading Economics website in monthly intervals, followed by the “Manufacturing Purchasing Managers Index” then „Chinese Exports“ and lastly by the „USD / RMB exchange rate“.

With regards to the autoregressive models Autoregressive (AR), Autoregressive with Integrated Moving Average (ARIMA) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH), all models adequately capture the LME copper cash settlement price movement volatility; however the GARCH (1,1) seems to be the most promising in predictions.

The conclusion from the analysis points to the idea that the single best economic data indicator in China which correlates most to copper prices is the Leading Economic Index. A look once again at the chart of the last 5 year’s prices shows the following:

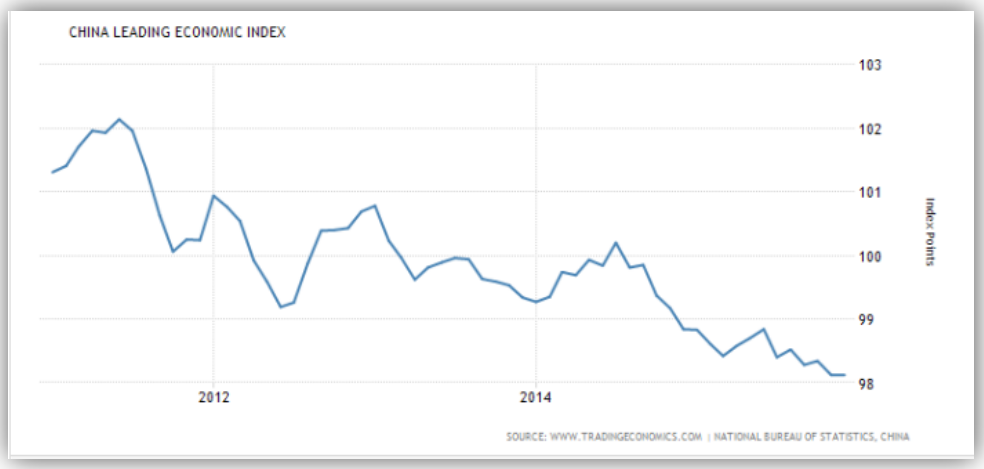

Figure 33: China Leading Economic Index

One look at the above chart is a reminder of the similarities found in most metals including copper over the last five years. Copper prices have also slid in a similar fashion as the above index leading one to apply a relationship to both the leading economic index in China and LME copper prices.

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9. Appendix

1) Structure of the survey to copper industry professionals:

The professionals were chosen as those who have an extraordinary knowledge of the copper industry in Europe. It was assumed that their knowledge may also translate to knowledge of copper in China.

a. The positions of the 5 participants were as follows:
    i. Senior Analyst of copper at Macquarie Bank in London
    ii. Managing director of a large German base metal recycler
    iii. Owner of a mid-sized copper trading company in Switzerland
    iv. Managing director of a very large European metals trader
    v. Managing director of a copper trading company in Germany
b. The options which were able to be chosen were the following:
    i. General
        USD-CNY FX rate
        SSE Composite
        New Orders

    ii. Labor Force
        Unemployment rate
        Wages
        Wages in Manufacturing

    iii. Prices
        Consumer Price Index (CPI)
        Core Inflation Rate (MoM)
        Copper Inventories
        Producer Prices

    iv. Economy & Manufacturing
        Industrial Production
        Manufacturing PMI

Leading Economic Index
Exports
Imports

c. Result of the survey – Highest vote-getters as also outlined on page 40

Industrial Production - 4 Votes

Copper Inventories – 4 Votes

USD-CNY exchange rate – 3 Votes

Manufacturing Purchasing Managers Index (PMI) – 3 Votes

Consumer Price Index (CPI) – 2 Votes

2) Software Used

The software used for the analysis was R "World Famous Astronaut" v. 3.2.1 and R Studio v. 0.99.441.

With regards to possible software available for such statistical analysis, one may choose from user friendly versions such as ModelRisk or NumXL or more powerful programming software such as R or Matlab.[26]

The R software was preferred over other statistical packages mainly due to its widespread use with statisticians and its powerful ability to model multiple regression and time series functions efficiently. In the community of statisticians, the R programming language is considered to be one of the most powerful and useful software to perform data analysis. Therefore, R was chosen as the modelling option for this analysis.

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