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BASE METALS INVENTORIES AND THEIR INFLUENCE ON FUTURES MARKETS

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Abstract

Even though commodity futures have been traded through organized exchanges all over the world for several decades, it is only recently that investors commenced allocating significant shares of their resources to this specific asset class. The returns generated by futures contracts are significantly influenced by physical inventories of commodities on which these instruments have been structured, which in turn are impacted by the general state of global economy. In order to assess the manner in which metals futures returns are influenced by base metals inventory levels a clear distinction is made between a pre and post economic crisis period. I empirically and directly examine the link between metals futures (excess) returns and aggregate inventory levels using a cross-section of industrial metals: Aluminum, Copper, Lead, Nickel, Tin and Zinc.

Firstly, the relation between aggregate metals inventory levels and the state of global economy is studied. Unfortunately, the model explanatory power is relatively low, with the beta coefficients being not significantly different from zero. This relation is further investigated and one of the main findings suggests that periods of economic turmoil are associated with a relative abundance in aggregate metals inventories due to a depressed demand and generally a poor state of the global economy. Secondly, the convenience yield received by holders of physical inventories is observed to be inversely related to aggregate metals inventories. Furthermore, this relation varies in magnitude between the two studied periods, with base metals convenience yields being on average lower throughout post-crisis periods. Lastly, the outcomes of this analysis confirm the inverse relation between futures risk premia and aggregate inventories for three out of the six metals studied. Contrary to expectations, futures risk premia are more sensitive to changes in inventory levels during post than during pre-crisis periods.

KEYWORDS

Base Metals, Inventories, Futures, Returns, Risk Premia, China Factor, Economic Turmoil, Financial Crisis, LME, Chinese Demand

1. Introduction

Even though commodity futures have been traded all over the world for several decades, it was only recently that investors commenced allocating significant shares of their financial resources to this specific asset class. A commodity futures contract is an agreement to purchase or sell a predetermined amount of a specific commodity at a predetermined price and delivery period. Traditionally, sellers of this type of financial instruments have been industrial entities who attempt to cover the price risk inherent to the underlying commodity, while buyers employ these contracts in their attempt to mitigate the risks associated with uncertainties about the future production and price of the underlying commodities.

Literature published just before the burst of the recent financial crisis labeled commodities futures as good and safe investments during periods of financial turmoil. Examples include Erb and Harvey (2006) and Gorton and Rouwenhorst (2006), who found that commodities futures risk premia are similar to those of equities while being negatively correlated with both equity and bond market returns. This view is also shared by Chong and Miffre (2010), who note that during periods of increased volatility in equity markets the correlation between commodity futures and equities declines. This is of particular importance for the long investors who require the benefits of diversification during these periods the most. Furthermore, investments in commodities futures are regarded as a good hedge against inflation, which is preponderantly pronounced during periods of economic instability, as noted by Edwards and Park (1996) and Bodie (1983).

Khan, Khokher and Simin (2006) investigate the manner in which scarcity in physical inventories determine variations in commodities futures risk premia and found mainly that futures risk premia increase during periods of scarcity, particularly when stocks are withdrawn from storage. They also note that the interaction between inventories and the futures risk premia is omitted by current contingent claims models, thus under reporting risk exposures.

Returns on futures having as underlying assets base metals are influenced by the state of inventories of those specific metals. In particular, when inventory levels are low, futures contracts prices are less volatile than spot prices. The low state of inventories is generated mainly by shocks in either the supply and/or demand of various base metals, which usually arise during pre-crisis periods. In times when inventories are sufficient, spot and futures prices have roughly the same volatility. Brooks, Lazar and Prokopczuk (2011) find that scarcity, defined as periods of low physical inventories, is informative with regards to the shape of the forward curve, and mainly that price volatility is an increasing linear function of scarcity for most of the commodities in their sample.

Literature has long attempted to identify the existence of a risk premium contained in futures prices. This risk premium is regarded as a compensation for insurance against future spot price risk. However, determining whether future prices include a risk premium has been particularly difficult mainly due to the lack of correlation between commodity futures returns and conventional measures of systematic risk provided by current literature focusing on asset pricing.

This paper is set to investigate the time-series variation in base metals futures risk premia, which in turn are determined by the level of inventories of a specific metal in observable warehouses. A distinction is made between a post-crisis period starting in week 27 2008 and ending in week 13 2009, totaling 40 weeks; and two pre-crisis periods ranging from week 1 1998 to week 26 2008, and from week 14 2009 up to week 53 2013. Periods of financial/economic turmoil are associated with a relative abundance in aggregate metals inventories due to depressed (Chinese) demand and poor state of the global economy. Conversely, during periods of economic expansion more frequent and violent periods of scarcity are expected to be observed, which are determined primarily by the heightened demand for industrial metals.

The global economy is proxied by the weighted average Market Index[1] which is monthly rebalanced and comprises the world's top ten strongest economies: US, China, Japan, Germany, France, UK, Brazil, Russia, Italy and India. The Market Index is considered to be a pertinent reflection of the global economy, and economic cycles thereafter, as it captures approximately 60% of the variation in the global GDP. Furthermore, the so-called 'China effect' or 'China factor' (C_f) and its impact on physical inventory levels is assessed through employing the Shanghai Stock Exchange Industrial Index as a proxy for Chinese demand for industrial metals.

In terms of commodities, this paper will focus on the following storable industrial metals: Aluminum, Copper, Lead, Nickel, Tin, and Zinc. I have chosen these particular industrial metals due to their economic importance and wide usage by the industry and due to the fact that data regarding their characteristic aggregate inventory levels can be obtained with a consistent frequency. Moreover, the flexibility provided by the LME in trading futures contracts structured on these metals make them a pertinent choice as it eliminates the noise induced by the rolling process of these contracts.

This paper empirically and directly examines the link between commodity futures risk premia and aggregate commodities inventory levels using a cross-section of industrial metals, thus providing current literature with an ex post perspective of the impact aggregate inventory levels

[1] Definition and methodology of construction in the Appendix

have on commodity futures returns during pre and post crisis periods. Therefore, periods of financial/economic turmoil are associated with a relative abundance in aggregate metals inventories due to the depressed (Chinese) demand and poor state of global economy. Conversely, during periods of economic expansion more frequent and violent stages of scarcity have been observed, intuitively determined by the heightened demand.

The results of this paper confirm the prediction stating that convenience yields received by holders of physical inventories are inversely related to aggregate metals inventories. As inventories increase, the convenience yield subsequently declines. Even in the case where spontaneous shocks in the supply/demand of a particular metals occur, they can be easily absorbed by the abundant levels of inventories observed during post crisis periods. This relation varies in magnitude across the two studied periods, with the convenience yield being relatively lower throughout post-crisis periods. Furthermore, the China factor has been observed to have a positive and significant effect on base metals convenience yields.

The inverse relation between futures risk premia and aggregate metals inventory levels is significant and confirmed solely for Copper Lead and Zinc. Thus, during post-crisis periods stocks of industrial metals typically accumulate, leading to a lower conditional volatility of the future spot price, which is associated with a depressed risk premium. The futures risk premia are more sensitive to changes in inventory levels during post than during pre-crisis periods. The exact determinants of this unexpected degree of variation throughout the two periods are still to be identified, thus opening the way for further research.

2. Conceptual Framework and Research Design

The framework employed in this paper is illustrated in Diagram 1

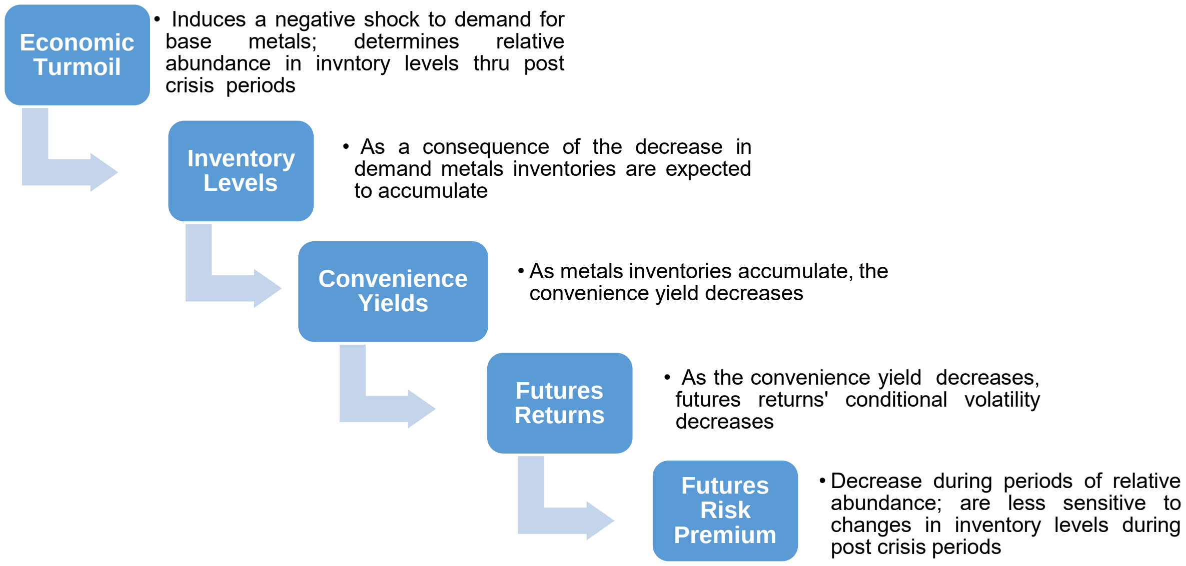


Diagram 1: Conceptual Framework.

The relationships in this framework will be investigated through a string of OLS regression analyses. The first analysis will focus on the relation between economic crises, the aggregate industrial metals inventory levels and the China factor. Therefore, the dependent variables are the metals inventory levels, while the independent variables are the state of economy, proxied through a so-called Market Index, the China factor and the Crisis dummy variable. In addition, the frequency and magnitude of the relative scarcity in metals stock levels is investigated. The second analysis will focus on the relation between the convenience yield and the aggregate metals inventory levels. In this case the dependent variable is the convenience yield, while the independent variables are: the ratio of discretionary to total inventory levels, computed as described in Appendix B, the China factor and the Crisis dummy variable. The third and last analysis will study the sensitivity of metals futures risk premia to changes in aggregate inventory levels during pre and post economic crisis. The dependent variables in this case are the futures excess returns (or risk premia), while the explanatory variables are the de-trended metals inventory levels, the China factor and the Crisis dummy variable

This paper covers an horizon of 841 weeks starting on the 1st of January 1998 and ending on the 31st of December 2013, and focuses on two different time periods in order to emphasize the magnitude of the influence state of inventories has on metals futures risk premia during these two periods. The post crisis period is defined as starting in week 27 2008 (1st of July 2008) and ending in week 13 2009 (29th of March 2009), totaling 40 weeks; while the pre-crisis periods are defined as follows: week 1 1998 to week 26 2008, and week 14 2009 up to week 53 2013.

These two different analyzed periods have been determined according to the G20 GDP growth rates. Therefore, whenever the G20 GDP growth rate was negative, this period was associated with an economic crisis and was thus labelled as post-crisis period. Conversely, when the growth rate showed a positive sign, this meant that the global economy was in a state other than a recession and it was thus associated with a pre-crisis period. The data concerning the definition of pre/post crisis periods was retrieved from the OECD statistical database.

3. Base Metals Stockpiles, the State of Economy and the China Factor

Shocks in the supply and/or demand of commodities are usually generated by exogenous factors, such as crises of financial or economic nature. A lack of liquidity (i.e. credit crunch) would limit the access to the financing market of both hedgers and speculators. Hedgers (i.e. farmers, commodities processors) would not be able to obtain the funds necessary for developing their crops/harvested acreage, leading to a lower supply, and subsequently to a decrease in inventory levels. Traders, without access to trade finance, would not be able to contribute to the smoothing of the global demand, by moving core commodities from areas where there is an oversupply to areas where there is a shortage. Therefore, crises of financial natures alter the state of the (global) economy, which thereafter impacts the aggregate levels of commodities inventories. In this case the choice of industrial metals most closely reflects the underlying economic developments.

The aforementioned situation is characterized by a relative scarcity in physical stocks of metals during pre-crisis periods and a relative abundance of stocks during post-crisis periods. In the model I develop the overall state of the economy will be proxied through the Market Index. This is similar to the methodology employed by Khan, Khokher and Simin (2006) in their study, except for the fact that the authors select the S&P500 Index. The Market Index is considered to be a pertinent representation of the global economy as it reflects the top 10 most strongest economies, which taken together account for more than 60% of the global GDP.

Since China has recently become such a major player in the base metals industry, its demand for industrial metals is considered to have the capacity to place a tremendous pressure on worldwide stocks and supply of these products. Thus, its potential effects are assessed through the China factor, which is incorporated in all of the proposed models.

Consequently, aggregate metals inventory levels are estimated to be negatively related to the state of global economy as well as to the Chinese demand for these particular products.

In order to assess the aforementioned relationship during two distinct periods: pre and post crisis several ordinary least squares (OLS) regressions have been performed. The independent variables have been lagged by 1 period (week) as in reality there will most likely be a specific time lag from the point when an economic/financial crisis occurs and the time when the impact of this crisis on metals stocks actually takes place or is actually observed. This arbitrary lag has been selected after running the model several times and observing the lag which enables the model to generate the highest explanatory power.

The variables employed for testing the aforementioned relationship, in particular metals stockpiles, the Market Index, China factor and the Crisis dummy variable have been defined in Appendix A, while their measurement is revealed by Appendix B. Furthermore, the regression model is illustrated below, while a description is provided in Appendix D Section 1.

$\mathrm{InvLev_t} = \alpha + \beta_1 \mathrm{Market\ Index_{t-1}} + \beta_2 \mathrm{C_f}_{\mathrm{t-1}} + \beta_3 \mathrm{Crisis_{t-1}} + \varepsilon,\ \ \varepsilon \sim \mathrm{n}(0, \sigma)$, where:

$\mathrm{InvLev_t}$ is the percentage change (%Δ) in aggregate metals inventory levels at time t

$\mathrm{Market\ Index_{t-1}}$ is the percentage change (%Δ) in the Market Index at time t-1

$C_{f\,t-1}$ is the percentage change (%Δ) in the Shanghai Industrial Index at time t-1

$Crisis_{t-1}$ is the dummy variable which takes the value 0 for pre-crisis periods and 1 for post-crisis periods, at time t-1

The results from running the aforementioned regression model, which is also described in Appendix D Section 1, are illustrated in Table 1 below.

Table 1 The table reports the results of an OLS linear regression of weekly percentage changes in aggregate metals inventories on 1 period (week) lagged weekly percentage changes in the Market Index, the China factor and the Crisis dummy variable. The columns 'Market Index', 'Cf' and 'Crisis' reveal the slope coefficients of the model explanatory variables. Due to data presenting signs of heteroscedasticity and autocorrelation, thus violating the standard assumptions of OLS regressions, the Newey-West heteroscedasticity and autocorrelation consistent (HAC) standard errors are computed. Thus, column 't-Stat' reveals the t-statistics computed using the aforementioned methodology with a time lag of 52 periods (weeks). The last column illustrates the model explanatory power.

	α	t-Stat	β MarketIndex	t-Stat	β Cf	t-Stat	β Crisis	t-Stat	RSq
Metals Index	0.000	-0.156	1.350%	1.099	2.653%	1.902	0.011	6.192	2.225%
Aluminum	0.000	-0.324	1.802%	1.140	1.957%	2.495	0.012	11.223	2.398%
Copper	-0.004	-1.384	0.298%	0.077	8.030%	1.529	0.032	7.926	3.439%
Lead	-0.003	-0.855	-1.607%	-0.229	3.442%	1.050	0.006	1.692	2.590%
Nickel	0.001	0.349	8.814%	1.428	-7.525%	-2.462	0.018	5.495	2.263%
Tin	-0.004	-2.393	4.981%	0.698	-0.030%	-0.013	0.011	4.620	1.462%
Zinc	-0.002	-1.233	-3.291%	-1.856	-4.957%	-3.526	0.004	1.764	1.429%

The intercept coefficient is either zero or very close to zero, signifying that the fitted regression line will pass through or very close to origin. The Market Index coefficients are positive for all metals except Lead and Zinc for which they show negative signs, which implies that as an economy expands the metal stocks will increase as well, but to a much lesser extent clearly. In the case of Aluminum for instance, when the global economy advances by 1%, stocks would be expected to increase by 1.8%. This relation is contrary to what was expected, as during expansionary periods more frequent relative scarcity in metals stocks is anticipated. The highest Market Index beta coefficients can be observed for Nickel (8.8%) while the lowest one is associated with Zinc (-3.23%), which together with Lead (-1.6%) are the only metals that confirm the proposed thesis.

Half of the beta coefficients associated with the China factor are positive, with the exception of Nickel, Tin and Zinc. When Chinese driven demand for metals augments, the inventories consisting of Aluminum, Copper, Lead and the average Market Index are expected to increase as well, while Nickel, Tin and Zinc stocks are estimated to decline, which confirms the proposed hypothesis. The coefficients range from 8% for Copper to -7.5% for Nickel.

In order to identify whether the beta coefficients related to the Market Index and C_f are significantly different from zero, the t-test is employed. The rather small t-statistics that can be observed for the Market Index coefficients are associated with p-values much larger than 5% for all items studied, which leads to the non-rejection of the null hypothesis and concludes that the Market Index coefficients resulted from this regression analysis are not significantly different from zero, making the Market Index not a pertinent predictor of the variations in base metals inventory levels.

The C_f coefficients linked to the Metals Index, Aluminum, Nickel and Zinc are observed to be significantly different from zero as revealed by the relatively larger t-statistic and its associated p-value inferior to 5%[2]. Therefore, an increase in the Chinese demand for base metals is expected to lead to an increase in Aluminum inventories by ~2% and a decline in Nickel and Zinc stocks by 7.5% and 4.95% respectively.

For assessing the potential impact the Market Index and the C_f have on metals inventory levels during the two distinct studied periods, the dummy variable 'Crisis' has been included in the regression model. This variable takes the value 0 for pre-crisis periods and 1 for post-crisis periods. All beta coefficients related to the Crisis variable show a positive sign, which leads to the conclusion that metals stocks react to a higher extent to fluctuations in the global economy and Chinese demand for metals during post-crisis than thru pre-crisis periods, holding the Market Index and the C_f constant. Among the studied metals Copper and Nickel are expected to vary the most during post-crisis as a result of variations in the Market Index and C_f, as they show the largest coefficients.

In order to determine whether economic crises indeed affect base metals inventory levels in the manner described above, controlling for the global economy and Chinese demand for metals, the null hypothesis (β_3=0) is evaluated through a t-test. The rather large t-values associated with very small p-values allow for the rejection of the null hypothesis and lead to the conclusion that the Crisis beta coefficients are significantly different than zero. This further implies that changes in the Market Index and the C_f, will determine a larger variation in base metals inventory levels during post-crisis than thru pre-crisis.

When looking at the regression analysis R^2 it can be concluded the model explanatory power is rather low, with the R^2 ranging from 1.43% (Zinc) to 3.4% (Copper). Therefore, it can be concluded that only a small percentage in the variance of base metals inventories can be explained though variations in the Market Index and C_f, potentially indicating that the choice of these variables as proxies for the state of global economy and Chinese demand for metals might not be accurate enough. Nevertheless, similar R^2 values are obtained by Khan, Khokher and Simin (2006), except that in their study the S&P500 index was used instead of the Market Index.

As the relation between the state of economy and aggregate metals inventory levels is not as apparent as envisaged, as revealed by the previous analysis, I will employ the methodology

[2] Detected in a side analysis

proposed by Khan, Khokher and Simin (2006) to examine the period when a relative scarcity of base metals occurs together with its magnitude.

Figure 1 contains a visual representation of unadjusted aggregate inventories evolution for the metals approached in this analysis (blue line), while the red line reveals the Chinese demand for base metals. Following a visual inspection it can generally be asserted that the inventory levels and the Chinese demand for metals are inversely related to some extent and with a specific time lag. Attempting to visually assert whether seasonality is present in the data might be a difficult task. In order to test for seasonality, Khan, Khokher and Simin (2006) have performed regressions of individual metals inventories levels on weekly and monthly dummies and have concluded that 'there is little evidence of a seasonal component in metals inventories levels'.

Figure 1 The figure reveals the unadjusted aggregate base metals inventory levels and the Chinese demand for these metals

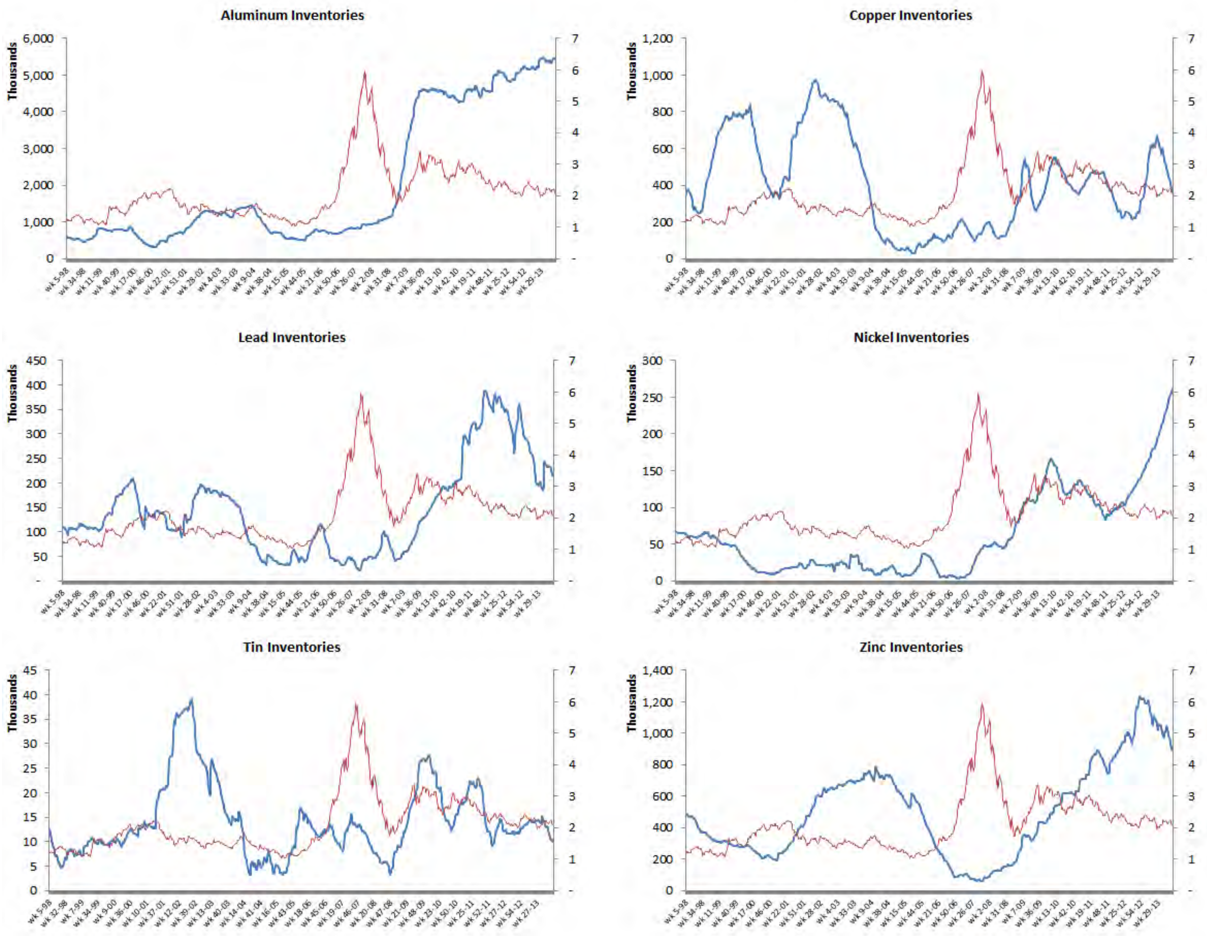


Figure 2 below illustrates the metals inventories series after the stochastic trend has been removed. These represent the stocks of metals held in storage in excess of those already committed to immediate consumption, and therefore they represent pertinent proxies for relative scarcity. It can be observed that for all metals periods of relative scarcity or abundance are quite frequent and at times quite extreme compared to more ‘normal’ levels. Aluminum, Copper, Nickel and Tim show the most brutal swings on the positive side, meaning that ‘speculative’ stocks of metals accumulated at some point in time due to various exogenous factors way above their average levels. This might have had something to do with more fundamental factors such a depressed demand, or the structure of forward prices which may have incentivized industry participants to store rather than deliver the product in question.

Figure 2 The figure shows the discretionary inventory levels for each metal studied throughout the entire analyzed period. The discretionary inventory levels are proxied for by removing a 4 week trailing moving average from the actual inventory figures retrieved from LME

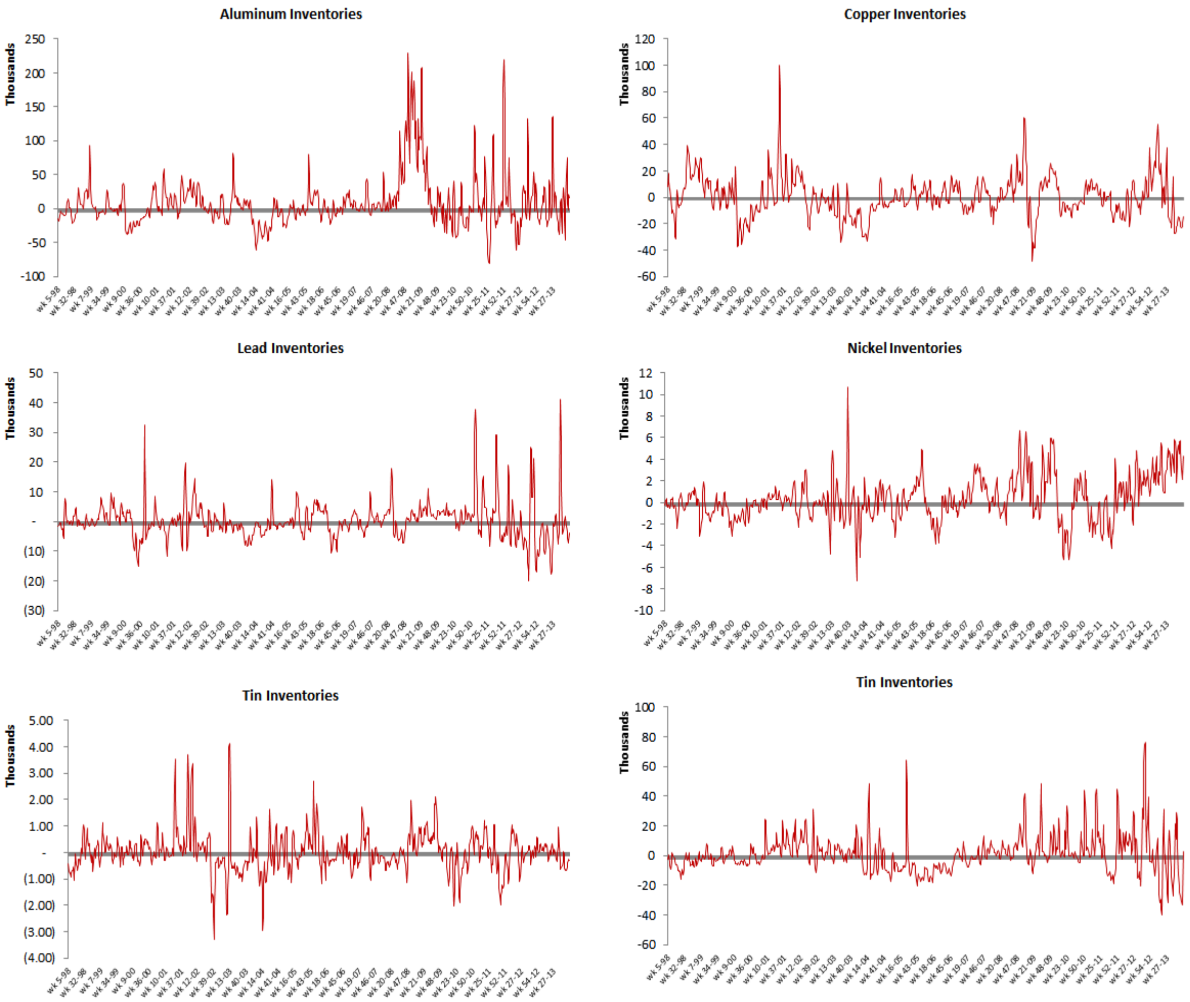


Figure 3 and Figure 4 depict the discretionary inventory levels distributed per analyzed periods: pre and post crisis. Figure 3 reveals the discretionary inventory levels during pre-crisis periods, while Figure 4 focuses solely on the post-crisis period.

Figure 3 The figure shows the discretionary inventory levels for each of the six metals studied thru pre-crisis periods. The discretionary inventory levels are proxied for by removing a 4 week trailing moving average from the actual inventories retrieved from LME

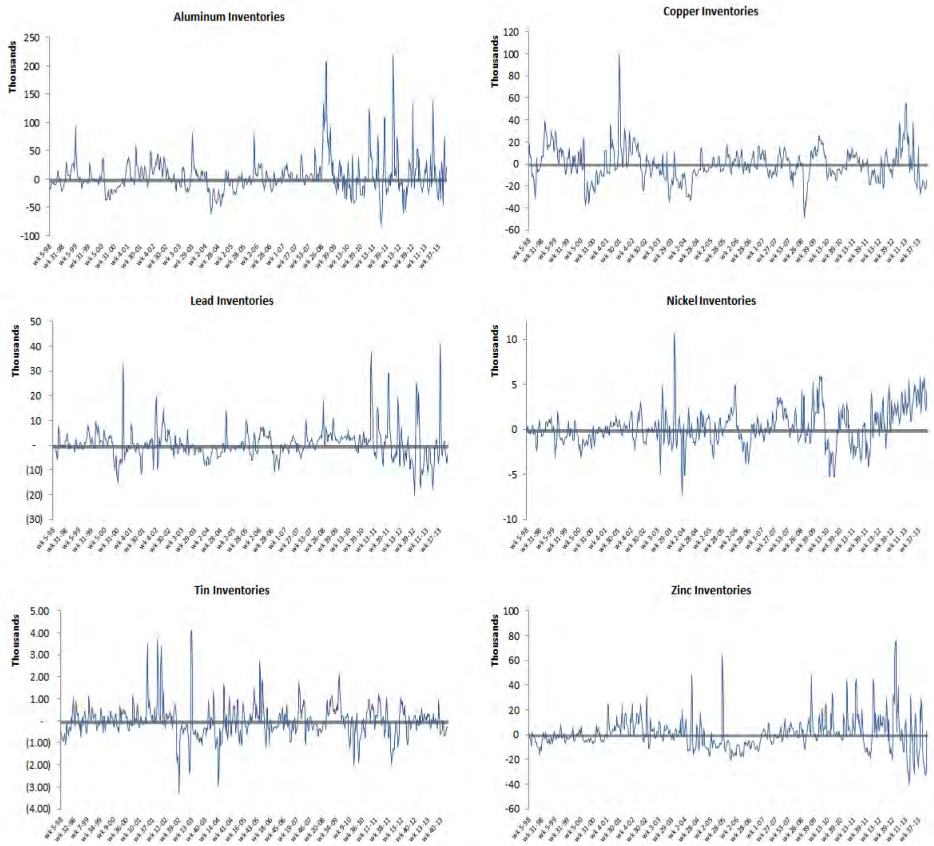
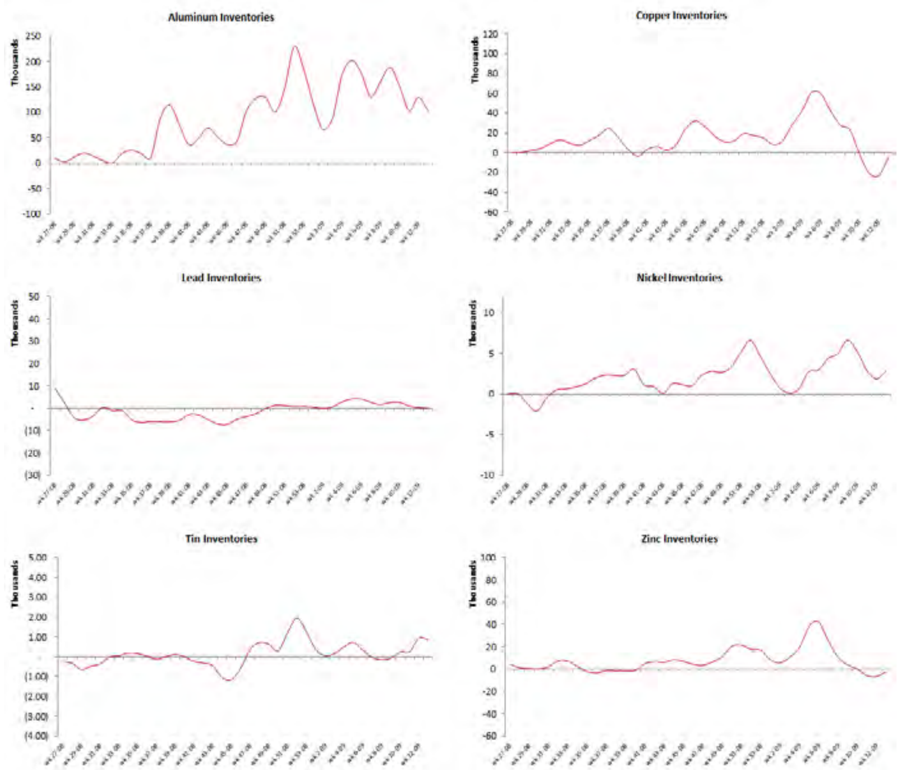


Figure 4 The figure reveals the discretionary inventory levels for each of the six metals studied during post-crisis periods. The discretionary inventory levels are proxied for by removing a 4 week trailing moving average from the actual inventory levels retrieved from LME



A visual inspection of the aforementioned charts leads to the conclusion that circumstances of relative scarcity occur more frequently during pre-crisis periods, when economies are typically in an expansionary state and demand for commodities, in particular for industrial metals, is relatively high. More importantly, the magnitude of these instances of relative scarcity is significantly higher during pre-crisis periods than during post-crisis periods, as revealed by the charts. The only metal for which the discretionary inventory levels varied with roughly the same amplitude throughput the two periods is Aluminum: during both pre and post crisis, the discretionary inventories augmented by ~25k MT in a matter of 10 to 12 weeks. Another point worth mentioning is the fact that during post-crisis periods weekly discretionary inventories tend to be more positive for longer periods, implying that the negative instances occur mostly thru pre-crisis periods, which confirms to the proposed hypothesis.

4. Discretionary Metals Inventories, the China factor and Convenience Yields

The Theory of Storage predicts that marginal convenience yield is a declining function of inventories. The convenience yield represents the benefit of physically storing a commodity for consumption or merchandising in a future period. The concept was first introduced by Brennan (1958) and provides an explanation of inventory holders' behavior in holding stocks of commodities during periods of expected decline in future spot prices. Commodity stock holders earn this convenience yield as available stocks ('on hand' stocks) provide them with an increased efficiency and flexibility when unexpected shocks in either supply or demand arise. In this model, the marginal convenience yield is computed following the methodology introduced by Ng and Pirrong (1994).

Negative supply and/or positive demand shocks for a specific commodity will lead to lower inventory levels, which implicitly lead to an increase in the spot price and its conditional volatility, Gorton, Hayashi and Rouwenhorst (2007). Therefore, spot metals prices signal the lack of a specific base metal for immediate consumption. The aforementioned shocks will also lead to an increase in commodities' futures price, but to a lesser extent. In line with the aforementioned prediction is the Cassassus and Collin-Dufresne (2005) finding, which suggests that the negative relation between physical inventories and spot prices underlies the convenience-yield spot price relationship. The futures price thus reflects market participants' expectations that inventories will finally be restored and spot prices will reach their normal, sustainable, levels.

Hence, the negative relation between aggregate metals inventories and the convenience yield is expected to be marginally weaker during post-crisis periods due to the relative abundance of industrial metals. In addition, metals convenience yields are estimated to be positively related to the China factor.

This sub section will examine the relation between convenience yields, the discretionary inventory levels computed by employing the stochastic de-trending technique proposed by Campbell and Perron (1990), and the China factor during two distinct periods: pre and post economic crisis. The definition and measurement of the aforementioned variables is provided by Appendix A and Appendix B respectively, while the regression model is illustrated below and presented in detail in Appendix D Section 2.

$\mathrm{c_t} = \alpha + \beta_1 \mathrm{DInv}_{t-2} + \beta_2 \mathrm{C_f}_{t-2} + \beta_3 \mathrm{Crisis}_{t-2} + \varepsilon, \varepsilon \sim \mathrm{n}(0, \sigma)$, where:

$\mathrm{c_t}$ is the convenience yield in period t
DInv_{t-2} is the ratio of the discretionary part of inventories to total inventories in period t-2
$\mathrm{C_f}_{t-2}$ is the percentage change (%Δ) in the Shanghai Industrial Index in period t-2
Crisis_{t-2} is the dummy variable in period t-2

Table 2 below contains the results of regressing the convenience yield on the ratio of the discretionary component of inventories to total inventories, the $\mathrm{C_f}$, and a dummy variable 'Crisis'. Due to the fact that in reality there will most likely be a time lag between the point when shocks in the supply of base metals occur and/or (Chinese) demand for metals spikes and the point in time when the impact of these variables on convenience yields can actually be observed, the independent variables in this model have been lagged by 2 periods (weeks). This 2-week lag has been observed to generate the highest model R^2, and has thus been chosen.

Table 2 The table presents the results of a 2 period (weeks) lagged regression having as dependent variables the convenience yield and as explanatory variables the ratio of the discretionary part of inventories to total inventories, the China factor and the Crisis dummy variable. The columns 'DiscrInv', 'Cf' and 'Crisi' show the model regressors slope coefficients. Due to data presenting signs of heteroscedasticity and autocorrelation, thus violating the standard assumptions of OLS regressions, the Newey-West heteroscedasticity and autocorrelation consistent (HAC) standard errors are computed. Thus, column 't-Stat' reveals the t-statistics computed using the aforementioned methodology with a time lag of 52 periods (weeks). The last column reveals the model explanatory power.

	α	t-Stat	**β DiscrInv**	t-Stat	**β Cf**	t-Stat	**β Crisis**	t-Stat	**RSq**
Metals Index	-0.038	-1.065	-5.168%	-0.159	5.961%	0.877	-0.016	-0.385	**5.52%**
Aluminum	0.022	1.994	-5.588%	-2.661	11.562%	3.093	0.007	2.694	**2.93%**
Copper	0.022	2.536	14.151%	2.389	13.122%	2.176	-0.012	-2.338	**6.05%**
Lead	0.009	0.880	13.911%	1.453	13.564%	2.565	-0.011	-1.024	**4.12%**
Nickel	0.022	2.779	-1.959%	-0.209	1.943%	0.783	0.005	0.741	**2.83%**
Tin	0.026	1.981	-0.394%	-0.071	5.490%	0.837	-0.019	-1.474	**2.52%**
Zinc	0.022	1.062	-33.924%	-2.456	5.112%	2.720	-0.001	-2.035	**8.78%**

The first column in Table 2 contains the dependent variables in the proposed model, while the second column reveals the y-intercept (α). The columns labelled β DiscrInv, β C_f, and β Crisis indicate the slope coefficients of discretionary inventory levels, the China factor and the Crisis dummy variable.

The y-intercept coefficient is somewhat small and positive for all metals except for the Metals Index, which shows a negative sign, therefore the regression line passes very close to the axes' intersection point.

As expected, the inventory levels-convenience yield relationship is negative for most of the metals analyzed, the only exceptions being Copper and Lead for which the slope coefficient shows a positive sign. However, the intensity with which the convenience yield reacts to changes in discretionary inventories varies significantly across the metals: in the case when Zinc inventories increase by 1%, the convenience yield is expected to drop by ~34%, while when Copper stocks increase by the same amount, the convenience yield is expected to augment as well by ~14%. These results are consistent with the findings of Khan, Khokher and Simin (2006).

The beta coefficients associated with the China factor are all positive and vary from ~1.9% for Nickel to 13.5% for Lead. This translates into the fact that whenever the Chinese demand for base metals surges, the convenience yield associated with each of the studied metals will augment as well. This scenario makes sense for both analyzed periods: during pre-crisis when the global economy and the demand for metals are strong, more instances of scarcity would be observed, which determine an increase of the cash price relative to the deferred price as well as an increase in then conditional volatility of the cash price due to the fact that there is a time lag between the point when a surge in demand occurs and when production catches up. This in turn leads to an escalation of the convenience yield. Conversely, thru post-crisis periods when demand is either low or declining, inventories are expected to accumulate, even though production is reduced to some extent, which in turn determines a drop in convenience yields.

When distinguishing between the two studied periods, the beta coefficient pertaining to the Crisis dummy variable provides the intuition as to how the convenience yield carries out thru each distinct period. As it can be observed in Table 2, the coefficients are negative for four out of the six studied metals including the Metals Index; Aluminum and Nickel coefficients being the only positive ones. This indicates that the y-intercept relating to the fitted regression line is, on average, lower during post-crisis periods, which further implies that the convenience yield is actually lower during these periods relative to pre-crisis periods, holding DiscrInv and C_f constant. Evidently, for Aluminum and Nickel this relation is not confirmed.

When assessing whether the beta coefficients are significantly different from zero, it can be concluded that Aluminum, Copper and Zinc are associated with coefficients indeed different from zero as indicated by the t-statistic (t-Stat column in Table 2) and a p-value lower than 5%[3]. For the other dependent variables the coefficient significance test yields mixed results, with some of the coefficients being significantly different from zero while others being very close to zero.

The model explanatory power is on average somewhat low and ranges from 2.52% for Aluminum to 8.78% for Zinc. In other words, discretionary inventories and the Chinese demand for metals account for ~9% of the variance in Zinc convenience yields, the remaining variance being attributed to factors not captured in this model. Nonetheless, these results are qualitatively similar to those obtained by Khan, Khokher and Simin (2006) in their paper.

All in all, it can be concluded that during periods when aggregate metals inventories are high, the convenience yield reaches lower levels and vice versa, as predicted by the Theory of Storage. However, the magnitude of this relation is significantly different during pre and post crisis periods for all metals studied, including the Metals Index. For Copper, Lead, Tin and Zinc, the convenience yield gained for storing these metals is highest during pre-crisis periods which are typically associated with a heightened (Chinese) demand, as hypothesized by Theory of Storage, and thus with a relative scarcity in inventories.

5. De-trended Base Metals Stockpiles, Chinese demand and Futures Risk Premia

When inventories are low, their ability to act as a buffer for spontaneous supply and demand shocks is significantly negatively impacted, thus raising the conditional volatility of future spot prices, Ng and Pirrong (1994). Hedgers (usually commodity producers, processors, farmers etc.) seek to shelter themselves from commodity price risk, thus the price risk, and are willing to pay a risk premium for the positions in the futures contracts they establish as noted by Khan, Khokher and Simin (2006). In this particular scenario, the mean excess return of commodity futures is expected to increase when the risk associated with the future spot price increases. Nash (2001), Erb and Harvey (2006) and Gorton and Rouwenhorts (2006) suggest that the mean futures excess returns (risk premia) and the inventory levels are inversely related.

Consequently, it is pertinent to expect that metals futures excess returns are positively impacted by the Chinese demand for base metals and are more sensitive to changes in aggregate inventory levels during pre than during post-crisis periods.

[3] Observed in a side analysis

The de-trended inventories levels are computed as the ratio of actual to normal inventories. The normal inventory levels have been estimated by applying a Hodrick-Prescott (HP) filter to the log of actual inventories in order to remove short term variations in stocks, typically generated by fundamental factors such as shocks in the supply/demand for these commodities or challenges in their respective supply chains. Ratios superior to 1 are associated with a relative abundance of metals while ratios inferior to 1 are related to relative scarcity. During periods of relative scarcity, inventories' ability to absorb shocks induced by supply and/or demand is considerably reduced, therefore leading to an increase in risk premia as cash and future spot prices and their conditional volatility augment. This implies a negative relation between futures risk premia and inventory levels. In addition, due to inventory levels' inability to absorb potential shocks, futures risk premia are expected to exhibit a higher sensitivity to changes in inventories levels during pre-crisis periods, typically associated with expansionary economies and heightened demand.

An important driver of prices that has been observed in the base metals business over the past decade is the Chinese unceasingly expansionary economy and its heightened appetite for these metals. This factor is thus considered to be a driver of metals futures risk premia and has been included in the model.

The variables used for testing the aforementioned hypothesis have been defined in Appendix A while their measurement is illustrated in Appendix B. The regression model is illustrated below and presented in detail in Appendix D Section 3.

$\mathrm{R_t^{ex}} = \alpha + \beta_1 \mathrm{DetrInv_{t-2}} + \beta_2 \mathrm{C_{f\,t-2}} + \beta_3 \mathrm{Crisis_{t-2}} + \varepsilon, \varepsilon \sim \mathrm{n}(0, \sigma)$, where:

$\mathrm{R_t^{ex}}$ is the metals futures risk premium (excess return) at time t
$\mathrm{DetrInv_{t-2}}$ is the ratio of actual to 'normal' inventory levels (I/I') in period t-2
$\mathrm{C_{f\,t-2}}$ is the percentage change (%Δ) in the Shanghai Industrial Index in period t-2
$\mathrm{Crisis_{t-2}}$ is the dummy variable in the period t-2

The Theory of Storage similarly predicts that the volume of metals held in storage at the end of one period could be a significant predictor of futures risk premium potentially gained during the immediate following period(s). Therefore, the explanatory variables in the regression equation have been lagged by two periods (weeks). This is most likely the case in a real environment where variations in the Chinese demand for base metals or swift fluctuations in inventory levels will not have an instant impact on futures risk premia, but rather after a certain period of time. The arbitrary 2-week time lag has been selected subsequent to running the model numerous times and observing that this specific lag maximizes the model's explanatory power.

Table 3 below contains the results from testing the aforementioned predictions. As was the case with the models related to the first two suppositions, the data describing metals (de-trended) inventories and the Chinese demand for these commodities presents signs of heteroscedasticity and autocorrelation.

Table 3 The table reports the outcomes of a regression analysis of weekly futures excess returns on 2 period (week) lagged de-trended inventories, the China factor and a Crisis dummy variable; the former is defined as the ratio of actual to 'normal' inventories, which in turn are obtained by applying a Hodrick-Prescott filter to the log of actual inventories. The columns 'DetrInv','Cf' and 'Crisis' contain the slope coefficients of the model explanatory variables. Due to data presenting signs of heteroscedasticity and autocorrelation, thus violating the standard assumptions of OLS regressions, the Newey-West heteroscedasticity and autocorrelation consistent (HAC) standard errors are computed. Thus, column 't-Stat' reveals the t-statistics computed using the aforementioned methodology with a time lag of 52 periods (weeks). The last column reveals the model explanatory power.

	α	t-Stat	**β DetrInv**	t-Stat	**β Cf**	t-Stat	**β Crisis**	t-Stat	**RSq**
Metals Index	-0.036	-0.306	4.540%	0.376	29.925%	3.409	-0.026	-8.579	**4.85%**
Aluminum	-0.068	-0.961	7.257%	1.028	28.697%	2.010	-0.047	-9.028	**5.48%**
Copper	-0.060	-1.483	-7.015%	-2.664	47.443%	2.470	-0.045	-7.839	**6.67%**
Lead	0.069	1.489	-5.754%	-2.163	30.565%	2.609	0.005	0.674	**3.83%**
Nickel	-0.096	-1.102	9.795%	1.078	42.462%	3.220	-0.043	-8.244	**4.07%**
Tin	0.047	0.539	-3.686%	-0.391	32.838%	2.418	-0.044	-3.844	**4.57%**
Zinc	-0.068	-1.022	-7.263%	-2.052	48.804%	3.009	-0.020	-1.936	**8.64%**

The envisaged negative relation between de-trended metals inventories and futures risk premia is confirmed for 4 out of the 6 studied metals: Copper, Lead, Tin and Zinc; the Metals Index, Aluminum and Nickel, on the other hand, show a positive relation. Hence, for the 4 aforementioned metals the excess returns are expected to surge when physical inventories drop. This occurs due to the fact that as metals stocks drop their potential of acting as a buffer to shocks diminishes and the conditional volatility of both nearby and deferred prices increases, which is in line with the Theory of Storage's predictions. The de-trended inventories slope coefficients range from -7.26% for Zinc to 9.8% for Nickel, which suggests that when Zinc stocks drop by 1% the Zinc futures excess return will augment by 7.26%. However, out of the entire metals sample the slope coefficients related to only three metals (Copper, Lead and Zinc) are significantly different from zero, as indicated by the t-statistic revealed in the 5th column of Table 3 and the p-values lower than 5%[4] associated with them. These finding are similar to those of Gorton, Hayashi and Rouwenhorst (2007), and overall one of the Theory of Storage's central predictions is partly confirmed by this analysis.

In order to assess the potential impact the China factor has on metals futures excess returns, the slope coefficients of the C_f will be further examined (column βC_f in Table 3). Surprisingly, the C_f has a rather significant influence on metals risk premia as indicated by the coefficients which range from 28.7% (Aluminum) to 48.8% (Zinc). Furthermore, all beta coefficients seem

[4] Observed in a side analysis

to be significantly different from zero. Thus, it can be inferred that from the point when Chinese demand for base metals increases by 1% in approximately 2 weeks metals futures risk premia are expected to surge on average by ~38%. This finding is in line with both previous expectations and the Theory of Storage and the explanation is given by the fact that unexpected spikes in demand for metals will lead to a depletion of stocks, as production cannot catch up in due time, which in turn lead to a surge of futures excess returns. These results are qualitatively similar to those of Khan, Khokher and Simin (2006), except that the authors used the S&P 500 index instead of the Shanghai Industrial Index.

The behavior of metals futures excess returns during the two analyzed periods (pre/post crisis) is revealed by the beta coefficients associated with the Crisis dummy variable in Table 3. It can be observed that all coefficients are negative, the only exception being Lead. In addition all coefficients, except for Lead, are significantly different from zero as indicated by the large values of the t-statistic which are associated with low p-values (<0.05[5]). Therefore, the y-intercept will be lower in post-crisis periods than thru pre-crisis periods, meaning that the metals futures excess returns will be on average lower during post-crisis periods. This statement is valid for all studied metals including the Metals Index, with the exception of Lead, and also confirms the initial predictions. The intuition behind this relation is provided by the Theory of Storage which states that during periods when commodities inventories are low the conditional variance of future (spot) prices increases and implicitly the risk premium augments. As concluded in the preceding part of this paper, low inventory levels are associated with a heightened demand typically occurring during pre-crisis periods. As a result, metals futures excess returns tend to be higher during this type of periods and, conversely, lower during post-crisis periods.

The model explanatory power is on average lower than 10% and ranges from 3.83% for Lead to 8.64% for Zinc. Therefore approximately 9% of the variation is Zinc futures excess returns is explained by movements in de-trended inventories and the Chinese demand for this metal. In order to confirm the pertinence of the model, the R^2 values attained in this paper are compared to those obtained by Gorton, Hayashi and Rouwenhorst (2007) and it can be ascertained that the values are similar to those published by the authors, if not even enhanced.

In order to determine whether metals futures excess returns are more sensitive to changes in inventories and Chinese demand for metals during pre- rather than during post-crisis periods an analysis of variance (ANOVA) is employed.

Table 4 below reveals the analysis of variance for each of the base metals analyzed together with the Metals Index. The first part of the table illustrates the standard deviation of metals

[5] Observed in a side analysis

futures excess returns in pre-crisis, post-crisis and throughout the entire period, while the second part of the table shows the Levene test values together with its associated probability. The Levene's test for Equality of Variances is an inferential statistic typically employed for evaluating the equality of variances for two or more (sub) groups. The null hypothesis which states that the variance of the two groups (excess returns in pre and post crisis) is equal (the groups are homogenous) will be tested and its rejection depends on the value of Levene's test and its associated p-value.

Table 4 The table reveals the results of an analysis of variance (ANOVA) of base metals futures excess returns. The futures excess returns' variance is distributed per analyzed periods according to the Crisis dummy variable. The second part of the table reveals the Levene significance test.

	Metals Index	Aluminum	Copper	Lead	Nickel	Tin	Zinc
	Standard Deviation						
Pre-Crisis	4.815%	4.599%	5.567%	6.329%	8.874%	6.011%	6.185%
Post-Crisis	4.790%	6.969%	7.817%	9.961%	9.262%	6.700%	8.290%
Overall	4.843%	4.756%	5.678%	6.403%	8.954%	6.066%	6.238%
	Levene Test						
Value	0.011	13.264	4.999	5.400	0.369	0.606	3.590
p-value	0.915	0.000	0.026	0.020	0.544	0.437	0.049

From the second part of Table 4 it can be observed that the Levene test is positive for all metals including the Metals Index and the related p-value is lower than the critical value (0.05) solely for Aluminum, Copper, Lead and Zinc. Therefore, the null hypothesis can be rejected only for the aforementioned four metals, for which it can also be concluded that there is a rather significant difference between excess returns' variances thru pre and post crisis periods.

Regarding the first section of Table 4 it can be concluded that for all the studied metals, the excess returns' standard deviation is higher during post-crisis than thru pre-crisis periods. The only exception is the Metals Index, whose excess returns show a post-crisis standard deviation slightly lower than the pre-crisis one.

This relation is divergent from what was initially expected, and implies that metals futures excess returns are more sensitive to movements in inventory levels and the C_f during post crisis periods which are typically associated with a relative abundance in base metals stocks.

This augmented standard deviation of metals futures excess returns throughout post-crisis periods is not likely to be determined by fundamental factors such as the state of economies and the demand for these particular products but rather by movements of speculative capital (managed money). Typically, during these types of financial turmoil non-commercial investors will attempt to reduce or even withdraw their commodities related placements as these are considered high risk investments. Together with these movements of capital, the volatility of commodities prices and in particular the volatility of futures excess returns (risk premia) characteristically increases significantly.

Nevertheless, the aforementioned relation is merely an attempt to explain the potential reason for which metals futures excess returns' standard deviations are higher during post that during pre-crisis periods, therefore further research in this area is required in order to confirm the aforementioned intuition.

6. Summary and Conclusion

This paper attempts to shed some light on the manner in which aggregate base metals inventories influence the excess returns of futures contracts structured on industrial metals throughout two distinct types of periods: pre and post economic/financial crisis. The data series covers one economic crisis which has taken place between week 27 in 2008 and week 13 in 2009, totaling 40 weeks.

Periods of financial/economic turmoil are associated with a relative abundance in aggregate metals inventories due to the depressed demand and generally poor state of the (global) economy. Conversely, during periods of economic expansion, more frequent and violent phases of scarcity have been observed, intuitively determined by the heightened (Chinese) demand for base metals.

The convenience yield, which is essentially solely received by holders of physical inventories and not by holders of financial contracts, is, on average, inversely related to the aggregate base metals inventories. Therefore, as inventories augment subsequently to an economic or financial turmoil, the convenience yield declines; even in the case when spontaneous shocks in the supply/demand of industrial metals may occur, they can be easily absorbed by the abundant stockpiles. This relation does vary in magnitude between the two studied periods, with base metals convenience yields being on average lower throughout post-crisis periods. Furthermore, the Chinese demand for base metals seems to positively impact their associated convenience yields throughout both pre and post crisis periods.

Finally, the inverse relation between futures risk premia (or excess returns) and aggregate inventories is confirmed for three out of the six metals studied. Furthermore, the metals futures excess returns have been observed to be on average lower during post crisis periods, when stocks of industrial metals are expected to accumulate leading to a lower conditional volatility of the cash and future spot prices; which in turn is associated with a lower risk in holding the futures contract and thus to a depressed risk premium. Conversely to what was initially expected, futures risk premia are more sensitive to variations in metals inventories and Chinese demand for base metals during post than during pre-crisis periods. The exact determinants of this unexpected amplitude across the two periods studied are still to be fully identified, thus opening the way for further research.

7. Limitations

Several of the limitations of this paper include the measurement and number of variables, the choice of time periods and data regarding inventories.

The measurement of variables is in accordance with other research papers which approached similar topics. However, better approaches for selecting and computing a proxy for the state of economy might be selected. In this particular case, a weighted average Market Index comprising the stock market indices of the world's top ten most strongest economies (US, China, Japan, Germany, France, UK, Brazil, Russia, Italy and India) was chosen, yielding in no significant relation between this variable and physical inventory levels for several of the base metals analyzed.

Data regarding stocks of industrial metals are only available for warehouses approved by the London Metals Exchange. However, no aggregate data exists regarding metals stocks which are held outside of exchange approved warehouses, but which could be efficiently be transported to the delivery location, typically an approved warehouse, on a short period of time. Moreover, an important challenge when attempting to assess the aggregate level of metals inventories is the absence of a common data source.

The definition of the pre-crisis and post-crisis periods closely follows the one derived from the OECD statistical database. In particular, on every occasion when the G20 GDP growth rate was negative, the associated period was considered to be an economic crisis and was thus labelled as post-crisis period; and whenever the growth rate showed a positive sign, this meant that the 'global' economy was in a state other than a recession and it was associated with a pre-crisis period. Therefore, the period ranging from 1998 to 2008 is considered a pre-crisis period, and is thus the control period which will be compared with the post-crisis period. However, in this control period the returns on metals futures might be somewhat different from normal. Moreover, the definition of a recession (crisis) as derived from the OECD approach might be slightly ambiguous when referring to the global economy as a whole due to the fact that the dynamics generated by the remaining 40% of the global GDP are not captured in the model.

Appendix A: Variables Definition

Aggregate metals inventory levels

Base metals' inventory levels represent the end-of-day stocks available in the Commodities Exchanges' authorized network of warehouses and storage facilities. In particular, the London Metals Exchange currently approves more than 700 warehouses and compounds in various locations across Europe, Asia, and the Americas.

Warehouse stock information regarding the metals approached in this paper is published by the London Metals Exchange on a daily basis, particularly at 9.00 a.m. London time. For the purpose of this study, weekly averages of aggregate metals inventory levels will be computed and employed.

Discretionary Inventories

Following the methodology employed by Khan, Khokher and Simin (2006), I will study the discretionary component of the commodities inventory levels in order to capture the relative scarcity/abundance of a particular metal. Discretionary inventories are stocks of commodities held in storage on top of those which are already reserved for immediate consumption, and determine the trade-off between the value of metals consumed today and the value of metals consumed on a future date.

De-trended inventories

The de-trended inventories are defined as aggregate commodity inventory levels from which potential seasonality has been removed by estimating 'normal' inventory trends for individual metals, Gorton, Hayashi, and Rouwenhorst (2007).

The Market Index

The Market index is a weighted average index which comprises the world's top ten strongest economies: US, China, Japan, Germany, France, UK, Brazil, Russia, Italy and India. Each country's most representative stock market index is chosen as a proxy for its economy and its weight is determined according to each country's GDP contribution to the sum of their GDPs. The Index is constituted on the 1st of Jan 1998 when it shows the following weights: US – 34%, China – 18%, Japan – 13%, Germany – 7%, France – 6%, UK – 5%, Brazil – 5%, Russia – 4%, Italy – 4%, India – 4%.

Therefore, the following stock market indices have been employed: Russell 3000 (US), Shanghai Composite (China), Nikkei (Japan), DAX (Germany), CAC40 (France), FTSE All Share (UK), Ibovespa (Brazil), MICEX (Russia), FTSE MIB (Italy), CNX Nifty (India). The Index is monthly rebalanced in order to restore the weights to their initial values and to avoid granting too much weight to a stock index (economy) that may appreciate (progress) much more than others.

The China Factor / Shanghai Stock Exchange Industrial Index

The Shanghai Stock Exchange Industrial Index is an indicator of China's industrial companies' market performance which comprises both A and B shares and has as a base day the 30th of April 1993. Increasing values of this index signify improving financial performance of industrial companies. There is a documented direct relationship between the performance of these companies and their demand for inputs, such as base metals, which translates into the fact that the better their financial performance, the higher their demand for industrial metals. This Index will be further referred to as the 'China factor' ($\mathrm{C_f}$).

Adjusted basis

The futures basis represents the spread between the current spot price of a particular metal and the nearest to maturity futures price of the same metal, as defined by the Theory of Storage. The adjusted basis is the futures basis adjusted for interest and storage costs associated with storing a particular metal from one period to the next, when consumption arises.

Convenience Yield

The convenience yield is the benefit that owners of physical commodities enjoy for storing the commodity during periods when markets are backwardated, or downward sloping. The positive yield results from the flexibility provided by on-hand stocks which can be promptly delivered when unexpected shocks in either supply or demand occur. Current literature shows a common approach in computing the convenience yield in the form of the opposite of the adjusted basis

Commodity Futures Returns

As previous literature dealing with investments in commodities futures suggests (Anson (1988), Greer (2000), Nash and Symk (2003), Heaney (2006), Zulauf (2006)), returns on commodity futures have mainly three sources. Typically, when investing in commodity futures for both short and long positions collateral is required, which will be used to settle gains or losses the futures position generates up to maturity. When considering the fact that the collateral is merely a portion of the notional value of the futures contract, the futures position can generate significant leverage. Thus, in current literature investments in futures contracts are typically fully collateralized, meaning that when an investor purchases a futures contract he will simultaneously invest the same amount in a deposit paying the 3 month LIBOR rate. Therefore, the returns on fully collateralized investments in commodity futures can be classified according to their three sources: spot returns, collateral returns and roll yields.

The spot return is generated by the variations in the price of a commodity in the cash market. The collateral return is the 3 month LIBOR rate generated by a deposit plus the interest on the initial margin posed when the futures contract was purchased.

The third source of return is the roll yield, which has the most important contribution to commodities futures returns and is obtained when the term structure of futures prices is downward sloping, in other words backwardated. The technique for obtaining this yield consists in selling a futures contract as it approaches maturity, and thus its price converges towards the price in the cash market, and purchasing another futures contract with a longer maturity. When the market is backwardated, maturing contracts are priced higher than longer-dated contracts, thus generating a yield.

Erb and Harvey (2006) illustrated that the roll yield has a R^2 of approximately 91%, indicating that this particular yield is responsible for approximately 91% of the return generated by a futures contract.

Futures Excess Returns (Risk Premia)

There is a large strand of literature focusing on the variation of commodities futures risk premia. Fama and French (1998) investigate the variation in the futures adjusted basis and the information content the adjusted basis has about futures risk premia and conclude that most of this information concerns movements of the expected future spot price. They achieve this by breaking up the variation in the adjusted basis into variation of the risk premium and variation of the expected spot price.

Basu, Oomen, and Stremme (2010) identify three different sources of the risk premium. Firstly, the commodity futures risk premium is caused by risk factors associated with the underlying commodity (i.e. shocks in supply and demand). Bessembinder (1992) also found a strong association between the risks affecting the underlying commodity and the futures risk premium. Erb and Harvey (2006) indicate that a second source of commodity futures risk premium is the term structure of futures prices, which implicitly drives a term premium. The term structure of futures represents the relationship between the price of the futures contract and its maturity. In the case where futures prices are below spot prices or long-dated futures prices are below short-dated futures prices, the futures curve is downward sloping and the market is in backwardation (also called an inverted market), as opposed to when the futures prices are above spot prices or long-dated futures prices are above short-dated futures prices, the futures curve is upward sloping and the market is in contango (also called a carry market).

A third source of risk premium is identified by the Theory of normal backwardation proposed by Keynes (1930), and represents commodities producers' necessity to hedge their price risk exposure. Thus, the purchaser of the futures contract can consider the amount of backwardation as a risk premium paid by commodities producers.

The roll yield, as previously described, can also be considered as a risk premium for the purchaser of the futures contracts having commodities as underlying assets.

The 'Crisis' dummy variable

This variable has the sole purpose of emphasizing the behavior of the studied variables throughout the two assessed periods: pre and post crisis. Therefore, during post-crisis or normal periods it will take the value 0, while for post-crisis periods it takes the value 1.

The Metals Index

The main reason for constructing an index composed of the analyzed metals is the partial removal of the noise in estimations which are run on a relatively short sample period with rather volatile data. Since commodities futures prices and in particular metals futures prices are considered to be rather volatile financial assets the index will allow for an intrinsic, unbiased analysis of the variables determining variations in futures risk premia.

The index is equally-weighted among the six metals and is monthly rebalanced so that allocating an artificially higher weight to a particular metal whose cash and forward price would increase more due to various exogenous factors could be avoided. The rebalancing takes place on the first business day of every month and is based on the close prices recorded on previous month's last business day. The methodology is similar to that employed by Gorton, Hayashi and Rouwenhorst (2007).

The Metals Index is expected to provide a pertinent overview of the base metals prices' behavior during the two studied periods (pre/post crisis). In what concerns the inventory levels associated with the index, they have been computed as the average stocks levels across the six base metals.

Appendix B: Variables Measurement

Commodity futures returns

The returns on commodities futures will be computed by employing three months rolling futures contracts. When the futures contract enters the maturity month, it will be sold and the following nearest-to-maturity futures contract will be purchased. This strategy is consistent with the one employed by Chong and Miffre (2010).

The formula used for computing the metals futures return is illustrated below:

$\mathrm{Ret}_{t+1} = \ln\left({}^{\mathrm{F}_{t+1}}/_{\mathrm{F}_t}\right)$, where:

Ret_{t+1} is the return on the commodity futures contract at time t+1.
F_t is the commodity futures contract price at time t,
F_{t+1} is the commodity futures contract price at mine t+1.

Commodity futures risk premia

The commodity futures risk premium is defined by literature as an excess return generated by a certain futures contract. Following Feldman and Till (2006), the excess return can be split into the Spot Return and Roll Return and measures the risk premium of a commodity futures position. The spot return is the proportional change in the price of the relevant futures contract, most of the times the near-month or ‘spot’ futures contract is considered. The spot return is a non-investable return. The roll return is obtained by selling an expiring futures contract and rolling the proceeds into another contract structured on the same commodity which will not expire during the following period in order to maintain the investment exposure. Considering the shape of the forward curve, the roll return can be either positive, in the case of backwardation, or negative, in the case of contango.

The following methodology is approached when computing roll returns: 3 months futures contracts trading on the London Metals Exchange and having as underlying assets the studied metals are employed. From the cash prompt date, LME contracts can be traded for delivery almost every business day forward up to 3 months. The latest point an outstanding futures position can be closed on the LME is 12:30pm the trading day before the prompt date. Considering the flexibility conveyed by the LME, a contract is purchased on any business day t and the position rolled on the first day of the maturity month. Thus, the position is held for 39 business days (t+38), and during the 40th day the contract is sold. With the proceeds another 3 months futures contract is purchased on the 41st business day (t+40). This methodology is illustrated in Figure 5. The roll yield is computed by using the formula:

$\ln\left({}^{F_{40}}/_{F_1}\right)$, where:

F_1 is the price of the futures contract on business day 1;
F_{40} is the price of the futures contract on business day 40
The spot return is computed as a percentage change of the commodity price in the cash market, therefore:

$\ln\left({}^{P_{t+1}}/_{P_t}\right)$, where

P_{t+1} is the commodity price in the cash market at time t+1;
P_t is the commodity price in the cash market at time t.
Thus, the excess return on commodity futures is computed as the sum between the roll return and the spot return. Transaction costs and execution slippage are ignored. This is consistent with the approach of Gorton and Rouwenhorst (2006).

Inventory levels

One important limitation when attempting to measure aggregate level of inventories is the fact that LME publishes levels of stocks only stored in its certified warehouses. Global stocks of a particular metal might very well be larger than those published by the LME. However, a common data source that would accurately identify worldwide stocks of a particular metal at any one point is absent, the LME being the next best choice. The same proxy for global inventories of metals, namely the stocks held in LME approved warehouses, is used by Gorton, Hayashi, and Rouwenhorst (2007).

Typically, when a futures contract matures, a physical delivery of the underlying commodity must be taken by the buyer at the predetermined location, usually the LME certified warehouse where the traded metal is kept Khan, Khokher and Simin (2006).

For all further computations the percentage change in inventories' levels will be used. The percentage change is computed using the following formula:

$\text{Change in Inventories}_c = \frac{\text{InvLev}_{m,t+1}}{\text{InvLev}_{m,t}} - 1$, where:

$\text{InvLev}_{m,t+1}$ is the aggregate level of inventory for metal m in period t+1;
$\text{InvLev}_{m,t}$ is the aggregate level of inventory for metal m in period t.

Discretionary Inventories

The discretionary component of commodities inventories is computed by removing the amount of stocks which is already committed to immediate consumption from total metals inventories. For calculating the committed portion of inventories the stochastic de-trending methodology proposed by Campbell and Perron (1990) will be employed. In particular, the committed inventories will be removed by deducting a trailing moving average of the previous four weekly lags from the inventories levels published by the LME.

De-trended inventories

Inventory long-term trends are estimated for each individual metal by applying a Hodrick-Prescott filter to the log of inventories levels published by the LME. The Hodrick-Prescott (HP) filter is a technique typically employed for removing short term variations in variables which are caused by the expansionary and recessionary business cycles, thus exposing solely the long term trends.

The Market Index

The Market Index is computed as follows:

$\mathrm{Market\ Index} = \frac{\sum \mathrm{w_i} * \mathrm{SI_i}}{\sum \mathrm{w_i}}$, where

$\mathrm{w_i}$ is the weight given to each country stock market's Index according to the country's GDP
$\mathrm{SI_i}$ is the individual stock market Index

The returns of the Market Index are computed by using the log difference:

$\mathrm{r_{Market\ Index}} = \ln \left({}^{\mathrm{Market\ Index_t}} / {}_{\mathrm{Market\ Index_{t-1}}} \right)$, where

$\mathrm{r_{Market\ Index}}$ is the return generated by the Market Index
$\mathrm{Market\ Index_t}$ is the value of the aforementioned Market Index at date t.

The Metals Index

The Metals Index is computed using the following approach:

$\mathrm{Metals\ Index} = \frac{\sum \mathrm{w_m} * \mathrm{P_m}}{\sum \mathrm{w_m}}$, where

$\mathrm{w_m}$ is the weight given to each of the six base metals (0.1667)
$\mathrm{P_m}$ is the (cash/future) price of each individual metal

The returns of the Metals Index are computed by using the log difference:

$r_{\text{Metals Index}} = \ln\left({\text{Metals Index}_t}/{\text{Metals Index}_{t-1}}\right)$, where

$r_{\text{Metals Index}}$ is the return generated by the Metals Index
Metals Index_t is the value of the aforementioned Metals Index at date t.

The SSE Industrial Index

The returns of the SSE Industrial Index (C_f) are computed by using the log difference:

$r_{SSE} = \ln\left({SSE_t}/{SSE_{t-1}}\right)$, where

r_{SSE} is the return generated by the Shanghai Industrial index
SSE_t is the value of the SSE Industrial index at date t.

The Adjusted Basis/Convenience yield

The futures basis is measured through the interest and storage adjusted spread[6], which equals the annualized percentage difference between the spot price and the futures price of a specific metal at date t, from which the marginal storage and interest costs associated with holding the inventory from date t to T are deducted (Ng and Pirrong (1994)). The same methodology for computing the adjusted basis is employed by Brooks, Lazar and Prokopczuk (2011) Dincerler, Khokher and Titman (2003), Khan, Khokher and Simin (2006). The aforementioned relation is illustrated below:

$b_t = \frac{F_T - S_T - w_{t,T}}{S_t} - r_{r,T}$, where

b_t is the interest and storage adjusted basis
F_T is the commodity futures price with delivery T
S_t is the spot commodity price at date t
$w_{t,T}$ is the cost of physically storing the commodity from date t to delivery date T
$r_{t,T}$ is the 3 months LIBOR rate

The Convenience yield

The convenience yield is computed as the opposite of the adjusted basis.

$c_{t.T} = -b_t$, where

[6] The term “adjusted spread” will be used onwards

$c_{t,T}$ is the convenience yield earned from storing the commodity from date t to delivery date T
b_t is the interested and storage adjusted basis;

Appendix C: Methodology

This paper focuses on the following six industrial metals: Aluminum, Copper, Lead, Nickel, Tin and Zinc. These selected commodities are representative for the base metals class as they are widely used by the industry. Data concerning these individual commodities has been collected from the Bloomberg Terminal. The six industrial metals are of significant importance as they are the most demanded mainstream base metals by both domestic and industrial entities

Appendix D: Statistical Tests

D1. Base Metals Inventories, the State of Economy and the China factor

In order to assess the impact of individual metals supply and demand shocks, mainly generated by crises of financial/economic nature (i.e. credit crunches), on aggregate inventory levels, a one period lagged regression analysis will be employed for each individual metal and the aggregated Metals Index. The motivation for studying this relationship is the increased importance of financial investment decisions in instruments having as underlying assets base metals which are made primarily on the basis of fundamental supply and demand relationships, Mayer (2009). A similar methodology was followed by Caballero, Farhi and Gourinchas (2008) and Khan, Khokher and Simin (2006), except that both papers used the S&P 500 stock market index instead of the Market Index as described above. In addition, the impact of the China factor on base metals inventories is studied by including the Shanghai Industrial Index in the regression equation. Therefore, the dependent variable in this regression equation is the weekly percentage change in aggregate metals inventory levels and the explanatory variables are the weekly percentage change in the value of the Market Index, the weekly percentage change in the Shanghai Industrial Index, and the dummy variable 'Crisis'.

The regression model is illustrated below:

$\mathrm{InvLev}_t = \alpha + \beta_1 \mathrm{Market\ Index}_{t-1} + \beta_2 \mathrm{C}_{f\,t-1} + \beta_3 \mathrm{Crisis}_{t-1} + \varepsilon,\ \ \varepsilon \sim \mathrm{n}(0, \sigma)$, where:

InvLev_t is the percentage change (%Δ) in aggregate metals inventory levels at time t
$\mathrm{Market\ Index}_{t-1}$ is the percentage change (%Δ) in the Market Index at time t-1
$\mathrm{C}_{f\,t-1}$ is the percentage change (%Δ) in the Shanghai Industrial Index at time t-1
Crisis_{t-1} is the dummy variable which takes the value 0 for pre-crisis periods and 1 for post-crisis periods, at time t-1

D2. Discretionary Metals Inventories, the China factor and Convenience Yields

In this model the Theory of Storage's central prediction will be tested, and for this the methodology proposed by Khan, Khokher and Simin (2006) is employed. In particular, the negative relation between convenience yields and inventory levels will be studied by using the discretionary component of inventories as a proxy for the relative scarcity during distinct post-crisis and pre-crisis periods. In addition, the potential impact the China factor has on metals convenience yields throughout the two assessed periods is evaluated. Therefore, a two periods (weeks) lagged regression having as a dependent variable the individual metals and Metals Index convenience yield and as explanatory variables the ratio of discretionary to total inventories(I_d/I), the China factor and the Crisis dummy variable will be run.

The regression model is illustrated below:

$c_t = \alpha + \beta_1 \mathrm{DInv}_{t-2} + \beta_2 C_{f\,t-2} + \beta_3 \mathrm{Crisis}_{t-2} + \varepsilon, \varepsilon \sim n(0, \sigma)$, where:

c_t is the convenience yield in period t
DInv_{t-2} is the ratio of the discretionary part of inventories to total inventories in period t-2
$C_{f\,t-2}$ is the percentage change (%Δ) in the Shanghai Industrial Index in period t-2
Crisis_{t-2} is the dummy variable in period t-2

D3. De-trended Metals Inventories, Chinese demand for Base Metals and Futures Risk Premia

Throughout this sub-section a similar methodology to that proposed by Gorton, Hayashi and Rouwenhorst (2007) will be employed; and namely, I estimate individual inventory trends by applying a Hodrick–Prescott (HP) filter to the log of inventories for each individual metal studied. The actual inventory levels are defined as I, while the normal inventories levels are defined as I`, both as weekly averages. The main differences between my analysis and the authors' are the following: I employ more recent data (up to Dec'13 vs. Dec`06); assess the impact of an economic crisis by distinguishing between two distinct periods; and evaluate the potential impact of the frequently quoted 'China factor' on base metals futures excess returns. These deviations from authors' initial model would provide a more focused and recent overview of the relation between physical metals inventory levels, the China factor and futures excess returns.

In the proposed model, hedgers (usually base metals producers) seek to insure themselves from variations in metals prices, thus the price risk, and are willing to give away a risk premium on the short positions in the futures contracts they undertake. In this particular scenario, the mean excess return of base metals futures is expected to increase when the risk associated with future spot prices increases. In other words, mean futures excess returns and inventory levels are inversely related. The risk associated with future spot price variations is typically higher during pre-crisis periods. The economic expansion and recession periods are established as per OECD's reports on G20 GDP growth rate.

In order to study the covariation between inventory levels and metals excess returns (risk premium), as suggested by Schwartz (1997) and Brennan (1958), during pre and post crisis periods a linear regression analysis is employed. The individual metals and Metals Index futures weekly excess return in period (week) t are regressed on the state of inventories, which is measured through the ratio of actual to 'normal' inventory levels in period (week) t-2, the China factor in period (week) t-2, and the Crisis dummy variable as well in period (week) t-2.

The regression model is stated as:

$R_t^{ex} = \alpha + \beta_1 \mathrm{DetrInv}_{t-2} + \beta_2 C_{f\,t-2} + \beta_3 \mathrm{Crisis}_{t-2} + \varepsilon, \varepsilon \sim n(0, \sigma)$, where:

R_t^{ex} is the metals futures risk premium (excess return) at time t
$\mathrm{DetrInv}_{t-2}$ is the ratio of actual to 'normal' inventory levels (I/I') in period t-2
$C_{f\,t-2}$ is the percentage change (%Δ) in the Shanghai Industrial Index in period t-2
Crisis_{t-2} is the dummy variable in the period t-2

References

Anson, M. (1998) ‘Spot Returns, Roll Yield, and Diversification with Commodity Futures’, *Journal of Alternative Investments* (winter): 16-32.

Basu, D., Oomen, R. and Stremme, A. (2010) ‘How to time the commodities markets’, *Journal of Derivatives & Hedge Funds* 16: 1-8.

Bessembinder, H. (1992) ‘Systematic Risk, Hedging Pressure, and Risk Premia in Futures Markets’, *Review of Financial Studies* 5(4): 637-667.

Bodie, Z. (1983) ‘Commodity futures as a hedge against inflation’, *Journal of Portfolio Management* (spring): 12-17.

Brennan, M. (1958) ‘The Supply of Storage’, *American Economic Review* 48: 50-72.

Brooks, C., Lazar, E. and Prokopczuk, M. (2011) ‘Futures basis, scarcity and commodity price Volatility: An empirical analysis’, *Working Paper, ICMA Centre Discussion Papers in Finance.*

Caballero, R., Farhi, E. and Gourinchas, P. (2008) ‘Financial Crash, Commodity Prices and Global Imbalances’, *Working Paper, Massachusetts Institute of Technology*.

Campbell, J. and Perron, P. (1990) ‘Pitfalls and Opportunities: What Macroeconomists Should Know about Unit Roots’, *NBER Macroeconomics* 1991(6): 141-220.

Casassus, J. and Collin-Dufresne, P. (2005) ‘Stochastic Convenience Yield Implied from Commodity Futures and Interest Rates’, *Journal of Finance* 60(5): 2283-2331.

Chong, J. and Miffre, J. (2010) ‘Conditional correlation and volatility in commodity futures and traditional asset markets’, *Journal of Alternative Investments* 12: 61-75.

Conover, C. M., Jensen, G. R., Johnson, R. R. and Mercer, J. M. (2009) ‘Can Precious Metals Make your Portfolio Shine?’, *Journal of Investing* 18(1): 75-86.

Dincerler, C., Khoker, Z. and Simin, T. (2004) ‘The Convenience Yield and Risk Premia of Storage’, *University of Western Ontario, Working paper.*

Edwards, F. and Park, J. (1996) ‘Do managed futures make good investments?’, *Journal of Futures Markets* 16(5): 475-517.

Erb, C. and Harvey, C. (2006) ‘The Strategic and Tactical Value of Commodity Futures’, *Financial Analysts Journal* 62: 69-97.

Fama, E. and French, K. (1987) ‘Commodity Futures Prices: Some Evidence on Forecast Power, Premia, and the Theory of Storage’, *Journal of Business* 60: 55-73.

Fama, E. and French, K. (1988) ‘Business Cycles and the Behavior of Metals Prices’, *Journal of Finance* 43(5): 1075-1093.

Feldman, B. and Till, H. (2006) ‘Backwardation and Commodity Futures Performance: Evidence from evolving Agricultural Markets’, *Journal of Alternative Investments* 9(3): 24-39.

Feldman, B. and Till, H. (2006) ‘Separating the Wheat from the Chaff: Backwardation as the Long-term Driver of Commodity Futures Performance’, *Journal of Alternative Investments*, 2006 (winter): 24-39.

Gorton, G. and Rouwenhorst, K. (2006) ‘Facts and Fantasies about Commodity Futures’, *Financial Analysis Journal* 62(2): 47-68.

Gorton, G., Hayashi, F. and Rouwenhorst, G. (2007) ‘The fundamentals of Commodity Futures Returns’, *Working Paper, National Bureau of Economic Research*.

Greer, R. (2000) ‘The Nature of Commodity Index Returns’, *Journal of Alternative Investments* 2000 (summer): 45-52.

Heaney, R. (2006) ‘An Empirical Analysis of Commodity Pricing’, *Journal of Futures Markets,* 26(4): 391-415.

Hillier, D., Draper, P. and Faff, R. (2006) ‘Do Precious Metals Shine? An Investment Perspective’, *Financial Analysts Journal* 62: 98-106.

Keynes, J. M. (1930) ‘*A Treatise on Money’, London: Macmillan*.

Khan, S., Khokher, Z. and Simin, T. (2006) ‘Commodity Prices, Scarcity and Risk Premia’, *Working Papier, Ivey School of Business, University of Western Ontario.*

Mayer, J. (2009) ‘The growing interdependence between financial and commodity markets’, *United Nations Conference on Trade and Development* 195

Nash, D. (2001) ‘Long-term Investing in Commodities’, *Global Pensions Quarterly*, Morgan Stanley Global Pensions Group 4(1): 25-31.

Nash, D. and Smyk, Y. (2003) ‘Backwardation of Commodities and Returns on a GSCI Investment’, *Morgan Stanley Global Pensions Group*.

Ng, V. K. and Pirrong, S. C. (1994) ‘Fundamentals and Volatility: Storage, Spreads, and the Dynamics of Metals Prices’, *Journal of Business* 67(2): 203-230.

Schwartz, E. (1997) ‘The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging’, *Journal of Finance* 52(3): 923-973.

Zulauf, C. R., Zhou, H. and Robert, M. (2006) ‘Updating the Estimation of the Supply of Storage’, *Journal of Futures Markets* 26(7): 657-676.

Figure 5 The figure depicts the rolling methodology employed for computing the metals futures excess returns (risk premia)