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Price Linkages in the Copper Futures, Primary, and Scrap Markets

Kentaka Aruga* and Shunsuke Managi

Abstract

This study investigates how markets for different levels of copper purity are interrelated by testing the long-run price linkage and causalities among the copper futures, primary, copper scrap, and brass scrap markets. It is expected that copper markets that deal with high purity levels, such as the futures, primary, and copper scrap markets, have a long-run relationship. However, brass scrap markets where copper with a lower purity is traded may not have a price linkage with other copper markets. The results reveal that a long-run relationship holds between the futures, primary, and copper scrap markets but the brass scrap market does not have a long-run relationship with the other markets. From the short-run and long-run causality tests, we determine that the futures market plays an important role in transmitting price information to other copper markets while such information flow is not found for the brass scrap market.

Keywords: futures market, copper scrap, brass scrap, cointegration, causality

JEL Classifications: C32, L61,

* Corresponding author.

E-mail addreses: kentka.aruga@gmail.com (K. Aruga)

1. Introduction

Scrap metals are becoming an essential domestic resource for countries that depend on imports for their metal resources. Scientists and economists have debated the availability and the sustainability of metal stocks (Tilton and Lagos, 2007) and there are arguments that some metal resources, such as copper, will become scarce in the future (Gordon et al., 2006). If it is likely that metal resources will become scarce, more metals will be obtained through recycling or reuse and the importance of the scrap metal market will rise. Therefore, more scrap metals will be used as a substitute for the primary metals and the inter-relationships between the primary metals market and the scrap metals market will become stronger. However, not many empirical studies have examined the interdependence between the primary metal markets and scrap metal markets to determine if these markets have a long-run relationship.

To help shed light on this issue, this study will test the long-run inter-market relationships and causalities among the copper futures, primary, copper scrap, and brass scrap markets. There are several studies investigating price linkage for metals such as the gold and silver futures markets (Ciner, 2001; Aruga and Managi, 2011) but compared to these metals there are very few studies that focus on the price linkage for the copper market. The New York Commodity Exchange Inc. (COMEX) copper price, which is the futures price of electrolytic copper, represents the futures price in this research. The Tokyo electrolytic copper represents the primary copper price, and the Tokyo no.1 copper wire and first grade copper are used for the copper scrap prices. Finally, the Tokyo new yellow brass and yellow brass red turning prices are used for the brass scrap prices. The copper purity of brass scrap copper is low in comparison to copper scrap, so including the brass scrap in the study provides empirical evidence on whether scrap markets of different levels of copper purity have a long-run price relationship. Thus, the results of our study will help determine how copper markets that deal with different purities are inter-related and will provide a useful source for policy makers to develop effective policies for conserving and recycling copper resources.

The first copper smelting can be traced back over 5000 years ago and copper is one of the most widely recycled metals. Copper can be recycled infinitely, whether it is pure or an alloy, such as brass, bronze, or nickel silver. Furthermore, almost one third of all copper consumed in the world today is recycled (USGS, 2009). Among the recycled copper studied in this paper, the two Tokyo copper scraps are very pure copper, but the two Tokyo brass scraps are alloys of copper and zinc; thus, their copper purities are lower. Both the copper scrap and brass scrap have different uses. Copper scrap is similar to electrolytic copper as it is mainly used for electrical wires, molding and electronic parts. On the other hand, brass scrap is used for boarding, electric bulbs, stationery goods, cases, and precision instruments. Because the use of copper scrap is similar to electrolytic copper, it is likely that the copper scraps will have a substitutive relationship with the futures and primary markets while the brass scraps may not have such relationships due to their different market structures. Hence, it can be expected that a long-run interdependence exist between the copper futures, primary and copper scrap markets but not with the brass copper markets.

In a prior work, Xiarchos and Fletcher (2009) evaluate the interaction between the copper primary and scrap markets and demonstrate that there are long-run price linkages among primary and scrap markets. They also found that, in the short run, information flows from the scrap market to the primary market. This study did not include the copper futures market even though the futures market has an important role when understanding both the price discovery process and how the price information flows between the future copper primary market and the scrap market.

There are several studies examining the long-run price relationship for the copper futures market. However, most of these studies are either testing the efficiency of the futures market or examining the spatial linkages among the copper futures markets of different regions. Xin et al. (2006) test the efficiency for the Chinese copper and aluminum futures markets, while Krehbiel and Adkins (1993) study the COMEX silver, copper, and gold futures markets and the New York Mercantile Exchange platinum futures markets. Then, Chowdhury (1991) examines the London Metal Exchange (LME) copper, lead, tin, and zinc futures markets. Moreover, Li and Zhang (2009) and Hua and Chen (2007) investigate the long-run relationship between the Shanghai Futures Exchange and LME copper futures markets to determine the spatial linkages of the Chinese copper futures market. All of these studies only include the copper futures price, which is based on the electrolytic copper market. Thus, none of the previous studies tested the long-run price relationships between the copper futures and copper scrap markets. Hence, this study fills this gap and analyzes the possibility of long-run interdependence and causalities among the copper futures, primary, and scrap markets.

Understanding the inter-linkages of copper futures, primary, and scrap markets will be helpful in determining the price discovery process for the market participants of the copper markets. Furthermore, it will provide valuable information for policy makers to develop plans to improve the utilization of the copper scrap market.

The next section explains the methods used in this paper, and the third section describes and discusses the data. The fourth section provides the results of the study and conclusions are offered in the final section.

2. Methods

The Johansen cointegration method (Johansen and Juselius, 1990) is used to test the long-run price relationships among the copper futures, primary, and scrap markets. Gonzalo (1994) argued that this method is better than other methods, such as the ordinary squares method used by Engle and Granger (1987) and nonlinear squares method used by Stock (1987), for testing the long-run equilibrium relationship among a set of time series variables.

To test for cointegration, all of the price series data that will be tested must be integrated at the same order. For this purpose, augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests are conducted on each price series. After it is confirmed that the copper price series are all integrated at the same order, the Johansen cointegration tests are performed on this price series.

The vector error correction model is used in the Johansen test:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \mu + \varepsilon_t \qquad (1):$$

where y_t is the $n \times 1$ vector of n endogenous nonstationary variables, p is the order of the vector autoregressive process, μ is the vector of the constant terms, ε_t is the normally distributed n-dimensional white noise process, $\Pi = -I + \sum_{i=1}^{p} \Pi_i$, and $\Gamma_i = -\sum_{j=i+1}^{p} \Pi_j$. The optimal lag order in the model is determined by the Akaike information criterion (AIC). Denoting r as the rank of Π matrix, the number of cointegration vectors will depend on r. For example, when $0 < r < n$, there will be r stationary linear combinations and the number of cointegrating vectors will be r. When $r < n$, Granger's representation theorem (Johansen, 1991; Engle and Granger, 1987) asserts that the Π matrix can be decomposed as $\Pi = \alpha\beta'$, where β is the matrix of cointegrating vector and α is the speed of the adjustment parameters.

The Johansen method allows for the testing of various restrictions by using the α and β matrixes. In this study, the long-run price leadership among the copper futures, primary, and scrap markets are examined through the weak exogeneity test, which implements restrictions on the α matrix. This test is conducted to see which copper price adjusts first in the long-run relationship when there are cointegration relationships between the pairs of copper prices. The exclusion test, which is the test of putting restrictions on the β matrix, determines if there are any copper prices that can be excluded from the cointegration space. We performed this test to determine which copper prices are not contributing significantly to the long-run relationship when testing the cointegration relationship of the whole copper market. Both the weak exogeneity and the exclusion tests are tested with the likelihood ratio tests.

The direction of the short run relationships is also tested in this study by the Granger causality test (Granger, 1969). The Granger causality test is conducted under the model

$$\Delta y_{1t} = c + \sum_{i=1}^{p} \alpha_i \Delta y_{1t-i} + \sum_{i=1}^{p} \beta_i \Delta y_{2t-i} + u_t \qquad (2)$$

where *c* is a constant, *p* is the order of the lags, y_{1t} and y_{2t} are the copper prices to be tested for their causality, and u_t is a random disturbance term. Using this model, the null hypothesis of y_{1t} is not Granger caused by y_{2t} can be investigated by testing the null hypothesis of $H_0: \beta_1 = \beta_2 = \cdots = \beta_p = 0$. This is examined with a F-test. Lastly, the orders of the lag lengths for the causality tests are determined by the AIC.

3. Data

First, this study uses six different copper prices. The time periods used for this study are 2000-2010. The COMEX copper futures price is used to represent the copper futures price and this data is obtained from the EODData, LLC. The futures prices are initially provided in a daily continuous form, and then the prices are converted to monthly data by taking the average of these prices. The copper traded at the COMEX is the grade 1 electrolytic copper cathode, which is produced by electrochemical deposition. The prices of the COMEX copper are measured as cent per pound. They are transformed into dollar per tonne to match the units of the Japanese copper prices.

The monthly data for the Japanese primary prices are from the Japan Metal Daily. The price unit is 1000 yen per tonne at the monthly price of Tokyo Electrolytic copper. The primary copper is produced through electrochemical deposition and its purity is over 99.8%. Similarly, monthly copper scrap prices are obtained from the Japan Metal Daily. There are two types of Tokyo copper scraps that are used in this paper: Tokyo no.1 copper wire and Tokyo first grade. The no.1 copper wire and first grade both have high purity levels (over 97%) and they are often used as substitutes for electrolytic copper. The no.1 wire is based on the Japanese Industrial Standard (JIS), and the diameter of the wire cannot be longer than 1.3 millimeters to be categorized as this type of copper scrap. The first grade is a scrap where its thickness has to be more than 0.3 millimeters, and the length is over 10 millimeters.

The brass scrap prices are also provided from the Japan Metal Daily. The monthly prices of both the Tokyo new yellow brass and the Tokyo yellow brass red turning are used for the brass scraps. The brass scraps are alloys of copper and zinc; therefore, they have low purity levels when compared to the copper scraps. The new yellow brass red turning is a brass scrap that has to be thicker than 0.2 millimeters and longer than 10 millimeters. On the other hand, the yellow brass red turning scrap is a powdered brass scrap with no width and length limits.

To match the currency units between the U.S. and Japanese copper prices, the Japanese primary, scrap, and brass copper prices are converted into U.S. dollars by using the monthly currency rate. The currency rate used for this purpose is obtained from the OANDA Corporation.

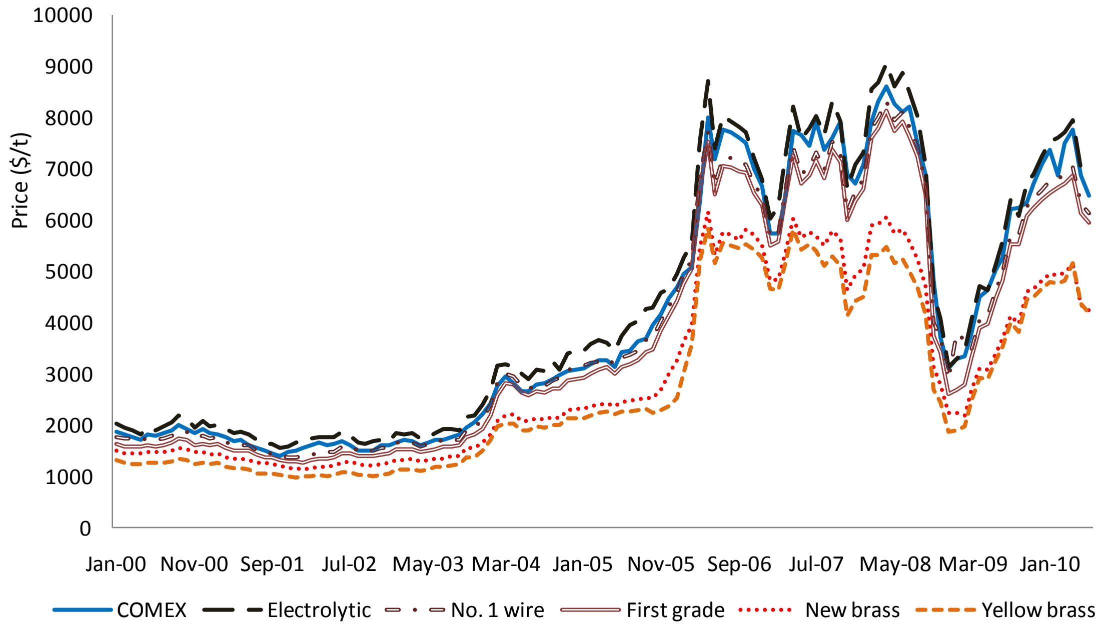

Fig. 1. Copper futures, primary, and scrap prices

Fig. 1 shows the copper price series investigated in this paper. The figure seems to indicate that a long-run linkage exists between the markets dealing with the same types of coppers. The COMEX copper futures and Tokyo Electrolytic copper futures are both very pure electrolytic copper markets; therefore, as long as the futures market is efficient, these prices are likely to have a long-run linkage. The no.1 wire and the first grade are both copper scraps and similarly, the new yellow brass and yellow brass red turning are both brass scraps; hence, it is expected that a long-run relationship will occur between these prices. It is likely that these long-run relationships will be found in the cointegration tests.

Table 1 Unit Root Tests

Variable	Level data			First differenced data		
	ADF	PP	KPSS	ADF	PP	KPSS
COMEX	-1.171	-1.294	1.091*	-3.731*	-7.801*	0.057
Electrolytic	-1.300	-1.333	1.085*	-3.574*	-8.825*	0.056
No. 1 wire	-1.239	-1.290	1.088*	-3.590*	-9.140*	0.061
First grade	-1.316	-1.386	1.069*	-3.642*	-8.590*	0.055
New brass	-1.417	-1.403	1.000*	-8.799*	-8.883*	0.068
Yellow brass	-1.693	-1.417	1.007*	-8.465*	-8.512*	0.061

Notes: * denotes significance at 5%. All the unit root tests for the level and first differences include a constant.

Table 2 Bivariate Cointegration Tests

Variables	H_0: rank=r	Trace test	Max test	Granger Causality tests	Chi-sq test
COMEX and Electrolytic	r=0	18.36*	15.93*	ΔCOMEX ≠→ ΔElectrolytic	11.58*
	r<=1	2.44	2.44	ΔElectrolytic ≠→ ΔCOMEX	3.59*
COMEX and No. 1 wire	r=0	30.44*	27.77*	ΔCOMEX ≠→ ΔNo. 1 wire	1.09
	r<=1	2.67	2.67	ΔNo. 1 wire ≠→ ΔCOMEX	5.26*
COMEX and First grade	r=0	20.08*	17.83*	ΔCOMEX ≠→ ΔFirst grade	4.39*
	r<=1	2.26	2.26	ΔFirst grade ≠→ ΔCOMEX	19.90*
COMEX and New brass	r=0	4.08	3.69	ΔCOMEX ≠→ ΔNew brass	1.97
	r<=1	0.38	0.38	ΔNew brass ≠→ ΔCOMEX	6.91*
COMEX and Yellow brass	r=0	11.61	8.86	ΔCOMEX ≠→ ΔYellow brass	3.71*
	r<=1	2.75	2.75	ΔYellow brass ≠→ ΔCOMEX	15.16*
Electrolytic and No. 1 wire	r=0	40.09*	38.25*	ΔElectrolytic ≠→ ΔNo. 1 wire	1.02
	r<=1	1.84	1.84	ΔNo. 1 wire ≠→ ΔElectrolytic	1.21
Electrolytic and First grade	r=0	27.74*	25.09*	ΔElectrolytic ≠→ ΔFirst grade	0.95
	r<=1	2.65	2.65	ΔFirst grade ≠→ Δelectrolytic	0.06
Electrolytic and New brass	r=0	6.86	4.70	ΔElectrolytic ≠→ ΔNew brass	5.34*
	r<=1	2.16	2.16	ΔNew brass ≠→ ΔElectrolytic	4.72*
Electrolytic and Yellow brass	r=0	11.64	9.36	ΔElectrolytic ≠→ ΔYellow brass	1.06
	r<=1	2.28	2.28	ΔYellow brass ≠→ ΔElectrolytic	1.02
No. 1 wire and First grade	r=0	29.56*	28.15*	ΔNo. 1 wire ≠→ ΔFirst grade	0.44
	r<=1	1.41	1.41	ΔFirst grade ≠→ ΔNo. 1 wire	1.03
No. 1 wire and New brass	r=0	6.61	4.04	ΔNo. 1 wire≠→ ΔNew brass	2.68
	r<=1	2.57	2.57	ΔNew brass ≠→ ΔNo. 1 wire	1.19
No. 1 wire and Yellow brass	r=0	12.28	9.83	ΔNo. 1 wire ≠→ ΔYellow brass	1.37
	r<=1	2.45	2.45	ΔYellow brass ≠→ ΔNo. 1 wire	2.82
First grade and New brass	r=0	9.07	6.45	ΔFirst grade ≠→ ΔNew brass	0.34
	r<=1	2.62	2.62	ΔNew brass ≠→ ΔFirst grade	0.06
First grade and Yellow brass	r=0	12.03	9.22	ΔFirst grade ≠→ ΔYellow brass	0.65
	r<=1	2.81	2.81	ΔYellow brass ≠→ ΔFirst grade	1.21
New brass and Yellow brass	r=0	15.83*	13.63*	ΔNew brass ≠→ ΔYellow brass	3.33
	r<=1	2.20	2.20	ΔYellow brass ≠→ ΔNew brass	2.93

Note: * represents significance at 5% level. ≠→ denotes the variable does not Granger cause the other.

4. Results

The results of the unit root tests reveal that all copper price series are integrated of order one. As reported in Table 1, the null hypothesis for the unit root is not rejected for the level data in the ADF and PP tests. However, the hypothesis is rejected for the first differenced data. The KPSS tests for stationarity also suggested that all price series become stationary after the first differencing of the price series.

First, as seen in Table 2, the pair-wise cointegration tests were performed on the copper prices. The results suggest that cointegration relationships exist between both the pairs of markets trading the same types of copper and among the futures, primary, and copper scrap markets. The cointegration relationships between the COMEX and the Tokyo electrolytic copper, the no.1 wire and the first grade, and the new yellow brass and yellow brass red turning are expected results because, as explained in the data section, these copper markets trade the same types of copper. The long-run relationships found between both the COMEX futures market and the two copper scrap markets and between the Tokyo electrolytic primary copper market and the two copper scrap markets reveal that futures, primary and copper scrap markets have long-run linkages. This is perhaps because the no.1 copper wire and first grade copper are all over 97% pure copper; thus, these coppers are often used as substitutes or complements for the electrolytic copper.

The results in Table 2 also reveal that the two brass scrap prices are not cointegrated with any of the other copper prices except within the brass scrap markets. This implies that the brass scraps do not have a long-run price linkage with the futures, primary, and copper scrap prices and that the two brass scrap markets move independently from other copper markets in the long run. The copper purity of new yellow brass and yellow brass red turning is low in comparison with the other kinds of copper. Indeed, these brass scraps are used for different purposes from the electrolytic copper. Therefore, it is possible that the brass scrap markets have a different market structure when compared to the futures, primary, and copper scrap markets.

Table 3 Weak Exogeneity Tests

Variables	LR statistic under exogeneity
COMEX → Electrolytic	0.76
Electrolytic → COMEX	4.53*
COMEX → No. 1 wire	1.90
No. 1 wire → COMEX	0.55
COMEX → First grade	0.13
First grade → COMEX	3.58
Electrolytic → No. 1 wire	2.59
No. 1 wire → Electrolytic	0.01
Electrolytic → First grade	0.03
First grade → Electrolytic	0.55
No. 1 wire → First grade	3.65
First grade → No. 1 wire	7.31*
New brass → Yellow brass	0.90
Yellow brass → New brass	2.16

Note: * represents significance at 5% level.

Short-run and long-run causality tests were also conducted among the pairs of copper prices. The short-run causality test is conducted using the Granger causality tests. This result is presented in Table 2. We can see from the table that most of the short-run causalities occurred between the COMEX futures and the other copper markets. In addition, no causalities were found between the copper scrap market and the brass scrap market. Besides the causality between the COMEX futures and other copper markets, a short-run causality also exists between the electrolytic copper market and new yellow brass market. Most of the short-run causalities are two-way, except for the causalities between both the COMEX futures and the no.1 wire prices and between the COMEX futures and new yellow brass prices. The causalities between the futures and the no.1 wire and between the futures and the new yellow brass scrap markets are one-way causalities, from the no.1 wire to the futures market and from the new yellow brass scrap to the futures market.

The long-run causality is tested under the weak exogeneity test. This test is performed using the Johansen method, which states that the pairs of copper prices must be cointegrated to conduct the test; therefore, the results are shown only for the pairs that were cointegrated. Table 3 provides the result of this test. There are mostly two-way causality directions, but price leadership exists between both the futures and electrolytic copper prices and between the no.1 wire and first grade prices. We find that the copper futures price leads the electrolytic copper price and the no.1 wire price leads the first grade price to a long-run equilibrium relationship. This suggests that copper futures and no.1 copper wire scrap markets are weakly exogenous to the primary and first grade markets and that the discrepancy from the cointegration relationships are adjusted by these markets.

Table 4 Multivariate Cointegration test

Test variables	H_0: rank=r	Trace statistic	Max-Eigen statistic	Exclusion test
Comex	r=0	132.53*	50.55*	12.41*
Electrolytic	r<=1	81.99*	34.86*	2.42
First grade	r<=2	47.12	27.18	7.61*
No. 1 wire	r<=3	19.94	12.93	15.11*
New brass	r<=4	7.01	6.99	0.05
Yellow brass	r<=5	0.02	0.02	0.00

Note: * represents significance at 5% level. The exclusion test statistic is based on the likelihod ratio test statistic and is distributed as chi-square.

Finally, a cointegration test is performed on all copper prices to analyze the linkages of the whole copper market including the futures, primary, scrap, and brass scrap prices in one model. The results in Table 4 suggest that there are two cointegration relationships between the copper prices and that some copper markets do not move together with the whole copper market. The exclusion test indicates that the prices of the primary scrap and brass scrap can be excluded from the cointegration space. This implies that these prices do not contribute significantly to the long-run relationship within the whole copper market. The exclusion test supports the results in the pair-wise cointegration tests where the new yellow brass and yellow brass red turning markets were not cointegrated with the futures and primary copper markets. Furthermore, it reveals that the brass scrap market move independently from other copper markets. In addition, it is noticeable that the electrolytic copper price is not significant while the COMEX futures price is highly significant. This implies that, in the long run, the futures market plays a stronger role than the primary market when determining if the whole copper market is moving together in the long run.

5. Conclusion

This paper investigates how copper markets for different levels of copper purity are interrelated. For this purpose, we examined the price linkages and causalities among the copper futures, primary, copper scrap, and brass scrap markets. The results of this paper would be valuable for participants involved in the copper market and managers developing effective policy to conserve, recycle and support the sustainable use of copper resources.

The result of the cointegration and causality tests indicates that price linkages exist among copper futures, primary, and copper scrap markets, which deal with high purity copper. This implies that the copper scrap market is interlinked with the high purity copper market and that the policies that influence the copper scrap market will also affect the highly pure electrolytic copper market. Thus, when conducting effective policies to utilize the copper scrap market for sustainable use of copper resource, we need to consider this long-run price linkage. However, such price linkage with the electrolytic copper market was not found for the brass scrap market, which trades copper with a lower purity in comparison to the copper scrap. This suggests that the brass scrap market moves independently from the electrolytic copper market. Furthermore, it is likely that the brass market is not a substitute market for the electrolytic copper market. This may be because the brass copper market has a different market structure from the electrolytic copper market; thus, this market must be treated differently from the electrolytic copper market.

This study provides a strong rationale for conducting similar studies using scrap copper markets that deal with different levels of copper purity. As the demand for copper resources continues to increase, more copper will be recycled or reused and the copper scrap markets will become more important. Thus, our study would be helpful for creating effective policies to utilize the copper scrap markets and to support the sustainable use of copper.

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