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The World Aluminium Market:
An analysis of Market Structure and Price Developments

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Abstract

This paper provides an insight into the structure of the global aluminium market and estimates the probability distribution function of daily LME spot prices for Aluminium. The market is basically competitive on the supply side, but the larger producers/countries are to be found in Asia. Demand, which originally enjoyed strong growth from Western sources, has over the past nine years, shifted to the eastern bloc. The market has been in surplus over the past three years, leading to a significant accumulation of inventories over this period. In relation to LME prices over time, we find, using the Cramer-Von Mises, Watson, Anderson-Darling and Lilliefors tests for goodness-of-fit of empirical probability distribution functions to their theoretical counterparts, that the underlying distribution of aluminium prices does not conform to the Normal, Chi-squared, Exponential, Log-Normal, Gamma nor the Logistic theoretical forms.

[1] The views expressed in this paper do not necessarily reflect those of the Bank of Jamaica.

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Introduction

This paper sketches a review of the international market for aluminium. We place emphasis on the structure of the global industry and spend some time on the characteristics and the distribution of aluminium price changes, knowledge of which will yield insights into the future viability of Jamaica's mining industry.

The mining industry in Jamaica, which is dominated by the bauxite/alumina sector, is a significant part of the country's balance of payments. The country's real economy is also affected by the industry through its impact on employment and the earning capabilities of the country and perhaps, most importantly, government revenues and by extension the fiscal account. Therefore, in light of its potential impact on the domestic economy, it is important that the structure and dynamics of the global aluminium industry be explored.

In the paper, we find that the global market for aluminium is highly sensitive to world demand and consequently global GDP growth. Countries like China and Russia dominate world production through the actions of large aluminium producing firms like CHALCO and UC RUSAL, while the top consumers (China and the U.S.) predominantly use this metal in their transportation and construction sectors. From statistical tests for the most appropriate distribution of the time series of aluminium price changes, we found that prices have a non-normal distribution, which has implications for the forecasting methods for this variable.

The rest of the paper will proceed as follows; section 2 presents the history of the Aluminium Market. Section 3 will provide insight into the current Global Aluminium Industry. Section 4 explains the methodology, data analyzed and the results. Section 5 provides a conclusion of the main findings and their implications for the Industry analysis.

The History of the Aluminium Industry

Aluminium has been produced on an industrial scale since 1886 and, since then, its use has become a vital part of everyday life. In 1900, global annual aluminium production amounted to 1000 tonnes. By the end of the century, production had increased dramatically to 32.0 million tonnes.

The global aluminium industry was dominated by an oligopoly of six vertically integrated corporations until the 1980's.[2] After the oil shocks of the 1970's, the aluminium market became fragmented and the producer dominated pricing system that had been in existence came to an end.[3] The decline in the concentration of ownership in primary aluminium production that had been taking place since the early years of the industry has played an integral role in the change of pricing decisions which, since the 1980's has been based on trades on the London Metal Exchange (LME).

Between the beginning of 2002 and the end of 2003, monthly aluminium prices remained relatively stable, averaging US$1,390.5 per tonne on the LME and deviating within a range of only US$263.00 in that span of two years. However, between 2004 and July 2008, monthly LME prices doubled to approximately US$3 071.2 per tonne (See Table 1, Appendix II). The average growth rate between these years was 21.8 per cent, despite the onset of the sub-prime crisis in the United States in 2007. Monthly aluminium prices have been falling at a rate of 5.9 per cent since it attained its peak in the summer of 2008 with the largest decline of 20 per cent being realised between November and December of the same year. These changes in global aluminium prices have also had an impact on the Jamaican mining industry.

[2] These six corporations were: Aluminium Company of America (ALCOA), Aluminium Company of Canada Limited (ALCAN), Pechiney (PUK), Reynolds, Alusuisse, Kaiser

[3] See T. Lines: Restructuring of The Aluminium Industry" Implications for Developing Countries

Figure 1

The Jamaican Mining Industry: Recent Developments

Since 2000, approximately 56.0 per cent of Jamaica's export earnings have been from bauxite/alumina. The mining sector contributed 10.0 per cent to Jamaica's GDP on average over the period 2000 and 2007 and is one of the largest single contributors to GOJ revenue. [4]

In the context of the global downturn in demand, bauxite and alumina companies such as Alumina Partners of Jamaica (Alpart) and West Indies Alumina Company (Windalco) closed down their operations (See Table 3, Appendix II) in early 2009 in light of the severe declines in this industry. Forecasted cuts in production in the bauxite and alumina are 34 per cent and 55 per cent respectively while 2,314 low skill workers lost their jobs between July of 2008 and the 24th of July 2009. In addition, the earnings of the government have been hampered by its holding company in one of the largest Alumina companies in the country Clarendon Alumina Partners (C.A.P.). GOJ has, up to 2007, suffered US$1.0 billion on losses through C.A.P.

[4] See Table 2, Appendix II for Bauxite Levy and Tax revenue contributions to the Jamaican Economy

The Global Aluminium Market

The developed nations dominated the consumption and production of aluminium from the 1950's to the mid 1970's as they were the only countries with the manufacturing capabilities to produce the metal and industries that utilized it on a large scale. In this sense, the main agents who supply to the market were easily identifiable. Because of the fragmentation and emergence of new powers of production within the market and the globalization of the industrialization processes in the world, however, the dynamics of supply has become more complicated.

Consumption

The more developed nations are at the forefront of aluminium consumption (See Table 5, Appendix II). Products associated with this metal range from aluminium foil to space shuttles. The most important source of demand for aluminium has been the transportation, packaging, construction, electrical industries. In the transportation sector, vehicle manufacture, railway and train manufacture as well as the aerospace market have been responsible for approximately 28 per cent of global aluminium consumption between 2000 and 2008 (See Figures 1 &2, Appendix II). The construction sector uses aluminium to make window frames, doors and support framing for roofs and walls among other uses while flat aluminium sheets are used extensively in the packaging activities such as soda can manufacture.

In 2008, Asia was responsible for approximately 44.0 per cent of primary aluminium consumption, and both Europe and the Americas have consumption levels of 27.0 per cent. China has dominated demand over the past ten years, accounting for 36.5 per cent of world demand in 2008. China has also been one of the largest importers of the metal. Between 2001 and 2008, this demand was exhibited in the car production, roads and the railway sector of the transportation industry and in the country's electronics industry.

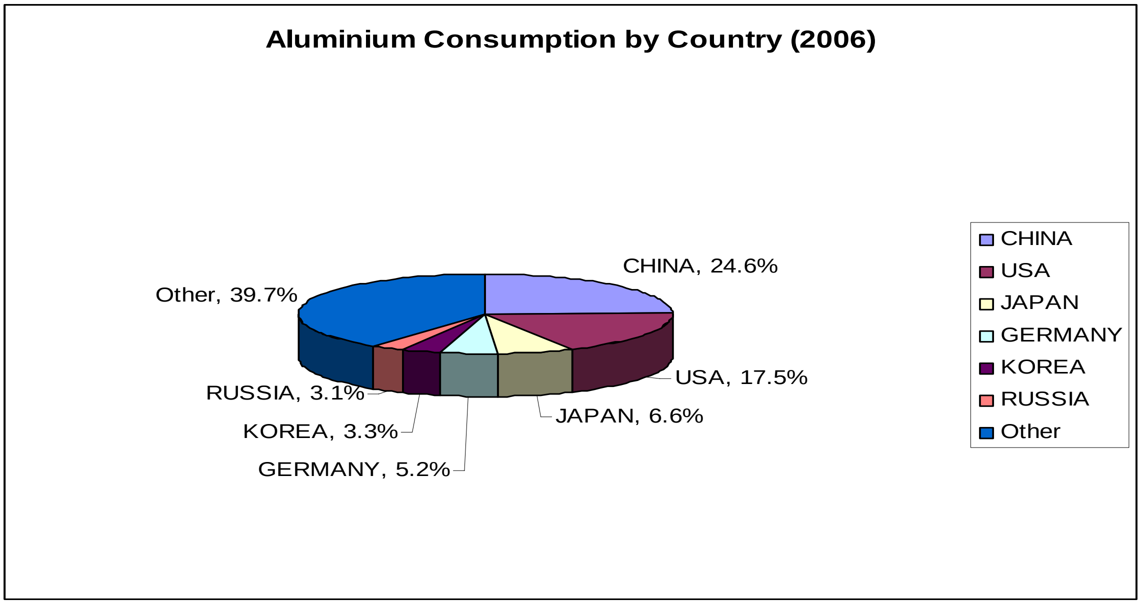

Figure 2

The United States is the second largest world consumer of primary aluminium. The country was responsible for 13.4 per cent of the global consumption in 2008. Japan is third in the world in terms of global aluminium consumption, utilizing 5.0 per cent of the world's usage in 2008. The country ranks among the highest in terms of aluminium imports. Japan, like the United States, has several end users of aluminium in the automotive industry.

Between 1998 and 2007, primary aluminium consumption globally grew at an annual average rate of 5.6 per cent. After the onset of the global economic crisis there was still consumption growth of 4.9 per cent between 2007 and 2008. After a slight decline in 2001, the growth rate of aluminium use has been steadily increasing driven by the Chinese demand as they have increased their consumption by 23.7 per cent between 2001 and 2007.

Since the third quarter of 2008, global demand for the metal has stagnated. In 2007, China increased its consumption of the metal by 37.9 per cent and in 2008. This growth in demand remained unusually high at 25.0 per cent, despite the impact of the global economic recession.

There have however been declines in the United States' aluminium use between 2008 and June 2009, in line with the global economic recession. America's aluminium consumption declined by 8.4 per cent in 2007 and a further 2.0 per cent in 2008, primarily due to the contraction in the country's housing and transportation industries. Even though there have been attempts to stimulate the US economy, the lack of consumer confidence has served to cause demand to remain low and thus aluminium consumption has remained low.

Toward the end of 2007, Japan started to experience weak demand in its housing and transportation industries. Japan has little or no demand in the country's industries that heavily utilize aluminium.

Production

Although aluminium is a relatively new metal in comparison to others, in terms of quantities traded, it is the second most utilized metal in the world. Between the 1950's and the middle of 1970's, six large corporations dominated the supply of the metal.[5] Bauxite, the raw material used in aluminium production, was found mainly in developing countries[6] such as Jamaica, Guinea, Suriname and Venezuela, among others, and although the lead companies had operations in these nations, the smelting capacity was not developed to produce the metal.

The production of aluminium occurs in three stages. Firstly, it is mined in the form of bauxite ore, after which it is refined to produce aluminium oxide or alumina, with the third and final stage being the smelting of the oxide into aluminium. The final two stages of production are capital and energy intensive with 60.0 per cent of the costs associated with aluminium production accruing at the third (smelting) stage.

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[5] These were USA, France, Canada and Switzerland with 3 of the 6 dominant companies in the industry being located in the United States.

[6] USGS has estimated that the world's Bauxite resources have been found mainly in Africa (33%), Oceania (24%), South America and the Caribbean (22%) and Asia (15%)

Between 2000 and 2008, the global production of aluminium has consistently met the global consumption, and on the occasions that it did not, the deficit was only marginal. Production in the industry since 2000 has been consistently increasing although there has been variation in prices on the market. As a result of the location of its manufacturing capabilities, the U.S. was once the leader in terms of aluminium production and this remained so up until the earlier in this decade. More recently, however Canada, Russia and most notably China have exceeded the US in terms of primary aluminium production.

In these countries, as well as others such as Australia, there were high levels of capital investment in new smelters and in increasing smelter capacity in the late 1990s. Aluminium Company of America (ALCOA), Aluminium Company of Canada Limited (ALCAN), United Company RUSAL (UC RUSAL) and Hydro Aluminium among others have had a major hand in the worldwide increase in aluminium production, seeking to expand their market share by investing in different countries. In general, the supply of aluminium has been affected the most by high energy costs, problems with bauxite and alumina supply, environmental issues and decreasing demand due to the economic state of the nations utilizing the metal. More recently the global economic recession has decreased demand and caused major declines in prices on the market which has caused a decline in production levels and hence global supply.

China is the largest national producer in aluminium on the global market and in 2007 the country increased its production by 35.0 per cent relative to the previous year. In November 2008, China had approximately 34.0 per cent of the total global production representing a 6.0 per cent increase from the previous year's production.

In total, China had about 14 million tonnes in aluminium production capacity in 2007 of which it was utilizing 90 per cent. The main problems affecting China's aluminium production includes reliance on imported bauxite, power supply issues and high production costs. The Chinese government's interventions in the industry have included the implementation of a 15.0 per cent export tax on aluminium bars and eliminated a 5%

tariff on primary aluminium imports in 2007 to increase domestic aluminium supply. Despite the global economic recession, China continues to increase production, due to the fact that in addition to being the largest producer of the metal, China is also the largest consumer of aluminium. The country has a constant market for its supply.

Although it is the home to UC RUSAL, the world's largest aluminium producing corporations, Russia is a ranked second in terms of production and sale to the global market. Since 2000, there have been numerous mergers of the smaller aluminium producing companies and projects increasing smelter capacities in the country. The industry has also been improving the efficiency of its smelters through an emphasis on technological improvements. Russia utilizes approximately 90.0 per cent of the country's production capabilities. The country also has input concerns as they have turn to alumina from Australia in order to supplement the process although parts of the country is rich in bauxite resources due to concerns that these reserves would produce aluminium which is poor in quality.

Canada is third globally in terms of aluminium production with the country utilizing just about 100.0 per cent of its production capabilities. This is a reflection of ALCAN, the country's main aluminium producing firm which in the world market was also third in production until its merger with Rio-Tinto in 2007 made it the largest aluminium producer worldwide[7]. Since 2000 the country has been increasing its smelting capabilities but has temporarily closed some of their smelters in an attempt to save power for other productive plants.

In contrast to the top three aluminium producers in the world, The United States has been steadily reducing its production in recent times. The country has been decreasing its production since the year 2000 with a number of its smelters specifically in Pacific Northwest being closed due to losses brought about by increased energy costs. The U.S. has also chosen to import the aluminium that it utilizes for manufacturing. Closures that

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[7] See Appendix II, Table 7 for a complete list of aluminium producing companies and their rankings in the world market

triggered the decline in the US aluminium production have been the result of high energy costs as well as issues with cost of imported raw materials such as bauxite and alumina[8]. There was also the issue of low demand within the US market that surfaced from 2002. This has continued to become more pronounced after the economic crisis. The country's main aluminium producing company has been a big part of the decreases in production with ALCOA suspending activity in a number of its smelters.

Australia is a new-comer to the top-five aluminium producing countries, replacing Brazil in 2007. The country benefited early in the decade from investments made by various companies like Pechiney and ALCOA that made investments or bought shares in some of the country's smelting firms. The combined entities then made improvements to the smelting capacities and increased the efficiency of some of the facilities that aided in the decrease of the pollution caused by the production process. Investments improved the country's productive capacities while the presence of a vast supply of bauxite served to decrease costs and improve the country's aluminium earnings.

In general the top five aluminium producers in the world account for over 60 per cent of the aluminium production globally (See Table 6, Appendix II) and although other countries have been increasing their capacities and production there hasn't been significant increases in global output.

Although there have been increases in aluminium consumption worldwide, the market has, since 2007, been in surplus. In this context, there have been extremely high levels of registered[9] and unregistered aluminium stocks in the LME warehouses and backwardation in LME prices.

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[8] The US also had issues with supply of alumina from Jamaica due to hurricanes which temporarily hindered local production

[9] Registered LME stocks are metals that have passed the specifications stated by the LME to make the aluminium smelter's product tradable under their contracts. The specifications include the chemical composition of the metal and payment of registration fees among other terms

Figure 3

Prices

Although aluminium started trading on the London Metal Exchange (LME) in 1978, the effect that large corporations had on the price determination of the metal did not begin to wane until the mid 1980's when concentration began to decline. In addition to the LME, other exchanges on which aluminium is traded include the Commodities Exchange (COMEX) on the New York Mercantile Exchange (NYMEX), the Shanghai Metal Exchange (SHME) on the Shanghai Futures Exchange, Osaka Mercantile Exchange and Tokyo Commodity Exchange. The majority of this metal is traded on stock exchanges as a means of hedging[10] against risk. However some aluminium producers like the Norwegian company Norsk Hydro have chosen to trade on over the counter locations[11]. The LME is the leader in aluminium future and option trading with the SHME closely following it for second place while the COMEX places third in the industry. LME aluminium futures are the largest traded contract on the exchange and in 2008 the volume increased 20.0 per cent from 2007 to 48.3 million lots.

[10] Approximately 0.5% of LME contracts end in delivery which is an indicator of the high level of speculation in the aluminium industry: see LME website

[11] This leading aluminium producing company has decided to trade on Pink OTC Markets Inc while other corporations like Kaiser and Century Aluminium of the US trade on NASDAQ, widely considered an Over The Counter trader

Stylised Facts: Aluminium Prices

In this section we evaluate the time series of quarterly, monthly and daily aluminium prices for salient stylised facts. In the first place we decompose the series into its seasonal, trend and cyclical components. Other components of the time series, including its volatility and times at which there are structural breaks are also assessed.

Quarterly aluminium spot prices on the LME averaged US$1 838.3 per tonne over the period Q1 1999 – Q1 2009. Over this period, the average quarterly change in prices was 0.85 per cent. This small increase can be attributed to the increase in demand in the industry which was driven by China and its use for the metal in construction and its electronics sectors while towards the latter part of the sample, there was a countervailing force of the global economic recession.

The standard deviation over the period was US$543.3 per tonne and the range of the monthly prices was approximately US$2000.00 per tonne. This variation in prices can be attributed to the nature of the LME, which provides contracts for mostly speculative purposes.

There was no deterministic seasonal component identified in the data set although seasonal factors (Table 1) implied marginally higher prices in the first two quarters of the year. LME prices in the period assessed did not exhibit any sustained trend as there was constant fluctuation in the time series. There was an upward path in the time series, but this was disturbed by the state of the economies in this present economic recession as the effects of this caused aluminium price to decline rapidly, this was the only major structural break exhibited in the data set as prices have started to increase again in 2009.

Table 1

SEASONAL FACTORS 1999 to 2009				
	Q1	Q2	Q3	Q4
Average Seasonal Factors	1.029424	1.016301	0.967973	0.984647

Further analysis of the data proved to exhibit that there was some cyclicality as an auto-regressive (AR) process found in the time series. The average length of time between peaks in the review period was 4 quarters, or one year while the average of time between troughs were slightly more than a year.

Initial examination of the distribution found that although the distribution was symmetric but there appeared to be excess kurtosis (see Appendix I, Figure 1). This spoke to an incidence of non-normality. The Jarque-Bera test is a goodness-of-fit test of an empirical distribution's normality utilizing the sample's kurtosis and skewness. The test statistic is given by the equation:

$$JB = \frac{n}{6}\left(S^2 + \frac{(K-3)^2}{4}\right),$$

In the equation *n* is the number of observations, *S* is the sample skewness and *K* is the sample kurtosis given by the following equations:

$$S = \frac{\mu_3}{\sigma^3} = \frac{\mu_3}{\left(\sigma^2\right)^{3/2}} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^3}{\left(\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2\right)^{3/2}}$$

$$K = \frac{\mu_4}{\sigma^4} = \frac{\mu_4}{\left(\sigma^2\right)^{2}} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^4}{\left(\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2\right)^{2}}$$

In the equations, μ_3 and μ_4 are the third and fourth central moments while $\bar{x}$ is the sample mean, and σ^2 is the variance. The test statistic has a chi-squared distribution and the null hypothesis of the test is that the sample is from a normal distribution with skewness and excess kurtosis of 0. The test results indicate the null is rejected at the 5 per cent level of significance, suggesting that the distribution of aluminium price change is not normal.

Assessing the Time series Properties of Aluminium Prices

In this section, changes in the daily time series of aluminium prices from 2004 to 2009 is tested for the nature of the probability distribution function of aluminium. Knowing both the dynamics and the characteristics of the time series will provide a basis for more indepth analysis and forecasting of future movements in the aluminium prices on the global market.

Empirical determination of the probability distribution function (PDF) of economic variables is critical in many stochastic analyses. However, for most models for analytical convenience, the normal distribution is often used although empirical evidence suggests that many random variables are not normally distributed. It is therefore important to estimate the probability function as an important first step in empirical analysis.

Candidate Probability Distribution Functions: Descriptions, Tests and Results

A menu of possible distributions was examined and possible distribution structures were found (see Appendix I, Table B); which include the Normal, Chi-squared, Exponential, Log-Normal, Gamma and the Logistic distributions.

We start with the Normal Gaussian distribution as a point of departure. The normal distribution is used to describe or approximate almost any variable that tends to cluster around its mean because it has properties that can be easily analyzed. The central limit makes the analysis of many different variables with this distribution possible as it states that under certain conditions the sum of a large number of random variables is approximately normally distributed. It has been used widely in statistical analysis and is assumed to be the underlying distribution of stock prices, commodity prices and various financial returns among other applications. Its PDF is described by the equation.

$$F(x) = (2\pi)^{-½}\ e^{-x^2/2} \quad for\ -\infty < x < \infty$$

The logistic distribution is a continuous probability distribution function which resembles the normal distribution with the exception that it has a higher kurtosis. It is a symmetric distribution with its median, mode and mean equal and has no shape parameter. The distribution has been differentiated from the normal distribution by the fact that it has longer tails. The logistic distribution's PDF can be expressed by the following equation:

$$F(x) = e^x / 1 + e^x \text{ Where } -\infty < x < \infty$$

The lognormal distribution or the Galton distribution is based on the normal distribution. If the logarithm of a variable is normally distributed then that variable is considered lognormal. The Lognormal distribution can be utilized in reliability analysis and can also be used to model variables such as the long-term return rate on stock investment. Its PDF is expressed as:

$$F(x,m,s^{12}) = [1/x\sqrt{2\pi}\, s^2] e^{-(\log x-m)^\wedge 2 /(2s^\wedge 2)} \text{ , } x>0, -\infty < m < \infty \text{ and } s > 0$$

The Gamma distribution is a continuous probability distribution which has a scale and shape parameter. Its PDF equation is:

$$F(x,b,r) = b^{-r} x^{r-1} e^{-x/b} / \Gamma(r) \text{ for } x \geq 0 \text{ and } b,r^{13} > 0$$

To identify if the empirical distribution in the changes in aluminium prices conform to the theoretical models, we employ four tests: The Lilliefors, Cramer-Von Mises, Anderson-Darling and Watson empirical distribution tests. In all of the aforementioned the null hypothesis was that the empirical distribution was drawn from a hypothesized PDF while the alternative hypothesis was that it did not come from the specified PDF. We will now give brief discussions on the calculation of the test statistics, the decision rules applying in each goodness-of-fit test carried out and the results from the analysis.

The single sample ***Kolmogorov-Smirnov (K-S)*** test is a goodness-of- fit test which is utilized to determine the maximum distance between the empirical distribution function of a sample and the cumulative distribution function of the normal distribution. The empirical distribution function F_n for n observations X_i is defined as

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[12] In the equation m is the mean and s is the standard deviation of the distribution
[13] Where b is the scale parameter and r is the shape parameter

$$F_n(x) = \frac{1}{n}\sum_{i=1}^{n} I_{X_i \leq x}$$

$I_{X_i \leq x}$ is the indicator function, equal to 1 if $X_i \leq x$ and equal to 0 otherwise. The K–S test statistic for a given cumulative distribution function $F(x)$ is

$$D_n = \sup_x |F_n(x) - F(x)|,$$

Sup S is the supremum of set S. By the Glivenko–Cantelli theorem, if the sample comes from distribution $F(x)$, then D_n converges to 0 almost surely. The *goodness-of-fit* test or the K–S test is constructed by using the critical values of the Kolmogorov distribution. The null hypothesis is rejected at level α if

$$\sqrt{n}D_n > K_\alpha,$$

K_α is found from

$$\Pr(K \leq K_\alpha) = 1 - \alpha.$$

If the form or parameters of $F(x)$ are determined from the X_i, the inequality may not hold. The ***Lilliefors*** test is used in this case. It is a special case of the K-S test. The test in this case is implemented using the sample mean and standard deviation as the mean and standard deviation of the theoretical distribution against which the empirical distribution is compared. The maximum discrepancy in the case of the Lilliefors test is smaller than that of the K-S test.

According to the Lilliefors test, the empirical distribution of aluminium prices did not fit the normal nor lognormal distributions at the 5% level of significance (Table 2).

Table 2

LILLIEFORS TEST (D)			
Distribution	**Test Statistic**	**Adjusted Test Statistic**	**Probability**
Log-Normal	0.14072	N/A	0.0000
Normal	0.158782	N/A	0.0000

The single sample ***Cramer-Von-Mises*** (C-MV) test is used to calculate the goodness of fit of a theoretical distribution F^* compared to a given empirical distribution function F_n without the parameters of the theoretical distribution being specified. It is defined as:

$$\omega^2 = \int_{-\infty}^{\infty} [F_n(x) - F^*(x)]^2 \, \mathrm{d}F(x)$$

The test statistic for the C-MV test, T, is defined as follows:

$$T = n\omega^2 = \frac{1}{12n} + \sum_{i=1}^{n} \left[\frac{2i-1}{2n} - F(x_i) \right]^2 .$$

If this value is larger than the tabulated value we can reject the hypothesis that the data comes from the theoretical distribution F (.).

Utilizing the C-MV test the null hypothesis that the empirical distribution is drawn from either the Normal, Chi-squared, Exponential, Log-Normal, Gamma and the Logistic distributions were all rejected at the 5% level of significance (Table 3).

Table 3

CRAMER-VON MISES TEST (W2)			
Distribution	**Test Statistic**	**Adjusted Test Statistic**	**Probability**
Chi-Squared	46.8721	46.8721	<0.005
Exponential	0.768124	0.768213	0.0001
Gamma	0.529326	0.529326	<0.005
Logistic	4.125888	4.128808	<0.005
Log-Normal	6.553044	6.555407	0.0000
Normal	11.92602	11.93032	0.0000

The single sample ***Anderson-Darling (A-D)***[14] tests whether a sample comes from a specified distribution. The A-D test is used where a family of distributions is being assessed in which the parameters of that family needs to be estimated. The test-statistic or critical values must be adjusted whenever this is the case and the method of parameter estimation must also be noted. The formula for the test statistic A to assess if data which

[14] The test makes use of the fact that, when given a hypothesized underlying distribution and assuming the data does arise from this distribution, the data can be transformed to a uniform distribution. The transformed sample data can be then tested for uniformity with a distance test (Shapiro 1980).

is in increasing order comes from a distribution with cumulative distribution function (CDF) F is

$$A^2 = -n - S\,,$$

S is calculated by:

$$S = \sum_{k=1}^{n} \frac{2k-1}{n} \left[\ln F(Y_k) + \ln\left(1 - F(Y_{n+1-k})\right)\right].$$

The test statistic can then be compared against the critical values of the theoretical distribution[15].

Utilizing the A-D test the null hypothesis that the empirical distribution is drawn from either the Normal, Chi-squared, Exponential, Log-Normal, Gamma and the Logistic distributions were all rejected at the 5% level of significance (Table 4).

Table 4

ANDERSON-DARLING TEST (A2)			
Distribution	**Test Statistic**	**Adjusted Test Statistic**	**Probability**
Chi-Squared	1369.593	1369.593	< 0.005
Exponential	202.1441	202.2316	0.0000
Gamma	3.92056	3.92056	<0.005
Logistic	37.49196	37.49871	<0.005
Log-Normal	34.85867	34.87756	0.0000
Normal	69.94834	69.98624	0.0000

Watson's test is the fourth goodness-of-fit test under which the empirical distributions were analyzed. When the observations are denoted by the symbol θ_1, θ_2... θ_n the empirical distribution function can be written as

$$\bar{F} = \frac{1}{n} \sum_{j=1}^{n} \mathrm{F}(\theta_j),$$

F (θ) is the probability of a value in the interval (0, θ). The test statistic is U^2, given by:

[15] Note that in this case no parameters are estimated in relation to the distribution function F

$$U^2 = \sum_{j=1}^{n} \{F(\theta_j)\}^2 - \frac{1}{n} \sum_{j=1}^{n} \{(2j-1)F(\theta_j)\} + n\left\{\frac{1}{3} - \left(\bar{F} - \frac{1}{2}\right)^2\right\}.$$

A large value of U^2 in comparison to the critical values that are given in the U^2 tables leads to a rejection of the null hypothesis.

Testing of the aforementioned distributions under the Watson test once again led to the rejection of the null hypothesis[16].

Table 5

WATSON TEST (U2)			
Distribution	**Test Statistic**	**Adjusted Test Statistic**	**Probability**
Chi-Squared	38.96976	38.96976	< 0.005
Exponential	0.64614	0.646214	0.0000
Gamma	0.479218	0.479218	<0.005
Logistic	4.125888	4.128808	<0.005
Log-Normal	6.457855	6.460183	0.0000
Normal	9.835311	9.838856	0.0000

Of the theoretical distributions assessed there were none that matched the empirical distribution at the 5% level of significance according to the goodness of fit tests mentioned. This result suggests that the PDF of aluminium prices may follow another; more intricate distributions so there must be more detailed testing done in order to assess this.

Conclusion

In this paper, we discussed the structure of the global aluminium industry as well as the time series properties of aluminium prices. It was noted that North America, that was once at the head of both consumption and production in the industry has slowly given way to the eastern super power of China. This country is dominating both supply and demand spectrums of the aluminium industry so the activity of the industry is dependent on China's economic growth rate and its movements within the market. Japan and the

[16] Note that in all the aforementioned tests, the decision rule is to reject the null hypothesis at the 5% level of significance if the probability is less than 0.05.

U.S. have also been very important consumers of the metal. The activity in these markets, especially their recovery from the global economic crisis is very important in determining the feasibility of the local bauxite/alumina industry.

Production has been influenced widely by multinational aluminium producers like Rio Tinto ALCAN, ALCOA and UC RUSAL. These producers have operations all over the world and in Jamaica, their operations was suspended or closed down because of the lack of cost-competitiveness.

The paper also found that the distribution of changes in aluminium prices was non-normal, but the nature of the underlying distribution could not be confirmed from the statistical tests. Other tests of the empirical distribution as well as other theoretical distributions such as the Pearson family of distributions, which have been used to model economic data and stock prices will be explored in future analyses.

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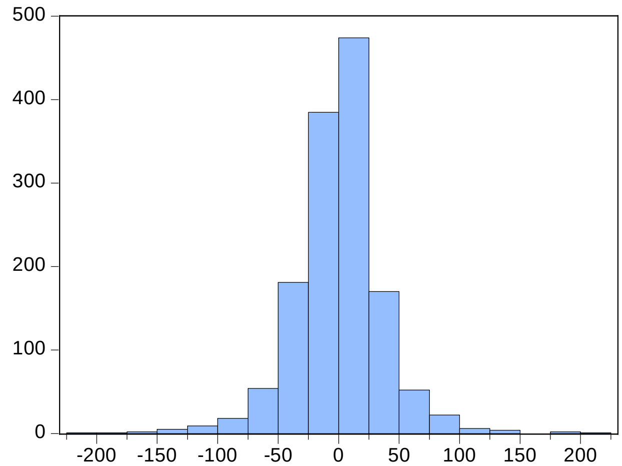
Appendix I:

Figure 1



Series: DALUMINIUMCASHSELLER
Sample 1/05/2004 6/30/2009
Observations 1387

Mean	0.010815
Median	1.000000
Maximum	212.0000
Minimum	-218.0000
Std. Dev.	36.74331
Skewness	-0.146783
Kurtosis	7.413885
Jarque-Bera	1130.900
Probability	0.000000

Table A

Distribution Type	**Characteristics**	**Function**
Laplace	Symmetric, uni-modal, excess kurtosis, fat tails	$F(x)=\frac{1}{2} e^{-\lvert x\rvert}$
Logistic	Symmetric, no shape parameter, excess kurtosis	$F(x)= e^{x} /1 + e^{x}$
Lognormal	Single tailed distribution, the variables, when logged become normal	$F(x,m,s)= [1/x\sqrt{2\pi s^{2}}]e^{-(logx-m)^{2}/(2s^{2})}$
Normal	Symmetric, bell shaped	$F(x) = (2\pi)^{-\frac{1}{2}} e^{-x^{2}/2}$
Extreme Value	Positively skewed, excess kurtosis	$F(x) = exp(x - e^{x})$
Gamma	Has both scale and shape parameter to govern the characteristics of the distribution	$F(x,b,r)= b^{-r} x^{r-1} e^{-x/b}/ \Gamma(r)$
Exponential		$F(x,m)= 1 / m (e^{-x/m})$
Chi-Square		$F(x,v) = 1 / [2^{v/2}\Gamma(v/2)] x^{v/2-1} e^{-x/2}$

Appendix II: Description of The Global Aluminium Industry

Table 1

RECENT DEVELOPMENTS IN ALUMINIUM PRICES				
YEAR	AVERAGE PRICE OF ALUMINIUM	% change in Prices	Range in Monthly Prices	
1999	$1,361.05		$1,554.00	$1,181.60
2000	$1,549.08	13.82%	$1,680.00	$1,457.00
2001	$1,443.67	-6.81%	$1,616.00	$1,283.00
2002	$1,349.92	-6.49%	$1,405.00	$1,292.00
2003	$1,431.17	6.02%	$1,555.00	$1,332.00
2004	$1,715.58	19.87%	$1,849.00	$1,606.00
2005	$1,900.67	10.79%	$2,247.45	$1,731.00
2006	$2,563.39	34.87%	$2,861.00	$2,378.00
2007	$2,638.18	2.92%	$2,832.20	$2,381.69
2008	$2,572.79	-2.48%	$3,071.24	$1,490.43

Table 2

CONTRIBUTION OF JAMAICAN MINING INDUSTRY (Bauxite & Alumina)			
YEAR	BAUXITE LEVY(J$ million)	TAX REVENUE (J$ million)	EMPLOYMENT
2004	$2,137.90	$745.20	3780
2005	$2,479.10	$189.60	3551
2006	$3,124.60	$887.80	3498
2007	$4,169.90	$1,413.30	3570
2008	$4,998.30	$731.50	3444

Table 3

JAMAICAN MINING INDUSTRY (Bauxite & Alumina)			
COMPANY	CAPACITY (Tonnes)	OWNERSHIP	POST-RECESSION STATUS
BAUXITE			
St. Ann Jamaica Bauxite Partners Limited	4,700,000	St. Ann Bauxite Partners*** - 49% GOJ **- 51%	Operations cut by 30%
ALUMINA			
West Indies Alumina Company-Ewarton, St. Catherine	625,000	UC Rusal *- 93% GOJ- 7%	Operations suspended Indefinitely
West Indies Alumina Company-Kirkvine, Manchester	675,000	UC RUSAL *- 93% GOJ- 7%	Operations suspended indefinitely
Jamalco	1,500,000	ALCOA ****- 56% C.A.P.- 44%	Operations cut
Alumina Partners of Jamaica (Alpart)	1,700,000	UC Rusal* - 65% Hydro Aluminium - 35%	Operations suspended for at least 1 year

* UC Rusal's ownership is divided into different parts: Oled Deripaska's BASIC ELEMENT 53.8%, SUAL 18.9%, Onexim 18.5% & Glencore 9.7%

** GOJ's owner ship in ST. Ann Bauxite is limited to assets ownership for which it receives a defined return on investment and no access to production

*** Ownership is split: 50% Century Aluminium of the USA and 50% Noranda Inc USA

**** 60% ALCOA and 40% Alumina Limited of Australia

Table 4

ALUMINUM MARKET ('000 tonnes)						
YEAR	ALUMINUM PRODUCTION	ALUMINUM CONSUMPTION	SPOT PRICE	ALUMINA PRODUCTION	ALUMINA CONSUMPTION	SPOT PRICE
2003	28,028	27,670	$1,431.00	54,869	55,047	$291.00
2004	29,832	30,267	$1,715.00	58,158	58,380	$410.00
2005	31,841	31,850	$1,898.00	60,859	62,238	$468.00
2006	33,801	34,122	$2,576.00	67,562	66,109	$438.00
2007	38,126	37,563	$2,639.00	74,029	74,639	$346.00
2008	40,012	39,387	$2,576.00	78,859	78,352	$230.00

Table 5

ALUMINUM CONSUMPTION 2006 ('000 tonnes)		
COUNTRY	ALUMINIUM CONSUMPTION	ALUMINIUM IMPORT
China	8,648.00	512.00
USA	6,150.00	3,461.00
Japan	2,323.00	3,036.00
Germany	1,823.00	2,073.00
S. Korea	1,153.00	1,204.00
India	1,080.00	49.00
Russia	1,047.00	1.26
Italy	1,021.00	986.00
Canada	846.00	14.00
Brazil	773.00	1.71

Table 6

COUNTRY PRODUCERS OF ALUMINUM (2008)			
COUNTRY	PRODUCTION ('000 tonnes)	EXPORT QUANTITY ('000 tonnes)	MAIN CHALLENGES
China	12,600	1,212	Energy Costs
Russia	3,960	3,183	Energy Costs
Canada	3,090	2,360	Efficiency
United States	2,554	420	Energy Costs/Demand
Australia	1,960	1,618	Pollution
Brazil	1,660	842	Pollution
Norway	1,300	1,539	Input costs
India	1,220	119	Pollution
South Africa	899	601	Input Costs
United Arab Emirates, Dubai	890	n/a	Energy Costs

Table 7

FIRM PRODUCERS OF ALUMINUM (2007)		
FIRM	COUNTRY	SHARE OF WORLD PRODUCTION
UC RUSAL	Russia	12.40%
Rio Tinto Alcan	Canada/Australia	11.98%
Alcoa	USA	11.70%
Chalco	China	6.00%
Hydro Aluminium	Norway	4.65%
BHP Billiton	Australia	3.98%
Dubal	United Arab Emirates	2.57%
Alba	India	2.54%
Century Aluminium	USA	2.19%

Table 8

LONDON METAL EXCHANGE PRICE DATA			
Year	Spot Price	3-Mnth Forward Price	Contango
2003	$1,432.00	$1,429.00	-$3.00
2004	$1,717.00	$1,722.00	$5.00
2005	$1,898.00	$1,899.00	$1.00
2006	$2,567.00	$2,592.00	$25.00
2007	$2,639.00	$2,662.00	$23.00
2008	$2,576.00	$2,625.00	$49.00
Jan-09	$1,413.00	$1,449.00	$36.00
Feb-09	$1,330.00	$1,368.00	$38.00
Mar-09	$1,336.00	$1,373.00	$37.00
Apr-09	$1,421.00	$1,459.00	$38.00

Figure 1

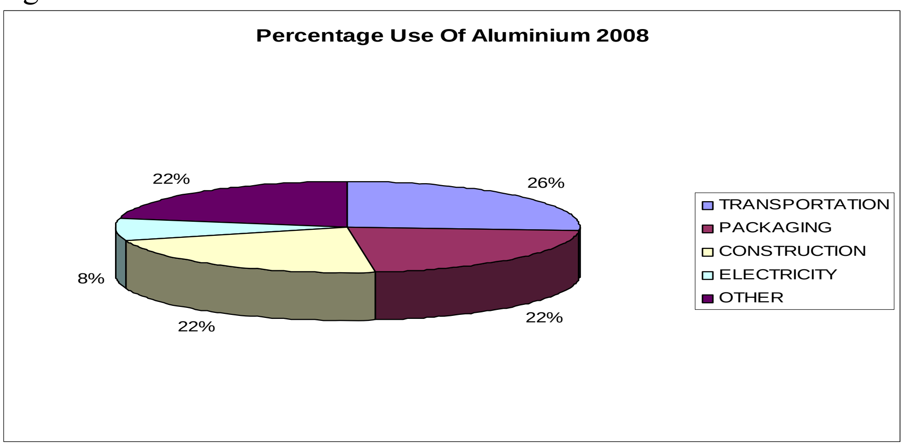


Figure 2