# INTEGRATION OF THE CHINESE ALUMINUM MARKET INTO THE GLOBAL ECONOMY AND THE EFFICIENCY OF THE SHANGHAI FUTURES EXCHANGE: EMPIRICAL STUDY

by

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In my thesis I address two questions regarding the aluminum market in China. The first question analyzes the degree to which the Chinese aluminum market is integrated into the world market. I use the Johansen test for cointegration of time series data in SAS statistical software to compare the volatility of daily aluminum spot prices quoted at the Chinese aluminum Commodity Exchange market in Shanghai (SHFE) relative to its counterparts in London (LME), and New York (COMEX) in order to determine the degree to which prices at SHFE follow the same pattern as prices at LME and COMEX. I also perform a series of cointegration tests to determine whether the results derived for Commodity Exchanges also apply to the physical aluminum markets. The results indicate that the three Commodity Exchange markets are not integrated together as one market system. SHFE displays a certain degree of economic integration with the LME but cannot be regarded as economically integrated with COMEX. Nevertheless, LME and COMEX exhibit a relatively high degree of economic integration between themselves. The results can be extended to the physical aluminum market in the Shanghai region but not to China as a whole, most likely because of insufficient number of data observations. The second question concerns the efficiency of aluminum trading at SHFE, relative to COMEX and LME. The precision, with which termed aluminum futures contract prices on their maturity are able to predict spot prices, serves as a standard measure of Commodity Exchange efficiency. Using the same testing procedure as for the first question I compare relative volatility of spot and futures prices at each Commodity Exchange, and rank their relative performance. The results show that SHFE displays somewhat better efficiency results than LME but worse than COMEX. In level terms, the efficiency of LME cannot be confirmed, SHFE comes close to being efficient and COMEX can be regarded as highly efficient.

# PREFACE

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## Introduction

In my thesis I address two questions regarding the aluminum market in China:

1. The degree to which the Chinese aluminum Commodity Exchange market in Shanghai is integrated into the system of global Commodity Exchange markets in London and New York, and whether this result is indicative of the physical aluminum markets;
2. The efficiency of aluminum trading at the Chinese aluminum Commodity Exchange market in Shanghai relative to its counterparts in London and New York.

In order to answer the first question, I analyze the degree to which prices at the aluminum Commodity Exchange market in Shanghai, the *Shanghai Futures Exchange* (SHFE), follow the same pattern as prices at Commodity Exchanges in London and New York, the *London Metal Exchange* (LME) and the *New York Mercantile Exchange Commodity Exchange Division* (COMEX), respectively. Using the Johansen test for cointegration of time series data in SAS statistical software, I compare the relative volatility of daily aluminum spot prices quoted at COMEX, LME, and SHFE. If prices quoted on SHFE are cointegrated with prices on COMEX and LME, and hypothesized restrictions on cointegration coefficients implied by theory are not rejected, then SHFE can be regarded as integrated into the global system of Commodity Exchange markets.

I perform the market integration analysis for the time period between May 20, 1999 to August 6, 2003. Then I split this period into two half-periods of equal lengths and carry out the analysis for each of them separately in order to investigate market integration dynamics.

I also investigate the link between aluminum physical trading market in China and aluminum Commodity Exchange market at SHFE. If aluminum spot prices at SHFE are found to reflect well the physical aluminum market in China, then the results of the integration analysis can be extended to the physical aluminum markets, since both LME and COMEX are reported to provide reliable indication of the physical market prices in their geographic sphere of influence (NYMEX Official Bulletin, 2001).

The second question explored in my thesis concerns the efficiency of aluminum trading at SHFE, relative to COMEX and LME. The precision with which termed aluminum futures contracts on their maturity are able to predict spot prices, serves as a standard measure of a Commodity Exchange efficiency. In the empirical analysis, I use the same testing procedure as for the first question, with different data series and different restrictions on cointegration coefficients to be tested. I conduct aluminum trading efficiency tests for SHFE, COMEX, and LME, and compare their relative performance.

My thesis is organized as follows: the first section introduces the global aluminum market characteristics and specific issues pertaining to China. Section two provides motivation for study of market integration, elaborates its concept and reviews the relevant literature. In the third section the Futures Exchanges (SHFE, COMEX and LME) and hedging procedures are introduced, along with motivation for studying the relative efficiency of SHFE and relevant literature. The fourth section addresses the methodological background to the Johansen cointegration test. Description of the data used is given in section five. Section six serves as a guide through all tests performed in statistical software. Empirical results are presented in section seven and discussed in section eight. Section nine concludes the thesis.

## 1. Aluminum Markets

Aluminum has been chosen as a commodity because of its promising future. Due to its outstanding characteristics for industrial use, such as light weight, corrosion resistance, and abundance of its production inputs, aluminum is becoming the metal of choice, substituting for iron, steel, and even zinc. For these reasons, aluminum industry has a wide range of consumers: construction, electricity, machinery and packaging industries, transportation and most notably the automobile sector and railroad cars plants, aerospace plants and national defense sector. Chart 1 in Appendix 1 illustrates the proportions of aluminum consumption distributed among various industries.

World aluminum consumers have been steadily expanding their demand for the metal over the last 50 years. Graph 1 in Appendix 1 demonstrates the scope of the increase in the world aluminum consumption since 1900. In China, national demand for aluminum has been surging. In 2000 and 2001 the demand grew at the rate of 17.1% and 12.7% respectively. The average growth rate in demand for figured or special shaped aluminum was more than 20% for the last twenty years. Graph 2 and Graph 3 in Appendix 1 reflect the mounting trends of Chinese domestic aluminum production between the years of 1954 and 2002. Escalating numbers of Chinese imports and relatively stagnating exports of aluminum during the 1990s are represented on Chart 2 and in Appendix 1. In the virtual absence of exports, both growing numbers of domestic production and, in absolute terms, smaller import numbers indicate increasing demand for the metal in China. This is attributed to China's rapid economic development in various industries over the past two decades. Both China's entry to WTO and its

commitment to accommodate the Olympic Games in 2008 on its territory boosted China's construction industry, the major consumer of aluminum industry.

Aluminum scrap is among the most easily recycled metals available today, which adds to the strategic importance of the metal in the face of gradual natural resource depletion. In 2000, 145,178 metric tons of aluminum produced in China were recovered from scrap (The Yearbook of Nonferrous Metals Industry of China, 2001, p. 315). That amounts to 5% of all aluminum produced that year.

Unwrought aluminum can be considered a global product due to homogeneity of its structure across different geographical locations and the ease of its transportability. Given its relatively simple production technology, aluminum allows for the third world countries with cheaper labor and sometimes electricity to compete with developed countries. In fact, after the year 2001, China and Russia have been taking lead over the U.S. and Canada in aluminum production, as can be seen in Chart 3 in Appendix 1. Numerous western companies take strategic decisions to place part of their productive capacity of aluminum abroad in less developed countries.

At the same time, aluminum industries are subject to large fluctuations depending on the current market conditions. Global events, national prices of electricity, worldwide depletion of bauxite ore – all these and other risk factors can alter economic patterns within the aluminum industry and create considerable uncertainty as to the future direction of market conditions. Uncertainty leads to market price volatility and given the time lag between conclusion of an aluminum delivery contract and the actual delivery, adverse price movement may result in significant losses for aluminum industries.

One of the major factors behind aluminum price fluctuations is electricity prices. In the U.S. west coast, for instance, a number of aluminum plants were shut down in 1999 after electrical companies of the region raised their fees (U.S. Geological Survey, 2000). Another significant source of shocks and fluctuations in the industry comes from competitors' behavior. In early 1990s, for example, after the collapse of the Soviet Union, Russian aluminum companies entered the world market and pushed world prices for primary aluminum down to such an extent that U.S. companies' aluminum exports decreased about 30% between the years of 1991 and 1993 (U.S. Geological Survey). Unexpected shocks to the industry might be also associated with price reduction on bauxites or alumina, major inputs into production of the primary aluminum. In 2001, for instance, prices of alumina fell sharply as a response to an increase of the world supply (Report from the Second Forum on Colored Metals in China, 2001).

Answers to the two questions addressed in this paper concerning Chinese aluminum market integration and efficiency will provide valuable guidance through the volatile global aluminum market environment. The degree of Chinese aluminum market integration helps us evaluate the extent to which frequent shocks to the aluminum market are transmitted across the globe. The concept of efficiency as defined in the paper will provide a measure of how successfully aluminum market participants can protect themselves from risk associated with the aluminum market volatility.

## 2. Market Integration

### 2.1 The Concept of Market Integration

There are two definitions of integrated markets depending on whether transfer costs are considered or not. *Transfer costs* comprise transportation, storage and processing charges of commodities in question, plus a modest allowance for trader's normal profit. Transfer costs determine the bounds within which the prices of a commodity in two markets can differ from one another (Baulch, 1997, p. 514).

Abstracting from transfer costs, regional markets are said to be *integrated* if the Law of One Price (LOP) holds among them. That is, when each commodity has a single price, defined in a common currency, throughout the world. This effect should in theory arise due to efficient market arbitrage (Ardeni, 1989, p. 661). The process of efficient market arbitrage exploits all possibilities for profit arising from real price differentials by simultaneous purchase and sale of a commodity at two different places.

When transfer costs are considered, market integration is a situation in which prices in different markets move together if their price differential equals transfer costs (Baulch, 1997, p. 513). If markets are integrated, the price differential or spread between markets cannot exceed the transfer costs. Arbitrage activities of traders, who buy and sell a commodity between low and high price locations, will raise price in some markets whilst lowering them in others until price differentials equals transfer costs and all opportunities for earning excess trading profits have been exhausted (Baulch, 1997, p. 515).

## 2.2 Discussion of China's Aluminum Market Integration

The failure to adhere to the LOP, that is frequently empirically observed even when allowing for transfer costs, may be explained by either of the following considerations: (i) the regions are not linked by arbitrage and thus represent autarkic markets, (ii) there are impediments to efficient arbitrage such as trade barriers, imperfect information or risk aversion, and (iii) there is imperfect competition in one or more of the markets (Sexton et al., 1991, p. 567).

In addressing the question posed above, I use the concept of *spatial market integration*. Markets located in distinct geographic regions are said to be *spatially integrated* if the price in one region equals the price in another region plus the unit transfer cost incurred by moving between the two (Ravallion, 1986, p. 103).

Over space, commodity prices fluctuate continuously. The causes of these fluctuations are identified in the literature on commodity price instability and linkages between commodity markets and the macro economy. Even if none of the imperfections listed above is present, the LOP might still fail to hold due to regional market-specific conditions. Among the main examples are (iv) quantity shocks given relative differences in demand and supply elasticities, (v) excess derivative trading activity such as that occurring when speculation exceeds hedging needs, (vi) variation in national income, industrial production and inflation, (vii) variation in national liquidity and exchange rates, and (viii) changes in related policies or cartel behavior (Bukenya and Labys, 2002, p.10).

During the 1990s, China was undergoing the process of integration into the world economy, using an approach of gradual opening and partial adjustments. Its entry in 2001

to WTO accelerated dismantling of trade controls and facilitated overall market liberalization.

Nevertheless, there are numerous instances when many of the factors listed above are present in the Chinese aluminum market, hindering its integration into the global market. The most significant impediments to integration of the Chinese aluminum market are its ownership structure, level of competitiveness, legislation, trade barriers, and price determination.

### 2.2.1 Ownership

The ownership structure within the aluminum industry in China has been changing in favor of private owners and investors, most significantly with regard to small local plants in the south of the country. However, large plants are mostly state owned with the government holding the biggest stakes in the market via its share in Chalco, the largest aluminum producer in China and the world's third largest alumina refiner.

Irrespective of ownership, it is possible that monopolistic Chalco and other aluminum market players in China comply with global market forces and have fully integrated into the world economy. It is equally possible that command elements still prevail in the aluminum market, leaving determination of price and hence trade flows to some sort of a planning authority that is unresponsive to international market forces.

### 2.2.2 Competitiveness

A relative technical underdevelopment of the aluminum industry in China raises doubts about the ability of the industry to compete on equal terms with other countries in the world arena. Table 1 compares technical parameters of aluminum production in China

in 1996 with their counterparts abroad. All parameters being compared demonstrate a certain technological lag of China in the industry under analysis.

**Table 1: Comparison of Norms in Aluminum Production Economy and Technology in China and Abroad, 1996**

| Item | Foreign Level | China's Level |
|---|---|---|
| Heating Efficiency of Melting Furnace (percentage) | 50-70 | 20-40 |
| Gas Containment in Aluminum Nuggets (mL/100 g Al) | 0.05-0.1 | 0.14-0.24 |
| Cold Rolling Margin Thickness (mm) | ±0.002-0.005 | ±0.005-0.03 |
| Percentage of Grade A Finished Product | >80 | 60-70 |
| Labor Productivity (tons per person annually) | 200-500 | 5-20 |

Source: Wang, Zh. (1998).

In China, electricity prices are government-controlled and are higher than in most industrialized countries. High electricity prices in China are also viewed as potential causes of reduction of Chinese aluminum industry's competitiveness.

### 2.2.3 Legislation

The legislation of "Aluminum Smelters Building Limitation/Restriction", issued by the PRC State Council on April 15, 2002, undermines another principle of market competition - free entry of market participants. By this legislation the PRC government decided to limit construction of new aluminum smelters in China, as a response to overproduction of aluminum in the country/overheating of the industry in the country. All new projects, including those with foreign capital involved, are to be reported to SETC (State Economy and Trade Commission) and to SDPC (State Development Planning

Commission) for consideration. The legislation applies alike to all existing, being built and planned for construction aluminum smelters, i.e. those approved by local governments without Beijing authorization (Report from the Second Forum on Colored Metals in China, 2001).

The actual purpose of this legislation could be any of the following: a tightening governmental grip on one of its lucrative industries while leaving an increasing number of small private entities out of business; a desire of the government to implement the environment protection policy; authorities' intention to bring a chaotic aluminum refining to order and decrease waste of their own capital by technological upgrading of the industry owned essentially by themselves. Irrespective of real Beijing considerations, however, and contingent upon its implementation, this legislation would deprive domestic small private businesses of access to a scarce capital - a phenomenon described in Rawski (1999, 2001).

Another interesting point to be mentioned about this policy is the way it was supposed to be implemented. To determine if a certain project meets the requirements of the government, SETC and SDPC worked out a list of production types, products and technologies to be approved by the existing state policy of the central government. Then both organizations are to evaluate demand for an industrial product on the market, the project's development tendencies and technological equipment (Report from the Second Forum on Colored Metals in China, 2001). After China's long experience of centrally planned economy, however, it remains difficult to acknowledge the ability of the Communist government, represented by SETC and SDPC, to assess the movements of market forces, such as demand of the industrial product. Hence, besides restrictions

created for new entities, this legislation could bring a distortion to market determination of supply and demand in aluminum industry, and could be taken as another reason not to expect the Chinese aluminum market to be integrated into the global market system.

### 2.2.4 Trade Barriers

The same legislation of 2002 emphasized the MOFTEC regulation No. 567 (2001), which reserved the function of managing bauxite imports for the central government (Report from the Second Forum on Colored Metals in China, 2001), and thus restricted free access to imports of inputs into production to private companies. Not only can trade barriers hamper the competitiveness of the Chinese aluminum industry, but they are also viewed by Sexton et al. (1991) as "impediments to efficient arbitrage" and hence as potential reasons for markets not to be integrated.

### 2.2.5 Price Determination in Chinese Regions

Another reason not to expect Chinese aluminum market to be integrated into the global system is its domestic aluminum price differentials. Graph 4 in Appendix 1 demonstrates that monthly aluminum prices in four different Chinese provinces do not follow the same pattern, and often move in the opposite direction. Such situation suggests a centrally planned nature of the market which would preclude any intentions of integrating into the world market.

## 2.3 Motivation

The first part of my thesis addresses the following question: to what extent do spot prices at SHFE follow price volatility patterns at two major global Commodity Exchanges, COMEX and LME, and, hence, to what extent has the Chinese aluminum market been integrated into the global market? The dynamic evolution integration process is also of interest.

In the absence of international market integration producers and consumers of aluminum will not realize the gains from liberalization of international trade, the correct price signals will not be transmitted down the marketing chain, and producers will fail to specialize according to comparative advantage (Baulch, 1997, p. 513). Information on China's aluminum international market integration may also provide specific evidence concerning the global competitiveness of the Chinese aluminum market.

As such, knowledge about the degree of market integration has application to policy questions regarding the appropriate form of government intervention in international aluminum trade (Alexander and Wyeth, 1994, p. 303).

Generally, measurement of market integration can be viewed as "basic data for an understanding of how specific markets work" (Ravallion, 1986, p. 103-104).

## 2.4 Testing for Market Integration

In answering my questions, I use the Johansen cointegration test (Johansen, 1988, 1992, 1997). The reasons for the choice are as follows:

1. the test is adjusted for the nonstationary nature of time series data;
2. the test allows hypothesis testing on the parameters in the cointegration vector, which is necessary for answering my questions;

3. the performance of the test is relatively simple in the user-friendly environment of the SAS statistical software;
4. the prevalent use of the test in current literature.

In addition to the Johansen test, there are three other commonly used econometric approaches to testing market integration (Baulch, 1997, p. 515): the Richardson test, the Ravallion model, and Granger test (Engle and Granger, 1987).

The *Richardson test* is a test for the integration of markets within a single data period and in its usual form involves the regression of the current price change in one market on a constant and the price changes in another market. The test therefore does not take into account the dynamic structure of the data series (Baulch, 1997, p. 517).

The *Ravallion model* allows price adjustment between markets to take time, but nests within it a test that is equivalent to the Ravallion test. The structure of the test is not suitable for testing nonstationary data series (Baulch, 1997, p. 517).

The *Granger test* (Engle and Granger, 1987) is close to the Johansen test in terms of methodological approach but, unlike the Johansen test, it does not allow for testing parameter restriction on the cointegration vector. These restrictions are stipulated by the theory of market integration and the hypothesis test is therefore a crucial element in determining the degree of market integration (Asche, Osmundsen, Tvertas, 2000).

The key concepts used in my analysis, including data stationarity, cointegration, restrictions on parameters in the cointegration vector, and the Johansen testing procedure, are discussed in detail in the Methodology section.

## 2.5 Literature overview

Market integration has been studied quite extensively for various commodities. Ardeni (1989) used the cointegration approach to test the Law of One Price and market integration in seven commodities (wheat, wool, beef, sugar, tea, tin and zinc) among four countries (Australia, Canada, U.K. and U.S.A). Alexander and Wyeth (1994) applied market integration analysis to rice traded in various regions in Indonesia and Asche, Bremnes and Wessells (1999) to world salmon trade. Asche, Osmundsen and Tvertas (2000) analyzed the degree of market integration for French imports of Dutch, Norwegian and Russian natural gas. Bukenya and Labys (2002) utilized measures of market integration, cointegration and impulse function analysis for six commodities (coffee, cotton, wheat, lead, copper and tin).

Brandt (1985) studied integration of the Chinese rice markets into the international market during the late 19th and early 20th century. He contended that by the 1890s, the Chinese rice market was integrated with the international economy. His methodology falls in line with the body of literature published before Engle and Granger's (1987) critique of classical regression and correlation treatment of nonstationary time series data. Brandt's analysis draws on nonstationary time series data and hence, as Engle and Granger (1987) showed, the classical correlation coefficients method employed in Brandt's study might lead to misleading conclusions.

To the best of my knowledge, no study has emerged yet to analyze market integration of aluminum between China, U.S. and Europe, as addressed in this paper.

## 3. Market Efficiency

The second part of my thesis analyzes efficiency of the Chinese aluminum Commodity Exchange market at the Shanghai Futures Exchange (SHFE). A measure of SHFE efficiency is compared to its counterpart measures of the U.S. aluminum Commodity Exchange market at the New York Mercantile Exchange (COMEX) and the European aluminum Commodity Exchange market at the London Metal Exchange (LME).

At SHFE, futures contracts with aluminum have been continuously traded since 1999, serving as principal risk management instrument and source of circulating capital for aluminum industries and traders in China. Introductory background regarding Commodity Exchange operations, spot and futures contract prices is reviewed before providing the motivation for the market efficiency analysis.

### 3.1 Futures Exchanges and Futures Contracts

*Futures Exchanges* (which include Metal and Mercantile Exchanges) are institutions, where buyers and sellers meet to trade futures contracts for registered commodities. *Futures contracts* are "firm commitments to make or accept delivery of a specified quantity and quality of a commodity during a specific month in the future at a price agreed upon at the time the commitment is made" (Official Bulletin of the NYMEX, 2001, p. 4).

However, only a small part of futures contracts (less than 1% in case of metals) results in an actual delivery of a commodity. Instead of actual deliveries, though, traders generally offset their futures positions before their contracts mature. In an offsetting

operation, a buyer will liquidate his position by selling the contract and the seller will liquidate by buying back an offsetting contract. The difference between the initial purchase or sale price and the price of the offsetting transaction represents a realized profit or loss (Official Bulletin of the NYMEX, 2001, p. 4).

Futures contracts serve as a principal risk management instrument available to participants in the market, and their prices are main pricing indicators for the world markets (Official Bulletin of the NYMEX, 2001, p. 1).

### 3.1.1 Risk Management and Hedging

Commodity Exchange markets attract private and institutional investors who seek to profit by assuming the risks that industries strive to avoid, in exchange for the possibility of rewards. Buying and selling of futures, a procedure called *hedging*, allows a market participant to lock in prices and margins in advance and reduces the potential for unanticipated loss. Hedging reduces exposure to price risk for commodity producers and traders by shifting that risk to speculators who are willing to accept the risk in exchange for profit opportunity. Hedging with futures eliminates the risk of fluctuating prices, but also means limiting the opportunity for future profits for commodity producers and traders, should prices move favorably (Official Bulletin of the NYMEX, 2001, p. 8).

*The futures price* represents the current market opinion of what a commodity will be worth at some time in the future. Under normal market conditions in the absence of unexpected market shocks, the price of the physical commodity for future delivery will be approximately equal to the present cash price, plus the amount it costs to carry or store the commodity from the present to the month of delivery (Official Bulletin of the

NYMEX, 2001, p. 6). Specific examples of hedging at a Futures Exchange are provided in Appendix 2 for further clarification of the concept.

Cash and futures prices tend to move in tandem, converging as each delivery month contract reaches expiration. As a futures contract approaches its last day of trading, there should be little difference between it and the cash price. A futures contract nearing expiration becomes, in effect, a *spot contract* (Official Bulletin of the NYMEX, 2001, p. 7). The main point is that even though the difference between the cash and futures prices may widen or narrow as cash and futures prices fluctuate, the risk of an adverse change in this relationship is generally much less than the risk of going unhedged (Official Bulletin of the NYMEX, 2001, p. 8).

### 3.1.2 Price Discovery

The prices displayed on the trading floor of the Exchange and disseminated through media and internet to subscribers and news services worldwide, reflect the marketplace's collective valuation of how much buyers are willing to pay and how much sellers are willing to accept. The larger the group of participants in the market, the greater the likelihood that the futures price will reflect widely held industry consensus on the value of the commodity (Official Bulletin of the NYMEX, 2001, p. 8). Futures markets aim to represent an assimilation of all relevant public information regarding the supply/demand relationship for a given commodity in some future time period (Fortenbery, Zapata, 1993, p. 921).

### 3.2 SHFE, COMEX and LME

**The Shanghai Futures Exchange (SHFE)** is a self-regulated non-profit entity, providing the place, facilities and services for the centralized trading of futures contracts. At present, aluminum is one of the five commodities traded at the Exchange. Other actively traded commodities include copper and natural rubber, while plywood and long-grained rice are still under modification (SHFE Official Website).

In August 1998, three Shanghai Exchanges (the Shanghai Metal Exchange, the Shanghai Cereals and Oils Exchange, and the Shanghai Commodity Exchange) were conglomerated as the Shanghai Futures Exchange that started its formal operation in December 1999 (SHFE Official Website).

In 2002, the trading volume was 24,346,166 contracts. By the end of April in 2002, the Shanghai Futures Exchange had established 132 distant trading terminals in 23 provinces and cities of China (SHFE Official Website).

**The New York Mercantile Exchange** is the world's largest physical commodity futures exchange (Official Bulletin of the NYMEX, 2001). Its COMEX Division lists futures on aluminum among other metals. Aluminum futures opened for trading in May, 1999.

**The London Metal Exchange (LME)** is the world's premier non-ferrous metals market, with highly liquid contracts. The origins of the London Metal Exchange can be traced as far back as the opening of the Royal Exchange in 1571. The primary roles of LME are defined as "pricing, hedging and physical delivery" (LME official website).

### 3.3 Commodity Exchange Market Efficiency

A classical definition of an efficient market was given by Fama (1970, cited in Wang and Ke, 2002, p. 2). An *efficient market* is one in which prices always "fully reflect" available information and where no traders in the market can make a profit with monopolistically controlled information. Dwyer and Wallace define an *efficient market* as "one in which there are no risk-free returns above opportunity cost available to agents given transaction costs and agents' information" (Dwyer and Wallace, 1992, p. 319).

In an *efficient commodity market* the futures price will be an unbiased forecast of the spot price at contract termination. The futures price converges to its maturity price that can differ from the spot price only to the extent of a random unpredictable zero-mean error. An efficient commodity futures market can provide effective signals for the spot market price and eliminate the possibility that profit can be guaranteed (Wang and Ke, 2002).

There are numerous reasons why, empirically, a commodity futures market can fail to be efficient (Kellard, 1999, p. 414):

- Presence of a risk premium
- Inability of the futures price to reflect all publicly available information
- Inefficiency of agents as information processors
- Markets for commodities in which returns to storage or transportation are nonstationary

### 3.4 Market Efficiency – Motivation

The notion of market efficiency is of importance to any commodity producer, investor, or trader who wishes to use these markets to hedge against price risk (Chowdhury, 1991, p. 577-78).

Higher efficiency of SHFE implies better performance of SHFE futures as risk management instrument for commodity producers and traders and lower profit volatility for all aluminum futures markets participants. Clearly, the efficiency of SHFE, measured relative to COMEX and LME, will be of interest to any entity involved in aluminum trade with China.

An efficient futures market can have important implications for international commodity agreements, domestic price stabilization schemes and the appropriate choice of government intervention forms (Chowdhury, 1991, p. 577-78).

### 3.5 Literature overview

According to Wang and Ke (2002), studies of China's futures market are rare. Most of the existing studies are focused on legislative regulation of Commodity Exchanges and their development. The majority of market efficiency studies focus on non-metal products. Noteworthy is the study of Zhang and Li (2003), who are testing China's Shanghai Stock Exchange Market using an evolving market efficiency test. Among the papers that analyze metals, aluminum is a rare commodity of choice.

There are numerous studies, both theoretical and empirical, that analyze the efficiency of futures markets in developed countries. Some of them investigate efficiency of aluminum futures markets at LME, but their results are mixed. Goss (1988) conducts a semi-strong form test of the efficiency in the copper and aluminum markets at LME. His

test consists of a comparison of the predictive powers of the futures markets and the results indicate that the hypothesis of an efficient copper and aluminum market cannot be rejected.

Sephton and Cochrane (1990) examined the market efficiency hypothesis with respect to six metals, including aluminum, also traded on LME. They use both single and multimarket models to find evidence contradictory to the tenet that LME was an efficient market. To determine the degree of market efficiency, Sephton and Cochrane examine forecast errors relative to their history. The scholars define a forecast error as the difference between the future price of a metal and the spot price on the futures contract maturity date. The authors looked at data on aluminum from 1979 to 1988. Findings from single market tests in Sephton and Cochrane's analysis support efficient market hypothesis. Their market studies of six metals at LME proved the existence of market inefficiency. The authors conclude that the metals traded on LME do not seem to pass the efficient markets test.

To my knowledge, there does not exist any study of aluminum futures market efficiency that is based on data quoted in recent years at COMEX, LME or SHFE.

### 3.6 Testing for Chinese Aluminum Metal Exchange Efficiency

In testing efficiency of SHFE I use the Johansen cointegration test, essentially the same procedure as in the case of market integration. As in the case of market integration, the test analyzes common patterns in price variability. The difference lies in the specific data series used and in the restrictions on hypothesized cointegration coefficients to be tested. The reasons for using the Johansen test in analyzing price variability were identified in the section on Market Integration. Again, the choice of the Johansen test was

motivated by its prevalent use throughout the 1990s and in the current literature, stemming from its ability to test specified coefficient restrictions stipulated by economic theory and the relative ease of performance.

In general, there are three conventional ways of testing the efficiency of futures markets (Chowdhury, 1991, p. 578):

- Weak form test of market efficiency;
- Semi-strong form test of market efficiency;
- Cointegration.

The *weak form tests* of efficiency rely on the historical sequence of prices and involve regressing cash price at futures contract maturity on the contract's previous future price. These tests thus do not take into account possible nonstationary nature of the data analyzed (Chowdhury, 1991, p. 578).

In the case of a *semi-strong form test*, an econometric model is employed to compare the forecast error of the model with that of future price. However, results from this test are often contradictory (Chowdhury, 1991, p. 578).

Presently used methods for testing market efficiency relate to *cointegration theory* and also include the Johansen test. These methods, which account for nonstationarity in price series, were first used in the context of market efficiency by Hakkio and Rush (1989) in an application to the Sterling and Deutschemark exchange markets. Shen and Wang (1990) introduced cointegration techniques to testing futures market efficiency.

## 4. Methodology

Before the application of the Johansen test to integration of the Chinese aluminum market into the world economy and efficiency of SHFE, some basic concepts of time-series quantitative methods need to be reviewed. Even though the actual tests are performed by statistical computer software, an introductory level time-series background is necessary for linking the economic theory to be tested to the type of test to be carried out and parameter restrictions to be tested.

### 4.1 Data (Non)stationarity

Two fundamental categories of economic data are *time-series data* and *cross-section data*. The intrinsic nature of a *time-series data* is that its observations are ordered in time and the modeling strategies of time series must take into account this property. This does not occur with *cross-section data* where the sequence of data points does not matter. The objectives of time-series analysis are to describe the regularity patterns present in the data and to forecast future observations (Moral and Gonzalez, 2003).

Any real-world phenomenon or activity that generates data is called *a process*. An example of a process are trading and arbitrage activities at SHFE that generate aluminum contract price data by interaction of supply and demand. In modeling time-series processes, i.e. processes that generate time-series data, two basic categories are distinguished: stationary and nonstationary processes, generating stationary and nonstationary data, respectively (Moral and Gonzalez, 2003).

Such distinction is necessary for selection of the appropriate quantitative procedure of data analysis. Stationary time-series data can be analyzed using classical

regression techniques such as Ordinary Least Squares (OLS) whereas for nonstationary time-series data the classical inference does not hold and the cointegration approach, namely the Johansen test, becomes the appropriate analysis tool.

A *stationary data series* is defined as a data series whose statistical properties, such as the mean and the variance, do not vary with time. A stationary data series is generated by a *stationary process* that tends to adjust the series back towards its mean, corresponding to an equilibrium of the process, if the data variable departs too far from it. This occurs due to the stationary nature of the random error distribution around the mean (Kennedy, 1998). An example of a stationary data series is provided in Appendix 3.

Conversely, time-series data whose statistical properties do change over time are referred to as *nonstationary* (Kennedy, 1998). A nonstationary data series does not fluctuate about its mean but can trend away or drift away from it. In fact, nonstationarity in a time series can occur in many different ways. Usually, a nonstationary time series displays time-changing levels of mean and/or variance. Empirically, most time series data appearing in economics are nonstationary (Moral and Gonzalez, 2003). An example of nonstationary data series is given in the Appendix 3.

### 4.2 Orders of Integration

Time-series data can be further classified by their *order of integration*. This classification is important especially for nonstationary data since running the proper version of the Johansen cointegration test requires knowledge of the order of data integration.

A stationary time series is called *integrated of order zero*, denoted *I(0)* whereas a nonstationary series can be intergrated of order one or higher, denoted *I(1)* or *I(d)* where

*d*>1, respectively. A series is I(1) if it is in itself nonstationary, but becomes stationary after being *differenced once*. Differencing means creating new sequence out of the original one by taking differences between individual data points of the original sequence. Such new sequence is referred to as the *original sequence differenced once*. In general, a series which is stationary after being differenced *d* times is said to be *integrated of order d*, denoted *I(d)* (Otto 2003).

The terminology is somewhat confusing, since the orders of integration refer to statistical integration, while the concept of market integration concerns an economic phenomenon. The two concepts are mutually unrelated and care needs to be taken in distinguishing the two any time they are used.

Table 2 below summarizes the basic system of time-series data classification that is used in my analysis. Each term refers to an individual data series, i.e. not pairs or combinations of them.

**Table 2: Basic System of Time-series Data Classification**

| **Data-generating Process** | Stationary Process | Nonstationary Process | | |
|---|---|---|---|---|
| **Nature of Data Stationarity** | Stationary Data Series | Nonstationary Data Series | | |
| **Order of Data Integration** | I(0) | I(1) | I(2) | I(d) |
| **Data Analysis Technique** | OLS | Johansen test (1) | Johansen test (2) | |

### 4.3 Augmented Dickey Fuller Test

The standard procedure for determining the order of integration of any time-series data is the *Augmented Dickey-Fuller test* (ADF). The order of integration also conveys

the knowledge of data (non)stationarity. The ADF test can be performed, for example, using the VARMAX procedure in SAS statistical software. The null hypothesis of the test is that the data series in question is at least I(1) against the alternative to the series is I(0). The two main outcomes of the test that I focus on are the *ADF test statistic tau* and the *p-value*. The ADF test statistic *tau* is a negative number with lower values implying stronger rejection of the null at some level of confidence (Dickey and Fuller, 1979). If the null cannot be rejected at a selected level of confidence then a series cannot be stationary and it may be I(1) or I(2), or have an even higher order of integration. The p-value smaller than 0.05, corresponding to the most common 95% confidence level, implies rejection of the null (Otto, 2003).

To determine the exact order of integration, the test is repeated using the data series differenced once. If the null is now rejected, i.e. when the p-value is smaller than 0.05, then the original series is I(1). If the null cannot be rejected again, the whole procedure is repeated with the data series differenced twice, and so on, until the exact order of integration is found. The order of integration of the data series will be the same as the number of additional ADF tests needed to perform after the initial one (Alexander and Wyeth, p. 304).

I performed the ADF in SAS for each of the data series in question to determine its order of integration, as the first step in the analysis. The results are presented in the Empirical Results section.

### 4.4 Cointegration

Up to this point the discussion of stationarity and orders of integration concerned only a single individual time-series. The concept of *cointegration*, in turn, examines a relationship between two or more data series.

Two series are said to be *cointegrated* when each series is I(1) but their linear combination is I(0). The variables then share similar stochastic trends. The concept of cointegration allows two (or more) individual series to be nonstationary, as they appear to be in reality, and still have the property that a linear relation between the variables is stationary. A cointegrating relation can be considered the statistical formulation of long-run relations in the economy (Johansen, 1997). Two examples of variables, with and without the presence of cointegration, are provided in the Appendix 4.

Sections 3.6 and 3.7 develop parameter restrictions for testing market integration and efficiency based on linear regression relations among price data series. Provided the price data are I(1), establishing the presence of cointegration among the price data series is vital for tests of the restrictions to be valid.

If two series are I(1) and with no intrinsic mutual relation, for example LME aluminum price data and average price of opera tickets in Chicago, then we might expect to find no relationship when regressing one variable on the other. However, we might find that the regression does not reflect this. Instead, the results might indicate that the variation in the opera ticket prices "explains well" the variation in LME aluminum prices. This phenomenon is called *spurious regression* and arises due to similar overall trends of price increases for both variables. Thus, for example, the correlation coefficient and the coefficient of determination ($R^2$) might appear high even if there is no fundamental

relation between the variables. The presence of spurious regression is one of the fundamental reasons why I(0) and I(1) series are distinguished (Granger and Newbold, 1974, Phillips 1986).

The only case when regression results for I(1) variables will correctly indicate an intrinsic relationship occurs if the series are cointegrated. Cointegration implies that both variables follow similar stochastic trends and most random disturbances will be common to both variables. This would not arise in the case of spurious regression where both variables merely follow a similar general trend, each subject to its own random disturbances affecting the variable independently of the other one.

An extension of the concept of cointegration to the case when more than two series are considered is straightforward. When several series share a common stochastic trend in the sense that there is a long-run relationship among them, each individual series is I(1) and one of their linear combinations is I(0), then the series are cointegrated.

### 4.5 The Johansen Cointegration Test

The Johansen cointegration test is used in the current literature as a standard procedure for determining the degree of cointegration among several economic variables and to test hypotheses stipulated by economic theory regarding the variables. The Johansen test is used in my paper in several different ways.

In addressing the question of *market integration*, the test is applied to the data to determine whether SHFE aluminum spot prices are cointegrated with the corresponding spot prices in LME and COMEX. If so, the test will determine whether the hypothesis of market integration based on linear regression relations among price data from SHFE, LME and COMEX is valid. In order to establish whether the results can be extended to

the physical markets, the Johansen cointegration test is run for SHFE spot prices and the Chinese physical market prices. If the price series turn out to be cointegrated and the cointegration parameter restrictions satisfied, then the results do extend, otherwise they do not.

On the *market efficiency* issue, the Johansen test will decide about the existence of cointegration between spot and futures prices of aluminum at each individual futures market. If the outcome is positive, the test will establish the degree to which the hypothesis of market efficiency is correct at each location.

### 4.6 Linking Theory and Data

Detection of presence of cointegration among several data series can be carried out using several tests.[1] The key advantage of the Johansent test is that its structure also allows for testing specific restrictions on the cointegration parameters. These restrictions are stipulated by economic theory of market integration and efficiency and hence, by confronting the restrictions with empirical data, the test can provide answers to the two fundamental questions that I address in this paper.

The link between economic theory and the empirical data in the Johansen testing procedure is based on a mathematical expression called *Error-correction Model* (ECM). An example of ECM used in market integration analysis by Asche, Osmundsen and Tveteras (2000) is given in Appendix 5.

Economic theory helps formulate the ECM through parameters restrictions that are embedded in the ECM expression. These restrictions on the ECM coefficients are then tested for their validity with time-series data that are substituted into the ECM with

[1] The Engle and Granger test is widely used, in addition to the Johansen test.

statistical software. The Johansen testing procedure then analyzes changes in the ECM as a result of the data substitution and concludes whether the restrictions given by the theory are valid or not and hence whether the theory itself, such as market integration and efficiency theory, is valid or not, for the available data.

ECMs have been applied to time-series data since the work of Sargant (1994). Engle and Granger (1987) clarified the relation between ECMs and cointegration in the sense that any ECM will generate cointegrated variables and cointegrated variables can be expressed as solutions to ECMs (Johansen, 1997).

### 4.7 Parameter Restrictions on Testing Market Intergration

The link between economic theory of market integration and the empirical cointegration test is based on Asche, Osmundsen and Tveteras[2] (2000) who used the Johansen test to investigate the degree of market integration for natural gas imported into France from the Netherlands, Norway and Russia. Their analysis is based on Stigler's (1985) definition of a market as "the area within which the price of a good tends to uniformity, allowances being made for transportation costs." This and similar definitions (Cournot [18], Marshall [19] ) have led to an "extensive literature testing for market integration based on relationship between prices" (Asche, Osmundsen and Tveteras, 2000).

In Stigler's definition, a stable long-run relationship between price time-series data implies that the goods are in the same market or that the geographically separated

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markets for a good are economically integrated. For nonstationary price data such stable long-run relationship occurs only when the price series are cointegrated and satisfy restrictions on cointegration coefficients. It follows that if time-series price data from SHFE, COMEX and LME are found to be cointegrated and satisfy restrictions derived below, I can conclude that SHFE is integrated in the world economy represented by COMEX and LME. By the same token, if price data from SHFE and the Chinese physical market turn out to be cointegrated and satisfy cointegration paramter restrictions, then SHFE can be considered as representative of the physical market in China and the outcome of the market integration analysis can be extended to the physical markets.

Before looking at restrictions for all three variables it is easier to start with only two of them. Consider two price series, for example: $SHFE_t$ and $COMEX_t$ where *t* is a time index. The basic relationship between the prices to be investigated is then

$$SHFE_t = \gamma (COMEX_t)^{\beta} \qquad (1)$$

or after linearizing by taking the logs of each side

$$\ln SHFE_t = \alpha + \beta \ln COMEX_t \qquad (2)$$

where $\alpha = \ln\gamma$ .

The coefficient $\beta$ provides the relationship between the prices. If $\beta = 0$ then there is no relationship while if

$$\beta = 1 \qquad (3)$$

then the Law of One Price holds and the relative price between $SHFE_t$ and $COMEX_t$ is constant. The Johansen cointegration procedure then tests the null hypothesis that $\beta = 1$ against the alternative that $\beta \neq 1$. $\alpha$ is a constant term (the log of a proportionality

coefficient $\gamma$ ) and holds information about the mean difference between the prices when the LOP holds (Asche, Osmundsen and Tveteras, 2000).

Traditionally, relationships such as (2) have been estimated with Ordinary Least Squares (OLS). However, since the late 1980s it has been recognized that when the data series are nonstationary, the OLS inference, based on certain stability assumption on the data, does not hold. Cointegration theory is viewed as the appropriate tool to use under such circumstances.

The extension to the case when more than two variables are considered can be expressed in the vector-form counterpart of equation (2). Asche, Osmundsen and Tvertas (2000, p. 12) devise the restriction on parameter coefficients contained in a (3x2) matrix $\beta$ , as opposed to a scalar in the case of two variables. When the *identifying normalization* is imposed on the vector counterpart of (2), the restriction is given in the form

$$\beta = \begin{bmatrix} 1 & 1 \\ -\beta_1 & 0 \\ 0 & -\beta_2 \end{bmatrix} \qquad (4).$$

If both parameters $\beta_1$ and $\beta_2$ in the matrix are equal to 1, then the LOP holds. These restrictions

$$\beta_1 = \beta_2 = 1 \qquad (5)$$

can be tested using the multivariate Johansen cointegration test in statistical software. The specific data used in my analysis of Chinese aluminum market integration is described in the Data section. The computer program for SAS software used in the analysis is included in the Appendix 7.

### 4.8 Parameter Restrictions on Testing Efficiency

Attention will now turn to the quantitative methods background for the second question addressed in my paper - testing the efficiency of the Shanghai Futures Exchange trade with aluminum contracts. The methodology for this section is based on the work of Wang and Ke[3] (2002). These scholars analyze the efficiency of the Chinese wheat futures market at the Zhengzhou Grain Wholesale Market (ZGWM) and soybean futures market at Tianjin Grain Wholesale Market (TGWM). The second major source for methodology relating to futures market efficiency is Kellard, Newbold, Rayner and Ennew[4] (1999) who studied U.S. futures markets for soybeans, live cattle, live hogs, gasoil, crude oil and the Deutschmark / US Dollar exchange market.

A Futures Exchange Market is considered *efficient* if its agents are able to process all available information so that the futures price at a time *t-i* provides an *unbiased predictive signal* for the cash price $i$ periods ahead, at time *t* (Wang and Ke, 2002). This means that futures price, for example, for March determined at SHFE in January will give on average a reliable prediction of the SHFE March cash price. In such case, *t* = March and *i* = 3 months.

The theory of cointegration relates to the study of the efficiency of a futures market as follows: let $C_t^{SHFE}$ be the cash price at SHFE at time $t$ and $F_{t-i}^{SHFE}$ be futures price at SHFE taken at $i$ periods before the contract matures at time $t$. The index $i$ represents the number of periods of interest, in my case three months. If $F_{t-i}^{SHFE}$ provides a predictive signal for $C_t^{SHFE}$, and hence the market is efficient, then some linear

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combination of $C_t^{SHFE}$ and $F_{t-i}^{SHFE}$ is expected to be stationary, that is there exist $a$ and $b$ such that

$$C_t^{SHFE} = a + bF_{t-i}^{SHFE} + z_t \qquad (6)$$

where $z_t$ is stationary with mean 0.

If both $C_t^{SHFE}$ and $F_{t-i}^{SHFE}$ are I(1) then the relationship (6) can hold only if $C_t^{SHFE}$ and $F_{t-i}^{SHFE}$ are cointegrated, at a selected confidence level. Cointegration ensures that there exists a long-run equilibrium relationship between the two series. If $C_t^{SHFE}$ and $F_{t-i}^{SHFE}$ are not cointegrated at the selected confidence level then the futures price is not considered to be an unbiased predictor of the cash price (Wang and Ke 2002, p. 7). In addition to cointegration, market efficiency also requires an unbiased forecast of futures price on cash price. This is expressed by the restrictions

$$a = 0 \text{ and } b = 1 \qquad (7)$$

in equation (6).

Hence market efficiency is tested in two steps:

1. The cointegration relationship between $C_t^{SHFE}$ and $F_{t-i}^{SHFE}$ is examined;
2. The parameter restrictions $a = 0$ and $b = 1$ are tested.

The second step can be performed in several ways – either using a joint hypothesis or testing each coefficient separately. The parameter $a$ will be non-zero under the existence of risk premium and / or transportation costs even when the market is efficient. Hence the constraint $b = 1$ is a more important indicator for the existence of market efficiency (Wang and Ke 2002, p. 7), (Kellard et al 1999, p. 416) and (Chowdhury, p. 578). In analyzing the output of the test, I focus on the coefficient *b* only.

## 5. Data

I obtained six series of data used in my analysis from official websites of SHFE, COMEX and LME. These series are:

1. SHFE aluminum spot prices;
2. COMEX aluminum spot prices;
3. LME aluminum spot prices;
4. SHFE aluminum three-month futures prices;
5. COMEX aluminum three-month futures prices;
6. LME aluminum three-month futures prices.

The data in each series are of daily frequency, except with no quotes for weekends and occasional holidays. The data range over the period from May 20, 1999 to August 7, 2003. Since each series consists of 951 data points, my data sets can be considered sufficiently rich for the analysis to be statistically valid.

Aluminum futures at COMEX started trading in May 1999 and aluminum price data are available from May 20, 1999. Both SHFE and LME provide aluminum price data from January 1, 1999.

The SHFE service displays historical daily prices on the screen after a search request specifying the exact date and hence each daily recording had to be copy-pasted from the website. LME offers all historical data in freely downloadable files. COMEX itself does not publish their aluminum price data but these can be obtained in the form of a comprehensive table from Metalprices.com (2003).

I chose the time length of the futures contract as three months because this was the only one available that was common for all Futures Exchanges. SHFE specifically

publishes futures prices in excess of the three-month contract for relatively few data points.

I obtained two additional data series from an official Chinese statistical journal *China Price*. These series are:

7. Physical market aluminum prices averaged across the whole China;

8. Physical market aluminum prices collected for the Shanghai region.

These data series are of monthly frequency and hence only 42 data points are contained in each series. Statistical significance of tests involving these series might therefore be questionable.

In international markets, the prices must be compared in the same currency. However, in primary goods markets the price is often quoted in a single currency (usually US$). When this is not the case, a *perfect exchange rate pass through* is assumed and the prices are converted to a common currency. This assumption implies that any change in exchange rates is instantaneously offset by a corresponding change in the nominal price of the good so that the real price expressed in a common currency is unaffected (Asche, Osmundsen and Tveteras, 2000).

I chose the US$ as the common currency in which all data are analyzed. LME publishes aluminum price data directly in US$ and hence no conversion was necessary. I converted SHFE price data published in Renminbi to US$ using daily RMB/US$ exchange rate data for the time period in question obtained from the website of Pacific Exchange Rate Service maintained by Prof. Werner Antweiler at the University of British Columbia, Vancouver, Canada.

## 6. Testing Procedure

All tests were performed using the VARMAX procedure in SAS that is capable of carrying out both ADF and the multivariate Johansen tests with specified restrictions.

### 6.1 Testing I(1) with ADF test

Using the cointegration approach and thus the Johansen test requires that each time series entering the test be I(1). As the first step, therefore, the six individual data series used in the analysis were run through the ADF test in VARMAX to confirm that they are indeed I(1) as conjectured.

Graphical representation of all data series entering the test, in their original form and differenced once, is given in Appendix 6.

### 6.2 Testing Market Integration

**Test of Market Integration 1:** in the first market integration test, three time-series data sets were used as inputs into VARMAX from the empirical side:

(i) SHFE spot prices

(ii) COMEX spot prices

(iii) LME spot prices.

From the economic theoretical side, restriction on coefficients (5) identified in section 3.7 were also specified in VARMAX.

The VARMAX procedure tests both for presence of cointegration among all three series as well as the null hypothesis that the three series are integrated as specified by the parameter restrictions.

The results proved inconclusive (see the Empirical Results section) and therefore I decided to run three additional bilateral tests for market integration between:

**Test of Market Integration 2:** SHFE spot prices and COMEX spot prices;

**Test of Market Integration 3:** SHFE spot prices and LME spot prices;

**Test of Market Integration 4:** LME spot prices and COMEX spot prices.

These tests provided more insights into the system and enabled me to determine the relative ranking of bilateral market integration.

In order to investigate the dynamics of bilateral market integration, I ran the tests 2-4 also separately for two half-periods of the overall time frame. The first half-period stretches from May 20, 1999 to June 17, 2001 and the second half-period covers the time between June 18, 2001 to August 6, 2003.

**Test of Market Integration 5:** first half-period SHFE and COMEX spot prices;

**Test of Market Integration 6:** first half-period SHFE and LME spot prices;

**Test of Market Integration 7:** first half-period LME and COMEX spot prices;

**Test of Market Integration 8:** second half-period SHFE and COMEX spot prices;

**Test of Market Integration 9:** second half-period SHFE and LME spot prices;

**Test of Market Integration 10:** second half-period LME and COMEX spot prices.

The purpose of the last two tests is to determine whether the previous analysis extends to the physical markets.

**Test of Market Integration 11:** SHFE spot prices and physical aluminum market prices averaged across China;

**Test of Market Integration 12:** SHFE spot prices and physical aluminum market prices quoted for the Shanghai region.

For Market Integration tests 2 – 12, restriction on coefficients (3) identified in section 4.7 were also specified in VARMAX. The procedure tests for both presence of cointegration among the two series in question as well as the null hypothesis that the two series are integrated as specified by the parameter restrictions (3).

The part of VARMAX testing for the presence of cointegration generates output specifying a *trace test statistic* to be compared with a *critical value* which is also given in the computer output. If the test statistic exceeds the critical value then the null hypothesis is rejected and vice versa. In the bilateral tests the trace test statistic can be compared among the different pairs of Futures Exchanges that are tested for market integration. The higher the trace statistic, the higher is the confidence level at which the pair of Exchanges is considered to be integrated.

The result of the test of parameter restriction is summarized in the *p-value* statistic. If the p-value is lower than 0.05 then the null hypothesis is rejected at 95% confidence level. If the p-value is higher than 0.05 then null is not rejected at the corresponding confidence level.

Graphical representation of data series entering each test is shown in Appendix 6.

### 6.3 Testing Market Efficiency

For the part regarding market efficiency, two time-series data sets at a time were used as inputs into VARMAX from the empirical side. Thus, three separate tests are run:

**Test of Efficiency 1 - SHFE:** (i) SHFE spot prices and (ii) SHFE lagged three-month futures prices;

**Test of Efficiency 2 - COMEX:** (i) COMEX spot prices and (ii) COMEX lagged three-month futures prices;

**Test of Efficiency 3 - LME:** (i) LME spot prices and (ii) LME lagged three-month futures prices.

From the economic theoretical side, restriction on coefficients (7) identified in section 4.8 were also specified in VARMAX.

In each test, VARMAX tests for both the presence of cointegration between the two variables in question and the restrictions (7). Similar to the previous section, the trace statistic can be used to compare relative efficiency of each market. The higher the trace statistic, the higher is the confidence level at which the Futures Exchange in question is considered to be efficient.

Graphical representation of data series entering each test is shown in Appendix 6.

## 7. Empirical Results

Empirical results of all tests performed are presented in tables in Appendix 8.

### 7.1 Dickey-Fuller Test

The results of the Dickey-Fuller test for all variables are presented in Table 3. The p-values for all variables can not reject the null at 95% confidence level for either model. Therefore, the test has to be repeated for all series differenced once.

### 7.2 Dickey-Fuller Test for the Series Differenced Once

The results of the Dickey-Fuller test for all variables differenced once are presented in Table 4. The p-value for physical monthly prices of aluminum averaged across China cannot reject the null even at 90% confidence level and therefore the variable is nonstationary and integrated of order higher than 1. In addition to the intrinsic nature of the variable, one possible reason for this outcome might be insufficient number of data observations contained in this series. The p-values for all other variables reject the null at 95% confidence level and hence they are nonstationary and integrated of order one.

The implication of the test for the physical monthly prices of aluminum averaged across China is that this variable cannot be further included in the Johansen test cointegration analysis because the variable is not compatible with the Shanghai spot monthly prices in terms of order of integration, which is a requirement of the Johansen test.

### 7.3 Market Integration Test 1 - All Three Markets

The results of the multivariate Johansen cointegration test are shown in Table 5. The trace test statistic does not exceed the critical value and therefore the null hypothesis of no cointegration among all three variables cannot be rejected. In the absence of cointegration of all three variables together, it is not necessary to look further on testing the restrictions on parameters $\beta$ . It follows that the futures exchange markets SHFE, LME and COMEX are not integrated as a system.

### 7.4 Market Integration Tests 2 – 4 (Bilateral Tests of Commodity Exchanges)

The trace test statistics for all three tests are listed in Table 6, and the critical values for these tests at three different confidence levels are shown in Table 9. The results demonstrate that SHFE spot prices are not cointegrated with COMEX spot prices even at 90% confidence level, SHFE spot prices are cointegrated with LME spot prices at 90%, but not at 95% confidence level, and COMEX and LME spot prices are cointegrated at 95%, even if not at 99% confidence level.

The p-values of the parameter restriction tests are given in Table 6. Since spot prices at SHFE and COMEX are not cointegrated, their respective p-value can be excluded from further analysis. The SHFE-LME p-value rejects the null hypothesis that $\beta = 1$ in this case and hence the two markets do not exactly follow the law of one price. The LME-COMEX p-value cannot reject the null and hence the law of one price holds between these two markets.

Hence, SHFE market can be regarded as not economically integrated with the COMEX market, but it displays a certain degree of economic integration with the LME

market. However, LME and COMEX exhibit a relatively high degree of economic integration.

### 7.5 Market Integration Tests 5-10 (Bilateral Tests of Commodity Exchagnes for Two Half-periods)

The trace statistics for tests 5-10 are listed in Table 7 for both half-periods, with the critical values given in Table 9. The results show a substantial increase of SHFE price cointegration with both COMEX and LME over the two half-periods. While in the first half-period no economic integration is indicated, in the second half-period SHFE turns out integrated with LME at 90% confidence level and with COMEX at 95% confidence level.

LME and COMEX remain clearly integrated at 95% (close to 99%) confidence level, with only a negligible change over the two half-periods.

The p-values of the parameter restriction tests are also given in Table 7. In the first half-period only the p-value related to LME-COMEX test is relevant since only in this case spot prices are found to be cointegrated. The null hypothesis that $\beta = 1$ cannot be rejected and hence the Law of One Price holds between LME and COMEX in the first half-period.

In the second half-period, only the SHFE-LME p-value indicates compliance with the Law of One Price. SHFE and LME are integrated only in a weak sense (at 90% confidence level) and hence the LOP in this case is not entirely immune to questioning its statistical significance.

### 7.6 Bilateral Market Integration Tests 5 – 6 (Bilateral Tests of Chinese Physical Market Prices)

The trace test statistic is listed in Table 8 and the critical values at three different confidence levels are shown in Table 9. The trace statistic exceeds the critical value at 99% confidence level and hence SHFE spot price is cointegrated with physical market aluminum prices averaged the Shanghai region. The Shanghai physical prices also satisfy parameter restrictions at 95% confidence level. This implies that SHFE spot prices and aluminum physical prices in the Shaghai region follow the same pattern very closely.

These findings confirm that the results of the market integration analysis for the Commodity Exchanges can be extended to the physical market with aluminum with respect to the Shanghai region.

### 7.7 Market Efficiency Tests

The trace test statistics for all three efficiency tests are presented in Table 10. The critical values for these tests (in Table 9) stay the same as for bilateral market integration tests, since exactly the same test procedure was employed. LME spot and futures prices not cointegrated even at 90% confidence level. SHFE spot and futures prices are cointegrated at 90% confidence level, but already not at 95%. COMEX spot and futures prices are cointegrated even at 99% confidence level.

The p-values for parameter restrictions test can be excluded in LME case since no cointegration was detected. SHFE efficiency test p-values cannot reject the null hypothesis that $\alpha = 0$ and $\beta = 1$, and hence efficiency can be confirmed for 90% confidence level. COMEX p-values do not reject the null for $\alpha$, reject the null for $\beta$ at 95%, but not at 99% confidence level.

Thus, LME displays the lowest level of efficiency, SHFE gives somewhat better efficiency results and COMEX is by far the most efficient market among the three under analysis.

## 8. Discussion of Results

### 8.1 Market Integration

The most significant finding is undoubtedly the substantial rise of the trace statistics when the cointegration analysis was split into two periods. With time, SHFE is becoming unquestionably more integrated into the system of world Commodity Exchanges, displaying relatively high level of integration during several past years. These conclusions also apply to the Shanghai physical market, even though no inference can be made about the rest of China.

There are numerous factors stemming from the Chinese general marketization trend that can stand behind the market integration results. Among others, factors discussed in section 2.2 have undergone substantial changes. Perhaps the most important processes behind increasing integration relate to technological advancements, cost of production, dismantling trade barriers upon China's entry to WTO.

#### 8.1.1 Technology

In 2001, the President of Chalco Guo Shengkun admitted that aluminum production costs in China are much higher than abroad. However, he hoped that the company's "going public on the world stage" would allow to tighten its management control and to pay more attention to technological innovations in the industry. In 2001, Chalco was planning to invest $313 mn into capacity modernization (Fedin, Ivanov (2001)).

Although aluminum smelters in China still utilize the outdated Sodberg technology, their number was continuously decreasing during the period of time under

research. In 1999, 66% of all aluminum produced in China was refined using Sodberg technolgy, whereas by the end of 2001 this percentage declined to 35,7 (Report from the Second Forum on Colored Metals in China, 2001).

Now, like many other joint ventures in China, Alcoa's JV faces the same problem of maintaining a technological or innovative edge, as any new product developments are quickly copied by Chinese competitors (O'Carroll, 2002).

### 8.1.2 Costs of Production

In spite of high electricity prices in China due to government control of the power sector, China's primary aluminum producers find their own way to get a preferential electric energy prices. In 2000, for instance, Chalco formed a strategic alliance with Beijing Datang Power Generation company to secure a 25-year power supply for a new smelter it is building in Shanxi. Although the smelter will not be built until 2005, Chalco's electricity cost will then be 20% cheaper than its present costs (O'Carroll, 2002).

In recent years, several energy companies in China have either started developing ingot smelter projects on their own, or have merged with local aluminum smelters to expand capacities. One of these companies was Qinghai Qiaotou Aluminum and Electricity Co, whose first aluminum project was to be finished by June, 2003 (O'Carroll, 2002).

### 8.1.2 Trade Barriers

Trade barriers could be viewed as hindrance of competitiveness of the Chinese aluminum industry and "impediments to efficient arbitrage", both referred by Sexton et al. (1991) to potential reasons for markets not to be integrated. However, before and after China entered WTO in late 2001, its government embarked on the policy of dismantling export and import tariffs, as required of a member nation of the organization. Beijing reduced its protection of aluminum industry by decreasing 9% import tariff on primary aluminum to a WTO member tariff of 5% (Report from the Second Forum on Colored Metals in China, 2001).

To apply Sexton's statement about market integration with the presence of trade barriers, a distinction should be made between tariffs on finished goods and inputs into their production. For instance, a WTO member import tariff on bauxite ore (the main input into aluminum production) was scheduled to be decreased to 8% in 2004, and hence has not been reduced yet. Nevertheless, this trade barrier might not be viewed as significant as the import tariff on primary aluminum, mentioned above, for explaining the degree of China's aluminum market integration. Besides, import tariffs on bauxite ore were cut by Beijing authorities from 18% to 14% at the moment of China's entry to WTO, and to 12% in 2002 (Report from the Second Forum on Colored Metals in China, 2001).

By the same token, MOFTEC regulation No.567 (2001), which provided for government management of bauxite imports, can be viewed as not crucial for the analysis of China's aluminum market integration. Moreover, this regulation could only be applicable to small plants without affecting state owned aluminum enterprises.

## 8.2 Market Efficiency

It could be a treacherous undertaking to put forward arguments aiming at explaining different levels of Commodity Exchanges' efficiency without insider's knowledge of working of each specific market. I will therefore restrict myself to only a few considerations.

It is apparent from Graph 10 that prices at SHFE are subject to lower volatility than at LME and COMEX, most likely due to relative price stability throughout China (see Graph 4). Higher price stability makes a futures market more predictable and hence implies higher efficiency.

Empirically, LME has been reported as relatively inefficient by some authors for various commodities but their findings were disputed by others who used different quantitative methods (Chowdhury, 1991). LME is the principal trading market for aluminum dealers from Europe and parts of Asia, including Russia, and higher degree of market uncertainty in those regions might lead to loss of LME's efficiency.

## 9. Conclusions

In my thesis I addressed two questions regarding the aluminum market in China: the degree of its integration into the world market and the efficiency of aluminum trading at the Shanghai Futures Exchange (SHFE) relative to its counterparts in London (LME) and New York (COMEX).

An initial pre-test, the Augmented Dickey Fuller test, was applied to all data series in question, confirming that each series used in the analyis was nonstationary and integrated of order one.

The first question dealt with determining the degree to which SHFE is integrated into the world market, that is, whether prices at the aluminum market in China follow the same pattern as prices in the U.S. and Europe, or whether they are determined separately. Moreover, by testing for the degree to which SHFE spot prices are indicative of the physical market prices in China, I aimed to establish whether the results of the Commodity Exchange tests can be extrapolated to the physical markets.

Using the Johansen test for cointegration of time series data in SAS statistical software, I compared the relative volatility of daily aluminum spot prices quoted on SHFE, COMEX, and LME. The results show that the three Commodity Exchange markets are not integrated together as one market system.

A series of bilateral tests between each pair combination of the three Commodity Exchange markets over the whole time period showed that SHFE displays a certain degree of economic integration with the LME but cannot be regarded as economically integrated with COMEX. Nevertheless, LME and COMEX exhibit a relatively high degree of economic integration between themselves.

When the market integration analysis was repeated separately for each half-period of the entire time frame, SHFE displayed a significant increase in its degree of market integration with both LME and COMEX between the first and the second half-period. While no integration of SHFE could be integrated in the first half-period, SHFE turned weakly integrated with LME and strongly integrated with COMEX in the second half-period. LME and COMEX remained highly integrated together during both half-periods.

No conclusion could be drawn about the link between the physical monthly prices of aluminum averaged across China and SHFE spot prices since the former variable turned out incompatible with the latter one in terms of order of integration, perhaps due to insufficient sample size. Nevertheless, the tests performed did show that physical monthly prices of aluminum in the Shanghai region displayed a very tight link with the SHFE spot prices. Hence, the market integration analysis results obtained for the Commodity Exchanges can be extended to the physical aluminum market in the Shanghai region. In the case of LME and COMEX, such extension to their respective physical markets of reference was assumed as given and hence not tested.

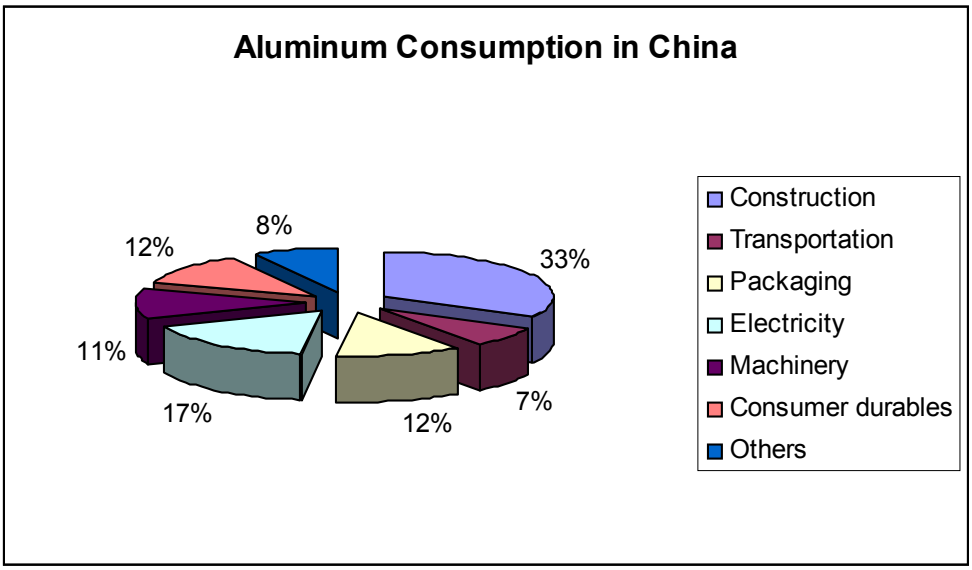
The second question explored in my thesis concerns the efficiency of SHFE, relative to COMEX and LME. The precision with which termed future contracts for aluminum at SHFE are able to predict the spot prices on their maturity served as a standard measure of Commodity Exchange efficiency. The results show that SHFE displays somewhat better efficiency results than LME but worse than COMEX. In level terms, the efficiency of LME cannot be confirmed, SHFE comes close to being efficient and COMEX can be regarded as highly efficient.

# APPENDICES

## Appendix 1

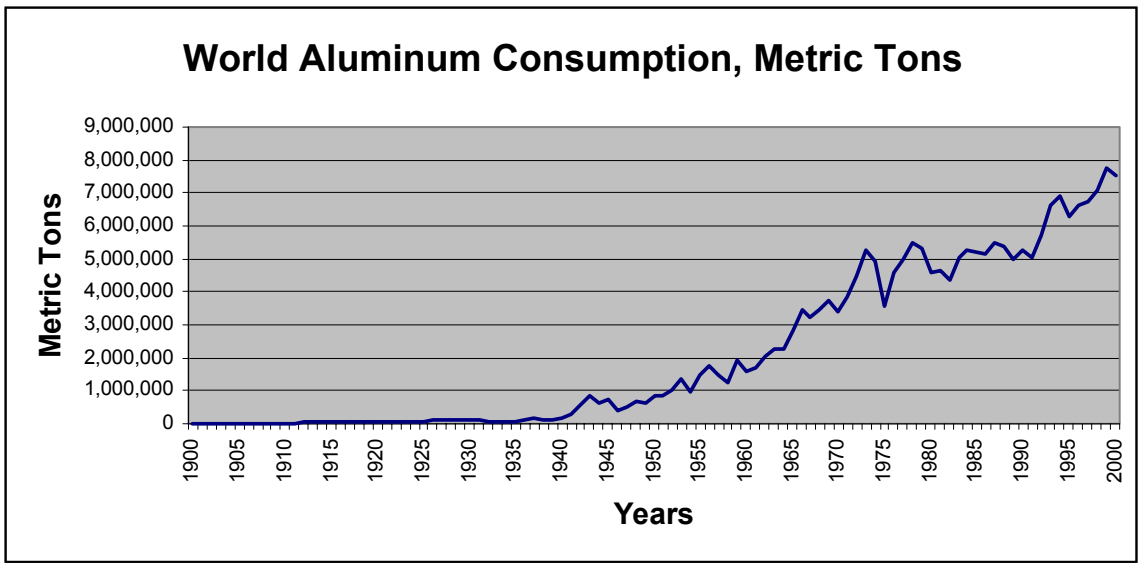
## Aluminum Markets

**Chart 1: Aluminum Consumption in China**



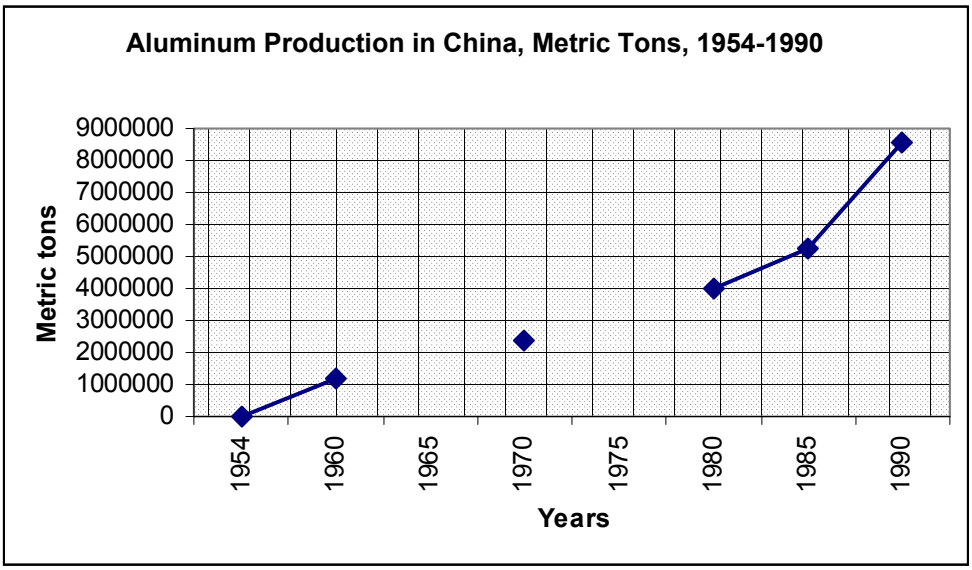

Source: Interfax (2002)

**Graph 1: World Aluminum Consumption**



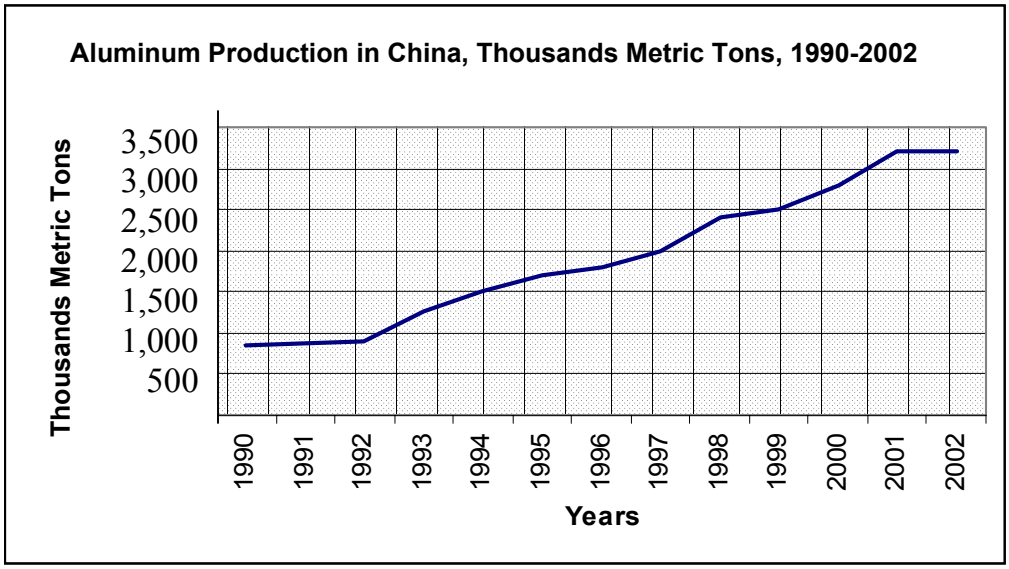

Source: U.S. Geological Survey, 2002

**Graph 2: Aluminum Production in China, 1954-1990**



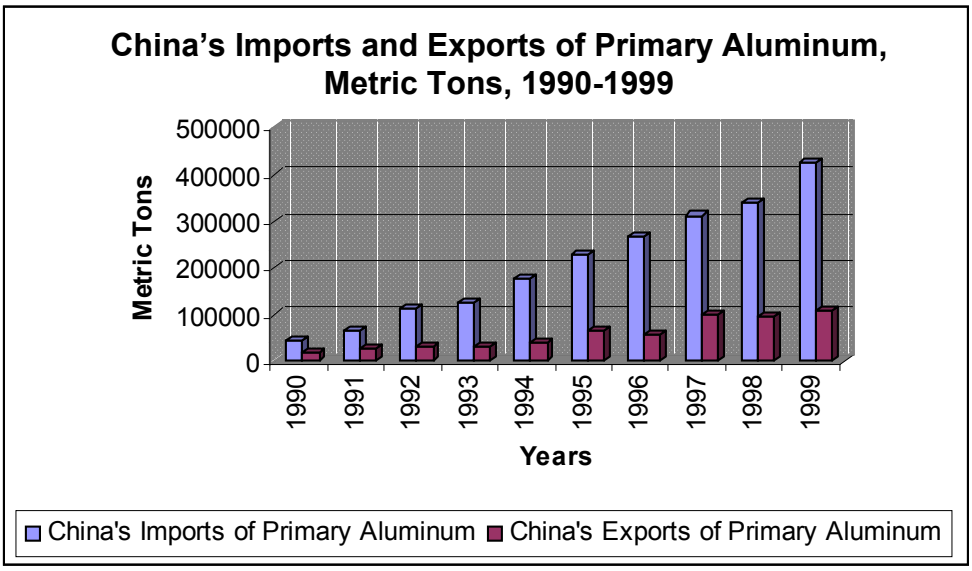

Source: Qun (1994).

**Graph 3: Aluminum Production in China, 1990-2002**



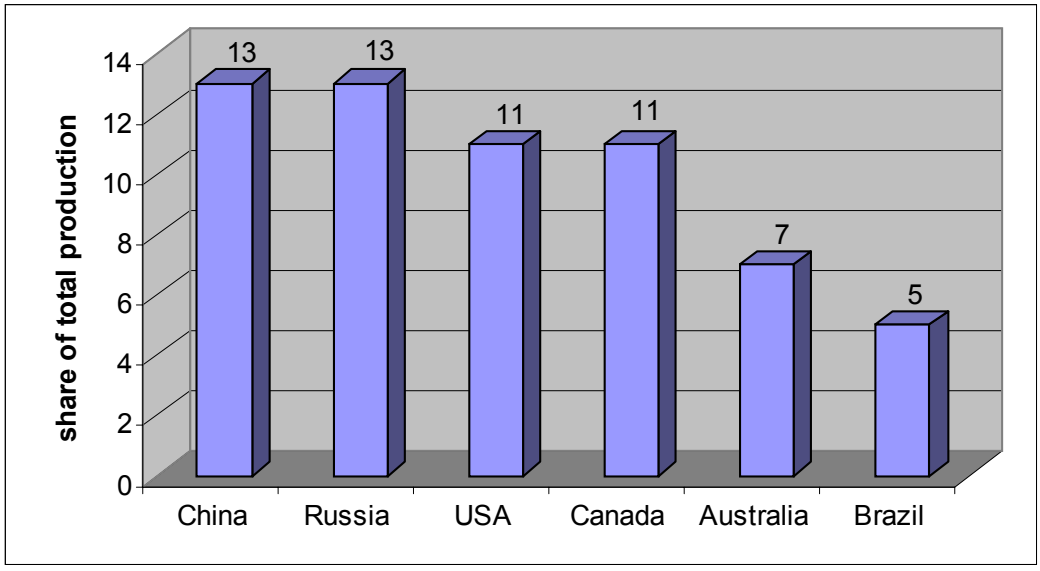

Source: U.S. Geological Survey, 2002

**Chart 2: China's Imports and Exports of Primary Aluminum**



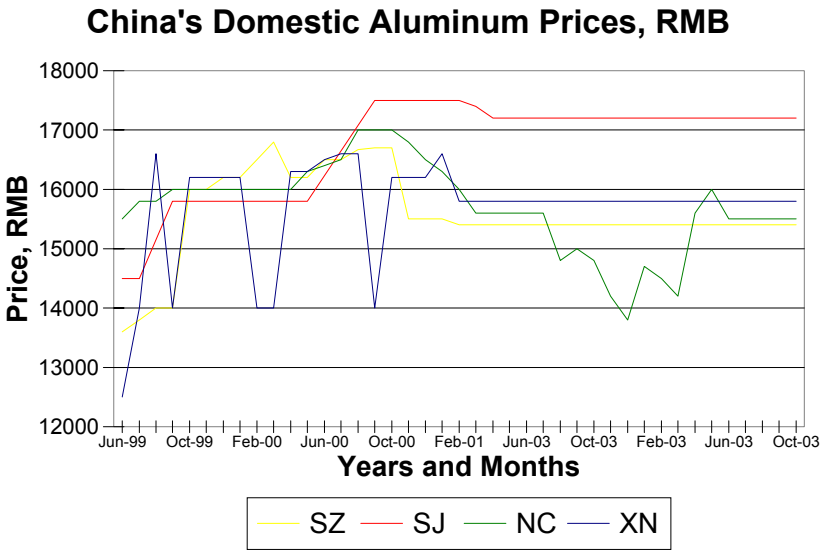

Source: Import/Export Data for years 1990-1993 is taken from Wang (1995);
Import/Export Data for years 1994-1997 is taken from Tang and Chen (1998);
Import/Export Data for years 1998-1999 is taken from *International Trade Statistics Yearbook*, issues 1998,1999,2000

**Chart 3: World Shares of Aluminum Production (in Percentage Terms), 2002**




Source: *U.S. Geological Survey*, 1994-2002

**Graph 4: China's Domestic Aluminum Prices, RMB**




SZ:Shenzhen, Guangdong
SJ: Shijiazhuang, Hebei
NC: Nancheng, Jiangxi
XN: Xining, Qinghai

**Appendix 2**

## Risk Management via Hedging on a Metal Futures Exchange - Examples

The following examples have been adapted from the COMEX Guide to Hedging.

### Example 1 – Aluminum Producer's Hedge

The producer's hedge is of particular use to metal producing industries, especially during periods of high price volatility. Because spot and futures metals prices almost always change in the same direction, metal futures have remove much of the risk associated with unexpected price movements and revenue forecasting.

In February, an official of a new mining venture reviews the company's most recent aluminum production plans. The sales and production projections suggest that the company will have 3 tons of newly cast aluminum available for sale the following July. The executive considers the current price of the August aluminum futures contract at $1,500 favorable, given the company's total production costs, including interest and depreciation, of $900 per ton. As a result, the mining executive decides to lock in a profit by hedging his anticipated production.

| Cash Market | Futures Market |
|---|---|
| ***In February:*** Aluminum spot price on the COMEX Division is $1,390. A smelting company decides to hedge to lock in a sales price in excess of the break-even production cost level of $900. | Sells 10 August aluminum contracts at $1,500 per ton. |
| ***In July:*** The price of aluminum drops over the intervening five months to $1,150. The smelting company sells 10 tons of aluminum at this price, which is still above estimated production costs but below the price prevailing in February. | Buys 10 August aluminum contracts at $1,210 per ton |
| **Cash Loss: $240/ton** | **Futures Profit: $290/ton** |

**Overall profit from the hedging transaction: $50 per ton**

The $240 loss on the cash side of the transaction is not realized but simply represents the fall in spot aluminum prices over the five-month hedge. Had the producer not hedged, the 10 tons of aluminum would have been sold at $1,150. While still acceptable from a cost of production standpoint, an opportunity cost is also implied. This is equal to the price risk of not hedging. By hedging, the producer enjoyed a significantly more attractive return. The futures side of the transaction was associated with a profit of $290 per ton, for a net hedge profit of $290, after accounting for the cash market loss.

Since the producer sold a newly refined ton of aluminum at $1,150, the effective sales price in a falling market, including the hedge profit, was $1,440.

The producer could have captured the entire gain by delivering the 10 tons of newly refined aluminum, fulfilling the obligation incurred by the 10 August futures. In

practice, however, producers generally opt to sell their metal through their normal distribution channels, and liquidate their futures positions.

**Example 2 – Aluminum Dealer's Inventory Hedge**

In February, an aluminum dealer contracts with a producer to buy 500 tons for immediate delivery at the prevailing market price of $1,300 per ton. The dealer will ultimately resell the metal to fabricators. In the meantime, to protect his profit from a decline in the market and a loss of inventory value, he sells May aluminum futures simultaneously with his agreement to buy the metal from the producer.

The dealer sells 500 May futures, the equivalent of 500 tons. The dealer will not liquidate his hedge until he finds a buyer for the metal.

In mid-April, the dealer finds a customer for his metal who agrees to purchase the aluminum on the basis of the May futures settlement price on April 15, at which time the dealer must liquidate his futures position. The hedge looks like this:

| **Cash Market** | **Futures Market** |
|---|---|
| ***In February:*** | |
| Dealer buys 500 tons at $1,300 per ton. | Sells 500 May futures contracts at $1,360 per ton. |
| ***April 15:*** | |
| Sell 500 tons at $1,340 per ton. | Buy 500 contracts at $1,380 per ton. |
| **Result: Gain of $40 per ton** | **Loss of $20 per ton** |

**Overall Profit $20 per ton**

Not only did the futures market permit the dealer to cover his forward risk, but his hedge enabled him to carry his inventory until he was able to sell his aluminum, earning an anticipated profit. Since he purchased his futures contracts simultaneously with his sale of the metal, he was fully compensated for the cost of carrying inventory until mid-April.

Had he not hedged the 500 tons, he would have had a cash market profit of $40 per ton, but the price of aluminum could just as easily gone against him, creating a major inventory loss that the dealer sought to avoid.

## Appendix 3

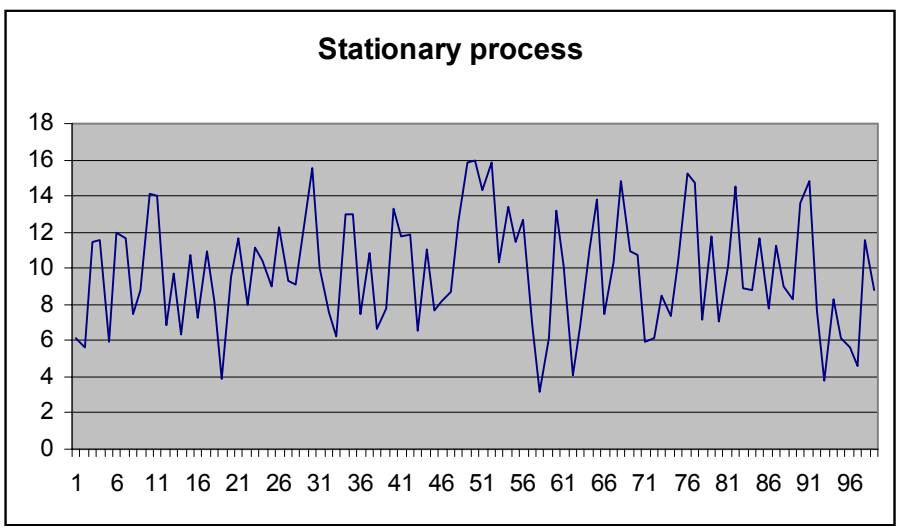
## Stationary and Nonstationary Data

An example of a stationary process is the so-called *moving average* process, MA(1), generated by the equation

$$X_t = \mu + \varepsilon_t + \delta\varepsilon_{t-1} \qquad \text{(A1)}$$

where $\mu$ is the data series mean and $\varepsilon_t$ is a random shock at time *t* with zero mean and a distribution function that is stable across individual data points (Kennedy, 1998). The following data series was generated in Excel in accordance with (A1) for $\mu = 10, \delta = 0.5$ and $\varepsilon_t$ distributed uniformly across the interval -5 and 5. The equation =$F$2+C2+$E$2*C1 was used where the column C stored a series of random errors generated by =RAND()*10-5.

**Graph 5: Stationary Process**



A typical example of a nonstationary process is the so-called *random walk with a drift* process. The data series is generated by the equation

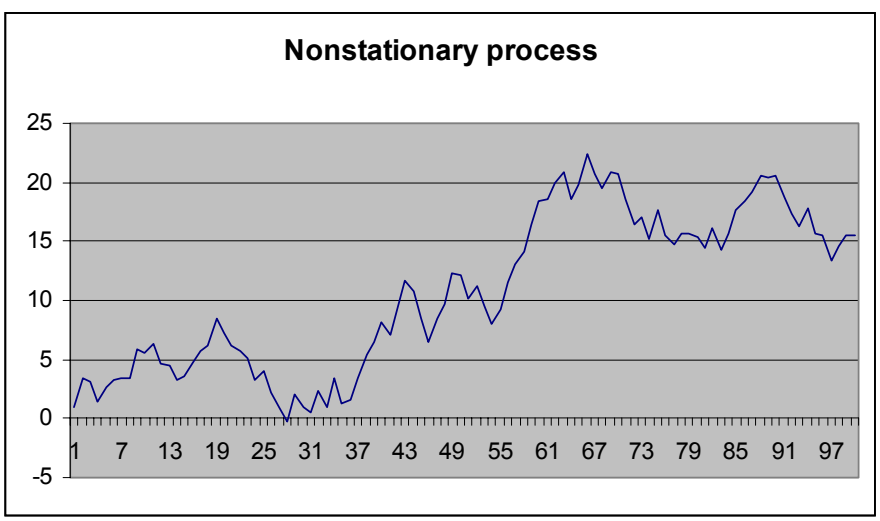
$$y_t = y_{t-1} + \delta + \varepsilon_t \qquad \text{(A2)}$$

where $\delta$ is a constant term representing the drift and $\varepsilon_t$ is a random error term with the Gaussian distribution function. This process reaches a new level at each period $t$ and starts from there the next period. Thus the mean of the process will shift each $t$ and the series will be nonstationary. If a new series is created by taking the differences between individual data points, the new series will be determined by the equation

$$\Delta y_t = \delta + \varepsilon_t \qquad \text{(A3)}$$

which represents a stationary process since the probability distribution (i.e. statistical properties) of $\varepsilon_t$ remain the same each period $t$. This implies that the original process (A2) is integrated of order 1 or I(1) (Kennedy, 1998). The following series was generated in Excel to comply with (A2) by the equation =A1+0.2+RAND()*5-2.5:

**Graph 6: Nonstationary Process**



## Appendix 4

## Variables with and without the Presence of Cointegration

The key feature of variables that are cointegrated is that they follow a similar stochastic trend, which implies that a random shock is common, to a certain degree, to all of them. Variables that are not cointegrated may follow a similar deterministic trend but any random shocks are unique to each variable. Such variables may thus "rise together" in their deterministic component due to, for example, inflation push on prices, but still not exhibit the presence of cointegration (Kennedy, 1998).

Graph 7 shows variables that follow the same deterministic trend but are not cointegrated since they each experience a separate random shock. The series have been generated in Excel over 100 data points using the following formulas:

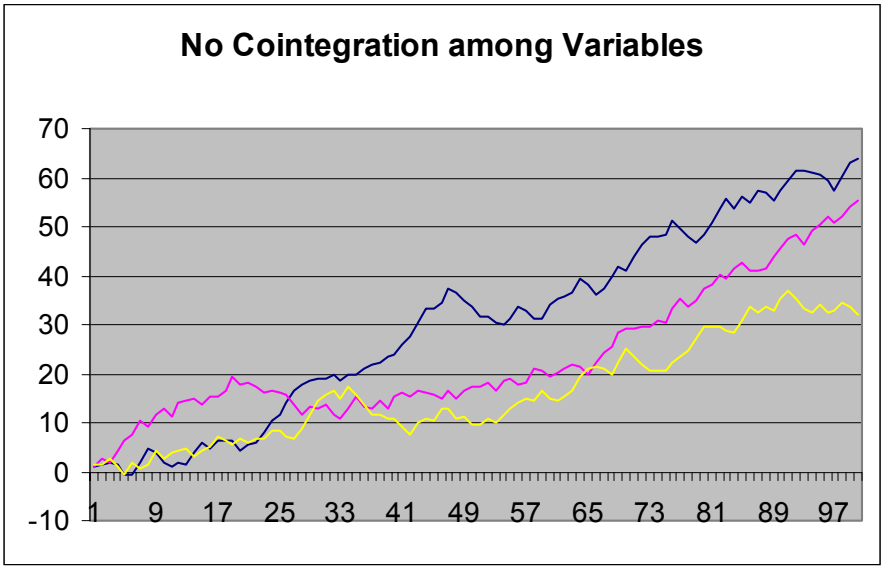
Series 1: =A1+0.4+RAND()*5-2.5

Series 2: =B1+0.4+RAND()*5-2.5

Series 3: =C1+0.4+RAND()*5-2.5

Thus each variable rises by an additive deterministic component of 0.4 plus at random shock distributed uniformly between -2.5 and 2.5. The intercept at the first data point is 1, 1.2, and 1.5 respectively.

**Graph 7: No Cointegration among Variables**




Graph 8 shows an example of variables that are cointegrated. The three series were generated in the following way: first a reference sequence of random numbers uniformly distributed between -10 and 10 was generated by the command =RAND()*20-10 in column E. Then each of the three variables in Graph 8 was derived from the reference sequence using the formulas

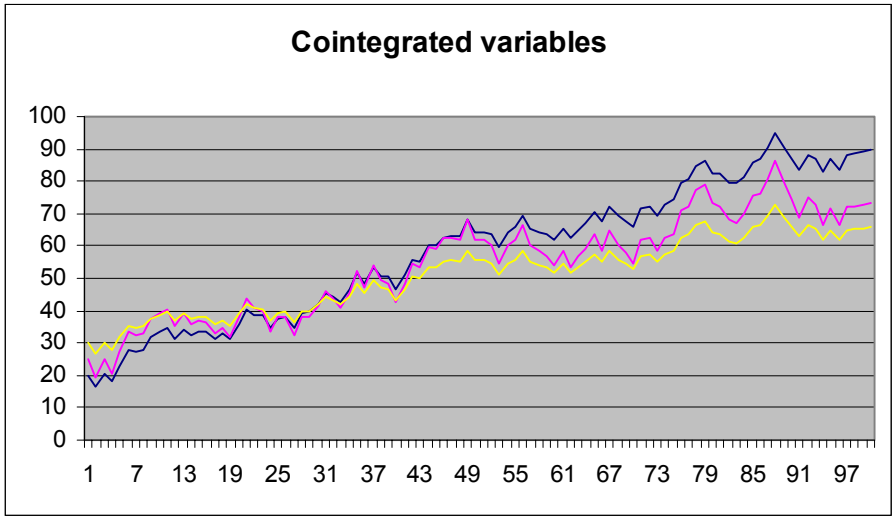
Series 1: =A2+0.5+0.5*$E3

Series 2: =B2+0.2+0.7*$E3

Series 3: =C2+0.2+0.4*$E3

Each of the series follows its own deterministic trend (0.5, 0.2 and 0.2 respectively) and each of them also rises by a proportion of the common random reference shock (50%, 70% and 40% respectively). The intercept at the first data point of occurs at 20, 25 and 30 respectively.

**Graph 8: Cointegrated Variables**



## Appendix 5

## ECM Example

The following serves only as an example of what an Error-correction model looks like and was taken directly from Asche, Osmundsen and Tvertas (2000). Statistical software takes care of the proper form of the ECM and execution of the Johansen test using the ECM and the data. Thorough understanding of the following is therefore not required for performing the Johansen test.

The vector counterpart of (2) expressed in the ECM form can be written as

$$\Delta \mathbf{x}_t = \sum_{i=1}^{k-1} \Gamma_i \Delta \mathbf{x}_{t-i} + \Pi_K \mathbf{x}_{t-k} + \mu + e_t \qquad \text{(A4).}$$

where $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$, $i = 1, \ldots, k-1$. The vector $\mathbf{x}_t$ contains all the $N$ variables to be tested for cointegration, assumed to be generated by an unrestricted $k^{th}$ order vector autoregression in the levels of the variables;

$$\mathbf{x}_t = \Pi_1 \mathbf{x}_{t-1} + \ldots \Pi_k \mathbf{x}_{t-k} + \mu + e_t \qquad \text{(A5)}$$

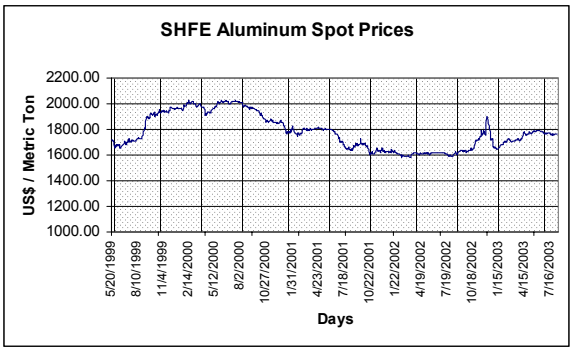
where each of the $\Pi_i$ is a $(N \times N)$ matrix of parameters, $\mu$ a constant term and $e_t \sim iid(0, \Omega)$. $\Pi_k$ is the long-run level solution to (A5). If $\mathbf{x}_t$ is a vector of I(1) variables, the left-hand side and the first ($k$ - 1) elements of (A4) are I(0), and the last element of (A4) is a linear combination of I(1) variables. Given the assumption on the error term, this last element must also be I(0).

# Appendix 6

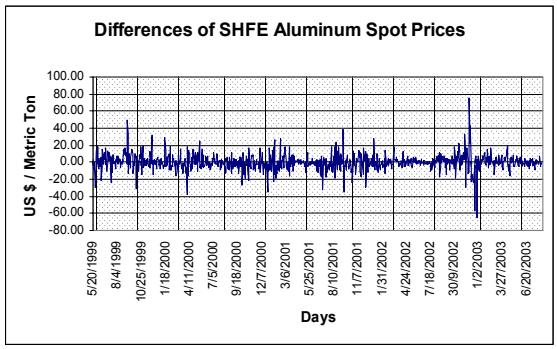
# Test Data Graphical Presentation

## Graphs 9 (a) – (p): Augmented Dickey-Fuller Test

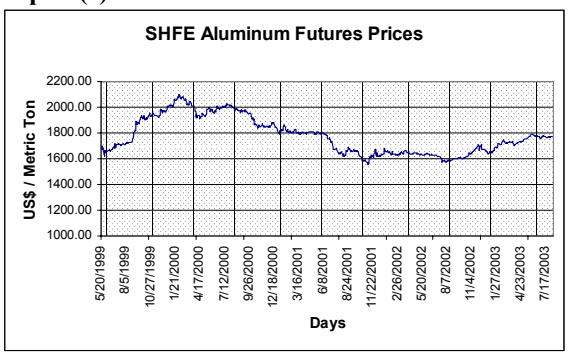
### Graph 9(a)



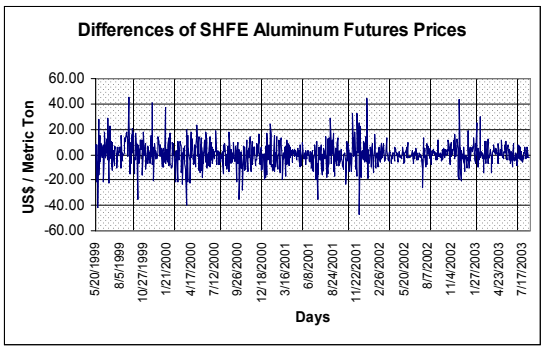

### Graph 9(b)



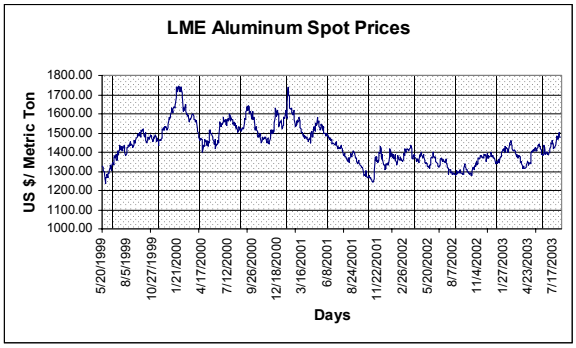

### Graph 9(c)



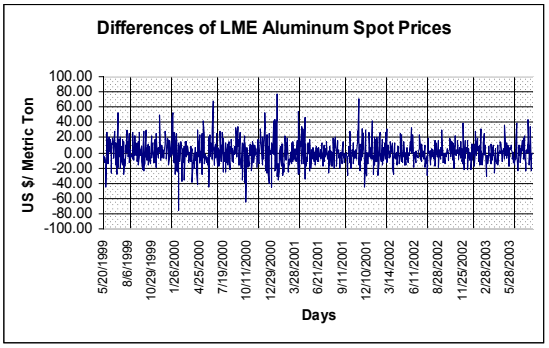

### Graph 9(d)



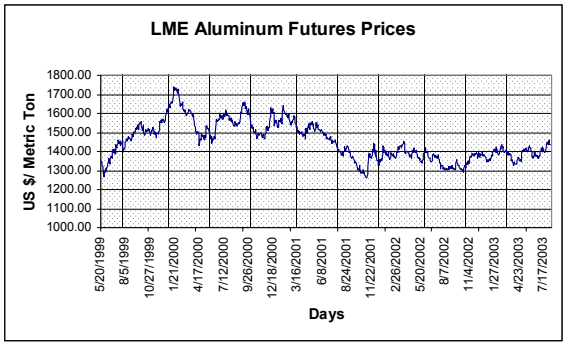

### Graph 9(e)



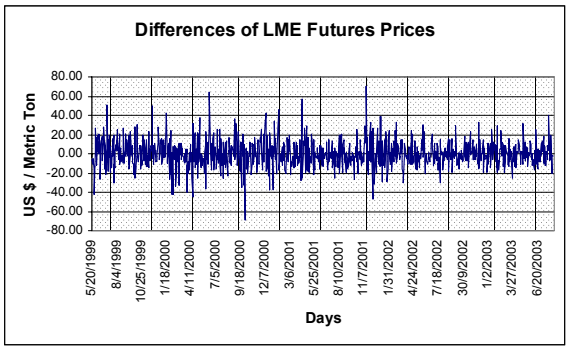

### Graph 9(f)



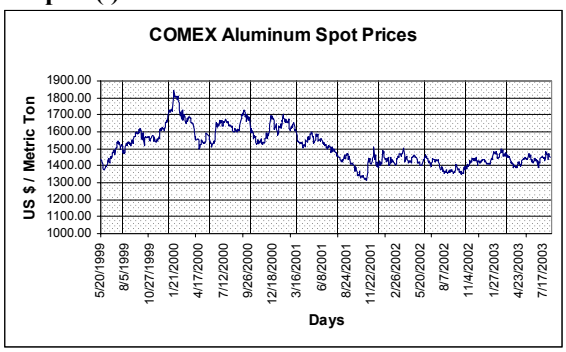
**Graph 9(g)**



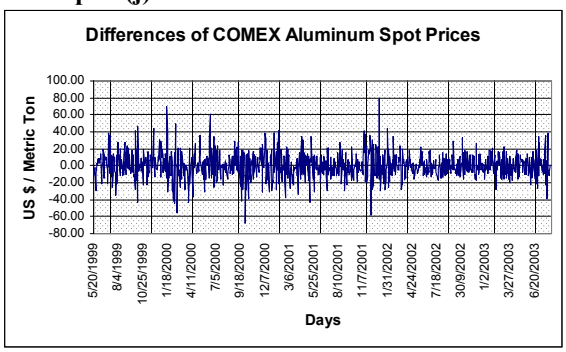

**Graph 9(h)**



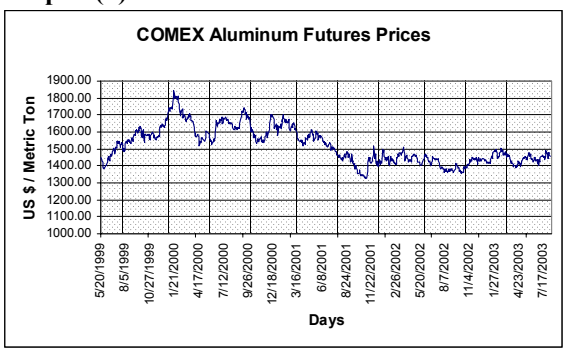

**Graph 9(i)**



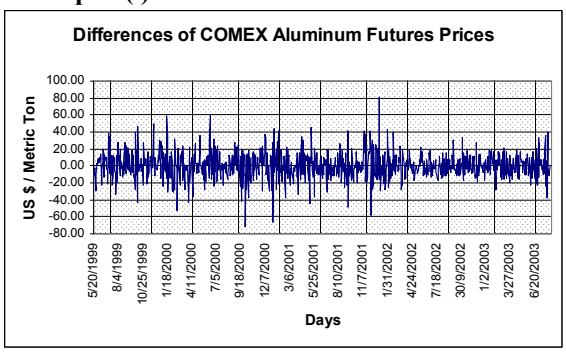

**Graph 9(j)**




**Graph 9(k)**

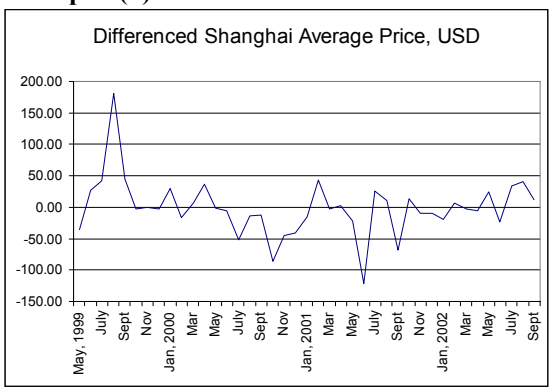



**Graph 9(l)**

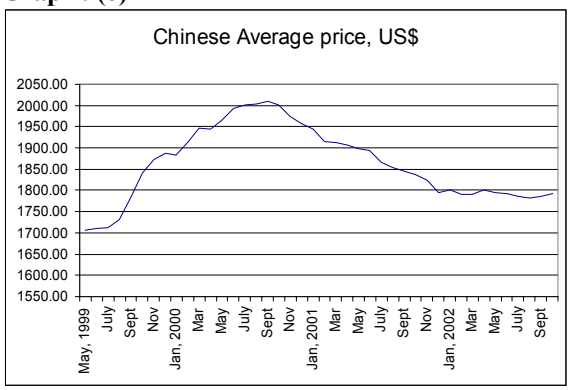


**Graph 9(m)**

**Graph 9(n)**

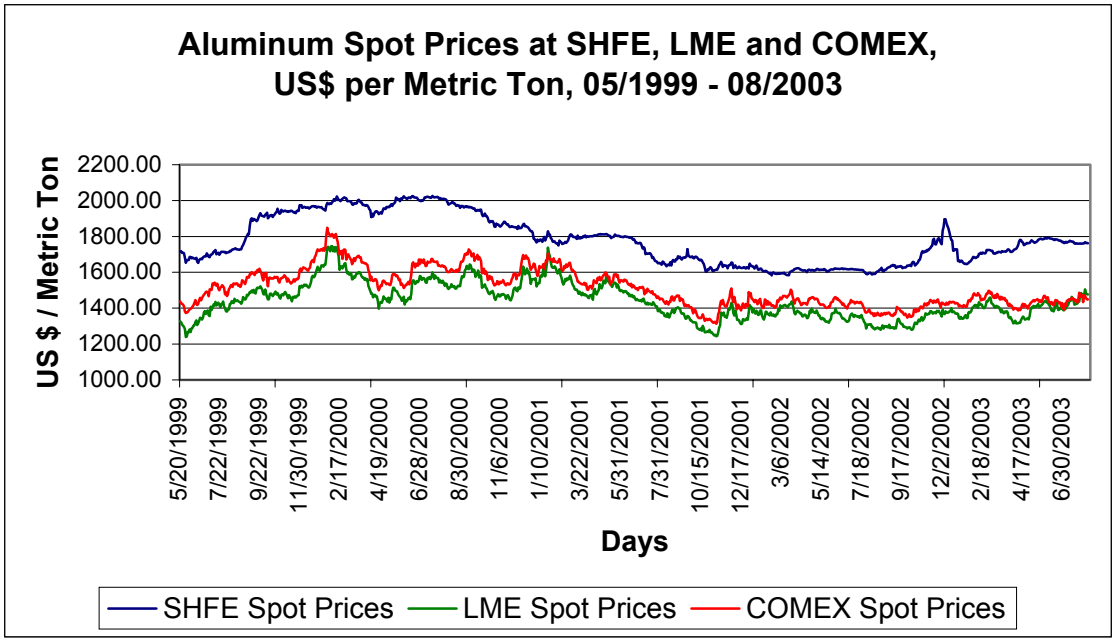



**Graph 9(o)**

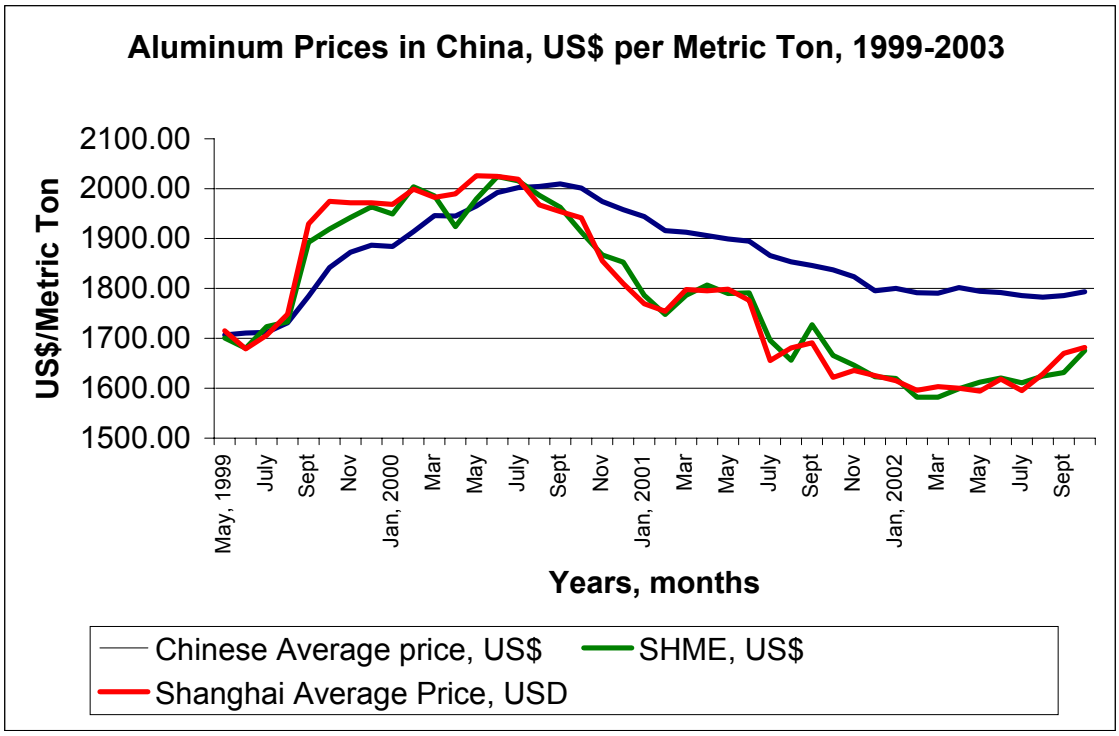



**Graph 9(p)**

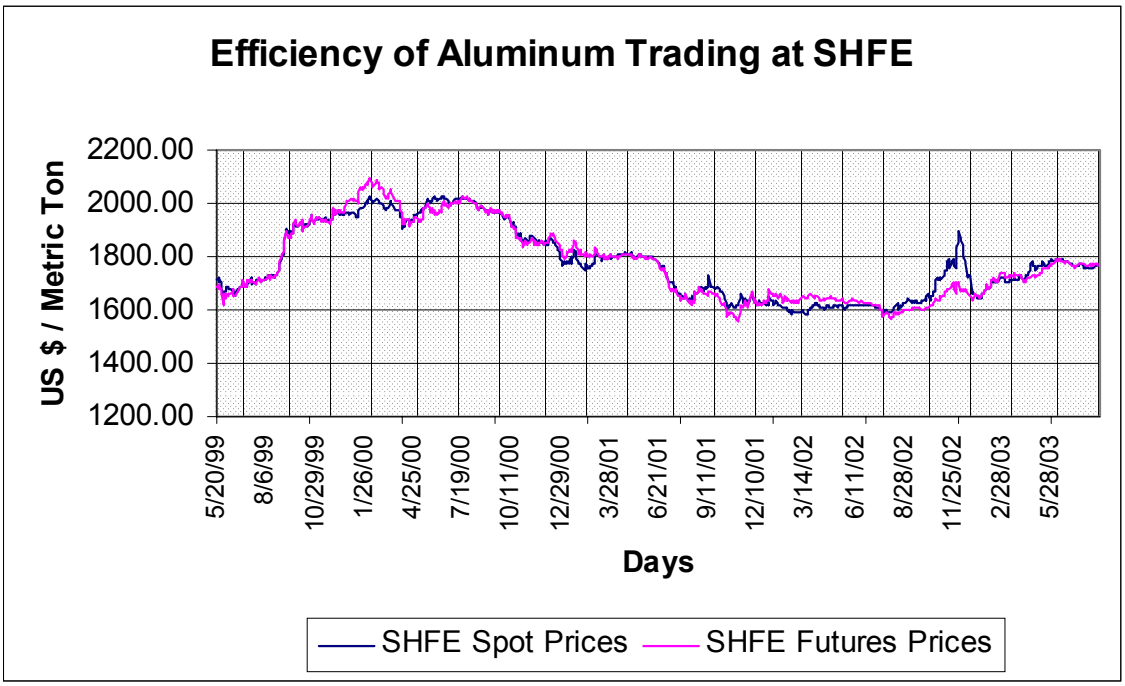
**Graph 10: Tests of Market Integration of Commodity Exchanges**



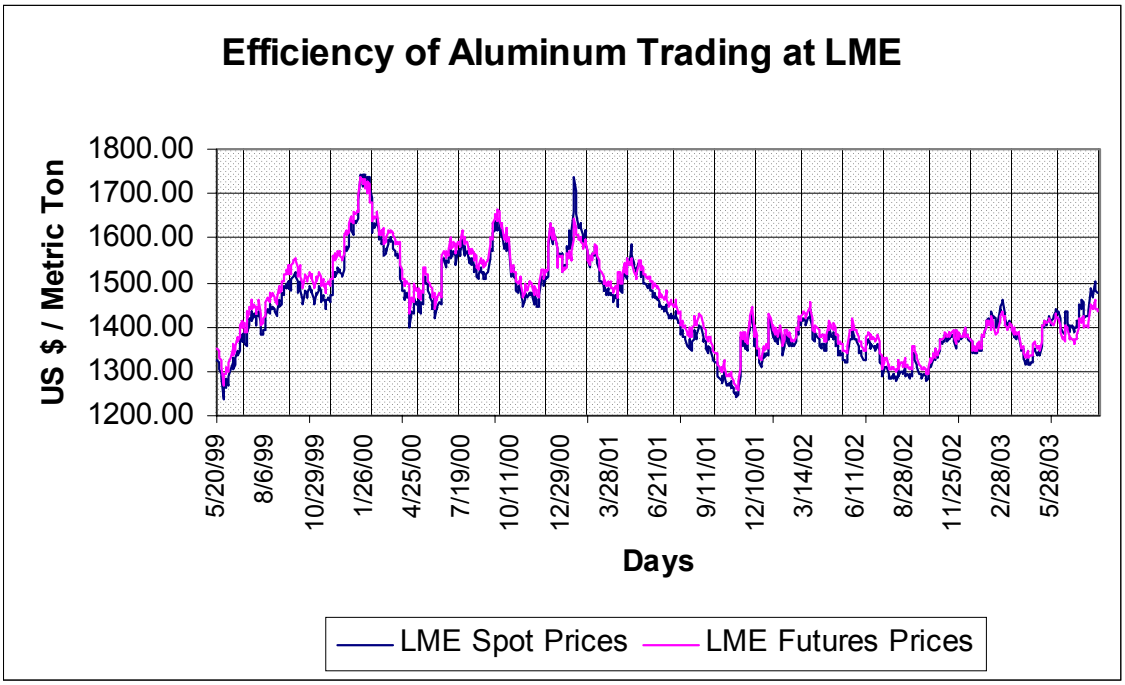

**Graph 11: Tests of Market Integration of Chinese Physical Prices**



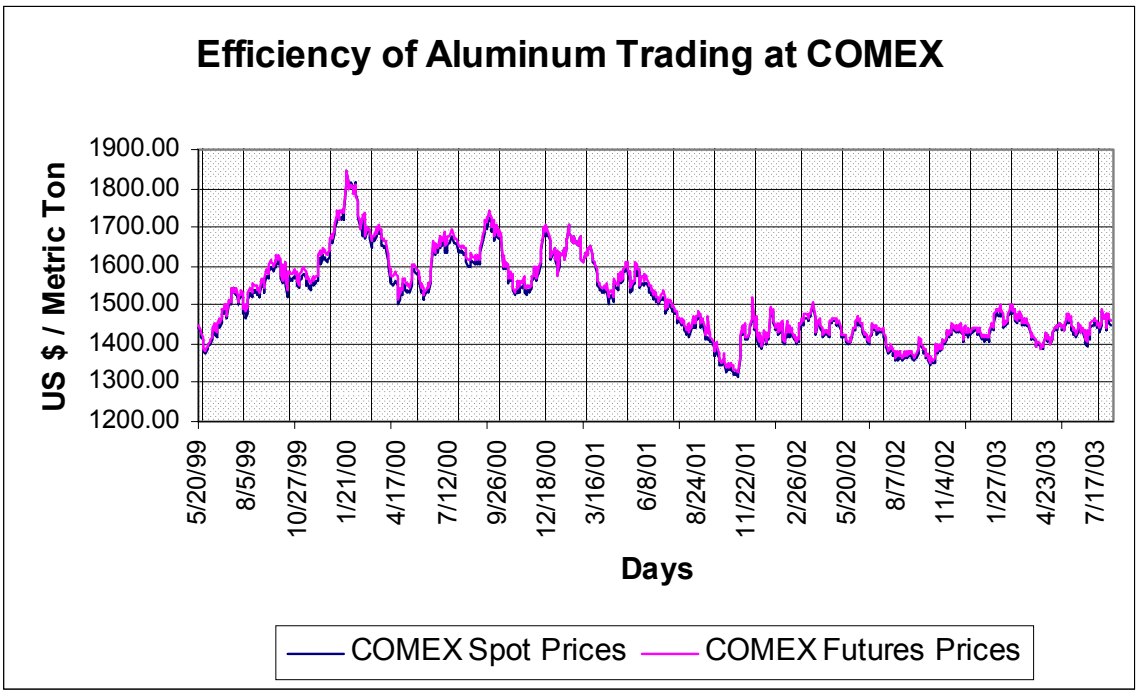
**Graph 12: Efficiency of Aluminum Trading at SHFE**




**Graph 13: Efficiency of Aluminum Trading at LME**



**Graph 14: Efficiency of Aluminum Trading at COMEX**



## Appendix 7

## VARMAX in SAS

### a) Dickey-Fuller Test:

```
proc varmax data=datasheet;
model
      SHFEspotUSD SHFEfuturesUSD
      LMEspot LMEfutures
      COMEXspot COMEXfutures
      SHFEmonth ShPhysAv ChPhysAv
      / p=3 dftest;
run;
```

### b) Dickey-Fuller Test for the Series Differenced Once:

```
proc varmax data=datasheet;
model
      SHFEspotUSD SHFEfuturesUSD
      LMEspot LMEfutures
      COMEXspot COMEXfutures
      / p=3
      dif=(SHFEspotUSD(1) SHFEfuturesUSD(1)
      LMEspot(1) LMEfutures(1))
      COMEXspot(1) COMEXfutures(1)
      SHFEmonth(1) ShPhysAv(1) ChPhysAv(1))
dftest;
```

### c) Test of Market Integration 1 - all three markets:

```
proc varmax data=datasheet;
model
      LMEspot COMEXspot SHFEspotUSD
      / p=3
      ecm=(rank=2 normalize=LMEspot)
      cointtest=(johansen=(IOrder=1 normalize=LMEspot));
cointeg rank=2 h=(1 1, -1 0, 0 -1) normalize=LMEspot;
run;
```

### d) Test of Market Integration 2 – SHFE and COMEX:

```
proc varmax data=datasheet;
model
      SHFEspotUSD COMEXspot
      / p=3
      ecm=(rank=1 normalize=COMEXspot)
      cointtest=(johansen=(IOrder=1 normalize=COMEXspot));
cointeg rank=1 h=(1, -1) normalize=COMEXspot;
run;
```

**e) Test of Market Integration 3 – SHFE and LME:**

```
proc varmax data=datasheet;
model
      LMEspot SHFEspotUSD
      / p=3
      ecm=(rank=1 normalize=LMEspot)
      cointtest=(johansen=(IOrder=1 normalize=LMEspot));
cointeg rank=1 h=(1, -1) normalize=LMEspot;
run;
```

**f) Test of Market Integration 4 – LME and COMEX:**

```
proc varmax data=datasheet;
model
      LMEspot COMEXspot
      / p=3
      ecm=(rank=1 normalize=LMEspot)
      cointtest=(johansen=(IOrder=1 normalize=LMEspot));
cointeg rank=1 h=(1, -1) normalize=LMEspot;
```

**g) Test of Market Integration 6 – SHFE spot monthly Shanghai Physical Average:**

```
proc varmax data=datasheet;
model
      SHFEmonth ShPhysAv
      / p=3
      ecm=(rank=1 normalize=SHFEmonth)
      cointtest=(johansen=(IOrder=1 normalize=SHFEmonth));
cointeg rank=1 h=(1, -1) normalize=SHFEmonth;
run;
```

**h) Test of Efficiency 1 - SHFE:**

```
proc varmax data=datasheet;
model
      SHFEspotUSD SHFEfuturesUSD
      / p=3
      ecm=(rank=1 normalize=SHFEspotUSD)
      cointtest=(johansen=(IOrder=1 normalize=SHFEspotUSD));
cointeg rank=1 h=(1, -1) j=(1, 0) normalize=SHFEspotUSD;
run;
```

**i) Test of Efficiency 2 - COMEX:**

```
proc varmax data=datasheet;
model
      COMEXspot COMEXfutures
      / p=3
```

```
      ecm=(rank=1 normalize=COMEXspot)
      cointtest=(johansen=(IOrder=1 normalize=COMEXspot));
cointeg rank=1 h=(1, -1) j=(1, 0) normalize=COMEXspot;
run;
```

## j) Test of Efficiency 3 - LME:

```
proc varmax data=datasheet;
model
LMEspot LMEfutures
      / p=3
      ecm=(rank=1 normalize=LMEspot)
      cointtest=(johansen=(IOrder=1 normalize=LMEspot));
cointeg rank=1 h=(1, -1) j=(1, 0) normalize=LMEspot;
run;
```

# Appendix 8

## Empirical Results

**Table 3: Augmented Dickey-Fuller Tests**

| Variable | Type | Tau | Prob<Tau |
|---|---|---|---|
| **SHFEspot** | Single Mean | -1.18 | 0.69 |
| | Trend | -1.75 | 0.73 |
| **SHFEfutures** | Single Mean | -1.09 | 0.72 |
| | Trend | -1.77 | 0.72 |
| **LMEspot** | Single Mean | -2.52 | 0.11 |
| | Trend | -3.10 | 0.11 |
| **LMEfutures** | Single Mean | -2.30 | 0.17 |
| | Trend | -3.29 | 0.07 |
| **COMEXspot** | Single Mean | -2.18 | 0.21 |
| | Trend | -3.35 | 0.06 |
| **COMEXfutures** | Single Mean | -2.12 | 0.24 |
| | Trend | -3.34 | 0.06 |
| **SHFEspot monthly** | Single Mean | -2.68 | 0.68 |
| | Trend | -9.27 | 0.44 |
| **China phys avg** | Single Mean | -6.61 | 0.28 |
| | Trend | -5.82 | 0.74 |
| **Shanghai phys avg** | Single Mean | -3.28 | 0.61 |
| | Trend | -11.08 | 0.31 |

**Table 4: Augmented Dickey-Fuller Tests for the Series Differenced Once**

| Variable | Type | Tau | Prob<Tau |
|---|---|---|---|
| **SHFEspot** | Single Mean | -20.48 | <.0001 |
| | Trend | -20.48 | <.0001 |
| **SHFEfutures** | Single Mean | -22.31 | <.0001 |
| | Trend | -22.32 | <.0001 |
| **LMEspot** | Single Mean | -23.06 | <.0001 |
| | Trend | -23.05 | <.0001 |
| **LMEfutures** | Single Mean | -23.18 | <.0001 |
| | Trend | -23.18 | <.0001 |
| **COMEXspot** | Single Mean | -23.09 | <.0001 |
| | Trend | -23.09 | <.0001 |
| **COMEXfutures** | Single Mean | -23.22 | <.0001 |
| | Trend | -23.22 | <.0001 |
| **SHFE spot monthly** | Single Mean | -30.71 | 0.0069 |
| | Trend | -34.47 | 0.0280 |
| **China phys avg** | Single Mean | -12.96 | 0.1372 |
| | Trend | -22.40 | 0.1182 |
| **Shanghai phys avg** | Single Mean | -27.64 | 0.0112 |
| | Trend | -30.48 | 0.0403 |

**Table 5: Test of Market Integration 1 (All Three Variables)**

| Variables | Trace statistic | Critical value | Test of restrictions on β (p-value) |
|---|---|---|---|
| LMEspot – COMEXspot - SHFEspot | 26.56 | 29.38 | 0.0508 |

**Table 6: Market Integration Tests 2 – 4 (Bilateral Tests Involving Commodity Exchanges)**

| Variables | Trace statistic | Test of restrictions on β (p-value) |
|---|---|---|
| SHFEspot - COMEXspot | 12.83 | 0.0499 |
| SHFEspot - LMEspot | 14.24 | 0.0206 |
| LMEspot - COMEXspot | 16.70 | 0.1060 |

**Table 7: Market Integration Tests 5-10 (Bilateral Tests of Commodity Exchagnes for Two Half-periods)**

| Variables | Trace statistic 1st period | Trace statistic 2nd period | Test of β restrictions (p-value) 1st period | Test of β restrictions (p-value) 2nd period |
|---|---|---|---|---|
| SHFEspot - COMEXspot | 9.73 | 16.82 | 0.0271 | 0.0026 |
| SHFEspot - LMEspot | 9.02 | 13.49 | 0.0232 | 0.1028 |
| LMEspot - COMEXspot | 19.53 | 19.80 | 0.6967 | 0.0001 |

**Table 8: Market Integration Test 12**

| Variables | Trace statistic | Test of restrictions on β (p-value) |
|---|---|---|
| SHFE spot monthly – Shanghai physical avg | 20.77 | 0.0684 |

**Table 9: Critical Values for Bivariate Tests at Different Confidence Levels**

| Confidence Level | Critical Value |
|---|---|
| 90% | 13.31 |
| 95% | 15.34 |
| 99% | 19.69 |

**Table 10: Efficiency Tests**

| Variables | Trace statistic | Test of restrictions on $\alpha$ (p-value) | Test of restrictions on $\beta$ (p-value) |
|---|---|---|---|
| SHFEspot - SHFEfutures | 14.66 | 0.4426 | 0.4231 |
| COMEXspot - COMEXfutures | 61.43 | 0.9325 | 0.0433 |
| LMEspot - LMEfutures | 12.53 | 0.1660 | 0.2089 |

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