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THE DAYS-OF-THE-WEEK ANOMALY CHANGE IN LME METAL MARKET～NONLINEAR APPROACH～

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Abstract

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The Days-of-the-Week Anomaly Change in LME Metal Market ~Nonlinear Approach~

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The Days-of-the-Week Anomaly Change in LME Metal Market
~Nonlinear Approach~

Abstract: This paper applies nonlinear nonparametric time series analytic tool by Wayland *et al.* (1993) and also proposes a test by random shuffling to detect existence of periodic pattern in a time series data and analyzes the days-of-the-week effect on London Metal Exchange listed non-ferrous metal returns. The proposed technique makes it possible to carry out hypotheses testing which has not been executed. The empirical analysis investigated the interpolated daily spot & futures price indexes of LME since 1989. The results indicate that there is not only an evidence of the days-of-the-week effect, but also a structural change in metal return weekly anomaly happened around the year of 2003. Why the metal return anomaly change happened is considered.

1. The Introduction

Interest in commodity prices and markets has grown for the past decade. Economic analysis of all the commodity prices is urgently required because of global commodity price-led stagflation happened till 2007 and monetary authority seeking appropriate policy reaction to it. The second reason might be that large institutional investors facing low performing traditional asset markets had globally sought alternative investments. The reason that they are related to environmental problem and resulting tradeoff between biofuel and food is also important.

Abnormal stock returns, for example, have been globally documented on specific days of the week and in specific months (see Tong (2000), among others). The phenomena are called as anomalies. However metal return anomalies have not been documented so far. Daily return movement of such commodities as metal futures contracts listed for the London Metal Exchange (LME) is investigated in this paper by means of high-frequency statistical analytic tools.

These phenomena require both appropriate treatment of data and appropriate tools of analysis because they are nonlinear and noisy. Methods of nonlinear time series analysis are applied to the days-of-the-week effect on LME listed nonferrous metal returns. We question “Do metal prices make peculiar fluctuations on Monday, Friday or other days?” The research is also important to both dealers and national resource policy maker because it is related to the working of metal market.

This paper applies nonlinear nonparametric time series analytic tool by Wayland *et al.* (1993) and also proposes a test by random shuffling of weekly rank to detect existence of periodic pattern in the time series data. Although the nonlinear time series technique by Wayland *et al.* is an improved and simpler measure of chaotic complexity, our proposed technique makes it possible to carry out hypotheses testing which has not been executed. The empirical analysis investigates interpolated daily spot & futures price indexes of the LME aluminum, copper, nickel, lead, and zinc since 1989.

Miyano and Tatsumi (2006) already observed the existence of metal return weekly anomaly (the days-of-the-week returns effect). We document a structural change in metal return weekly anomaly happened around the year of 2003. We also document specifically that there is no difference whether it is rare metals or ordinary metals and that it is observed regardless of the maturities. The phenomena are new aspects, unknown so far and additional to recent commodity price inflation. We consider next why the recent metal return anomaly change happened. Speculative or hedging behavior by market participants will have something to do with it.

The study is organized as follows. Section 2 reviews the literatures. Section 3 and sections 4 and 5 present data and methodology. Section 6 discusses results, and section 7 concludes.

2. Preceding and Related Researches

There are not many related researches, rigorously speaking, but notionally similar fields and their relationship with current study have to be briefly noted.

2-1. Metal Study

(1) Seasonality of Metal Return

It is well known that metal storage costs are low relative to value. It is also known that metals are not subject to seasonals in supply or demand. Accordingly metal futures prices showed less seasonality. This is a regression analytic conjecture, not rigorous verification of Fama and French (1997), studying monthly data of COMEX and NYMEX (New York Mercantile Exchange) for January 1967-May 1984, by comparison with such commodity futures as meat and agriculture.

What they did was to detect the monthly effect, not the weekly effect. They documented there was not the monthly effect [(1]. We will verify the weekly effect with statistically more satisfying tools.

(2) Volatility of Metal Return

Several authors examined the impact of pricing regime on price variability with reference to the nonferrous metals industry. Although theoretical arguments are ambiguous, they suggested that the extent of monopoly power is more important than pricing regime as a determinant of the variability.

Producers with market power had undertaken price smoothing in copper market. Since producer pricing system came to an end by the late 1970s, purchasers of copper had incentive to engage in hedging activities through futures contracts. It is also a common knowledge in the aluminum market that the price has behaved differently due to the development of derivatives.

Slade (1991) , with LME listed nonferrous metals monthly data from 1970 to 1986, documented that metal price volatility in the 1980s relative to the 1970s was explained by increased reliance on commodity exchanges, not by declines in the market structure and concentration variables. This was associated with a move from administered producer pricing to exchange pricing. However Figuerola-Ferretti and Gilbert (2001) extended Slade's sample to the recent years and showed that any early differences between the variability of producer and exchange prices had vanished.

2-2. Methodological Argument and Stock Return Anomaly Study

(1) Methodology

Modeling and analyzing high frequency and nonlinear data have become important in finance. Financial time series data exhibits significant nonlinearity, with this nonlinearity predominantly associated with a weekly pattern and also a seasonal pattern.

Since chaos study made clear that nonstochastic factors cause seemingly stochastic dynamic behavior, various methods of nonlinear time series analysis such as Wayland, Bromley, Pickett and Passamante (1993) and Bandt and Pompe (2002) have been presented. The nonlinear time series analysis begins with embeddings, which could naturally be applicable to periodicity analysis.

Another key element is noise. Most analytic methods break down as soon as noise is added to time series data. On these respects, both the nonlinear time series analysis proposed by Wayland *et al.* (1993) and permutation entropy method proposed by Bandt and Pompe (2002) are promising for the analysis of economic and financial time series data.

Equidistant time series data is required when time series analytic techniques are applied to data, if we would like to have satisfactory statistical properties. Most researches have been applied to unequidistant time series data, which cause additional noise. The current paper solves this problem by interpolating the missing data, which is inevitable for such high frequency data as daily data.

On stock market anomaly study, dummy variables for the days of the week or the months have been employed extensively in a linear OLS regression analysis. There is, however, a problem of multicolinearity among dummy variables in this approach. Chien, Lee and Wang (2002) noted the impact of stock price volatility throughout the week or the year on the application of dummy variable regression model and showed that it yields misleading results.

As for the analytical tool of comovement, the Copula analysis or Kendall's tau has been well known these days. Although Copula analysis or Kendall's tau has been utilized as a nonlinear devise, it carries out pair wise matching of two variables. This paper, however, analyzes the degree of coincidence in long run periodic movement of only one single variable.

(2) The Days-of-the-Week Effect on Stock Return

Nonlinear time series analyses explained below have been applied to Japanese financial time series data. After a framework of analysis is well designed, Miyano and Tatsumi (2004) and Miyano and Tatsumi (2008) applied the Wayland test and others to the daily stock price index data of Nikkei 225 and Nikkei JASDAQ Average from January 4, 1989 to August 29, 2003 to detect the days-of-the-week effect in the stock index returns and documented the existence of Monday and Friday effect for Nikkei 225.

3. Data

3-1. Data and Processing

(1) Data Analyzed

Since we will apply the methods of the nonlinear time series analysis to London Metal Exchange listed nonferrous metal returns, daily spot (hereafter ca, or cash), 3 month futures (hereafter 3m, or 3 month) and 15 month futures (hereafter 15m, or 15 month) price indexes of LME aluminum (Al), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) from January 4, 1989 (Tuesday) to February 29, 2008 (Friday) are chosen. This is only for liquidity reason. The trading volume of cash or 3 month futures compared to other longer term futures is so large enough in LME that there is no need to correct thin trading. The same thing can be said to the aluminum or the copper compared to other rare metals.

The daily price index is based on the settlement price. There is not any price limit in LME and therefore price jump has not often been observed.

The expiry date of the 3 month futures contract in LME is daily expired (the contract is settled daily on every business day) and there is no expiration effects observed often in the same commodities of longer expiration date and also other Exchange-listed products.

As breaking time point is chosen August 29, 2003(Friday) when the trading volumes had started to rise tremendously. There are 5352 days and 760 weeks for the period of 1989/01/03/Tue-2003/8/29/Fri, which we call below as past. There are 1645 days and 239 weeks for the period of 2003/8/30/Sat-2008/2/29/Fri, which we call below as recent.

(2) Interpolation

Monday return without Saturday and Sunday interpolation is the rate of change from Friday settlement price through Monday settlement price. Although this return calculates the rate of 3 day price change, the returns on the other days of the week calculate exactly 1 day change. If we combine these data into a series, data with different time intervals are mixed. Time series analytic tools require equidistant on the other hand. This is the reason why an interpolation method will be used extensively in the following.

The sample does not exist naturally on holidays and weekends. Also the data of the Bank holiday and the first day in January are not measured, since these days are the national holidays in UK. The nonexistent or missing data of metal prices are linearly interpolated in the following study. Monday return with the interpolation is therefore the rate of change from the estimated Sunday settlement price through Monday settlement price. Filling in the nonexistent values with the estimates, which comprise 6997 observations, these are then calculated to yield daily returns.

The method of the interpolation is to replace the missing values by the values interpolated by two days just before and just after when there exists data. If there are n consecutive data missing, the coefficient of interpolation for the i-th value will be ((n-i+1)/ (n+1), i/ (n+1)). Suppose there are no data on six consecutive days. Then the coefficients of interpolation will be (6/7, 1/7), (5/7, 2/7), (4/7, 3/7), (3/7, 4/7), (2/7, 5/7), and (1/7, 6/7).

(3) Return Calculation and Statistics

Ordinary return concept is utilized in the following. One exception is that interpolated price is used if on any day there is no settlement price in the market. Annualized percentage daily return is then calculated by multiplying 36000 to the return. Thus the daily returns which we use are strictly 24-hour returns. Fundamental statistics of the daily returns are in **Table 1**.

Aluminum daily returns haves lower standard deviation (SD) than those of copper and others. There is evidence of high kurtosis in the series and the skewness of metal returns is more eminent than that of the normal distribution. Furthermore the interpolated daily returns of the metals are distributed more closely to the normal distribution than those of Japanese stock returns (see Miyano and Tatsumi (2004)). Recently this tendency has become clearer.

3-2. Interaction Effect ~ Correlation Coefficients between Commodities

For the interpolated daily returns, correlation coefficients are calculated in **Table 2**. It is known that futures returns and cash returns comove so that only the correlations of the 3 month returns among commodities are shown. Other correlation coefficients are calculated also, but not shown in tables.

We would expect that some commodity-specific property might affect both spot and futures price behavior of the commodity. For example, the aluminum futures trading with higher liquidity might yield lower standard deviation of its return in comparison with that of copper, as shown in the preceding section. Liquidity might also affect correlations.

The correlation coefficients of over 0.5 between the aluminum return and the copper return has to be said high, although not extremely high. Arbitrage might partly cause the results, although it is also true that they are substitutes for some industrial use.

The correlations of the 3 month returns among the commodities have increased unanimously, seen from **Panel A** comparing with **Panel B** of **Table 2**. We would expect that some trading strategies among the commodities might affect both spot and futures price behaviors. We will come back this point later.

4. Periodicity Analysis by Rank

4-1. Analytical Framework

(1) Setting

Let a time series $\{u(t)\}$, $t=1,2,\cdots, N$, be given, consisting of N consecutive data points of variable u observed equidistant in time. Suppose we would like to detect whether m consecutive samples in the time series have any periodicity. For examples, m is 5 for a weekly pattern of daily data and 12 for a yearly pattern of monthly data. The latter is exactly the seasonality problem.

For simplicity of exposition without loss of generality, let N be μ times of m. The whole sample is then divided to μ groups by m consecutive samples. In terms of vectors, $\{u(t)\} = \{(u(1), u(2), \cdot\cdot, u(m)), (u(m+1), u(m+2), \cdot\cdot, u(2m)), (u(2m+1), u(2m+2), \cdot\cdot, u(3m)), \cdot\cdot\cdot\cdot, (u((\mu-1)m+1), u((\mu-1)m+2), \cdot\cdot, u(\mu m))\} = \{\mathbf{u}(m), \mathbf{u}(2m), \mathbf{u}(3m), \cdot\cdot\cdot\cdot, \mathbf{u}(\mu m)\}$.

We then compose vectors by rank, ranking among the m values.

$$\mathbf{y}(im) = (x((i-1)m+1), x((i-1)m+2), \cdot\cdot, x(im)), i=1,2,\cdots, \mu,$$

where x is the positive integer up to m. The number of combination of the rank becomes m! =M [(2]. We will call these μ vectors as the original data and consider the m-dimensional vectors separately in the original data.

(2) Hypothesis Testing in General

It may be likely that we would like to know whether the rank of a specific column is on average higher than that of other columns in the vectors. More specifically it is interesting to know whether the rank of a specific column has a tendency to be higher than the overall average. Here the overall average of the specific column is taken over the μ values.

The procedure to test this hypothesis follows. The ranks of the m columns in the original μ vectors are randomly shuffled 40 times in order to know how often the ranking would appear. The randomness is assured by utilizing the uniform and independent white noise. The numbers (40 times) of shuffling might be appropriate for the application of Central Limit Theorem.

For each column, 40 ranks thus obtained are used to calculate its average and standard deviation. The derived distribution of the ranks can be used to test a hypothesis whether the realized original rank is significantly larger or smaller than the overall average rank. If we could assume Gaussian process for x, this distribution could be utilized to test the hypothesis and its test statistics might become that of the familiar student's t-test. We could call the testing procedure as WRRS (Weekly Rank Random Shuffling).

Using this test statistics, Tatsumi and Miyano (2004) and also Miyano and Tatsumi (2008) rejected a null hypothesis that Monday stock index returns are smaller than their averages in Japan.

4-2. Application to Daily Metal Return Anomaly

(1) Weekly Rank Random Shuffling Analysis

When we consider the days-of-the-week effect by the random shuffling approach, the weekday returns are only considered. Let the metal returns on Monday through Friday be R_1, R_2, R_3, R_4, and R_5, and then calculate ranking among them. The highest return gets the number 1 and the lowest is 5. A weekly rank vector will be denoted as y (5) = (x_1, x_2, x_3, x_4, x_5). There will be 5! = 120 rank vectors.

The reason why we shuffle data is twofold. It is because they might be noisy, which is also the main reason to consider the rank instead of the absolute value. Second is to know the random process of the rank, since the random shuffling generates the random process.

(2) Method of Hypothesis Testing

The procedure of the hypothesis testing is as follows. We shuffle randomly the daily metal prices within week, that is, from Monday through Friday within the same week, 40 times. They are called as 40 surrogate data, getting 41 data sets including the original data.

For data with the interpolation, we then count their ranking within week. The highest return gets the number 1 and the lowest is 5.

For each day of the week we calculate the 40 surrogate return ranking and call it as the average surrogate return ranking. For each weekday we then calculate average and standard deviation of both the original return ranking and the average surrogate return ranking.

The difference between the average of the original return ranking and the average of the average surrogate return ranking divided by the standard deviation of the average surrogate return ranking for each day of the week would be considered the student's t distributed.

This t statistics has a statistical meaning under the null hypothesis that the metal return generating process for each day of the week is random and mutually independent [3]. The null hypothesis should be rejected if the t statistics satisfies the condition $|t| > 2.02$, because the degree of freedom is 40. We will call this null hypothesis as random process hypothesis.

(3) Presentation of WRRS Results

The hypothesis testing executed are presented in **Table 3s**. The null hypotheses on some days of the week are not rejected since the t statistics are lower.

From **Table 3s** it might be concluded that Tuesday and Thursday returns in the past are not random since Tuesday and Thursday returns for both cash and 3 month futures are significant. Tuesday effect is exceptionally clear for nickel and zinc. Positive ranking number on Tuesday means lower ranking (lower return) than the average, whereas negative ranking number on Thursday higher ranking (higher return). Monday and Friday in the past, well known globally in stock return anomaly are, generally speaking, insignificant.

We also find that significant days of the week had been certainly changed from Tuesday and Thursday to Monday and Friday for aluminum and copper. Even for nickel, lead and zinc the level of the significance had changed similarly.

5. Nonlinear and Nonparametric Analysis

5-1. Wayland Algorithm - the Degree of Visible Determinism

The nonlinear time series analysis by Wayland *et al.* (1993), based on the parallelness of neighboring trajectories in phase space, is an improved and simpler variant of the Kaplan and Glass algorithm (1993). We interpret it as a statistical method invented by physicians, but applicable to economic and financial time series data.

(1) Embedding and Time Translation

Given a time series $\{u(t)\}$, D-dimensional phase space is constructed at t_0 by embedding, as $\mathbf{u}(t_0) = \{u(t_0), u(t_0 - \triangle t), u(t_0 - 2\triangle t), \cdots, u(t_0 - (D-1)\triangle t)\}$, where D is the embedding dimension and $\triangle t$ is an appropriate time lag.

Embedding could describe pattern of the movement of the time series. If embedding vectors are close together, they might have a similar pattern.

The central point of the Wayland algorithm is as follows. K nearest neighbors of $\mathbf{u}(t_0)$, denoted as $\mathbf{u}(t_i)$, $i = 0,1,2,\cdots,K$, are randomly found then. The vector $\mathbf{u}(t_i + T\triangle t)$ is called the image of $\mathbf{u}(t_i)$ because each $\mathbf{u}(t_i)$ becomes $\mathbf{u}(t_i + T\triangle t)$ as a time of $T\triangle t$ passes.

The image is generated by time translation. Therefore the change in time series process as times go can be described approximately by translation vector $\boldsymbol{v}(t_i) = \mathbf{u}(t_i + T\triangle t) - \mathbf{u}(t_i)$.

(2) Translation Error and Properties of Wayland Test

The K translation vectors should point in similar directions if determinism is visible, i.e., the time series process is deterministic. The similarity in direction is gauged in terms of a measure referred to as translation error E_{trans}.

$$E_{trans} = \frac{1}{K+1} \sum_{i=0}^{K} \frac{\| \boldsymbol{v}(t_i) - \bar{\boldsymbol{v}} \|}{\| \bar{\boldsymbol{v}} \|},$$

where

$$\bar{\boldsymbol{v}} = \frac{1}{K+1} \sum_{i=0}^{K} \boldsymbol{v}(t_i).$$

The translation error measures how the pattern of the movement changes over time. In chaotic terms, it measures the diversity of directions of nearby trajectories, therefore the degree of visible determinism of the time series data. The more visible the determinism is, the smaller E_{trans} will be.

In Wayland test the E_{trans} estimator is dependent on the embedding dimension D. Further properties are in order. If $E_{trans} \to 0$, the original time series process is considered to be deterministic. If the original time series process is white-noise, then the translation vector $\boldsymbol{v}(t_i)$ becomes uniformly distributed and the E_{trans} estimate will be close to 1. If the E_{trans} estimate is larger than 1, the original time series process is considered to be stochastic.

If D is less than the intrinsic dimension of the original time series process, the E_{trans} estimate is higher. Even if D is larger than the intrinsic dimension, the E_{trans} estimate may be higher because of the redundancy of the embedding space. The detail is not well known for the intermediate range of D (Miyano (1996)).

5-2. Presentation of Wayland Test Results

We will try 1-week translation for weekly returns. In the following △t will be set 1 (weekly return), while *K* will be set 4. In the following experimental works the E_{trans} are estimated for 20 sets of 301 randomly chosen vectors **u** (t_0). To reduce the errors associated with the estimates, the median for each set of **u** (t_0) is sought and then the average over 20 medians is taken.

(1) Differences among Figures

Figures 1 to 5 are for the 5 metals, each having four figures both for 3m futures and cash and for the past and the recent. All figures are calculated by one week translation.

First of all, since the translation error of one week ahead is relatively small and actually minimized at the embedding dimension of 3 to 5 week patterns of weekly returns (see all the **Figures**), determinism is visible for the patterns. Furthermore there is a property of 4-week-periodicity for the weekly returns, roughly suggesting monthly periodicity.

From **Figures 1 to 5** we do not see any big difference among the metals. The same thing can be said between cash and futures, and also among the days of the week. Each translation error in every **Figure** moves very closely so that there are no differences among the days of week. Very narrow band, smaller than 0.1 except quite a few, is observed from **Fig. 1s** to **Fig. 5s**.

(2) Metal Return Dynamics

By the results of Wayland test we could know several other dynamic behaviors of the metal returns, which are below in order.

① Recent levels of the translation error in every commodity, both for futures and cash, are higher than those of the past. In the past the levels of the translation error are same among the listed commodities. They were approximately 0.2-0.3 when we take look at the dimension 4, whereas they vary recently between 0.25 and 0.50.

② Recent weekly patterns of the return movement (the range of the translation error) have been more volatile than before.

(3) Drawbacks of Wayland Test

There are several drawbacks in Wayland algorithm. First, there is no clear threshold of E_{trans} by which the underlying dynamics is classified into either a deterministic process or a stochastic process.

Secondly, in order to determine the appropriate value of the time translation T, we have no definite criterion, instead of trial-and-error. We rather introduce financial economics rationale in here, that is, time series anomalies.

Thirdly it is difficult, though not impossible, to estimate the reliable interval for estimates of E_{trans}, which in turn prohibits carrying out hypothesis testing. How can we judge, for example, when the E_{trans} have fluctuated drastically depending on the embedding dimension? Wayland test cannot generally give any simple and clear conclusion.

These might be the reason why we have proposed a much simpler procedure in the last section, although these techniques are different each other for highlighting different aspects of metal price dynamics.

5-3. The Days-of-the-Week Effect ~ Summary of Findings

(1) The Random Process Hypothesis

Since the random process hypothesis is rejected for Tuesday and Thursday in the past and for recent Monday and Friday, the cash and futures returns of the metals can be said to have the days-of-the-week effect. The effect means both non-randomness and return difference. It is also important to note that both cash and futures returns have shown non-random behavior on the specific days-of-the-week.

Because of Bank holidays in UK, Monday effect which is very familiar in stock market all over the world might move to Tuesday in the case of past LME metal returns (we may call this as Time Difference Hypothesis). In some countries, furthermore, offices and factories are closed on Friday for religious reason. It is sure, however, that further researches with different statistical tools need to be done[(4]. Financial economic reasoning on the specific days-of-the-week effect is also required, which will be our next work.

(2) Wayland Test

Both Wayland test and weekly rank random shuffling approach lead more consistently to the same conclusion in Japanese stock return anomaly studies of Miyano and Tatsumi (2004), Tatsumi and Miyano (2004) and Miyano and Tatsumi (2008).

Even if the translation errors of the cash and futures returns on the specific days of the week might be higher at first sight, it is just a conjecture since we do not have any tools to measure whether the difference among the days of the week is significant. We should say that they might be so or might not be so.

It seems to be sure that the days-of-the-week returns in Japanese stock indexes as shown in Miyano and Tatsumi (2004) move more divergently than those on the LME metals. It is not sure whether this is because the LME is a global market.

(3) The Effect of Interpolation

How we interpolate the Saturday and Sunday prices may affect Monday return and therefore weekly return ranking, leading naturally to a drastic change in the result [(5].

In the above experiment shown in **Table 3-1** Monday aluminum return is significant even in the past. This might have something to do with the interpolation, which in turn might be due to Bank holidays in UK.

6. Discussions and Remarks

Financial interpretation and methodological arguments are in order.

6-1. Preliminary Discussions

(1) Observation for All Metals and Maturities

Overall, the evidences suggest that the phenomena are observed for all the metals. What does this mean?

The importance of commodities in the world economy differs among them from time to time. Although individual commodities have their own specialty backgrounds(6, speculators could spread their effects. We think this had actually happened and therefore observe that there is no big difference whether it is rare metals or ordinary metals.

The main speculators were physical merchants and investors before 2003 and might have been some funds after 2003. The change in the days-of-the–week effect is observed not only for the 3 month but also the 15 month futures. It is observed regardless of the maturities and therefore regardless of the liquidity. We would expect that the phenomena are at least partly caused by the speculators.

(2) Hedging or Speculation: An Implication

We have found that by rejecting the random process hypothesis the metal returns have not behaved randomly for both spot and futures on the specific days of the week. The function of hedging by means of futures contract has to be recalled with this phenomenon.

The result of hedging by 3 month futures is made clear and determined in 3 months after future spot price is set. The term of 3 month futures contract is approximately 90 days. 90 are not multiples of 7 (one week). Therefore the settlement date of the futures contract might not be the same day of the week as the day of the week when the futures is traded.

If it is true that today's futures price contains information about market participants' expectations about the future (7, we will observe the same day-of-the-week effect between the settlement date of the futures contract and the date when the futures contract is traded. Since we have found the contrary, it implies that hedging has not necessarily fully been successful.

This might be either because market participants' expectations have been wrong or because hedging has been dominated by speculative behavior. Our tentative regression analysis shows that LME market participants' expectations have been realized (unbiasedness hypothesis holds). Therefore we are tempted to conclude that speculative behavior rather than hedging has been eminent since 1989.

(3) Seasonality Argument Once Again

It has been believed that there is no seasonality in metal futures prices and also no comovement of metal futures price with metal spot price. Seasonality in spot prices is not likely to influence futures returns because futures prices represent foreseeable fluctuations that are taken into account when market participants set futures prices. It is because if an event happens surely in August, 3 month futures price incorporate it early in May in advance. This might mean that there is an intrinsic factor which moves futures price, independently of spot price.

Recent empirical analysis by Gorton and Rouwenhorst (2006) also noted this belief, although they did not execute checking whether it is true or not, using their equally weighted monthly commodity futures price index.

This paper has shown that this is not valid at least for daily metal prices. Both on Tuesday and Thursday in the past and recently on Monday and Friday, we have found that the metal spot and futures returns have not behaved randomly by rejecting the random process hypothesis.

(4) Structural Change Test: Anomaly Shifting Testing

Why we have obtained such results that the days-of-the–week effect had been changed?

People might be naturally interested in the process of the transition. If it is true that the funds and emerging countries had suddenly come to the market without notice and caused the phenomena, the detail process of the transition is not needed to be described.

If introduction of any institution caused the phenomena, we need to explain the process neither. Introduction and existence of hedging tools which are implied in JASDAQ anomaly study by Tatsumi and Miyano (2004) and also Miyano and Tatsumi (2008) have nothing to do with the anomaly shifting simply because what we are doing is the analysis of effect of hedging in the presence of derivatives.

Do we need any statistical test of the structural change? There are several ways to nonparametrically test structural (distributional) change[(8] in time series. The most well known test is the Kolmogorov-Smirnov test. The Cramér-von Mises test is a generalization to the former. It is thought that the Cramér-von Mises test is more powerful than the Kolmogorov-Smirnov test, although not shown theoretically. The null hypothesis of these structural change tests is that two sets of samples come from the same distribution, although the test procedure is simply that if the value of test statistic is larger than the tabulated value, we reject the hypothesis.

Generally speaking researchers would like to know how different two population distributions are for structural change. Furthermore for the current study structural change tests have to be carried out within the frameworks of weekly random shuffling and Wayland test. Hence both the Kolmogorov-Smirnov test and the Cramér-von Mises test are not useful for the current analysis. In order to circumvent the problem, we have developed and introduced a new simulation-based statistical method.

Clearly from the construction the null hypothesis of the WRRS test is that the commodities prices move randomly. The null hypothesis of the WRRS randomness for the both periods is the same. If the tests for the both periods show different results, therefore it is evident that there is a structural change.

6-2. Possible Explanation: Hypotheses Raised

What happened eminently between years before and after 2003? Those are both technology and turnover. First of all let us consider these in order. Then institutional change made in the LME has to be explained and be connected to these influential factors.

(1) Technology

Information-communication technology (ICT) has been developed great deal, especially for the past 10 years. Although information processing and analysis took longer time in the past, various problems caused by a difference in time have disolved and various barriers have been overcome by virtue of ICT development and resulting globalization.

Advanced telecommunication technology and improved worldwide information network in recent years have made access to global information easier and faster. The impact of news revealed in one market can affect the returns and volatility in another market in a very short period of time [(9].

Thus market integration has reached to higher level and this is called as globalization. Investors all over the world can now have very easy access to current trading information by virtue of ICT. Lien-Li (2006) emphasized that globalization and ICT make information dissemination faster and return and volatility spillovers across international copper futures markets which they studied.

We could not deny the importance of the technology, but this effect is so overwhelming that it affects not only the specific days of the week, but also every day.

(2) Turnover: New Market Participants

As a global marketplace in the sense that more than 95% of its business comes from overseas, the LME has been attracting such commercial players as mining companies, industrial users, physical merchants and end consumers, other than traditional participants like banks, brokers and investors. Some players have been very active participants.

Such new market players as investment funds and industrial producers in BRICS countries have come into the Exchange. Institutional investors like pension funds, and larger funds like mutual funds and hedge funds had come to the market. But the available data does neither tell us what type of funds enters nor when they enter.

(3) Institutional Changes: Historical Facts of the Market

There are several institutional changes. Does this have any relationship with our observations?

The sample we analyze is in US dollars. For the some metals and/or the some past period of the sample, however, the price in the Exchange is denominated in British pounds. The denomination has not affected our conclusion. The fact that the Exchange ownership had changed in 2000 have little impact on the pricing.

An index contract -LMEX- based on the six primary metals traded on the Exchange was introduced on April 10, 2000. This base metals index is specifically designed to provide investors access to futures and traded options contracts based on nonferrous metals without the physically delivery, storage and transactions costs associated with the underlying commodity contracts.

An electronic trading platform called as the LME Select [(10] was introduced in 2001. For the LME Select, there has been an increase in liquidity. Fund managers are now able to attach their algorithmic trading models.

Although the liquidity has risen since the LME started to offer LME minis in December 2006, which are smaller-sized contracts for copper, aluminum and zinc, the size of the effect of the minis is however smaller than those of the LMEX or LME Select.

(4) Weekend Uncertainty and Uninformed Traders

In order to explain the daily metal return anomaly change the above time difference (Time Difference Hypothesis) could not be meaningful. If the days-of-the-week returns are furthermore in the match with their risk, that is, the days-of-the-week risk had changed similarly, the comovement simply implies well known risk-return relationship (we can call as risk-return hypothesis). However this does not solve the problem since we have to explain why the days-of-the-week risk had changed.

There is a possible explanation, due to stock index derivatives and weekend uncertainty, which causes specific days-of-the-week (for example Monday) loss on return and could be applied to commodity futures. We turn to this point finally.

Suppose that there are both informed traders and uninformed traders in market. The informed traders are likely to have better information from the weekend than the uninformed traders. Because the uninformed traders are at a disadvantage strategically on Monday, the uninformed stay out of the market and the market price is more likely to reveal information of the informed. Using such argument by Foster and Viswanathan (1990) we could conclude that the uninformed traders are unwilling to trade on Monday. This causes negative return and low liquidity on Monday (we can call as uninformed traders hypothesis).

The uninformed traders also might take defensive strategy on Friday to avoid the uncertainty of weekend. One of the strategy when there are no derivatives(11 will be to sell in order to avoid further loss occurred during the weekend. It might be sold to secure profit as far as enough profit is obtained. These behaviors lower the price and therefore the return on Friday. When there are any derivatives, the strategy towards uncertain weekend will be different.

Is it true that funds are the uninformed traders? Are industrial producers in BRICS countries another type of the uninformed traders?

With respect to other aspects we know that informed traders behave differently from uninformed traders. In stock market informed traders make order very quickly immediately after events occur and they have a tendency to submit limit orders generally. Unfortunately such data as the order type are not available in the LME metal futures.

Also uninformed traders might have a tendency to extensively utilize derivatives in order to hedge against the uncertainty of weekend. Unfortunately such order data by participant types are not available in the LME metal futures, so that we could not directly identify the uninformed traders.

Some funds are surely the uninformed traders. The uninformed traders hypothesis could be applied to pension funds and some commingle or multi-strategy hedge funds, which have been newcomers to commodities market.

Index funds in general affect price volatility and market liquidity. They buy (sell) when price goes up (down) and thus affect the price volatility. They hold specific items relatively longer time and thus are said to absorb the market liquidity and then increase the volatility.

Commodity index funds might have affected the price volatility and market liquidity of the LME. An index contract -LMEX- based on the six primary metals traded on the Exchange introduced in 2000 and also an electronic trading platform called as the LME Select introduced in 2001 had supported their transactions.

Emerging countries yielding new demand for industrial use of the basic nonferrous metals had been also newcomers to the LME and were surely the uninformed traders. As far as these countries are developing, the days-of-the-week effect will continue at least for a while before they become used to the market practices.

These market participants might not interested in arbitrage trading among the commodities, which might be a reason why the recent returns compared to the past move differently among the commodities.

(5) Summary of this Section

The recent metal return anomaly change might be caused by some behavior of funds and/or emerging countries. How does this happen?

It is true that lower interest rate (ease monetary condition) and lower performance of stocks might encourage funds investments in such alternatives as commodities. This might be a cause of recent till 2007 commodity price inflation together with the emerging of new industrial countries.

Funds are rather new market participants in commodities market. This might have brought additional problems mentioned in the previous subsection. We believe that these are consistent explanation with the data documented.

The analysis might answer a question whether thing happening in the commodity market is a blip in history or a beginning of a new era. Once the funds and the emerging countries get acquainted with commodities market and also after the anomaly becomes well known even among potential market participants, the anomaly will vanish.

6-3. Methodological Improvement Possibilities

We did not utilize GARCH, well-known as a nonlinear technique, because it is parametric and uses arbitrary function. As for a periodicity analysis we did not utilize ordinary spectral analysis because it is a linear technique in the sense that it detects periodicity from linear addition of nonlinear functions, i.e., Fourier expansion.

Although our random shuffling technique is simple and easily programmed, we are sure that an evidence of its power has been shown. The present paper makes it possible to carry out hypotheses testing. It is not rejected that with the weekends-and-holidays interpolation the metal returns are not random on the some days-of-the-week. There remain several remarks, however, on the methodology.

The nonlinear time series analysis could have begun with another embeddings [(12]. Given a time series $\{u(t)\}$, we construct m-dimensional phase space at t_0 with delayed vectors consisting of lagged sequences of data points as,

$$\mathbf{u}(t_0) = \{u(t_0), u(t_0-1), u(t_0-2), \cdots, u(t_0-(m-1))\},$$

where m is the embedding dimension and also periodic time. Then we have 5 times more samples in the experiment, which might be good for the case of small size sample, although experimental result may not change.

What kind of periodicity is this study detecting? The answer is average return. One might be interested in periodicity of volatility (standard deviation) or higher moments, which could have been executed similarly.

The final remark on perspective of nonlinear analysis is that because tools for nonlinear time series analysis are still developing, we have to watch their progress and judge which to use for nonlinear time series analytical tools.

7. The Conclusion

This paper has documented weekly anomaly of metal returns and also its change around the year of 2003 which have not been documented so far. Although it might be true that anomaly disappears after its researches have published (Dimson, Marsh and Stauton (2002)), what we have found is based on a firm background of data processing. We have carefully excluded noise and outliers by means of interpolation, ranking and shuffling, so that noise and outliers are not the cause of the anomaly.

We could also say to have applied subtle precision, although fundamental, statistics techniques. Considering both spot and futures returns together of various nonferrous metals, we conclude that a weekly anomaly of metal returns exists and it changed around the year of 2003.

FOOTNOTES

1) Fama and French (1997) also documented that metal futures prices showed weak forecast power of future spot price and expected premium.

2) Are there any tendencies in the frequency if we calculate its frequency f_j from the μ rank vector data? One extreme is the equal occurrence which leads to the uniform distribution of f_j, j=1, 2, ‥, M. The other extreme is the concentration at a periodic pattern, i.e., $f_j = 1$ for some j and 0 for other j's. It will be convenient to invent a measure to show how often a specific pattern is observed. The following quantity might have the desirable properties.

$$\sum_{j=1}^{M} \frac{M}{1-M}\left(f_j - \frac{1}{M}\right)^2$$

The minimum is zero when f_j distributes uniformly. The maximum 1 is attained when the frequency concentrates at a periodic pattern. This might be a rough measure of persistence of a periodic pattern.

3) It might be helpful for further understanding to explore the case of the frequencies of the rank vectors. The frequencies ought to be randomly shuffled 40 times. For each rank vector of 120, 40 frequencies are then used to calculate its average and standard deviation. The derived distribution of the frequencies can be utilized to test hypothesis whether the realized frequency is significantly larger or smaller than such a specific value as zero, 1/M, or others.

4) It should be also noted that Wednesday is the special day in the LME. Tuesday and Thursday are days of one day before and one day after the settlement. The LME trades for each business day out to 3m, then every Wednesday out to 6m and then for the third Wednesday of each month thereafter out to a maximum of 63 months for copper and aluminium. Wednesday is also the day of settlement for 15 month futures. LME European options expire on the first Wednesday of every month and settle against the third Wednesday.

5) In order to eliminate this problem, we might take Monday returns out and execute the ranking test in the same way as above. Table 3 in Tatsumi and Miyano (2004) shows the result for Japanese stock returns. Returns are random on Tuesday to Thursday for Nikkei 225, on Wednesday and Thursday for Nikkei JASDAQ Average, getting the same results as the interpolated case. These results might suggest that we have to interpolate the Saturday and Sunday stock prices, otherwise it leads to misleading results on Monday return.

6) For example the decade of 1990s is a very volatile and turbulent period for the copper market worldwide. Copper futures contracts were introduced in the Shanghai Futures Exchange (SHFE) in 1991.

7) This is the market efficiency hypothesis. In a future study we will test the market efficiency hypothesis by the nonlinear nonparametric time series analysis that futures prices

are good predictors of future spot prices.

8) To test for serial independence of the price changes the Ljung-Box-Pierce Q test or the von Neumann's ratio test is employed. Under the null hypothesis of no serial correlation, von Neumann showed that, for large sample, a ratio proposed is approximately a normal distribution with mean and variance given.

There is considerable disagreement, among researches which use such traditional techniques as the serial correlation test, runs test and spectral analysis, over the appropriateness of the random walk model as a suitable description of the price behavior in the commodity markets.

9) Wongswan (2006) found that macroeconomic announcements in U.S. and Japan induce large and significant but short-lived increases in Korea and Thailand return volatility. On average, these short-lived effects last about thirty minutes.

10) LME Select Screen Trading System is the official exchange operated electronic trading platform, available in addition to open outcry ring trading and the telephone market. Member firms are connected to the system which allows accredited traders to execute trades electronically.

Flexibility and functionality are the key words associated with this system. Flexibility is in the sense that the system allows traders a wide range of preferences for setting screens tailor made for their individual needs. Functionality is in the sense that the basic screens required for trading are supported by a number of screens giving in-depth analysis of the market and executed trades.

The system allows trading on all LME contracts, futures, options, traded average price options (TAPOs) and carries. It will also allow for straight through processing whereby LME Select trades will automatically be sent to the matching and clearing systems operated by the LCH.Clearnet. LME Select operates between 01:00 and 19:00 in London Time.

11) In JASDAQ we observed Monday loss and also Friday loss, instead of Friday gain in Nikkei 225. This might be due to investors in JASDAQ taking defensive strategy to avoid the uncertainty of weekend under the inconvenient circumstance of both nonexistence of stock index derivatives and short selling restriction.

12) Although many dynamical systems are subject to multiple independent variables to determine their time evolution, there are often cases where only a single variable can be observed. It has been claimed that the embedology is proved to guarantee to reproduce the whole characteristics of the underlying dynamics from time series data about a single variable despite a Q-dimensional multivariate system. However, our technique does not depend on this theorem.

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List of Figures and Tables

Table 1. Fundamental Statistics of Daily Returns

Table 2. Correlation Coefficients of Daily 3-month Futures Returns

Table 3-1. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Aluminum Returns within Week

Table 3-2. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Copper Returns within Week

Table 3-3. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Nickel Returns within Week

Table 3-4. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Lead Returns within Week

Table 3-5. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Zinc Returns within Week

Fig. 1-1-P Wayland Test of Aluminum Futures Return (Past)

Fig. 1-1-R Wayland Test of Aluminum Futures Return (Recent)

Fig. 1-2-P Wayland Test of Aluminum Cash Return (Past)

Fig. 1-2-R Wayland Test of Aluminum Cash Return (Recent)

Fig. 2-1-P Wayland Test of Copper Futures Return (Past)

Fig. 2-1-R Wayland Test of Copper Futures Return (Recent)

Fig. 2-2-R Wayland Test of Copper Cash Return (Recent)

Fig. 2-2-P Wayland Test of Copper Cash Return (Past)

Fig. 3-1-P Wayland Test of Nickle Futures Return (Past)

Fig. 3-1-R Wayland Test of Nickel Futures Return (Recent)

Fig. 3-2-P Wayland Test of Nickel Cash Return (Past)

Fig. 3-2-R Wayland Test of Nickel Cash Return (Recent)

Fig. 4-1-P Wayland Test of Lead Futures Return (Past)

Fig. 4-1-R Wayland Test of Lead Futures return (Recent)

Fig. 4-2-P Wayland Test of Lead Cash Return (Past)

Fig. 4-2-R Wayland Test of Lead Cash Return (Recent)

Fig. 5-1-P Wayland Test of Zinc Futures Return (Past)

Fig. 5-1-R Wayland Test of Zinc Futures Return (Recent)

Fig. 5-2-P Wayland Test of Zinc Cash Return (Past)

Fig. 5-2-R Wayland Test of Zinc Cash Return(Recent)

Table 1. Fundamental Statistics of Daily Returns

Panel A: Statistical Moments of Daily Returns

		Past (1989/1/3/Tue -2003/8/29/Fri)				Recent (2003/8/30/Sat-2008/2/29/Fri)			
		Average	SD	Skew	Kurt	Average	SD	Skew	Kurt
Al	Ca	-2.3540	345.8454	0.3184	7.7209	18.9169	389.8239	-0.0471	6.1545
	3m	-2.5368	302.7639	0.3674	7.7957	18.9790	363.1878	-0.2541	6.7817
Cu	Ca	-2.1956	427.0999	0.5555	14.1288	38.2247	499.8297	-0.0233	2.5149
	3m	-2.1548	357.7108	0.08216	7.2206	37.5148	472.6882	-0.0738	2.8588
Ni	Ca	-0.6769	531.7265	0.3025	6.8851	33.3871	715.9561	-0.0802	7.1917
	3m	-0.7024	493.9953	0.1917	6.8221	32.9865	668.3404	-0.3854	6.1688
Pb	Ca	0.8686	486.233	0.2683	14.5454	48.3089	671.1609	-0.1603	2.8650
	3m	-0.0597	399.5252	0.4575	9.7875	47.1167	613.133	-0.4462	3.4539
Zn	Ca	-2.6678	406.614	-0.6703	13.9385	31.5477	589.682	-0.0602	4.4541
	3m	-3.0818	332.3299	-0.1231	10.2421	30.8401	558.3053	-0.2059	3.8188

Table 1. Fundamental Statistics of Daily Returns

Panel B: Weekly Daily 3-month Futures Returns

			Monday	Tuesday	Wed.	Thursday	Friday
Past (1989/1/3/Tue - 2003/8/29/Fri) Size: 760	Al	Average	-18.3124	-15.6752	12.9286	37.7442	10.1414
		SD	130.7288	364.9374	412.8358	388.6148	363.1749
	Copper	Average	-20.2858	-14.1483	9.9727	53.0624	-0.5212
		SD	152.9631	432.3530	439.8787	469.8545	468.5128
	Nickel	Average	-28.8567	-46.0585	18.0285	49.3425	59.7160
		SD	205.6829	644.8744	615.1405	626.1671	603.6755
	Lead	Average	-31.2506	-22.6232	24.6904	77.4956	27.2368
		SD	164.8210	522.0027	517.5728	468.7598	508.9887
	Zinc	Average	-24.3562	-38.7989	21.0176	56.8161	22.4055
		SD	135.4872	445.6432	406.5463	434.9838	396.4346
Recent (2003/8/30/Sat - 2008/2/29/Fri) Size: 239	Al	Average	-16.2548	36.7940	2.9874	46.9908	90.1188
		SD	151.5571	384.3242	508.6237	493.1738	428.4196
	Copper	Average	6.9386	62.5028	-16.8817	79.0460	108.8058
		SD	206.8641	543.4810	611.2570	600.7978	613.0789
	Nickel	Average	4.6905	49.0477	-58.3065	90.0648	133.5237
		SD	266.9573	777.2161	996.0498	804.8806	799.90962
	Lead	Average	10.5868	85.6798	-3.9393	70.50434	131.3442
		SD	272.4130	721.8493	815.9423	813.1120	726.4166
	Zinc	Average	-13.2059	62.6454	-9.5963	91.3388	96.8775
		SD	244.7973	656.9030	669.8652	802.8709	659.5786

*) Abbreviations are as follows: Average (arithmetic mean), SD (standard deviation), Kurt (kurtosis), aluminum (Al), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), cash (Ca), 3-month (3m), and Wednesday (Wed.).

Table 2. Correlation Coefficients of Daily 3-month Futures Returns

Panel A: Past (1989/1/3/Tue -2003/8/29/Fri)

	Aluminum	Copper	Nickel	Lead	Zinc
Aluminum	1	0.5218	0.4103	0.3642	0.4549
Copper		1	0.4282	0.3911	0.4673
Nickel			1	0.3391	0.4015
Lead				1	0.4657
Zinc					1

Panel B: Recent (2003/8/30/Sat-2008/2/29/Fri)

	Aluminum	Copper	Nickel	Lead	Zinc
Aluminum	1	0.6800	0.4820	0.5532	0.6725
Copper		1	0.5086	0.6189	0.7184
Nickel			1	0.4626	0.5248
Lead				1	0.6336
Zinc					1

Table 3-1. Student's t-Statistical Test using Surrogate Returns
for the Case of Random Shuffle of Daily Aluminum Returns within Week

		Monday	Tuesday	Wed.	Thursday	Friday
3 month futures	89/1/03-03/8/29	1.4919	1.0996	-0.5899	-2.7145*	0.7201
	03/8/30-08/2/29	3.1218*	0.7014	1.1593	-1.4219	-2.9796*
	89/1/03-08/2/29	3.0721*	1.2659	-0.1315	-3.5951*	-0.8795
Cash	89/1/03-03/8/29	2.7308*	2.4397	-1.2699	-3.9614*	0.2161
	03/8/30-08/2/29	2.5157*	0.3956	1.1431	-0.6823	-3.4523*
	89/1/03-08/2/29	4.5317*	1.9502	-0.6479	-5.2523*	-1.5248
15 month futures	89/1/03-03/8/29	2.8584*	-0.9565	-1.2301	-0.9497	1.4979
	03/8/30-08/2/29	3.5818*	-0.8765	0.1189	-0.3098	-1.9749
	89/1/03-08/2/29	4.0265*	-1.1445	-1.6537	-1.9194	0.5810

Note: * indicates significance at the 95% confidence level for the both-sided test.

number of surrogates = 40.

Table 3-2. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Copper Returns within Week

		Monday	Tuesday	Wed.	Thursday	Friday
3 month futures	89/1/03-03/8/29	1.1261	1.2069	-0.3291	-1.9514	-0.2979
	03/8/30-08/2/29	1.4759	0.3704	1.4449	-1.4614	-1.7439
	89/1/03-08/2/29	2.5351*	1.3654	-0.1064	-3.1219*	-0.9435
Cash	89/1/03-03/8/29	1.2628	2.2041*	-0.1529	-2.8078*	-0.5046
	03/8/30-08/2/29	0.9011	0.8752	1.4228	-1.6041	-1.512
	89/1/03-08/2/29	2.4860*	2.4109*	0.1142	-3.9726*	-1.3508
15 month futures	89/1/03-03/8/29	0.8129	0.6548	-0.8233	-1.6932	0.9887
	03/8/30-08/2/29	1.2283	0.0463	0.8086	-1.2256	-0.6040
	89/1/03-08/2/29	2.2037*	0.6824	-0.9780	-2.8004*	0.5535

Note: * indicates significance at the 95% confidence level for the both-sided test.

number of surrogates = 40.

Table 3-3. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Nickel Returns within Week

		Monday	Tuesday	Wed.	Thursday	Friday
3 month futures	89/1/03-03/8/29	3.9346*	3.1852*	-1.6079	-2.4334*	-2.3158*
	03/8/30-08/2/29	1.3279	0.2030	1.1625	-0.6600	-1.8783
	89/1/03-08/2/29	4.2910*	2.7150*	-0.7610	-2.7820*	-3.0953*
Cash	89/1/03-03/8/29	3.1512*	3.3200*	-0.7133	-3.1369*	-2.1734*
	03/8/30-08/2/29	1.0053	0.2447	0.4622	0.7487	-2.0456*
	89/1/03-08/2/29	3.5573*	2.5710*	-0.4708	-2.7959*	-2.8386*
15 month futures	89/1/03-03/8/29	3.4939*	2.3930*	-1.5780	-2.2670*	-1.2177
	03/8/30-08/2/29	1.5745	-0.9866	1.2159	-0.0447	-1.4155
	89/1/03-08/2/29	3.4797*	1.5210	-0.7168	-2.5759*	-1.8597

Note: * indicates significance at the 95% confidence level for the both-sided test.

number of surrogates = 40.

Table 3-4. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Lead Returns within Week

		Monday	Tuesday	Wed.	Thursday	Friday
3 month futures	89/1/03-03/8/29	2.0699*	0.7550	-0.6832	-2.9277*	0.6806
	03/8/30-08/2/29	2.0921*	-0.7809	0.6210	-0.1694	-1.7755
	89/1/03-08/2/29	3.2954*	0.3301	-0.2508	-3.1343*	-0.0417
Cash	89/1/03-03/8/29	3.1563*	2.0981*	-1.0355	-4.7429*	0.3987
	03/8/30-08/2/29	1.1681	0.3247	0.7175	0.2912	-2.6594*
	89/1/03-08/2/29	2.9532*	2.3620*	-0.5707	-4.1959*	-0.7541
15 month futures	89/1/03-03/8/29	1.4977	0.4258	-0.3841	-2.6822*	1.0860
	03/8/30-08/2/29	1.7285	-0.7068	0.5777	-0.5216	-1.0518
	89/1/03-08/2/29	2.3804*	0.2506	-0.1939	-3.0498*	0.6577

Note: * indicates significance at the 95% confidence level for the both-sided test.

number of surrogates = 40.

Table 3-5. Student's t-Statistical Test using Surrogate Returns for the Case of Random Shuffle of Daily Zinc Returns within Week

		Monday	Tuesday	Wed.	Thursday	Friday
3 month futures	89/1/03-03/8/29	1.0796	2.6227*	-1.8504	-2.5841*	0.9751
	03/8/30-08/2/29	1.8889	0.1962	2.5759*	-1.5042	-2.6608*
	89/1/03-08/2/29	1.6102	2.1813*	-0.7032	-3.8632*	-0.1590
Cash	89/1/03-03/8/29	2.2728*	2.7974*	-1.6359	-3.3803*	0.2534
	03/8/30-08/2/29	1.6903	-0.4137	2.1183*	-0.9563	-2.0167*
	89/1/03-08/2/29	2.2035*	2.5455*	-0.6575	-4.6269*	-0.6146
15 month futures	89/1/03-03/8/29	2.7894*	1.6245	-2.9112*	-1.5145	0.7256
	03/8/30-08/2/29	3.4523*	0.1942	1.0859	-1.1745	-2.3747*
	89/1/03-08/2/29	3.3574*	1.4128	-2.7533*	-3.0476*	-0.3437

Note: * indicates significance at the 95% confidence level for the both-sided test.

number of surrogates = 40.

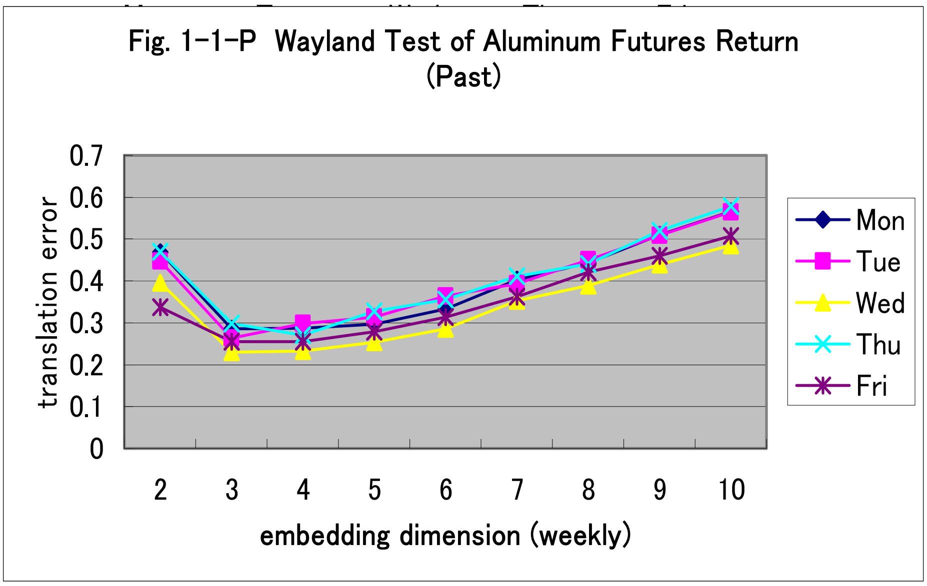
Fig. 1-1-P Wayland Test of Aluminum Futures Return
(Past)
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embedding dimension (weekly)
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Wed
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Fri

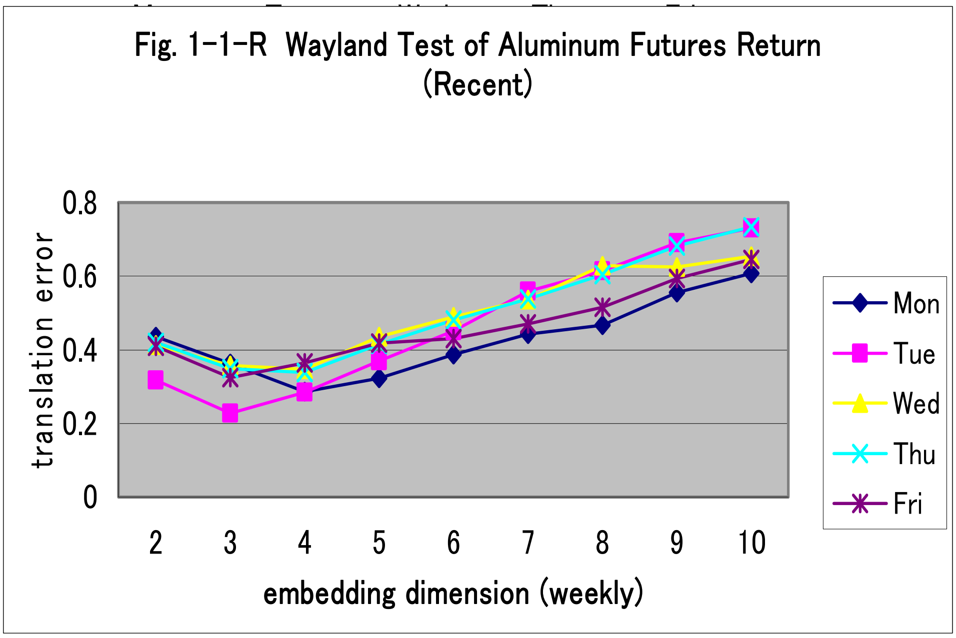
Fig. 1-1-R Wayland Test of Aluminum Futures Return
(Recent)
translation error
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0.6
0.4
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embedding dimension (weekly)
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Fri

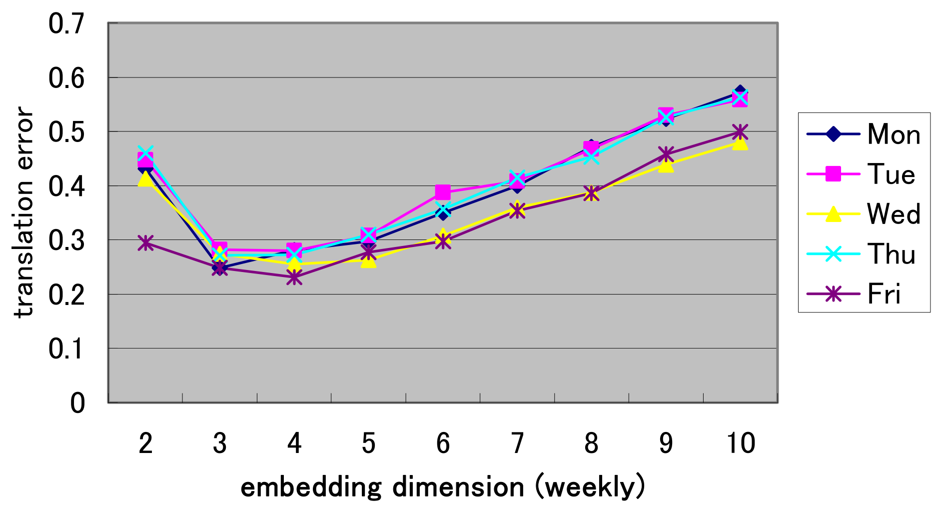

Fig. 1-2-P Wayland Test of Aluminum Cash Return (Past)

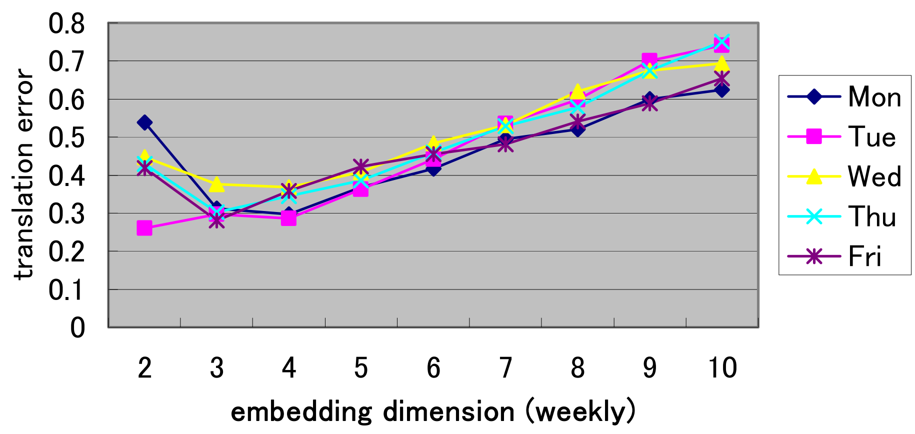

Fig. 1-2-R Wayland Test of Aluminum Cash Return (Recent)

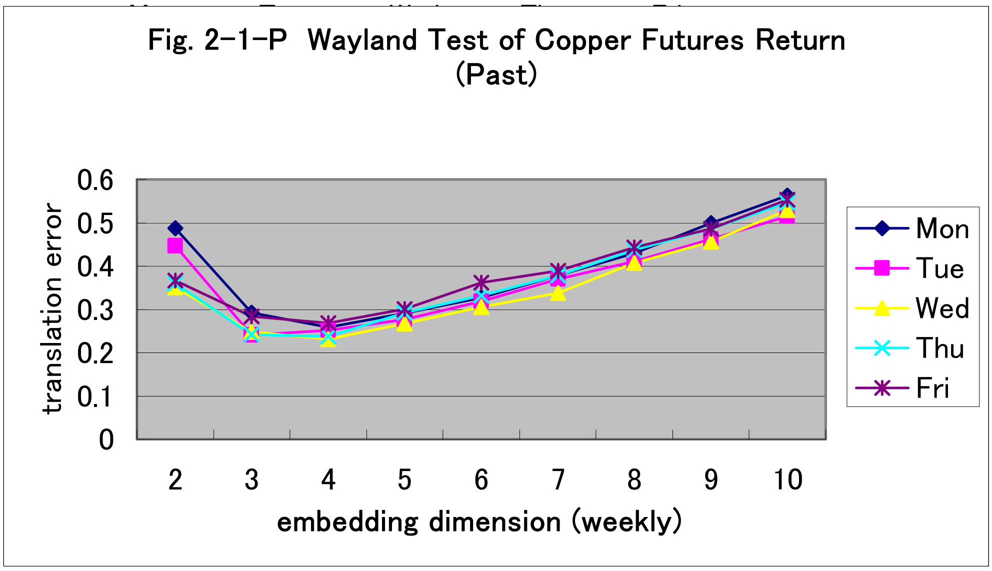
Fig. 2-1-P Wayland Test of Copper Futures Return (Past)
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embedding dimension (weekly)
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Tue
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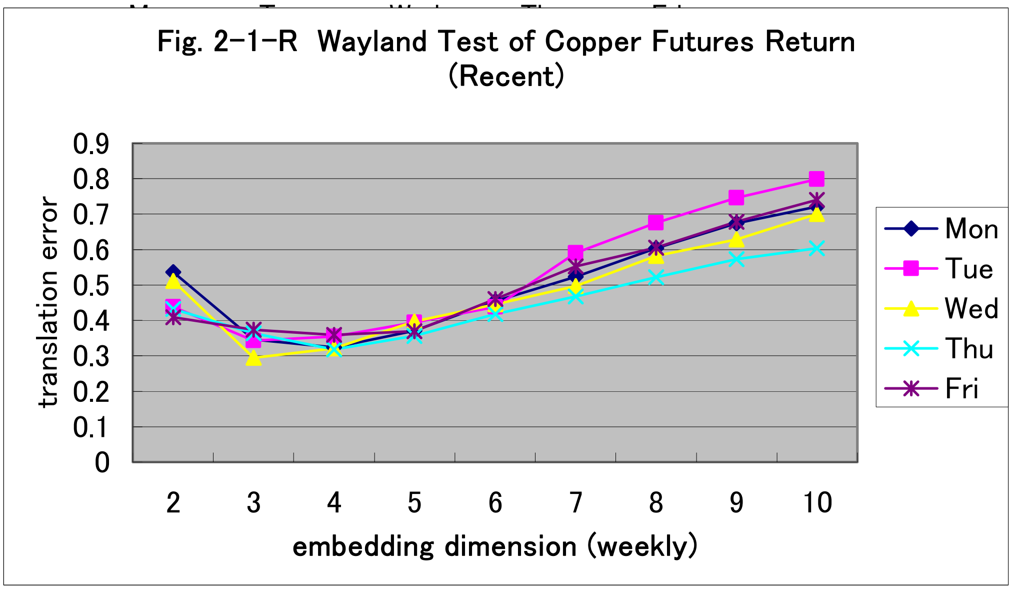
Thu
Fri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translation error
embedding dimension (weekly)
Mon
Tue
Wed
Thu
Fri

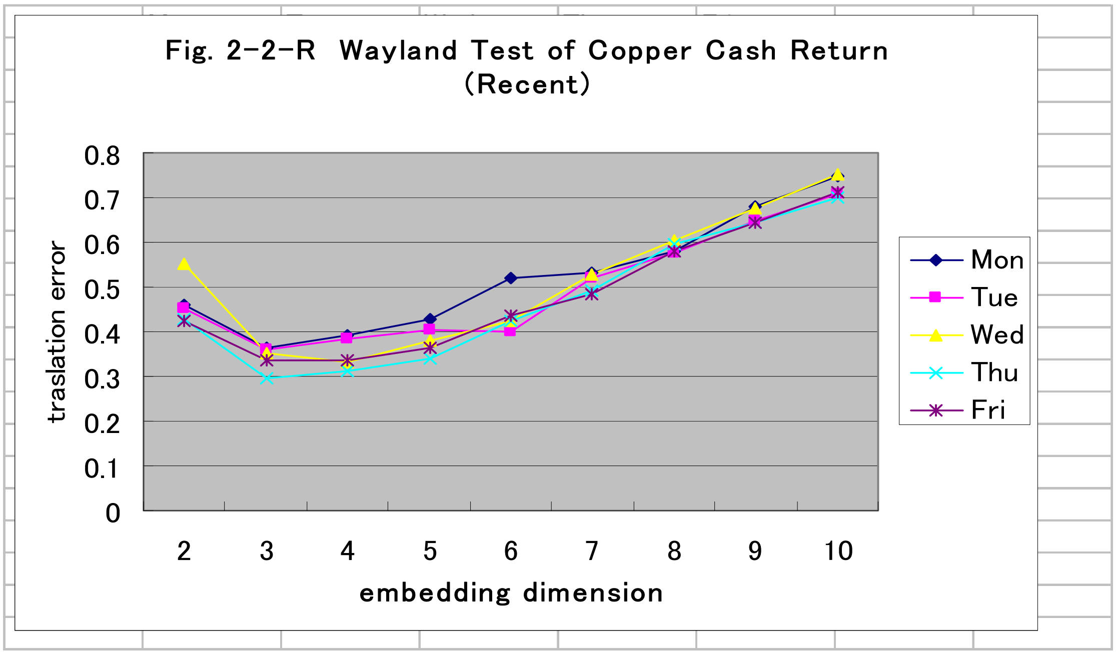
Fig. 2-2-R Wayland Test of Copper Cash Return (Recent)
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embedding dimension
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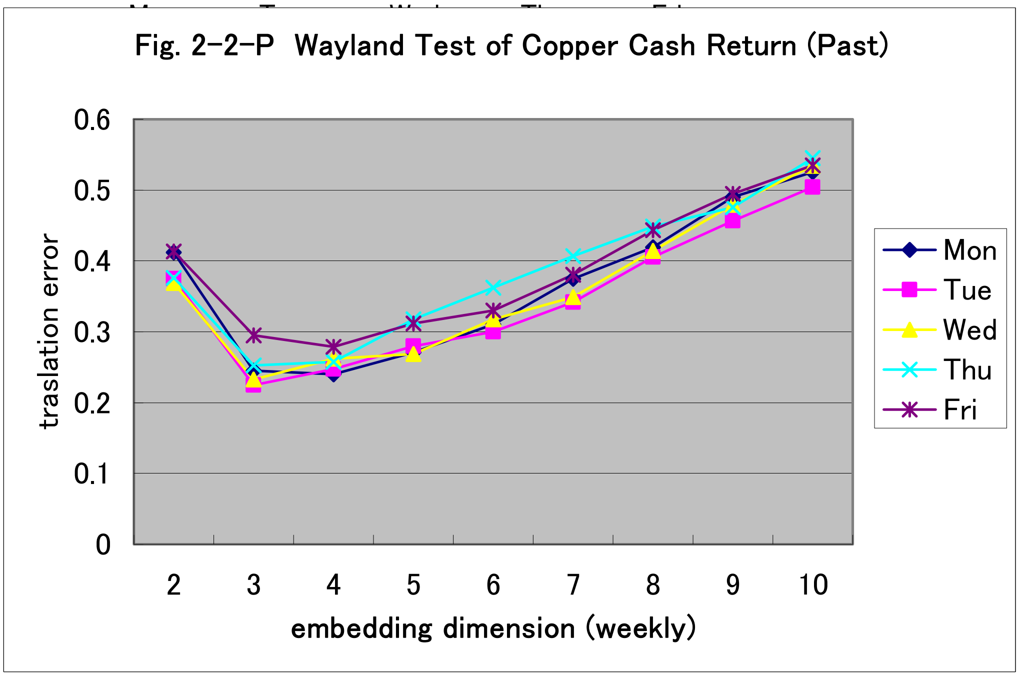
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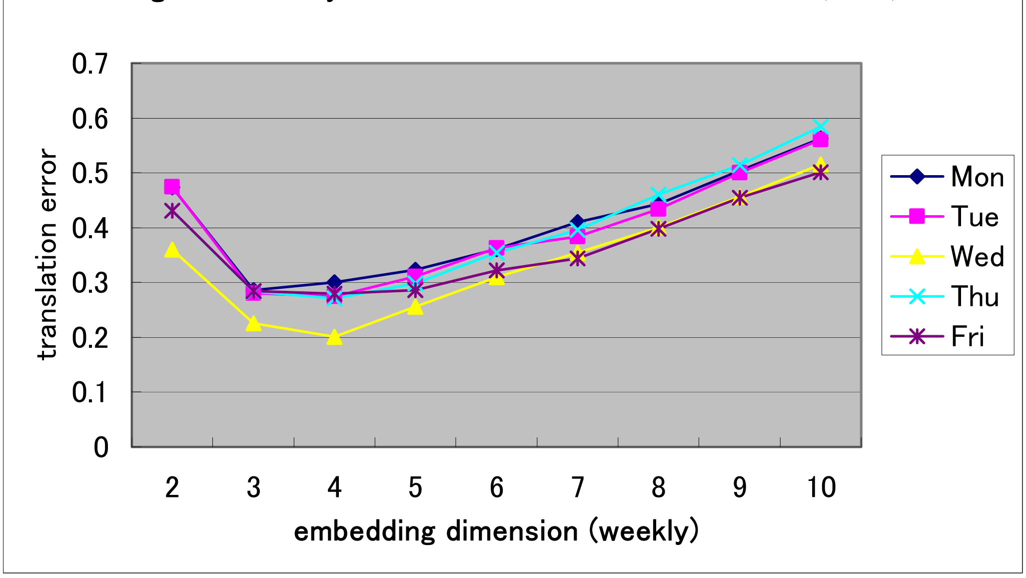

Fig. 3-1-P Wayland Test of Nickle Futures Return (Past)

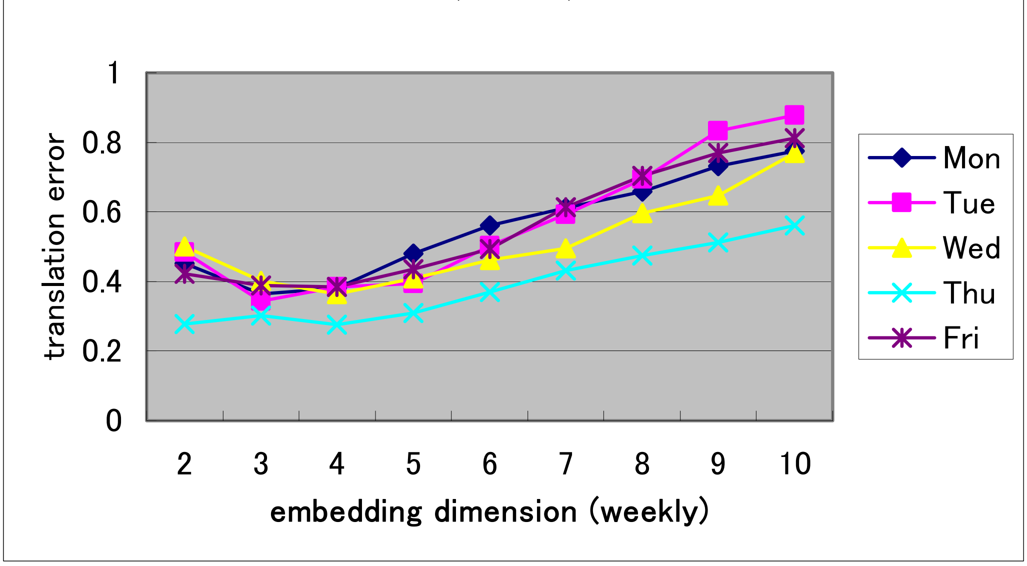

Fig. 3-1-R Wayland Test of Nickel Futures Return (Recent)

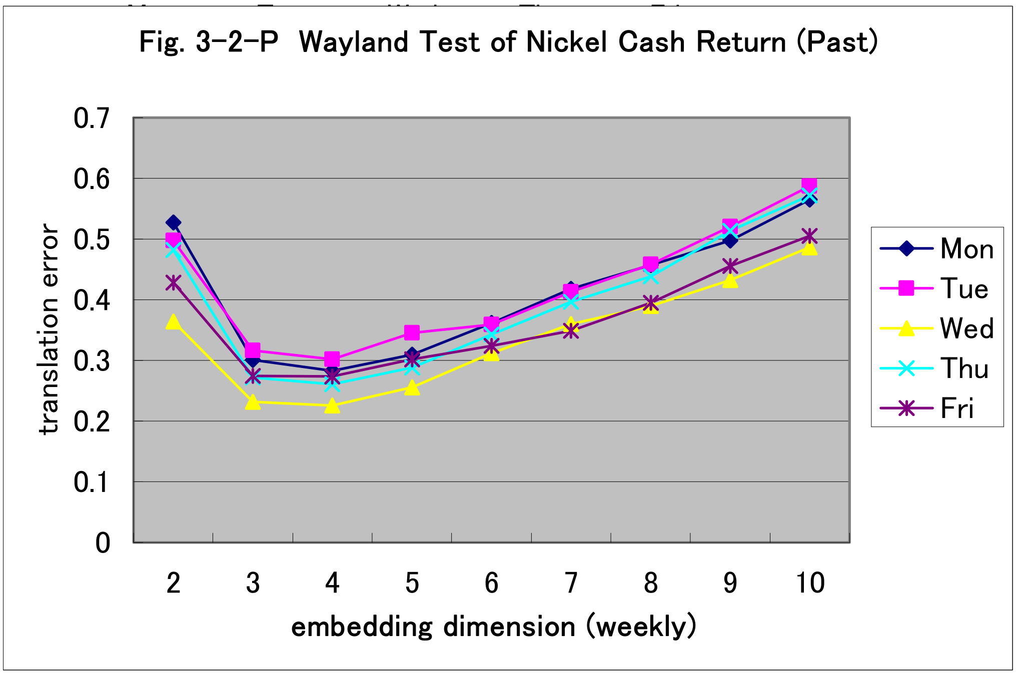
Fig. 3-2-P Wayland Test of Nickel Cash Return (Past)
translation error
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0.5
0.4
0.3
0.2
0.1
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embedding dimension (weekly)
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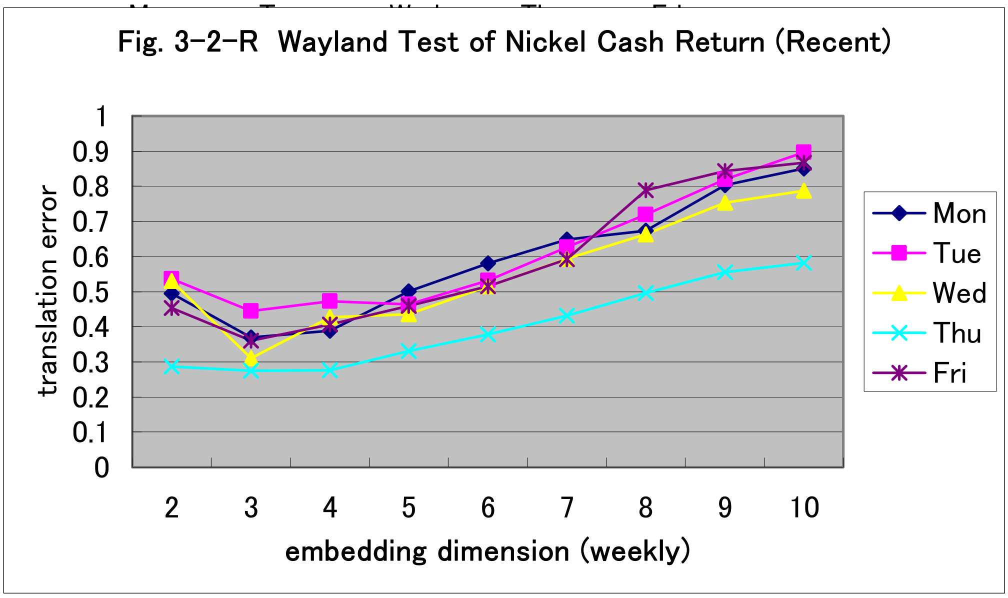
Fig. 3-2-R Wayland Test of Nickel Cash Return (Recent)
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embedding dimension (weekly)
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Fig. 4-1-P Wayland Test of Lead Futures Return (Past)

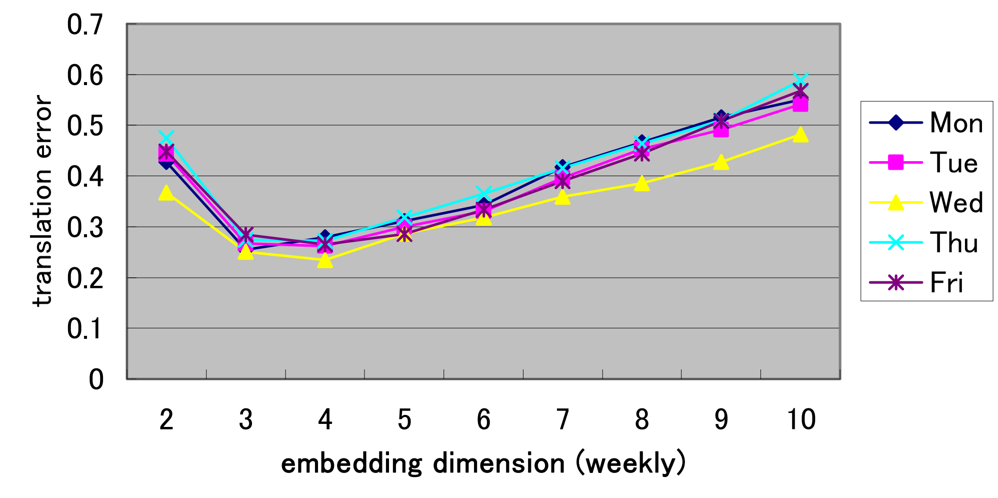

Fig. 4-1-R Wayland Test of Lead Futures return (Recent)

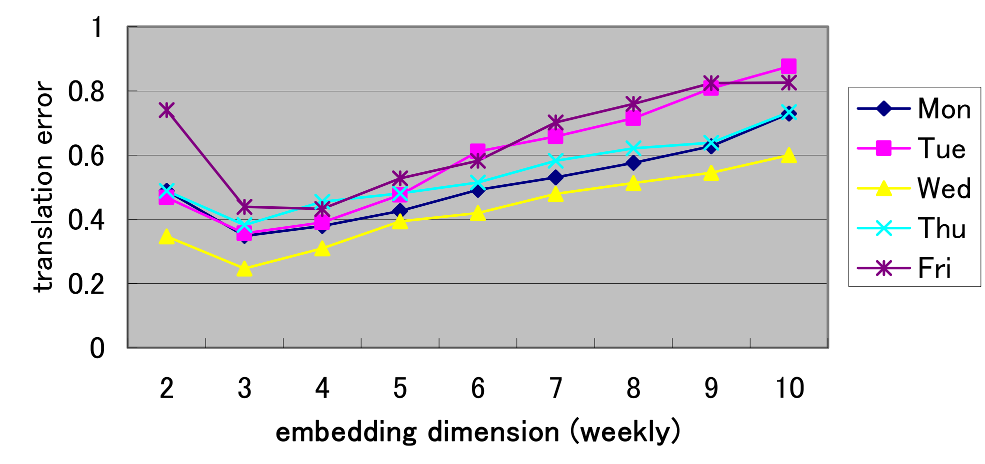

Fig. 4-2-P Wayland Test of Lead Cash Return (Past)

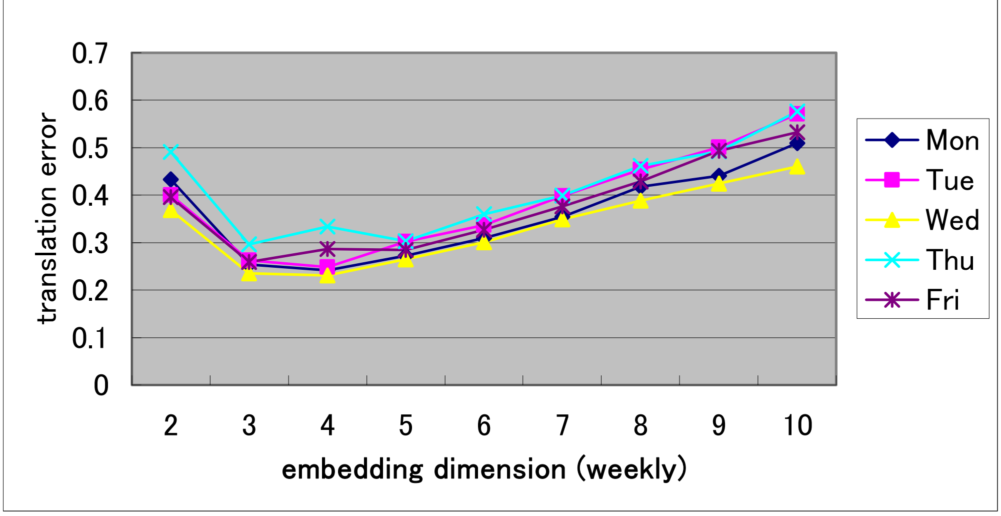

Fig. 4-2-R Wayland Test of Lead Cash Return (Recent)

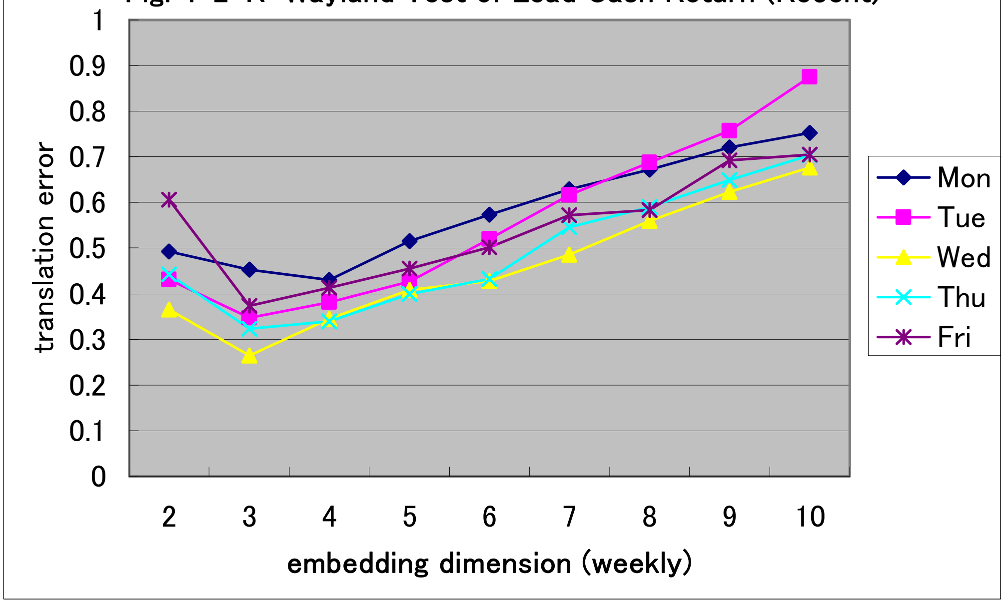

Fig. 5-1-P Wayland Test of Zinc Futures Return (Past)

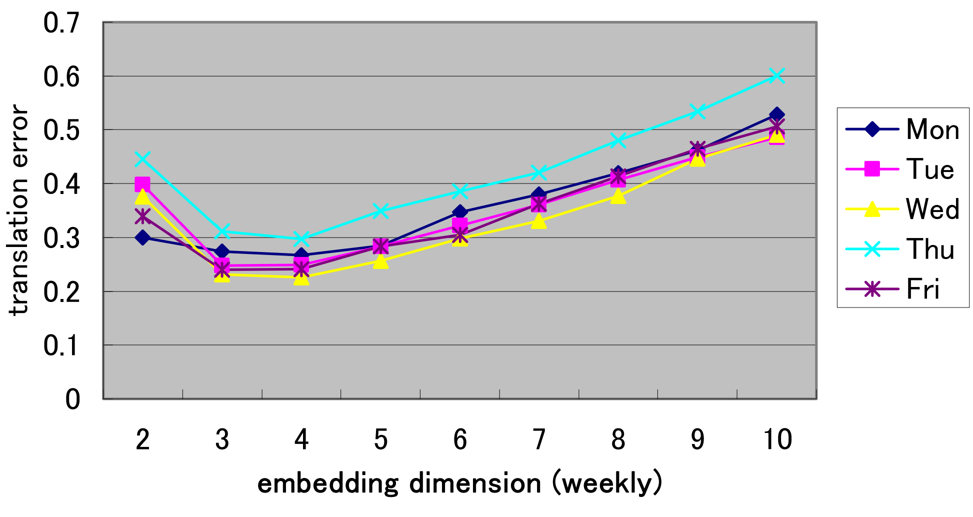

Fig. 5-1-R Wayland Test of Zinc Futures Return (Recent)

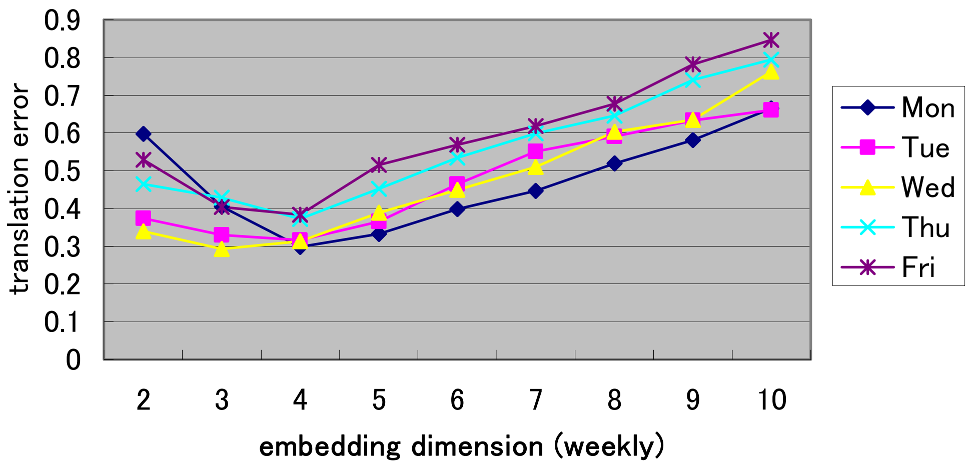

Fig. 5-2-P Wayland Test of Zinc Cash Return (Past)

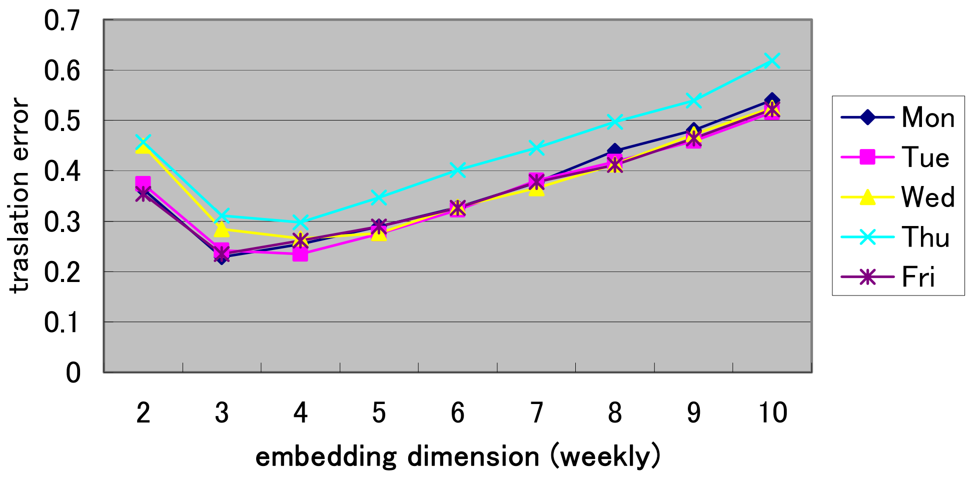

Fig. 5-2-R Wayland Test of Zinc Cash Return (Recent)