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Forecasting metal prices with a curvelet based multiscale methodology

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ABSTRACT

Metal price movement is a complicated process with significant fluctuations, exhibiting nonlinear characteristics. With the proposed Heterogeneous Market Hypothesis (HMH), we argue that the macroscale nonlinear price movement consists of a diverse range of data components such as chaotic and multi-scale data characteristics at the microscopic level. In order to model the hidden data features, we propose a new Curvelet based forecasting algorithm. To model the dynamic chaotic data characteristics in the original time series, we project the original time series into the reconstructed phase space using the time delay method. The Curvelet denoising method is used for separating and reducing the disruption from noise in the transformed state space. Results from empirical studies conducted in the major metal markets suggest that the proposed model achieves statistically more robust and superior performance than traditional benchmark model.

Introduction

The metal is a pivotal manufacturing input. The forecasting of movement and the management of unexpected fluctuations of the metal price are critical to the economic well-being and corporate survival in the manufacturing industry. On one hand, the metal price fluctuation has significant impact on the terms of trade as the metal export income represents significant portion of export revenues for many countries. It also has significant impact on the project valuation during the capital budgeting of the operation management process (Dooley and Lenihan, 2005). On the other hand, as the level of correlations between metal prices and other equities is low, the metal, as one of the financial assets, has also been viewed as an important hedging instrument in the financial markets. The movement of metal price also shapes the profitability expectations for the firms in the manufacturing industry, which further influence the movement of its equities price in the financial sector (Dooley and Lenihan, 2005).

Meanwhile, the metal market is known to be inefficient with the cyclical price patterns in the short run, exploitable for forecasting purposes (Arouri et al., 2013; Wang et al., 2011). For example, early work by Labys et al. (1998) showed initial evidence of existence of cycles in metal price movement (Labys et al., 1998). Later work by Cuddington and Jerrett (2008) and Jerrett and Cuddington (2008) have successfully used the band-pass filter to extract cyclical components in the historical metal price data (Cuddington and Jerrett, 2008; Jerrett and Cuddington, 2008). But when researchers attempted to compare and explore the forecasting power of different techniques from the econometrics theory to the artificial intelligence techniques, the results are mixed and inconclusive. For example, on the positive side, Shafiee and Topal (2010) proposed a modified econometric version of the long-term trend reverting jump and dip diffusion model and found improved forecasting performance than ARIMA model in the gold market (Shafiee and Topal, 2010). Issler et al. (2014) analyzed the metal price variation using data over the medium to long term frequency and found strong positive correlations between metal price variations and industry production variations. Parisi et al. (2008) found that the recursive and rolling neural network models is the best in forecasting performance among different neural network models (Parisi et al., 2008). Fernandez (2007) found that wavelet based models and Support Vector Machine (SVM) based models could improve the forecasting performance in the US metal markets (Fernandez, 2007). On the negative side, Dooley and Lenihan (2005) found that the

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performance of ARIMA model is marginally better than that of lagged forward price model to forecast monthly metal price (Dooley and Lenihan, 2005). Till now mainstream models are macroscale in nature, largely relying on the frequency domain measure to conduct the investigations (Costa et al., 2008).

Recently the Heterogeneous Market Hypothesis (HMH) provides some theoretical and methodological alternatives, taking more microscopic approaches in macroscale framework (Dacorogna et al., 2001). In HMH, the heterogeneous nature of the market participants are recognized during the market formation process. In HMH, investors are assumed to execute their transactions based on different preferences including different time horizon, frequency and investment patterns (Dacorogna et al., 2001). The observed cycles in the metal markets may have heterogeneous structures, i.e. there are cycles of different amplitude and length. This opened up a wide range of possibilities to model the nonlinear metal price movement methodologically, where a diverse range of data features, potentially characterized by their scales, can be used to achieve more efficient representation and modeling of data movement (Weinan and Engquist, 2003). Among different new data features drawing significant attentions recently, chaos and multiscale features are two recent developments.

The chaotic characteristics can be defined in the chaos theory as the data exhibiting small divergence and perturbations at the beginning of the time period grows exponentially into global uncertainties at later stage over time. And these limited subsets of initial conditions points represent the center of the orbits (Huang et al., 2010). It has received significant attentions in the economic field. For example, Muckley (2004) employed Rescaled-range analysis, the Correlation Dimension test, and the BDS test to analyze lengthy daily time series of financial data and provided the empirical evidence of existence of chaotic mechanisms behind the Pareto–Levy family of processes for the empirical asset movement and distribution (Muckley, 2004). Diks et al. (2013) identified long memory in the agent's decision making process as the cause for the chaotic behavior of the stock market, using an experimental approach (Diks et al., 2013). Huang et al. (2010) developed a new forecasting strategy that employed the phase space reconstruction and support vector regression, with the improved model performance than benchmark models like SVR and BPNN (Huang et al., 2010). But in the metal market research, limited work has been identified to show the existence of chaotic data feature. We found that work by Panas (2001) provided some initial evidence of chaotic data feature in the Zinc and Tin metal markets (Panas, 2001). And the researches utilizing the chaotic nonlinear dynamics in the modelling attempts are limited to this end so far.

The multiscale characteristics can be defined in the Multiscale Analysis (MA) theory as the data exhibiting multiple spatial-temporal scale organization and non-equilibrium dynamics, governed by different laws across different scales (Costa et al., 2008). The mixture of data features across scales can be separated and analyzed by their scales characteristics. Recent research using the univariate wavelet analysis in the metal market price forecasting shows some initial evidence of multiscale data features (Kriechbaumer et al., 2014). It has emerged to be the important data feature of relevance, but remained less exploited in the metal analysis and forecasting field. As the extension of the wavelet analysis to the higher dimensions, Curvelet analysis has shown some prospects in providing more accurate projection and modeling of the price movement, with edged and curvely singularities revealed in the higher dimensions in the engineering fields. For example, Oliveira et al. (2012) used Curvelet analysis to the removal of Ground Roll, and the Curvelet transform decomposes the original seismic data in scales and angular domains (Oliveira et al., 2012). Wang et al. (2014) used a novel curvelet-based registration method to multi-component seismic waves. They attempted to improve the prediction of registration for data with heavy random noises (Wang et al., 2014). Elaiwat et al. (2014) used the curvelet analysis to detect multiscale local surface descriptors from disruptions such as illumination conditions and facial expressions. It also improved the recognition rate using the benchmark dataset as a result (Elaiwat et al., 2014). Wu et al. (2014) proposed a Curvelet based nonlocal means denoising method, which reconstructs images from its noisy version and shows better performance in noise removal and detail preservation (Wu et al., 2014).

Thus in this paper within the newly introduced HMH framework, we proposed a multi-scale methodology to analyze the microstructure in the metal market. More specifically we proposed a new Curvelet based forecasting algorithm, integrating both the chaotic and multi-scale geometry characteristics in modeling and forecasting the metal price movement. Empirical studies have been conducted in the major metal markets including Zinc and Lead. Results in this study explore and unveil the complex market structure consisting of data components of different data characteristics modeled using Curvelet analysis and chaos theory. We also found the improved forecasting performance of the proposed model, against traditional benchmark models.

This paper makes contributions to the relevant literature from both theory, methodology and practical aspects. Theoretically, we provided further empirical evidence to the Heterogeneous Market Hypothesis as the viable theory. Methodologically, we proposed a new Curvelet based multi-scale forecasting methodology, that integrates the introduced Curvelet analysis, time delay embedding algorithm and minimum entropy measure. We introduce the time delay method as an effective feature transformation tool to transform the original data with obscure date feature into the reconstructed phase space with clearer data features. The Curvelet analysis is proposed to separate valuable data features while suppressing the disrupting ones, where the minimum entropy measure is proposed to determine the model specifications. Practically the proposed algorithm is of relevance to the metal price analysis and modeling in practice. The proposed methodology is semi parametric, which is capable of adapting to metal market data consisting of data features not fully accounted for in the traditional models. We have shown in this paper that Curvelet analysis and chaos theory as two exemplary methods that can be used to extract data components of interests underlying the increasingly complicated and nonlinearly behaved metal markets. The proposed methodology also serves as a general modeling framework. To account for the emerging diverse range of data features, more advanced nonlinear models beyond the linear ARMA model in the currently proposed models can be developed and integrated into the proposed methodology to more effectively model and forecast the data in practice.

The rest of the paper is organized as follows: in section “A curvelet based multiscale forecasting methodology”, we propose the curvelet based multiscale forecasting methodology. In section “Empirical studies”, experimental results from the empirical studies are reported and analyzed. In section “Conclusions” we summarize and conclude.

A curvelet based multiscale forecasting methodology

Theoretically the curvelet based multiscale forecasting methodology (CMFM) is proposed under the HMH theory. Traditional risk measurement methodologies are built on the Efficient Market Hypothesis (EMH) viewing the market as homogenous and rational. But the recent availability of high frequency data and results from empirical studies have provided the alternative evidence of the existence of the extremal, fractal and chaotic