Physica A 393 (2014) 364–375

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Volatility-constrained correlation identifies the directionality of the influence between Japan's Nikkei 225 and other financial markets

Tomoshiro Ochiai [a,*], Jose C. Nacher [b]

[a] School of Social Information Studies, Otsuma Women's University, 2-7-1 Karakida, Tama-shi, Tokyo 206-8540, Japan

[b] Department of Information Science, Faculty of Science, Toho University, Miyama 2-2-1, Funabashi, Chiba 274-8510, Japan

HIGHLIGHTS

- We analyze the correlation between the Nikkei 225 and other financial markets.
- The volatility-constrained correlation determines the directionality of the correlation.
- The proposed model reproduces the results observed in the empirical analysis.

ARTICLE INFO

Article history:
Received 19 May 2013
Received in revised form 2 August 2013
Available online 28 August 2013

Keywords:
Econophysics
Financial market
Data analysis
Correlation
Volatility
Multivariate stochastic model

ABSTRACT

Recent financial crises have shown the importance of determining the directionality of the influence between financial assets in order to identify the origin of market instabilities. Here, we analyze the correlation between Japan's Nikkei stock average index (Nikkei 225) and other financial markets by introducing a volatility-constrained correlation metric. The asymmetric feature of the metric reveals which asset is more influential than the other. As a result, this method allows us to unveil the directionality of the correlation effect, which could not be observed from the standard correlation analysis. Furthermore, we present a theoretical model that reproduces the results observed in empirical analysis.

1. Introduction

The availability of an increasingly large amount of financial data is providing opportunities to understand how macroscopic effects in markets emerge from interactions between microscopic system components. Financial markets can be regarded as an evolving complex system, where the assets prices change by traders sentiment which is also affected by multiple interactions among different financial assets. The emergence of the self-organized behavior of the market has been studied using a variety of approaches from statistical physics and non-linear dynamics to computer science.

A lesson learnt from the recent financial crisis initiated by the announcement of the bankruptcy of Lehman Brothers in 2008 is that the financial markets are getting more interconnected around the world. As a consequence of this interdependence, a perturbation in a single market may have a high impact in other financial markets, leading to *domino* losses. The Euro crisis is believed to be a systemic crisis involving many financial institutions which are closely connected to each other through capital flow and political linkages between countries. The financial institution network is strongly affected by the dynamics and correlation of financial assets such as bonds, stocks, foreign exchange rate, and vice versa. This urges us to understand and examine in depth the correlations among different financial markets, from a complex system

* Corresponding author. Tel.: +81 423390059.
E-mail addresses: ochiai@otsuma.ac.jp (T. Ochiai), nacher@is.sci.toho-u.ac.jp (J.C. Nacher).

0378-4371/$ – see front matter
http://dx.doi.org/10.1016/j.physa.2013.08.038

perspective, in an effort to determine the directionality of the influence between financial assets. This knowledge could then lead to identify the origin of market instabilities and prevent future global crises.

On the other hand, the dynamics and correlations of financial products have attracted the interest of asset managers in the field of portfolio risk management, in which data analyses have led to the development of financial management techniques such as the tail risk and market crash risk strategies. For price dynamics, several stylized facts are well known, such as fat tailed return distributions [1–5], the absence of autocorrelations of returns [6,7], volatility clustering [2,7–9] and aggregational normality [5,10]. Recently, the resistance (support) and breaking-acceleration effects in foreign exchange markets have also been reported [11]. Moreover, memory effects in the resistance and support lines for stock price dynamics have been studied in Ref. [12].

Research on the correlations between financial assets has been carried out in several works, mainly in terms of risk and portfolio management. International asset correlations increase in a period of high volatility of the market [13]. The average correlation between daily stock returns predicts subsequent stock market excess returns [14]. High volatile markets are directly related to strong correlations between them [15]. The average correlation among US stocks scales linearly with market stress and is reflected by normalized Dow Jones Index Average (DJIA) returns [16]. These results imply that when the market volatility drastically increases in response to any shock to the system (e.g., a bankruptcy that leads to a financial crisis), the correlation between assets could be stronger than that in a normal state. As a consequence, the dispersion effect of the portfolio could decrease significantly.

On the other hand, several studies have investigated correlations among financial markets from different view points. For example, the Index cohesive effect on stock market correlations was investigated in Ref. [17]. The results supported the view of the stock market as a Complex Adaptive System, CAS, as was proposed previously in Ref. [18]. Their findings implied that the Index is more than a weighted average of all the stocks. In other words, it represents a self-reference or a feedback loop between the market as a whole and the individual stocks [17].

Moreover, the analysis of the daily correlation present among market indices of stock exchanges located all over the world in long time periods revealed that the correlation among market indices presents a combination of both fast and a slow dynamics [19]. In addition, a partial correlation analysis of the stock market uncovered a dominating clasp of the financial sector [20]. A correlation-based framework was also proposed for quantitative assessments of the coupling and interdependences between different markets in the global financial village. This methodology was used to analyze the feedback between the micro (intra market) and the macro (inter markets) levels [21]. In Wang et al. [22], a study for 48 world indices was presented, one for each of 48 different countries. The results revealed a long-range power-law cross correlations in the absolute values of returns that quantify risk. In addition, their findings also indicate that cross correlations in the absolute values of returns decay much more slowly than cross correlations between the returns. Podobnik et al., [23] reported on the long-range cross-correlations in time series of absolute price fluctuation of NYSE members. The interplay between network dominance and node influence was recently introduced to study financial markets [24]. It is worth mentioning that a recent empirical study of stock returns in the Nikkei 225 Index for the period of Jan. 2007–Dec. 2009 showed that market-wide price co-movement becomes prominent before and after a large price decline such as an endogenous market crash [25]. However, although correlations among markets, using the specific frameworks have been extensively investigated, metrics that combine correlations with the directionality feature have not been studied before.

In this work, we focus on the correlation of returns for Japan's daily Nikkei 225 financial index and other markets: the Dow Jones Index Average (DJIA) and the foreign exchange rate of the US Dollar and Japanese Yen (USDJPY). We empirically analyze how the correlation between these assets relates to their volatility by introducing new metrics to capture the asymmetric correlation phenomena.

By definition, the standard correlation coefficient (Pearson's correlation coefficient) of returns for two financial assets does not vary by exchanging the two asset returns, because the concept of standard correlation coefficient $Cor(A, B)$ between A and B is symmetric by exchanging the two A and B variables. Here, we propose a measure of the correlation of returns, which is computed from a collection of pairs of returns constrained by its standard deviation. This *constrained correlation* metric has an asymmetric feature with respect to exchanging the two asset returns (A and B). As shown later, this asymmetric feature allows us to determine which asset (A or B) affects more to the other (B or A), respectively.

Our real-data driven approach using the asymmetric property of the constrained correlation determines which asset is more influential to the other. This is our main result and it indicates that we can measure not only the importance of the transmission channels among markets but also the directionality of the effects during a contagion event. The economic implications of this result are also discussed. At the same time, as a second result, our analysis reveals that when the volatility of returns increases, the correlation between the pair of assets becomes stronger. Namely, higher volatility implies a higher correlation and, conversely, lower volatility leads to a lower correlation between Japan's Nikkei stock average index (Nikkei 225) and other financial markets. A theoretical model is also proposed to investigate the origin of the observed directional correlation effects. The computer simulated results using the model shows a fair agreement with the empirical data, suggesting a way to explore the directional correlations using theoretical approaches.

2. Data description

In this work, we use the daily historical data of Japan's Nikkei 225 stock average index (Nikkei 225) [26], Dow Jones Industrial Average (DJIA) [27] and the foreign exchange rate from the United States Dollar to the Japanese Yen (USDJPY) [28],