Physica A 388 (2009) 2461–2468

Contents lists available at ScienceDirect

Physica A

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

Linkages between international stock markets: A multivariate long-memory approach

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A R T I C L E   I N F O

Article history:
Received 26 July 2007
Received in revised form 28 December 2007
Available online 26 February 2009

Keywords:
Stock markets
VARFIMA and impulse-response function

A B S T R A C T

This paper aims to analyze the linkages between international stock markets and to search for an optimum model for analyzing their interactions taking into consideration their geographical location, using the vector fractionally integrated autoregressive moving-average (VARFIMA) model. This model has not so far been employed in examining the interdependence among the stock markets of Germany, Japan, the UK, and the USA. The results of the paper show that there is an interconnection among the stock markets of these countries.

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1. Introduction

The collapse in 1987 triggered a great deal of interest in the interaction of global stock markets. Following this date, the international aspect of stock returns has become the focal point of many studies. Von Fuerstenberg and Jeon [1] led a study into which factors move the global markets and investigated the correlation between the main global stock markets such as New York, Tokyo, Frankfurt and London. Eun and Shim [2] conducted research into the Granger causality for the 1979–1985 periods among the USA and nine other stock markets and found out that the market in the USA had a dominant influence. Another study conducted by Kasa [3], and Arshanapalli and Doukas [4] revealed that there is a significant long-run co-movement between the USA and European markets. The findings of Cheung and Mak [5], Liu and Pan [6], and Wu and Su [7] have indicated that the stock markets of Asian countries are very much under the influence of the USA and Japanese stock markets. Similarly, Cha and Oh [8] have supported the evidence that the USA and Japanese stock markets have an enormous influence over the Hong Kong, Korea, Singapore, and Taiwan stock markets. Moreover, Narayan, Smyth and Nandha [9] have investigated the interdependence and dynamic linkages between the emerging stock markets of South Asia. As for the European stock markets, Gilmore and McMannus [10] have found that there is a correlation between the USA and some European stock markets: namely, the Czech Republic, Hungary, and Poland. Berument and Ince [11], and Berument et al. [12] put forward that effects of the S&P500 on emerging market returns has got to do with the geographical location of the markets and that these effects die out in a quick manner.

On the other hand, unlike the studies emphasizing the relation among stock markets, there are some studies claiming that there is no linkage between the stock markets. For example, the findings of Felix et al. [13] suggest that there is no long-run co-movement between the USA and emerging markets. In the same manner, the evidence provided by Byers and Peel [14] supports that no linkages between the stock markets of the USA and Europe exist. Likewise, Ghosh et al. [15] have found no evidence supporting the Japan stock exchange having had an influence on the markets of Taiwan and Thailand.

Moreover, there are studies that have found out significant interconnections for some countries and no connection for some others whatsoever. Employing an error correction method, Ghosh et al. [15], for instance, indicate that the USA has

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doi:10.1016/j.physa.2009.02.023

dominated some of the Asian–Pacific countries, whereas Japan dominates some others, and there are countries dominated neither by Japan nor the USA.

The empirical methodologies in the studies mentioned above are basically those with co-integration techniques to capture the long-run relationships between the markets, and those with Vector Autoregressive (VAR) models suitable for investigating the short-run dynamic relations between the stock returns. Specifically, the common strategies employed by the studies are as follows. To start with, the unit root in the stock market price series is tested. The next step is to search for the linkages between the series. Studies utilized Vector Autoregression (VAR) and the Vector Error Correction Model (VECM) in order to provide causality analysis and/or impulse response functions.

On the other hand, the studies performed in the 1980s and 1990s found that financial time series show non-linear dynamics [16,17]. Scheinkman and LeBaron [18] suggested that a substantial part of the variation of the USA weekly stock returns comes from non-linearities as opposed to randomness. Various non-parametric non-linear causality tests such as the test by Hiemstra and Jones [19], a modified version of the Baek and Brock [20] test, have been proposed in the literature. Ozdemir and Cakan [21], using the test by Hiemstra and Jones [19], have found strong dynamic interactions between the world's major stock market indices for the 1990–2006 period. Moreover, De Gooijer and Sivarajasingham [22] investigated long-term linear and non-linear causal linkages between eleven stock markets, six industrialized markets and five emerging markets of South-East Asia for the 1987–2006 period. One of their findings shows that the Asian stock markets have become more internationally integrated since the Asian financial crisis. They also find quite a few remaining significant bi-directional and uni-directional causal non-linear relationships in these series.

A common problem of the above studies is that the linear and non-linear time series are used to investigate the relationships between the stock exchange of the developing and developed countries empirically. However, these time series models are not flexible to capture the high- and low-frequency dynamics of a series, which are transitory and permanent components, respectively. Therefore, following Prebischb's [23] paper on center periphery relations, Olgun and Ozdemir [24] have examined the dynamic interrelations between the equity markets of the center (USA) and the periphery (nine emerging markets, namely Argentina, Brazil, China, Egypt, Israel, Mexico, Philippines, South Korea, and Turkey) using the VARFIMA model. The finding of their paper is that the S&P500 has permanent effects on the stock prices of these nine emerging markets. This paper, on the other hand, investigates the dynamic linkages between a selected group of major stock markets of the center by analyzing the interconnections among the daily stock exchange level series of Tokyo (Japan), Frankfurt (Germany), London (UK) and New York (USA), using a multivariate long-memory model. The reason for choosing these four stock markets is that they rank the highest in terms of both transactions volume and capitalized value. The multivariate long-memory model is a highly flexible model which is able to capture a wide range of high- and low-frequency dynamics in a time series. The interaction dynamics among stock price indices of these stock markets to be examined can be modelled with a class of generalized fractionally integrated process [25,26]. Fractional dynamics, related to non-linear dynamics called "fractal" [27], are long and irregular cycles and have long-standing memory [28]. The interactions between the stock price indices can be captured by fractional models, given that they present better approximations for low-frequency dynamics than standard time series models. Moreover, this model allows us to use the data in its level form without any transformation to preserve the low-frequency component of the series. For this reason, the VARFIMA model is employed to capture the interactions between the stock prices in this paper. The results of this study show that there are strong interrelations among Germany, Japan, UK, and USA stock markets. The main contribution concerning the internationalization of the stock exchanges that emerges from the findings of this study is that the world's major stock markets considered here become more internationally integrated after the October 1987 crash and the breakdown of the Japanese 'bubble economy' at the end of 1989.

The rest of the paper is organized as follows. The next section presents the methodology. Section 3 estimates and evaluates the empirical results. The fourth and final section concludes.

2. Methodology

To detect the relationship between the international stock markets, this paper utilizes the four-variate vector ARFIMA(p,d,q) (VARFIMA(p,d,q)) model to estimate the conditional means of the stock market price indices. Let a general four-variate VARFIMA(p,d,q) model for x_t vector process be

$$\Phi(L)\Delta^d(L)(x_t-\mu)=\Theta(L)\varepsilon_t \tag{1}$$

where x_t is a 4×1 column vector given by $x_t=(y_{1,t},y_{2,t},y_{3,t},y_{4,t})'$, L is the lag operator, μ is the mean vector, and ε_t, a 4×1 column vector given by $\varepsilon_t=(\varepsilon_{1,t},\varepsilon_{2,t},\varepsilon_{3,t},\varepsilon_{4,t})'$, is white noise with $E(\varepsilon_t)=0$ and $\mathrm{Var}(\varepsilon_t)=RR'$. The ARMA operators $\Phi(L)=1-\sum_{i=1}^{p}\Phi_iL^i$ and $\Theta(L)=1+\sum_{i=1}^{q}\Theta_iL^i$ are 4×4 matrix polynomials in the lag operator L with degrees p, q respectively. The coefficients of polynomials $\Phi(L)$ and $\Theta(L)$ are assumed to satisfy the standard stationarity and invertibility conditions. The operator $\Delta^d(L)$ is a 4×4 diagonal matrix characterized by the four parameters d_1, d_2, d_3 and d_4 as follows:

$$\Delta^d(L)=\begin{bmatrix}(1-L)^{d_1} & 0 & 0 & 0\\ 0 & (1-L)^{d_2} & 0 & 0\\ 0 & 0 & (1-L)^{d_3} & 0\\ 0 & 0 & 0 & (1-L)^{d_4}\end{bmatrix}$$

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