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Salient features of dependence in daily US stock market indices

Luis A. Gil-Alana, Juncal Cunado, Fernando Perez de Gracia *

Department of Economics, Universidad de Navarra, Spain

HIGHLIGHTS

- In general, we observe a slight decrease in the degree of dependence across the years in the sample.
- The results suggest the presence of one structural break in the series related with the stock market crash in October 1987.
- With respect to the volatility processes, there is strong evidence of some degree of stationary long memory.

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ABSTRACT

This paper deals with the analysis of long range dependence in the US stock market. We focus first on the log-values of the Dow Jones Industrial Average, Standard and Poors 500 and Nasdaq indices, daily from February, 1971 to February, 2007. The volatility processes are examined based on the squared and the absolute values of the returns series, and the stability of the parameters across time is also investigated in both the level and the volatility processes. A method that permits us to estimate fractional differencing parameters in the context of structural breaks is conducted in this paper. Finally, the "day of the week" effect is examined by looking at the order of integration for each day of the week, providing also a new modeling approach to describe the dependence in this context.

1. Introduction

There is ample financial literature devoted to analyzing, modeling and forecasting the behavior of stock markets. The finance theory suggests many stylized facts in daily stock prices. Thus, for example, mean reversion in stock market prices have been examined in many papers [1–7]. However, the empirical evidence on mean reversion in stock market prices is still inconclusive. For example, the seminal papers by Fama and French [1] and Poterba and Summers [2] documented mean reversion in the US stock prices, while other authors such as Lo and MacKinlay [3] detected evidence against mean reversion using weekly US data. Second, the volatility in the stock returns shows an autocorrelation function that decays slowly. Other studies found that absolute and squared returns have long memory [8–10]. Third, daily stock prices usually tend to present day of the week effect, along with some other calendar anomalies such as the January effect and the turn of the month effect. The day of the week effect is a relevant stock market anomaly, which is extensively documented in the financial literature [11–14]. This anomaly in the stock market has been recently observed in many other countries [15–17].

In this paper, we focus on the above stylized facts. Initially, we examine the long range dependence in three daily US stock market indices; then the volatility processes are also examined from a long memory viewpoint. Finally, the "day of the week" effect is investigated, proposing a fractionally integrated model where the long run dynamics depend exclusively on

* Correspondence to: University of Navarra, School of Economics, E-31080 Pamplona, Spain. Tel.: +34 948 425 625; fax: +34 948 425 626.
E-mail address: fgracia@unav.es (F.P. de Gracia).

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the day of the week. Long range dependence has been extensively examined in stock markets [18–21]. Most of the empirical evidence using long range dependence is inconclusive. Thus, some authors find little or no evidence of long memory in stock markets [22]. On the other hand, others' papers find evidence of long memory in monthly, weekly, and daily stock market returns [23–27]. Finally, long range cross-correlations among financial indices have been examined by Podobnik et al. [28] and more recently by Wang et al. [29].

The contribution of this work is two-folded: first we provide further evidence of the long memory properties of the stock market indices and their volatility processes along with an analysis of their stability across time. In this context, a recent procedure to determine fractional integration with structural breaks is implemented. Second, we introduce a new model also based on long memory to describe the day-of-the-week effect in financial markets. The rest of the paper is structured as follows. Section 2 briefly describes the statistical models employed in the paper. Section 3 describes the data; in Section 4 we present the main results of the paper, while Section 5 contains some concluding comments and extensions.

2. The statistical models

The statistical models employed across the paper are all based on different versions of fractionally integrated models. This allows a greater degree of flexibility than the standard approaches based on the stationary I(0) or nonstationary I(1) models since the number of differences required to get I(0) series may non-necessarily be an integer number but a real value. Following the work of Granger [30], Granger and Joyeux [31] and Hosking [32], a rapidly growing body of literature has emerged on fractionally integrated ARFIMA processes. Robinson [33,34], Beran [35], Baillie [36] and more recently Gil-Alana and Hualde [37] present surveys on this topic. A process x_t is said to be integrated of order d if,

$$(1-L)^d x_t = u_t, \quad t = 1, 2, \ldots, \tag{1}$$

with $x_t = 0,\ t \leq 0$, where u_t is an I(0) process, defined as a covariance stationary process with spectral density function that is positive and finite, and L is the backward shift operator ($Lx_t = x_{t-1}$). In the event that d is not an integer, the series x_t requires fractional differencing in order to obtain a stationary (possibly) ARMA series. ARIMA(p, d, q) models in which d is a positive integer are special cases of the general process in (1). If $d > 0$ in (1), x_t is said to long memory, so-named because of the strong association between observations widely separated in time.

For stock indices, the evidence in favor of long memory may be due to the effect of aggregation. In fact, that is one of the main sources of long memory. The key idea is that, aggregation of independent weakly dependent series can produce a strong dependent series. Robinson [38] and Granger [30] showed that fractional integration can arise as a result of aggregation when data are aggregated across heterogeneous autoregressive (AR) processes; data involving heterogeneous dynamic relationships at the individual level are then aggregated to form the time series. Moreover, the existence of long memory in financial asset returns suggests that new theoretical models based on nonlinear pricing models should be elaborated.[1] Mandelbrot [40] notes that in the presence of long memory, martingale models of asset prices cannot be obtained from arbitrage. In addition, statistical inference concerning asset pricing models based on standard testing procedures may not be appropriate in the context of long memory processes [41].

Throughout the paper we focus on Robinson's [42] parametric approach, which does not require preliminary differencing; it allows us to test any real value d in (1) encompassing stationary and nonstationary hypotheses. We use the following model:

$$y_t = \beta' z_t + x_t, \tag{2}$$

where y_t is the time series we observe, β is a $(k \times 1)$ vector of unknown parameters; z_t is a $(k \times 1)$ vector of deterministic components, and x_t is given by (1), testing the null hypothesis:

$$H_o:\ d = d_o, \tag{3}$$

for any real value d_o. Thus, the null hypothesized model is:

$$y_t = \beta' z_t + x_t; \qquad (1-L)^{d_o} x_t = u_t, \quad t = 1, 2, \ldots,$$

and a trend-stationary representation is obtained if $z_t = (1, t)^T$ and $d_o = 0$; a unit root model if $d_o = 1$; and fractional I(d) models if d_o is a fractional value. Another advantage of this approach is that the limit distribution is standard normal, and this limit behavior holds independently of the deterministic regressors used for z_t in (2) and the type of weak dependence (e.g. ARMA) processes used for the I(0) disturbance term u_t. In the final part of the article, Eq. (1) will be replaced by:

$$(1-L^5)^d y_t = u_t, \quad t = 1, 2, \ldots, \tag{4}$$

to take into account "day of the week" long memory effects. The functional form of this procedure can be found in Robinson [42] and in any of its numerous empirical applications [45]. Another approach that will be employed in the paper, due to Gil-Alana [44], will permit us to estimate models like (1) and (2) in the context of structural breaks where the number of breaks and the break dates are endogenously determined by the model.

1 Peters [39] defined the "Fractional Market Hypothesis" for modeling long-term dependence features in financial time series.