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US stock market efficiency over weekly, monthly, quarterly and yearly time scales

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HIGHLIGHTS

- The US market efficiency varies over time and time scales.
- High efficiency is exhibited over yearly time scales.
- Market efficiency is affected by cyclic dynamics.

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ABSTRACT

In financial markets, the weak form of the efficient market hypothesis implies that price returns are serially uncorrelated sequences. In other words, prices should follow a random walk behavior. Recent developments in evolutionary economic theory (Lo, 2004) have tailored the concept of adaptive market hypothesis (AMH) by proposing that market efficiency is not an all-or-none concept, but rather market efficiency is a characteristic that varies continuously over time and across markets. Within the AMH framework, this work considers the Dow Jones Index Average (DJIA) for studying the deviations from the random walk behavior over time. It is found that the market efficiency also varies over different time scales, from weeks to years. The well-known detrended fluctuation analysis was used for the characterization of the serial correlations of the return sequences. The results from the empirical showed that interday and intraday returns are more serially correlated than overnight returns. Also, some insights in the presence of business cycles (e.g., Juglar and Kuznets) are provided in terms of time variations of the scaling exponent.

1. Introduction

The concept of market efficiency was introduced for considering the role of information in the formation of prices [1]. The so-called efficient market hypothesis (EMH) states that the arriving information into the market is quickly incorporated and correctly reflected in the security price. Since the information flow can be uncertain, the impact of information on the formation of prices can also be uncertain. In this form, the opportunity of forming arbitrage conditions is drastically reduced by the action of informed market participants [2–5].

Within the EMH, price changes must be unforecastable if the information and expectations of the huge diversity of market participants are accurately incorporated [6,7]. As a consequence, price dynamics in efficient markets should follow a random

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walk behavior resulting from the action of many market participants trying to take advantage of the arriving information [8,9]. Theoretically, no profits can be obtained from technical (i.e., information-based) trading because the information on price patterns is evenly distributed, leaving only noise information associated with random price fluctuations. A plethora of scientific studies have focused on showing that prices follow a random walk behavior by studying the predictability of security returns on the basis of past price changes. The survey by Lim and Brooks [10] provides an interesting and detailed description of the main contributions in the empirical analysis of the random walk hypothesis.

Generally, the EMH has been posed as an "all-or-none" condition [10,11]. Some authors from behavioral economics have considered that posing the efficiency of markets within the "all-or-none" framework is restrictive as the incorporation of information into the market dynamics is a complex, non-instantaneous process. Motivated by behavioral economics, Lo [12] proposed an evolutionary framework for characterizing the efficiency of financial markets. Here, rather than an all-or-none condition, market efficiency is a characteristic that varies continuously over time and across markets. By extending the traditional EMH, Lo [12] proposed the adaptive market hypothesis (AMH) where markets behave as an evolutionary system with participants and instruments interacting and evolving dynamically according to intrinsic rules of economic selection (i.e., financial agents compete and evolve to survive). In contrast to the classic view, participants are equipped with bounded rationality [13], taking decisions within a highly uncertain environment that deviates the decisions from optimality [12,14,15]. In the AMH view, market efficiency reflects the complex interaction of the market environments with the behavioral structure of the market participants. The result is that the efficiency of the market varies over time, producing some periods of relative predictability. That is, the market dynamics can be predicted to some extent due to changing business (cycles, bubbles, crashes, etc.), social and political conditions [16]. Departures from "full efficiency" are allowed as the market dynamics adapts to changing conditions and external shocks. Convergence to equilibrium, which is a central concept for the EMH, is neither guaranteed nor likely to occur at any time within the AMH [17].

The aim of this work is to estimate the departures of the US stock market, as reflected by the Dow Jones Index, from the random walk hypothesis. This is done by computing the fractal scaling exponent from the detrended fluctuation analysis (DFA) implemented over a rolling window. The scaling exponent value of 0.5 reflects the dynamics associated with random walks, so departures from this value are considered as departures from full market efficiency. The use of fractal analysis for characterizing deviations from the random walk hypothesis is not new. In fact, several studies have indicated that the fractal analysis based on, e.g., DFA is a suitable framework for analyzing departures from the EMH. For instance, Cajueiro and Tabak [9] showed that the scaling exponent for financial time series is not constant, but exhibits important variations over time. In this way, it is apparent that Cajueiro and Tabak's work preceded Lo's work [12] on the AMH proposal. In the recent decade, the DFA and the R/S analysis have been widely used for detecting the presence of long-term correlations in a diversity of financial systems, from stock [10] to energy markets [18,19]. In this line, for the US market over the scrutinized period from 1929 to date, it is shown that the US stock market depends on both time and horizons (e.g., months, quarters, etc.). Specifically, relative to the existing results in the literature, our contribution can be summarized as follows: (a) in general, the testing of the market efficiency has been based on the analysis of interday price returns. We also considered overnight and intraday price returns and showed important differences in the scaling behavior with respect to the interday price return. (b) Some important departures from efficiency can be linked to large events, such as financial crises, wars, etc. (c) The presence of cycles in the scaling exponent dynamics was detected. Interestingly, the dominant cycling periods can be related to well-known business cycles (e.g., Juglar, Kuznets, etc.). Some implications of our results for stock market predictability are discussed in the last part of the paper.

2. Data

The time series for the DJIA was obtained with daily frequency from www.yahoo.com for the period from 1929 to date (March 2014). Only weekdays that are not associated with a national party day (e.g., Martin Luther King Day) are considered for stock market operation. These days are known as business days and are called in short as b-days. To the best of our knowledge, the DJIA is the oldest daily financial series and consists of 30 of the largest and most widely held public companies in the US. In this way, the DJIA is quite suitable to study the market efficiency dynamics as it should retain some important features of the US economy in the recent 80 years. The DJIA time series is composed of open ($P_{O,j}$) and close ($P_{C,j}$) prices. Based on these prices, we have considered the following logarithmic return:

(a) *Interday (close-to-close) return*: $R_{D,j} = (\log(P_{C,j}) - \log(P_{C,j-1}))/\log(P_{C,j})$. This return is the standard signal used for checking the predictability of stock markets.
(b) *Overnight (close-to-open) return*: $R_{N,j} = (\log(P_{O,j}) - \log(P_{C,j-1}))/\log(P_{O,j})$. This return corresponds to price changes due to close-to-open adjustments. The overnight return has been considered in combination with the interday return [20] for estimating the daily market volatility. Some studies have shown important differences between the dynamics of interday and overnight returns and suggested that the latter reflects the impact of global markets on the US stocks [21,22].
(c) *Intraday (open-to-close) return*: $R_{I,j} = (\log(P_{C,j}) - \log(P_{O,j}))/\log(P_{C,j})$. This return corresponds to the price change within a stock session. The dynamics of intraday returns have been poorly studied in the specialized literature. For instance, it has been found that return predictability persisted for up to 60 min according to nonlinear models, even though profitability decreases as time elapses [7,23].