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Estimating serial correlation and self-similarity in financial time series—A diversification approach with applications to high frequency data

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HIGHLIGHTS

- Review of self-similarity estimation methods for financial time series.
- Performance test for estimation methods under typical financial market conditions.
- Improved estimation by "diversification of methods" for sake of higher robustness.
- Naïve diversification and minimum variance portfolio approach.
- Application to real market data shows different regimes of serial correlation level.

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ABSTRACT

We derive a heuristic method to estimate the degree of self-similarity and serial correlation in financial time series. Especially, we propagate the use of a tailor-made selection of different estimation techniques that are used in various fields of time series analysis but until now have not consequently found their way into the finance literature. Following the idea of portfolio diversification, we show that considerable improvements with respect to robustness and unbiasedness can be achieved by using a basket of estimation methods.

With this methodological toolbox at hand, we investigate real market data to show that noticeable deviations from the assumptions of constant self-similarity and absence of serial correlation occur during certain periods. On the one hand, this may shed a new light on seemingly ambiguous scientific findings concerning serial correlation of financial time series. On the other hand, a proven time-changing degree of self-similarity may help to explain high-volatility clusters of stock price indices.

1. Introduction

The question whether or not financial time series exhibit serial correlation has been a topic of constant debate in empirical finance. As an early contribution to the question whether stock returns are serially correlated, Greene and Fielitz [1] find long-range dependence in stock returns based on daily observations of a five years lasting series. Booth et al. [2] receive similar results when analyzing foreign exchange rates, a finding that is later confirmed by Cheung [3]. Aydogan and Booth [4] use weekly returns over 18 years both for individual stocks and for stock indexes and find no evidence for long-range dependence. Fama and French [5] find negatively autocorrelated monthly returns implying intermediate memory.

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Poterba and Summers [6] also investigate monthly returns to conclude that returns over short periods seem to be positively correlated while over large intervals negative correlation could be found. Lo and MacKinley [7] use weekly and monthly stock index returns and derive significant long-range-dependence. However, Lo [8] using a modified test statistic that accounts for short-term dependence before measuring long-term effects, contradicts the earlier findings and suggests absence of long-range dependence both on daily and on monthly base. Cheung and Lai [9] and Jacobsen [10] using Lo's modification mainly confirm his finding when investigating international stock indices, while Barkoulas and Baum [11] use a spectral regression technique to discover long-term dependence in individual stock returns that disappear in the aggregate level. Teverovsky et al. [12] criticize the modification of Lo [8] and show that it is biased towards the acceptance of the null hypothesis that there is no long-range dependence. Furthermore, Willinger et al. [13] find evidence for long-range dependence in the same sample as Lo [8], conjecturing that "Lo's acceptance of the hypothesis [...] is less conclusive than is usually regarded in the econometrics literature". Following this prominent debate, during the first decade of this century, a plentitude of studies were published, using different kinds of estimation techniques, return intervals, underlying assets and observation periods which intuitively leads to a heterogeneous picture whether long memory is present or not (e.g. Cajueiro and Tabak [14], Cajueiro and Tabak [15], Erzgräber et al. [16], for a survey see e.g. Lim and Brooks [17]).

Surprisingly, only partly interlinked with the latter strand of literature, a closely related debate took place mainly in the 1990s with some early contributions in the late 1980s, the question of market efficiency, or whether asset prices are subject to periods of over- and/or underreaction. De Bondt and Thaler [18] derive abnormal returns from strategies that buy former "losers" and sell former "winners", i.e. apply reversal strategies. Zarowin [19] however shows that these findings are mainly driven by size effects, i.e. that small stocks outperform larger ones. Jegadeesh and Titman [20] observe significant profitability of momentum strategies, i.e. strategies of buying winners and selling losers outperform over holding periods of three to twelve months while over longer holding periods the effect vanishes or is even turned around and mainly find underreacting behavior of market participants (see e.g. Bernard and Thomas [21], Bernard and Thomas [22], Cutler et al. [23], Loughran and Ritter [24], Womack [25] or Chan et al. [26]).

Explanations for the under- or overreaction patterns are driven by agent-based models starting with Barberis et al. [27] and Daniel et al. [28]. The approaches incorporate psychological evidence and introduce behavioristic components as overconfidence of investors and investor sentiment. Fama [29] rejects these explanations to be generally valid. Based on a survey of several empirical studies and theoretical models he conjectures "that the anomalies are chance results, apparent overreaction of stock prices to information is about as common as underreaction".

Summarizing, the empirical evidence whether stock price returns do or do not exhibit serial correlation and so deviate from pure random walk properties is not at all unique. Neither the mathematical time series techniques on long range dependence nor the econometric tests on market efficiency suggest a clear conclusion towards an enduring market pattern. Moreover, periods of underreaction or overreaction seem to be transitory phenomena alternating with phases of market efficiency, but – following Fama [29] – not in a systematic fashion which leads him to reason that such temporary anomalies are consistent with the assumption of market efficiency. While the chance character of inefficiencies may or may not be regarded as an overall efficiency, the finding suggests a procedure for the related field of time series analysis: Temporary phases of positive or negative serial correlation might be compensating each other in the long run so that the overall shape of the time series again appears in the form of feigned serial independence. If so, a deeper investigation of financial time series on the stock price might help to solve the puzzle of seemingly controversial empirical evidence.

One way to account for different levels of serial dependence over time that recently enjoyed great popularity, is to replace the constant dependence parameter by a time-varying one. Focusing on Gaussian processes, this would mean, replace fractional Brownian motion of Mandelbrot and van Ness [30] by the so-called multifractional Brownian motion going back to Lévy-Véhel and Peltier [31]. Indeed, there is a remarkable number of empirical articles establishing a time-dependent estimator of the dependence parameter, typically leading to heavily fluctuating parameter estimates (see e.g. Cajueiro and Tabak [14], Cajueiro and Tabak [32], Alvarez-Ramirez et al. [33] or Kumar and Deo [34]). While these approaches look promising at first glance, their economic reasonability is still rather limited. This is due to different reasons: Some authors choose approaches using a moving-window-procedure where the dependence parameter of the next observation point is estimated by shifting the observation period one point further. Yet, these estimation procedures typically lack robustness, as the methods need a large number of data points within one window. For example, using daily observations with a reasonable estimation window of ± 1 year, yields less than 450 data points for one observation. Furthermore, no arguments are given which of the bunch of different estimation methods should be chosen. Other approaches (e.g. Bianchi and Pianese [35] and Bianchi et al. [36]) work appropriately with less data points, however, the methodology of these authors is parametric and imposes ex-ante limits on the shape of the parameter to be estimated.

In this paper, we establish a new approach to moving-window procedures: The key problem of robustness is accounted for in two ways: On the one hand, we increase the amount of observations by using high frequency data. With a period length of six months, this allows for subseries of 16,000–17,000 data points which will prove to be sufficient for reliable estimates. On the other hand, before starting the analysis of real market data, we will carefully check the performance of eight different existing mainly non-parametric methods to estimate the dependence parameter d which captures the extent of serial correlation and the Hurst parameter H indicating the degree of self-similarity. More precisely, as each of the methods looks at self-similarity and dependence from a different angle, they might or might not be well suited for estimation in certain types of time series. Against this background, we will perform an extensive Monte-Carlo simulation under different conditions. Using bootstrapping argumentation, we will so be able to check robustness of the available