Commodity futures and market efficiency: A fractional integrated approach

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**Abstract**

In financial time series, persistence or inertia is a feature usually observable in absolute returns, i.e., a proxy for volatility. Moreover, asset return series should be essentially unpredictable according to the efficiency market hypothesis (EMH) in its weak form. Surprisingly, recent literature has found evidence of anti-persistence in technology stocks and commodity futures returns. Anti-persistence would be indicative of an overreaction of asset prices to incoming information.

In this article, we concentrate on a sample of 20 DJ-AIG commodity future indices—including broad indices and sub-indices (e.g., energy, grains, industrial metals, and livestock) over the period January 1991–June 2008. We conclude that returns series either over-react or under-react to new market information, which disconfirms the EMH in its weak form. Such disconfirmation would make it possible for market participants to devise non-linear statistical models for improved index forecasting and derivatives valuation.

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**Introduction**

Lagged effects or persistence in time series has been the center of attention of various studies over the past two decades. Seminal work by Granger and Joyeux (1980) and Hosking (1981) characterized fractionally integrated processes, which include highly persistent but stationary processes. Such characterization made it possible to establish a bridge between scaling, a phenomenon extensively studied in physics, hydrology, and other sciences (e.g., Peng et al., 1994; Chen et al., 2002; Chamoli et al., 2007), and the long-memory or persistence feature observable in various economic and financial series. In particular, persistence in asset returns and asset volatility has drawn the attention of several recent studies in the fields of financial econometrics and econophysics (e.g., Pasquini and Serva, 1999; Barkoulas et al., 2000; Carbone et al., 2004; Mills, 2004; Mulligan, 2004; Connor and Rossiter, 2005; Fernandez, forthcoming; Ané and Ureche-Rangau, 2008; Los and Yu, 2008; Elder and Jin, 2009).1

In particular, a recent article by Elder and Jin (2009) found evidence of anti-persistence in grain and meat commodity futures returns over the period 1974–2006. The authors conclude that their findings imply that some commodity futures returns, such as soybeans, wheat, and lean hogs, are choppier than white noise, and, therefore, their price dynamics may be such that their returns over-react to incoming information. As a result, commodity futures returns would be subject to considerable periodic high-frequency variation.

The anti-persistence phenomenon in financial time series was previously documented by Mulligan (2004) for a sample of 54 technology securities over the period 1993–2001. Mulligan found that various return series in his sample exhibited such a feature, being AT&T, Cisco Systems, Dell Computer, and Time Warner Telecom examples of well-known firms. Mulligan also found evidence of persistence in a few return series, such as Intel, Advance Micro Devices, and Intraware. Persistence in asset returns was also documented by Barkoulas et al. (2000), who analyzed the Greek stock market during the 1980s and the early 1990s.

Various statistical methods aimed at quantifying the degree of fractional integration have been devised over time in various fields of knowledge. A thorough discussion on the mean squared-error, size, and power features of some of such methods (e.g., several variants of the rescaled range statistic (R/S), detrended fluctuation analysis (DFA), wavelets, quasi maximum likelihood, among others) can be found in three recent articles by Mielniczuk and Wojyllo (2007), Rea et al. (forthcoming), and Fernandez (forthcoming).

The estimation method utilized to gauge fractional integration may be a key factor when drawing conclusions as to the degree of persistence/anti-persistence exhibited by a time series. For instance, in Mulligan’s sample, R/S analysis lends much support to the anti-persistence hypothesis than the variogram method.
The sample varigram of a time series $y_t$ is measured as $V(A) = \frac{1}{N} \sum_{i=1}^{N} (y_{t+i} - y_t)^2$ where $N$ is the number of squared differences. The Hurst exponent, $H$, which equals the persistence parameter $d$ plus 0.5, is computed by a regression (in logs) from the relationship $V(A) = A^{2H}$.

The R/S statistic is not utilized in this article because it becomes very computationally intensive when working with a rolling sample window.

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The contribution of our work is two-fold. Firstly, unlike previous research, we rely upon a dynamic estimator of fractional integration, which allows us to unveil whether one single commodity may adjust too rapidly or too slowly to the arrival of new information, depending upon the time period under consideration. Such a feature cannot certainly be perceived when one relies upon a static estimator. Secondly, by resorting to such a dynamic estimation strategy, our conclusions differ from those found in recent research. For instance, under the three estimation methods that Elder and Jin (2009) use, they find evidence of anti-persistence in Lean Hogs returns, whereas we conclude the opposite. In addition, they find some evidence of anti-persistence in corn returns, while our five estimation methods indicate otherwise.

This article is organized as follows. Section 2 presents the statistical tools utilized in this study, namely, five alternative methodologies to gauge fractional integration. Section 3 is divided into two subsections: Section 3.1, which describes the data, and Section 3.2, which discusses the empirical findings. Finally, Section 4 presents a summary of the main findings.

**Theoretical background**

**Long-memory process**

A time series $y_t$ is a long-memory process or exhibits long-range dependence if its autocovariance function declines hyperbolically to zero. Two independent articles, by Granger and Joyeux (1980) and Hosking (1981), showed that a long-memory process can be parameterized by means of a fractionally integrated process, \((1-L)^d y_t = \epsilon_t\), where $L$ is the lag operator, $d$ is the fractional difference parameter, and $\epsilon_t$ is the expected value of $y_t$.

The fractional difference filter is defined by

\[
(1-L)^d y_t = \sum_{k=0}^{\lfloor d \rfloor} \binom{d}{k} (-L)^k y_t
\]

where $d$ is a real number, such that $d > -1$.

\[
\binom{d}{k} = \frac{d^k}{k!(d-k)!} = \frac{I(d+1)}{I(k+1)I(d-k+1)}
\]

and $I(.)$ is the gamma function, such that $y_t$ admits an $AR(\infty)$ representation.

When $|d| > 1/2$, $y_t$ is non-stationary; when $0 < d < 1/2$, $y_t$ is stationary and it exhibits long-memory; whereas if $-1/2 < d < 0$, $y_t$ is stationary and it displays short memory (i.e., anti-persistence).

**Alternatives methods to estimate the fractional integration parameter**

**Wavelet-based**

Veitch and Abry (1999) developed a weighted least-squares estimator of $d$ from a wavelet-based decomposition of the time series of interest. In particular, if $d(j,\tau_0)$ represents the wavelet variance of a time series $y_t$ at scale $\tau_0 = 2^{j-1}$, a discrete wavelet transform (DWT)-based estimator of it is given by

\[
d(j,\tau_0) = \frac{1}{n_j} \sum_{k=1}^{n_j} d^2_{jk}
\]

where $n_j$ is the number of wavelet coefficients at level $j$, and $d_{jk}$ is the $k$th DWT-wavelet coefficient at level $j$ (see, for instance, Percival and Walden, 2000, Chapter 9). Veitch and Abry derived a heteroscedastic regression model, which relates the wavelet
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