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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.

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

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[1] For an analysis of persistence in non-linear time series (e.g., logistic smooth transition autoregressive (LSTAR) models, exponential smooth transition autoregressive (ESTAR) models, and self-exciting threshold autoregressive (SETAR) models), see Kapetanios (2007).

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does.[2] Elder and Jin's computations in turn are based on Geweke and Porter-Hudak (1983)'s semi-parametric approach (GPH), Jensen (1999)'s wavelet ordinary least-square estimator (WOLS), and Jensen (2000)'s banded wavelet maximum-likelihood estimator (BWMLE). The GPH and BWMLE approaches lend support to the anti-persistence phenomenon in about the same futures commodity series, and they yield numerically similar estimates. The WOLS estimate by contrast tends to predict a smaller degree of anti-persistence, and it detects anti-persistence in a couple of futures commodities, for which neither the GPH nor the BWMLE approach finds evidence of such a feature.

The use of fractionally integrated processes has not been limited to in-sample modeling of time series data. Indeed, a strand of the literature has compared the forecast properties of fractional integrated and autoregressive processes, concluding that the former may outperform the latter. For instance, Barkoulas and Baum (2006) focused on US monetary indices and concluded that these series have a fractional order between one and two. When carrying out out-of-sample forecasting, Barkoulas and Baum found that the fitted fractional processes generally yielded consistently more accurate forecasts than benchmark autoregressive processes, as measured by their root-mean squared error. On the other hand, for some of the series analyzed, the authors concluded that the fractional specification encompassed the autoregressive one. An earlier article by Barkoulas et al. (2000) also concluded that a fractional specification may have a better out-of-sample performance than autoregressive and random walk specifications.

In this article, we focus on five alternative estimators to gauge fractional integration: a weighted wavelet-based estimator (e.g., Mielniczuk and Wojyllo, 2007; Fernandez, forthcoming), two periodogram-based estimators, obtained by ordinary least squares and least absolute deviations (e.g., Taqqu et al., 1995), GPH's estimator, and a quasi maximum-likelihood estimator obtained by Haslett–Raftery's method (1989). Our center of attention is a set of 20 commodity series belonging to the Dow Jones-AIG commodity index family, which includes 5 broad categories—energy, grains, industrial metals, livestock, and precious metals, and 15 sub-indexes. The sample period is January 1991–June 2008.

In order to allow for time-variant estimates of fractional integration for each series, we construct rolling estimates based on the above-mentioned methods. In general, our findings show that absolute returns are highly persistent. On the other hand, some returns series may exhibit either anti-persistence or persistence, which challenges the efficiency market hypothesis (EMH) in its weak form. However, the degree of persistence (anti-persistence) detected in the series may be sensitive to the estimation method under consideration. For instance, GPH's estimator tends to be more conservative than the other four approaches, as regards to the strength of anti-persistence/persistence detected.

Nonetheless, the alternative estimation methods considered tend to agree on the sign of fractional integration of some specific broad indexes and sub-indexes. Specifically, four out of the five methods support the existence of anti-persistence in the broad categories of Precious metals. On the other hand, the five methods agree upon the anti-persistence of returns on the Gold and Silver sub-indexes, while they all support the existence of persistence in natural gas, lean hogs, and corn returns.[3]

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, $(1-L)^d(y_t-\eta)=\varepsilon_t$, where L is the lag operator, d is the fractional difference parameter, η is the expected value of y_t and ε_t is a zero-mean and short-memory error term. The fractional difference filter is defined by

$$(1-L)^d = \sum_{k=0}^{\infty} \binom{d}{k} (-1)^k L^k$$

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

$$\binom{d}{k} = \frac{d!}{k!(d-k)!} = \frac{\Gamma(d+1)}{\Gamma(k+1)\Gamma(d-k+1)}$$

and $\Gamma(.)$ is the gamma function, such that y_t admits an AR(∞) 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 $\upsilon_y^2(\tau_j)$ represents the wavelet variance of a time series y_t at scale $\tau_j \equiv 2^{j-1}$, a discrete wavelet transform (DWT)-based estimator of it is given by

$$\hat{\upsilon}_y^2(\tau_j) \equiv \frac{1}{n_j} \sum_{k=1}^{n_j} d_{j,k}^2 \quad (1)$$

where n_j is the number of wavelet coefficients at level j, and $d_{j,k}$ is the kth 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

[2] The sample variogram of a time series y_t is measured as $V(\Delta)=\sum_t (y_{t+\Delta}-y_t)^2/N$, 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 $V(\Delta)=\Delta^{2H}$.

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