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Long-range dependence in the volatility of commodity futures prices: Wavelet-based evidence

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A B S T R A C T

Commodity futures have long been used to facilitate risk management and inventory stabilization. The study of commodity futures prices has attracted much attention in the literature because they are highly volatile and because commodities represent a large proportion of the export value in many developing countries. Previous research has found apparently contradictory findings about the presence of long memory or more generally, long-range dependence. This note investigates the nature of long-range dependence in the volatility of 14 energy and agricultural commodity futures price series using the improved Hurst coefficient (H) estimator of Abry, Teyssière and Veitch. This estimator is motivated by the ability of wavelets to detect self-similarity and also enables a test for the stability of H. The results show evidence of long-range dependence for all 14 commodities and of a non-stationary H for 9 of 14 commodities.

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1. Introduction

Commodities are physical assets such as gold, corn or crude oil that serve as the underlying for futures and futures options traded at financial and commodity exchanges such as the Chicago Mercantile Exchange. Some, such as silver or wheat, are storable while others, such as electricity or live cattle, are not. Commodity futures contracts have long been used by producers and processors to facilitate risk management and inventory stabilization. It has been found recently that commodities have highly desirable portfolio diversification properties [1,2], as a result of which non-traditional Index Traders such as pension funds have taken on large commodity futures positions from 2004 to 2008.

The period 2005–2008 was also characterized by a remarkable commodity bull cycle, which peaked in July 2008, before commodity prices started to decline rapidly. Fig. 1 illustrates the commodity bull cycle by presenting the dollar value of the S&P Goldman Sachs Commodity Index™over the period 2001–2009. This is a weighted index of various commodity futures, including (as of May 19, 2009) 67.65% energy commodities, 17.19% non-animal agricultural, 6.63% industrial metals, 5.20% livestock and 3.33% precious metals.

Commodity prices have historically attracted much attention in the research literature because their high volatility is difficult to reconcile with theoretical models based on the theory of storage [3,4]. They have also been amply studied in the development economics literature because commodities represent a large economic export value for most developing countries.

This paper considers the longstanding—yet still very active—problem of identifying, measuring and characterizing long-range dependence (also known as long memory) in the volatility of asset prices. For example, Alvarez-Ramirez et al. [5] use

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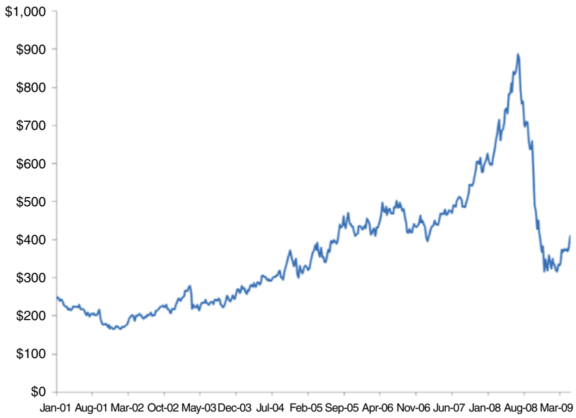

Fig. 1. S&P Goldman Sachs Commodity Index™ dollar value, 2001–2009. Source: Goldman Sachs.

detrended fluctuation analysis to show that the Hurst exponent for US stocks is clearly time varying and moreover that a key turning point was the end of the Bretton Woods system in 1972. Relatively less research has been done, however, using commodity futures data than using equity data. Moreover, studies of long-range dependence using commodity price data have focused on commodity prices, while the present paper studies commodity price volatility.

Long-range dependence implies that prices (or price volatility) may be predictable to some extent if we believe that markets are not even weak-form efficient as defined by Eugene Fama,[1] and also implies that option pricing solutions based on the Gaussian normal (e.g. Black-Scholes), GARCH or stochastic volatility frameworks may be substantially biased [6,7].

This paper uses a novel wavelet-based and improved R/S analysis framework to obtain new estimates of the time-varying Hurst coefficient of long-range dependence in 14 agricultural and energy commodity futures time series of price volatility. A time-varying Hurst coefficient can be interpreted in terms of the multifractal properties of asset prices, which imply that different moments of a variable's distribution are associated with different scaling laws [8].[2] The results show that the null hypothesis of geometric Brownian motion should be rejected for all commodities even after we have accounted for the possibility of a time-varying (non-stationary) Hurst coefficient. It is also found that the Hurst coefficient is time varying for most commodities. These findings may help us to reconcile previous, possibly contradictory results in the literature.

2. The Hurst coefficient and R/S analysis

The canonical model used to describe asset prices, such as commodity futures prices, consists of geometric Brownian motion (e.g., the Black–Scholes model):

$$dx = \alpha x dt + \sigma x dZ \tag{1}$$

where $dZ = \varepsilon\sqrt{t}$ is a Wiener process, x is a random variable independent of time and with instantaneous rate of change (drift) α and σ is the diffusion term or standard deviation. Increments of geometric Brownian motion are IID and stationary. In contrast, fractional Brownian motion describes a process whose increments are *not* independent:

$$dx = \alpha x dt + \sigma x dZ^H \tag{2}$$

where $0 < H < 1$ is a parameter known as the Hurst coefficient [9]. The variance of fractional Brownian motion over a time increment Δt depends on H as follows:

$$E\,[x(t + \Delta t) - x(t)]^2 = \sigma^2(\Delta t)^{2H}. \tag{3}$$

Note that the special case $H = 0.5$ implies geometric Brownian motion which is our null.

To recover the Hurst coefficient, a number of R/S analysis methods have been developed since Mandelbrot's [10] seminal study of cotton prices, in particular the early, influential work of Mandelbrot and Taqqu [11] and Lo [12].

The study of long-range dependence in financial and commodity prices is a large and currently very active area of research (see [13–26]). In the case of commodity futures, evidence of fractal-type dependence (e.g. fractional Brownian motion) as captured by the Hurst coefficient was found by Corazza, Malliaris and Nardelli [25], Cromwell, Labys and Kouassi [26] and Helms, Kaen, and Rosenman [16], among others. Turvey [24], however, finds that the null, i.e. $H = 0.5$, can be rejected in only two cases (wheat and live cattle) out of 17 agricultural commodity futures considered.

[1] We thank a journal reviewer for placing emphasis on this point and also for providing very helpful comments suggesting how to clarify a number of key concepts used in the paper. These suggestions have greatly improved the exposition in the paper.

[2] We thank a journal reviewer for bringing to our attention this reference and its implications for the present paper.