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Commodity futures and market efficiency

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ABSTRACT

We analyze the market efficiency of 25 commodity futures across various groups—metals, energies, soft commodities, grains and other agricultural commodities. To do so, we utilize the recently proposed Efficiency Index to find out that the most efficient among all of the analyzed commodities is heating oil, closely followed by WTI crude oil, cotton, wheat, and coffee. On the other end of the ranking scale we find live cattle and feeder cattle. The efficiency is also found to be characteristic for specific groups of commodities, with energy commodities being the most efficient and other agricultural commodities (composed mainly of livestock) the least efficient groups. We also discuss contributions of long-term memory, fractal dimension and approximate entropy to the total inefficiency. Last but not least, we come across the nonstandard relationship between the fractal dimension and the Hurst exponent. For the analyzed dataset, the relationship between these two variables is positive, meaning that local persistence (trending) is connected to global anti-persistence. We attribute this behavior to specifics of commodity futures: they may be predictable over a short term and locally, but over a long term they return to their fundamental prices.

1. Introduction

Efficient market hypothesis (EMH) has been a cornerstone of financial economics for decades and it has been brought to the forefront by the influential paper of Fama (1970), summarizing the empirical findings based on efficient market hypotheses by Fama (1965) and Samuelson (1965). Even though the actual definitions differ – the former study builds on a random walk definition and the latter on a martingale definition – the qualitative consequences are the same: the efficiency of a market originates in the impossibility of systematic control of the market, usually in the form of above-average risk-adjusted returns. Fama (1991) later subdivided the efficiency hypothesis into three forms – weak, medium and strong – which vary by the different information sets taken into consideration, and all are based on inclusion of the information sets in market prices. The weak-form EMH says that all past price movements (and associated statistics) are already reflected in the market prices. Prediction of market movements based on historical time series (technical analysis) is thus not possible for this form. The medium-form EMH states that all publicly available information is already contained in the prices, while the strong-form EMH adds all (even privately) available information. The medium form thus discards fundamental analysis and the strong form eliminates even insiders from making a profit. Evidently, a weaker form of EMH is always a subset of a stronger form. Even though EMH has been repeatedly disparaged both empirically and theoretically (Cont, 2001; Malkiel, 2003), and even more so after the Global Financial Crisis broke out in 2007/2008, its validity remains an open issue, yet still it persists in standard textbooks on financial economics (Elton et al., 2003).

Comparison of efficiency across various assets has been discussed in different studies. In a series of papers, Di Matteo et al. (2003, 2005) and Di Matteo (2007) study long-term memory and multi-scaling of a wide portfolio of stock indices, foreign exchange rates, Treasury rates and Eurodollar interbank interest rates using various estimators of long-term memory. They show that stock indices of more developed countries are also more efficient yet showing weak signs of anti-persistence (properties of long-term memory are described in detail in the Methodology section), finding no deviations from EMH for any of the analyzed maturities of Eurodollar and Treasury rates. For US dollar exchange rates, the authors find diverse results with no evident pattern connecting the exchange rate efficiency level with geographical or geopolitical properties. In another series of papers, Cajueiro and Tabak (2004a,b,c, 2005) compare stock market indices from different continents, finding that the US and Japanese markets are the most efficient whereas the Asian and Latin American ones are revealed to be the least efficient. Lim (2007) studies non-linear dependencies, their evolution in time and connection to market efficiency for a set of stock markets. The author finds the US market to be the most efficient, followed by Korea, Taiwan and Japan. On the other end of the ranking scale lie Malaysia, Chile and Argentina. Zunino et al. (2010) utilize the complexity–entropy causality plane to rank stock market

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indices to show that the emerging markets are less efficient than the developed ones, as one would expect. The difference is attributed to a lower entropy value and a higher complexity of the emergent markets. Kristoufek and Vosvrda (2013) introduce the Efficiency Index and come up with a ranking of stock market indices, finding that the most efficient markets are located in Western Europe, USA and Japan, whereas the least efficient markets are situated in Latin America and Asia.

However, to the best of our knowledge, proper attention has not been given to a comparison of the efficiency of commodity markets. In this paper, we analyze futures markets for a wide range of commodities – energy, metals, and various agricultural commodities – and compare their efficiency using the Efficiency Index proposed by Kristoufek and Vosvrda (2013). The paper is structured as follows. Section 2 covers literature dealing with the efficiency of commodities. Section 3 describes the methodology in detail. Section 4 describes the analyzed dataset and gives the results. Section 5 is the conclusion. We show that efficiency is related to a type of commodity (energy commodities being the most efficient and other agricultural commodities being the least efficient). In addition, we find a non-standard relationship between the local and global properties of the series: most of the series show local persistence, yet they are globally mean-reverting. The series thus follow quite strong local trends but over a long term, they return to their fundamental value.

2. Literature review

Testing the market efficiency in commodity markets has a long history. Roll (1972) examines the commodity price index and argues that the market is inefficient due to significant serial correlations among its returns. Danthine (1977) disputes such claims and shows that the violation of the standard martingale condition does not imply inefficiency in the commodity spot markets with support of risk aversion and no arbitrage opportunities. Gjolberg (1985) analyzes oil spot prices at the Rotterdam market, rejects the efficiency hypothesis and constructs a profitable trading rule for daily, weekly and monthly price changes. Panas (1991) studies the Rotterdam oil market as well, together with the Italian market, and based on leptokurtic monthly price changes, he rejects the markets' efficiency. Herbert and Kreil (1996) examine the US spot (cash) and futures markets for natural gas and find these to be inefficient. They argue that such inefficiency is caused by the specific structure of the US gas markets.

More recently, Tabak and Cajueiro (2007) analyze the efficiency of Brent and WTI crude oil using the rescaled range analysis and show that the markets are becoming more efficient in time. Alvarez-Ramirez et al. (2008) study the auto-correlation structure of the crude oil process using the detrended fluctuation analysis. They show that the market is efficient over a long term, but the auto-correlation structure leads to rejection of the efficiency over a short term. Alvarez-Ramirez et al. (2010) further inspect the crude oil markets using lagged detrended fluctuation analysis and argue that multi-scaling and deviations from the random walk behavior cause the spot prices to be inefficient. The research on evolution of efficiency in time is further extended by Wang and Liu (2010) where the authors study short-, medium- and long-term efficiency for various scales within the detrended fluctuation analysis approach. They show that the WTI crude oil becomes more efficient in time for all three of the analyzed scales. Also using the detrended fluctuation analysis, Wang et al. (2011) argue that WTI crude oil spot and futures are not efficient for time scales shorter than one month. Crude oil markets (Brent and WTI) are also analyzed by Charles and Darné (2009), who use the variance ratio tests to show that the Brent market is weak-form efficient but the WTI market is not, while providing some discussion about effects of deregulation on the markets.

Lee and Lee (2009) study four energy commodities – coal, oil, gas, and electricity – using panel data stationarity tests to uncover that none of the studied markets is efficient in the strict stationarity sense. Lean et al. (2010) study WTI crude oil spot and futures prices using mean–variance and stochastic dominance approaches, finding no arbitrage opportunities between spot and futures prices while the findings are robust for various sub-periods and critical events. Narayan et al. (2010) study the long-term relationship between spot and futures prices of gold and oil. They find that investors use the gold market to hedge against inflation, and – more importantly for our purposes – the crude oil market predicts the gold market and vice versa, implying inefficiency.

Wang and Yang (2010) study high-frequency futures data of crude oil, heating oil, gasoline, and natural gas using various non-linear models. For heating oil and natural gas, the authors find market inefficiencies which are profound mainly during the bull market conditions. Gebre-Mariam (2011) focuses on the US natural gas market (spot and futures) finding no arbitrage opportunities for daily prices but in general, the author claims that the markets can be seen as efficient only for contracts with approximately a month to maturity. Martina et al. (2011) utilize entropy approaches to WTI crude oil spot prices and find various cycles in its prices. Entropy is also applied by Ortiz-Cruz et al. (2012) who again study daily WTI prices, finding the market to be efficient with two episodes of inefficiency connected to the US recessions in the early 1990s and late 2000s. The authors stress that deregulation of the market has helped to improve its efficiency.

Zunino et al. (2011) apply information theory methods (specifically the permutation entropy and permutation statistical complexity) to the commodity markets for purposes of efficiency ranking, finding silver, copper and cotton to be the most efficient commodities. Wang et al. (2011) study the gold market using the multifractal detrended fluctuation analysis to show that the market, especially after 2001, becomes more efficient in time. Kim et al. (2011b) use the random matrix theory and network analysis to show that stock and commodity markets are well decoupled, except for oil and gold showing signs of inefficiency. Kim et al. (2011a) then focus on the Korean agricultural market using the detrended fluctuation analysis, finding anti-correlated series with strong volatility clustering that leans toward inefficiency.

From these selected papers, it is evident that analysis of the efficiency of commodity markets is fruitful with many approaches to the topic. However, the studies usually focus on a single (or a pair of) efficiency measure(s) to test whether the specific markets are or are not efficient. Moreover, the analysis is usually strongly focused on a single commodity or a small group of commodities. Here, we contribute to the literature by applying various efficiency measures on a wide portfolio of commodities ranging from energy and agricultural (with several subgroups) commodities to metals. Moreover, we utilize the efficiency measure introduced by Kristoufek and Vosvrda (2013) to rank the commodities according to their efficiency.

3. Methodology

An efficient market can be defined in several ways. The main distinction has its roots back in 1965 when Fama (1965) and Samuelson (1965) used different definitions—a random walk and a martingale, respectively. We stick to the martingale definition of efficiency because it is less restrictive. Based on this definition, we assume that the returns of a financial asset are serially uncorrelated and with finite variance for the efficient market situation. Such a simple definition allows us to use various measures of market efficiency, which are described in this section. Eventually, we refer to the Efficiency Index which takes these statistics into consideration and it helps to rank different assets according to their efficiency while using various dynamic properties of the time series under study.

3.1. Long-term memory

Long-term memory (long-range dependence) series are characterized by values in the (even distant, in theory infinitely distant) past