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Dynamic relationships between spot and futures prices. The case of energy and gold commodities

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ABSTRACT

According to the most common financial theories, the price of a futures contract is always influenced by the spot price of its underlying asset (the cost-of-carry model) or by the expected future spot price conditional on information set (the asset-pricing theory). The aim of this paper is to analyze the dynamic relationship between spot and futures prices, and to establish if there is the possibility of a valid "period by period" prediction of the futures price conditional on the prediction of the spot price, and vice-versa. The empirical analysis is conducted on the two most important energy commodities, crude oil and natural gas, and on gold, the most important commodity used for risk hedging and investment during financial turmoil, paying particular attention to the exogeneity issue. We estimate a battery of recursive bivariate VAR models over a sample of daily spot and futures prices, ranging from January 1997 to May 2014. Our results show that some interactions between spot and futures prices clearly exist and they mainly depend on commodity type and futures contracts maturity. Thus, a strong exogeneity operates in the case of the natural gas, while this is not the case for the crude oil, where the exogeneity generally is weak and depends on the contract maturity. On the gold market the results show no possibility of a valid forecasting between spot and futures prices.

Introduction

The price discovery role of futures contracts and the possibility they offer to reduce particular risks increase the importance of studying the futures markets and the relationship between spot and futures prices. The futures contract prices, particularly in commodity markets, transmit information to all economic agents. Producers may base their supply decisions on the futures contract prices, while physical traders might use futures contracts as a reference to price their commodities. Thus, there may be assumed that futures markets dominate spot commodity markets.

There are two main financial theories about the spot-futures prices interaction, the non-arbitrage theory (*cost-of-carry model*) and the asset pricing theory. According to the former approach, the futures price must hold the following condition in order to avoid arbitrage opportunities:

$$F_{t,\tau} = (1+r_\tau)S_t - (c_{t,\tau} - k_\tau), \tag{1}$$

where $F_{t,\tau}$ denotes the futures price of a commodity at time t for delivery at $t+\tau$, S_t is the spot price, r_τ is the risk-free τ-period interest rate, P_t represents the spot price at time t, $c_{t,\tau}$ is the capitalized flow of marginal convenience yield, and k_τ denotes the per-unit cost of physical storage. Cornell and French (1983) introduced the model for stocks. Later, various textbooks extended the theory also to different types of underlying assets such as commodities, non-dividend paying stocks, or currency (see, for example, Hull, 1991, 1993).

The second approach, namely the asset pricing theory, establishes a relationship between the futures price and the expected future spot price conditional on an information set I_t, $E_t(S_{t+\tau})$. In this case, the futures price is a biased estimate of the future spot price, and it is given by

$$F_{t,\tau} = E_t(S_{t+\tau}) - (R_\tau - r_\tau)S_\tau, \tag{2}$$

where R_τ denotes the risk-adjusted discount rate, and $(R_\tau - r_\tau)$ represents the risk premium.

Both approaches are used in numerous studies in order to analyze commodity markets; among them the most representative are those presented by Fama and French (1987) or Pindyck (2001).

The common way to value a futures contract is by using the *cost-of-carry model*, which underlines that the futures price should depend upon the current spot price and the cost of carrying or storing the underlying good from now until the delivery. Nevertheless, even if the above equations denote an explicit relationship between spot and futures, no information about the direction of

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causality between these prices is offered. This lacking is covered by different studies that use models as co-integration test, Granger causality test, Error Correction Model (ECM) or causality analysis in the frequency domain; see, for example, Bekiros and Diks (2008), or, more recently Joseph et al. (2014), Alzahrani et al. (2014), or Ding et al. (2014).

The aim of this paper is to verify if there are dynamic connections between spot and futures prices of crude oil, natural gas and gold commodities, as statued by the *cost-of-carry model*, and to identify the direction of causality. Thus, the paper contributes to the existing literature by empirically investigating the direction of information flows between spot and futures through a recursive analysis, in which we focus on the weak exogeneity and the Granger-causality (hereafter WE and GC) issues. It is well known that the former concept is required to obtain efficient inference in conditional models, while the latter represents a test for the impact of lagged explanatory variables onto the dependent variable, easy to compute. Given that the conjunction of weak exogeneity and Granger non-causality defines the strong exogeneity between two time series (see, for instance, Engle et al., 1983 or Urbain, 1992), our analysis aims to establish if it is possible a valid "period by period" prediction of spot prices conditional on prediction of futures prices, and vice-versa. In other words, if the strong exogeneity is found, a valid conditional forecasting between spot and futures prices is possible, since one variable does not depend on the other, and thus it can be treated as "fixed". Consequently, it can be considered that a joint analysis is required because the prediction of one variable is necessary to predict the other.

The results have implications for producers, policymakers, hedgers and speculators. As mentioned at the beginning of this section, producers may base their supply decisions on the commodity futures contract prices. Producers concerned about the risk of price decreases could hedge this risk by taking a short position in futures, while consumers worried about the risk of price increases could hedge the risk by taking a long futures position (Pindyck, 2001). Identifying the direction of information flows between spot and futures prices will help both producers and consumers to establish the most appropriate hedging strategy to be adopted. Our results are important for policymakers too, as long as many scholars emphasize the role of commodity prices in improving the macroeconomic policies. Thus, energy commodities are recognized as leading indicators of inflation (see, for instance, Pecchenino, 1992, Moosa, 1998, or Browne and Cronin, 2010), but also for their role in formulating monetary policy (Awokuse and Yang, 2003), while the role of gold is to hedge against inflation and exchange rate movements, and to diversify the risk in investment portfolios (Oxford Economics, 2011). Other contributions also suggest that price changes in commodity markets precede speculators' position changes, and not vice-versa (see, for instance, Büyükşahin and Harris, 2011 for crude oil case), and thus our results could be significant for speculators, too.

The remainder of this paper proceeds as follows. The section "Literature review" contains the literature review about the interactions between spot and futures prices, while the section "Empirical analysis" is dedicated to the data description, the applied methodology and the results of our analysis. Finally, the section "Concluding remarks" concludes.

Literature review

The literature examining spot and futures interactions in commodity markets is fairly extensive. Many studies provide evidence for efficient futures markets and equally large number contradicts an unbiased futures price prediction interpretation (Serletis, 1991; Bopp and Lady, 1991; Moosa and Al-Loughani, 1994).

Some of recent works are closer to our research in terms of studying a similar set of commodities (crude oil, natural gas and gold). Thus, Chinn and Coibion (2014) analyze four groups of commodities that also include crude oil, natural gas and gold. The aim of their research is to examine whether futures prices are unbiased and/or accurate predictors of subsequent prices, and results mainly show that precious metals are poor predictors of subsequent prices changes, while energy futures fair much better. They also emphasize a broad decline in the predictive content of commodity futures prices since the early 2000s. Arouri et al. (2013) also investigate the efficiency of energy and precious metal markets, by employing four linear and non-linear models. Their findings confirm that futures prices do not constitute unbiased predictors of future spot prices, although futures prices are found to be cointegrated with spot prices. Other recent works that focus on the ability of futures price to predict future changes in spot price are made by Alquist and Kilian (2010), and Alquist et al. (2013).

Crude oil

Researches regarding the interactions between crude oil's spot and futures prices are numerous. Many of them analyze the price of West Texas Intermediate (WTI), while others study the price of Brent and Dubai crude oil.

Studies with similar set of crude oil spot and futures prices are Bekiros and Diks (2008), Lee and Zeng (2011), Liu and Wan (2011) or Nicolau (2012). Bekiros and Diks (2008) investigate the causal linkages between daily spot and futures prices for maturities of one, two, three and four months of WTI crude oil over two periods: October 1991–October 1999 and November 1999–October 2007. The conventional linear GC test and a new nonparametric test for nonlinear causality after controlling for cointegration are applied. Their results show that the linear causal relationships disappear after cointegration filtering while, in some cases, causal relationships are found in both periods after using a GARCH filtering. This indicates that spot and futures returns may exhibit asymmetric GARCH effects and statistically significant higher order conditional moments. The results imply that, if nonlinear effects are accounted for, neither market leads or lags the other consistently.

Lee and Zeng (2011) use the same time series over a period ranging from January 2, 1986 to July 6, 2009. They test causalities between spot and futures oil prices with linear, nonlinear, and quantile methods. Linear and nonlinear methods present bi-directional Granger causalities, while the quantile method shows different results. In this case, spot oil prices indeed cause futures oil prices, but the causality goes in the opposite direction only for one-month futures. The same approach on newer weekly data regarding net long positions and the spot prices of WTI is used by Ding et al. (2014). Their results show that excessive financial speculation in the crude oil futures market destabilizes the spot price of crude oil, and the futures price can help explain the behavior of the spot price oil.

The analysis conducted by Nicolau (2012) covers the period 1999/01/01–2012/07/29. In this study a GC test on full sample and two subsamples (before and during the actual crisis) is carried to determine the direction of information flows between spot and futures oil markets. The paper concludes that the financial literature according to which futures prices predict spot prices does not apply for all types of WTI futures contracts. Only futures with shorter delivery dates influence West Texas Intermediate (WTI) spot prices.