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Volatility forecasting and risk management for commodity markets in the presence of asymmetry and long memory

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ABSTRACT

This paper explores the relevance of asymmetry and long memory in modeling and forecasting the conditional volatility and market risk of four widely traded commodities (crude oil, natural gas, gold, and silver). A broad set of the most popular linear and nonlinear GARCH-type models is used to investigate this relevancy. Our in-sample and out-of-sample results show that volatility of commodity returns can be better described by nonlinear volatility models accommodating the long memory and asymmetry features. In particular, the FIAPARCH model is found to be the best suited for estimating the *VaR* forecasts for both short and long trading positions. This model also gives for all four commodities the lowest number of violations under the Basel II Accord rule, given a risk exposure at the 99% confidence level. Several implications for commodity market risks, policy regulations and hedging strategies can be drawn from the obtained results.

1. Introduction

The literature on commodities has concentrated mainly on price co-movements and information transmission between returns. On the other hand, the research on conditional commodity return volatility and market risk has been less generous than the counterpart on commodity prices and returns. However, studies focusing on commodity volatility have been gaining importance due to rising volatility and the increasing role commodities play in the international asset markets (e.g., Creti et al., 2013; Dahl and Iglesias, 2009; Kang and Yoon, 2013; Regnier, 2007, Thuraisamy et al., 2013; Vivian and Wohar, 2012). The increased interest is also due to the fact that commodity returns possess empirical stylized characteristics such as non-normal distribution, asymmetry, structural breaks and fat tails that affect model performance (e.g., Aloui and Mabrouk, 2010; Cheng and Hung, 2011; Cheong, 2009; Hung et al., 2008), and thereby require experimentation with different volatility models. The traditional strand of research on commodity volatility largely addresses dynamic volatility behavior of a single commodity or volatility transmission across several commodities over time, using the standard volatility models. New studies however attempt to accommodate the varying characteristics of volatility of a commodity or a group of commodities in order to come up with a methodological representation that forecasts future volatility of a single commodity or a portfolio more accurately (e.g., Arouri et al., 2012a,b; Wei et al., 2010).

The research on commodity market risks often uses the value-at-risk (*VaR*) approach based on the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) family models to evaluate the validity and forecasts of volatility models. A model is said to be best suited for modeling the conditional volatility of commodity markets if it provides the most accurate *VaR* estimates and forecasts. Since the dust has not been settled and the jury is still out on the suitability of volatility models to model commodity volatility behavior, this article will therefore evaluate the accuracy of various linear and nonlinear models using, in addition to the *VaR* approach, different evaluation and forecasting criteria. Moreover, there are actually only a few studies that examine the choice between volatility models for commodities markets despite the increasing financialization and volatility of these markets, and they often fall short of adequately characterizing volatility

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behavior.[1] The results from this research are of great interest for various economic agents including international investors, energy managers, and policymakers who constantly seek to better understand the volatility dynamics of commodity prices in order to build efficient risk-hedging models as well as to implement sound policies to heed inflation pressure.

More concretely, our first objective is to examine the suitability of GARCH-class models in modeling conditional volatility and market risk (*VaR*) of four most widely traded commodities (crude oil, natural gas, gold and silver) in the presence of long memory and asymmetric effects. Moreover, these commodities have impacts on real economic activity, financial markets, and financial, economic and geopolitical risks. The importance of the long memory and asymmetry properties has been demonstrated not only for modeling the volatility of commodity volatility but also for improving the accuracy of VaR estimates and forecasts (e.g., Aloui and Mabrouk, 2010; Cheong, 2009; Wei et al., 2010). Our second objective is to compare the out-of-sample predictive performance of competing GARCH models based on commonly-used evaluation criteria and the *VaR* approach for both portfolio short and long positions. Furthermore, we evaluate the economic importance of our results by computing the Basel II Accord's daily capital requirements for individual commodities, given the *VaR* estimates derived from competing GARCH models. In comparison with existing studies on volatility forecasting, we consider a broader set of GARCH-type models which includes four linear specifications (GARCH, EGARCH, IGARCH, and RiskMetrics) and three nonlinear specifications (FIGARCH, FIAPARCH and HYGARCH). In comparison with previous studies, our dataset is extended to cover the spot and futures prices of natural gas, gold and silver, in addition to the frequently studied spot and futures price of crude oil (e.g., Agnolucci, 2009; Arouri et al., 2012b; Kang et al., 2009; Sadorsky, 2006; Wei et al., 2010). The choice of these four major commodities (crude oil, natural gas, gold, and silver) is motivated by the fact that they altogether represent the strategic commodities that have significant influences on the real sector, financial sector, and economic growth of national economy (e.g., Browne and Cronin, 2010; Cologni and Manera, 2009; Hamilton, 1996; Holmes and Wang, 2003). Moreover, while past studies have extensively investigated the issue of volatility modeling and forecasting for crude oil and related petroleum products (Arouri et al., 2012b; Wei et al., 2010; and references therein), none of them have extended their samples to include natural gas, gold, and silver at the same time in order to get a comparative view of volatility behavior across these different types of commodities. For instance, Baur and McDermott (2010) provide evidence that gold is both a hedge and a safe haven for major European stock markets and the US but not for Australia, Canada, Japan and large emerging markets such as the BRIC countries. Arouri et al. (2012a) investigate the potential of structural change and long memory (LM) properties in returns and volatility of the four major precious metals traded on the COMEX markets (gold, silver, platinum, and palladium) and show evidence that conditional volatility of precious metals is better explained by long memory than by structural breaks.

The paper distinguishes itself from the literature in several ways. The recent literature that deals with commodity markets separates asymmetry from long memory and concentrates more on the former than the latter. Our paper combines both statistical properties for these widely traded commodities, including natural gas which is not researched in the literature as much as crude oil and its refined products are. Moreover, the past research on volatility forecasting for commodity markets is limited as it has focused more on forecasting conditional return than conditional volatility. Our paper conducts conditional volatility forecasts in the presence of asymmetry and dual long memory. It also seeks to find the best suited model for estimating the *VaR* forecasts for both short and long trading positions. Finally, it examines the lowest number of violations under the Basel II Accord rule for the four commodities.

Overall, the main contributions of this study are the following: (1) over the in-sample period, the FIAPARCH is the best suited model in almost all cases, while the standard GARCH model is selected only once; (2) none of the competing models absolutely outperforms the others in terms of volatility forecasts, but the nonlinear GARCH models perform better than the linear models, regardless of the forecasting horizons; and (3) the FIAPARCH provides the best *VaR* estimates and forecasts for all commodities at almost all confidence levels. This model also leads to the lowest number of violations (i.e., number of times that actual losses exceed *VaR* estimates). The foremost implications of our findings have strong bearing to volatility model building for commodity markets. On the other hand, large violations under the Basel II Accord may lead to failures of financial institutions that invest in commodities, as the capital requirements implied by the VaR threshold forecasts may be insufficient to cover the realized losses. Lower than ten violations imply that these models do not lead to entry in the red zone which is important for an institutions' image, reputation, and risk management.

The remainder of the article is structured as follows. Section 2 reviews the major studies focusing on modeling and forecasting of commodity volatility. Section 3 presents the econometric approach. Section 4 describes the data used, while Section 5 reports and discusses the empirical results. The concluding remarks are provided in Section 6.

2. Literature review

There is actually increasing literature that studies the volatility asymmetry of commodities. More recent research attempts to combine in one model more than one volatility characteristic because modeling commodity volatility behavior may entail the incorporation of several characteristics. It may, for example, examine both symmetry or asymmetry and the long memory (LM) of commodity volatility behavior separately or simultaneously (Aloui and Mabrouk, 2010; Elder and Serletis, 2008; Wang et al., 2011). The presence of range dependency in the commodity volatility can be valuable to be recognized in producing forecasts which are important for asset valuation, hedging, and risk management. Choi and Hammoudeh (2009), for instance, find that LM-based univariate GARCH models have better forecasting commodity volatility than the standard GARCH models for oil and refined products markets. There are also studies that consider, in addition to symmetry or asymmetry, structural changes along with long memory for commodity markets (Arouri et al., 2012a,b). It is shown that the volatility of commodity returns is better explained by long memory than by structural breaks. Therefore, modeling LM and volatility characteristics accurately should produce better models that give rise to better forecasting and sounder policy analysis.

Mckenzie et al. (2001) study the suitability of the univariate power ARCH (PARCH) model to precious metals traded at the London Metal Exchange (LME), and find that asymmetric effects are not present. Hammoudeh and Yuan (2008) use univariate GARCH-based models to examine the properties of conditional volatility for three important metals (gold, silver, and copper) while controlling for shocks from global oil prices (i.e., WTI) and the three-month US Treasury bill interest rate. They focus particularly on these volatility characteristics: persistence, asymmetric reaction to the good and bad news, and transitory and permanent components. These authors find evidence that the conditional volatility of gold and silver is more persistent, but less sensitive to leverage effects than that of copper.

Hammoudeh et al. (2010) examine the conditional volatility, and correlation dependency and interdependency for the four major precious metals (gold, silver, platinum and palladium), while accounting

[1] By increasing financialization of commodity markets, we refer to a situation in which commodity prices are determined not only by primary supply and demand conditions, but also by the commodity derivatives trading and financial investors' activity. Several papers have recently addressed the issue of the financialization of commodity markets and its impact on volatility behavior and transmission (Creti et al., 2013; Domanski and Heath, 2007; Dwyer et al., 2011; Silvennoinen and Thorp, 2013; Vivian and Wohar, 2012).