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A Markov regime switching approach for hedging energy commodities ☆

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Abstract

This paper estimates constant and dynamic hedge ratios in the New York Mercantile Exchange oil futures markets and examines their hedging performance. We also introduce a Markov regime switching vector error correction model with GARCH error structure. This specification links the concept of disequilibrium with that of uncertainty (as measured by the conditional second moments) across high and low volatility regimes. Overall, in and out-of-sample tests indicate that state dependent hedge ratios are able to provide significant reduction in portfolio risk.

JEL classification: G13

Keywords: Commodity markets; Futures markets hedging; Dynamic hedging; Markov regime switching models

1. Introduction

Derivative markets allow market agents to reduce their price risk exposure. One parameter which is critical for the development of effective hedging strategies is the hedge ratio which provides the number of futures contracts to buy or sell for each unit of the underlying asset on which the hedger bears risk. Ederington (1979) derives hedge ratios that minimize the variance of the hedged portfolio, based on portfolio theory. Let ΔS_t and ΔF_t represent the price changes in spot and futures prices, respectively. Then, the minimum-variance hedge ratio is the ratio of the unconditional covariance between cash and futures price changes over the variance of futures price changes; this is equivalent to the slope coefficient, γ_1, in the following regression:

$$\Delta S_t = \gamma_0 + \gamma_1 \Delta F_t + u_t \quad u_t \sim iid(0, \sigma^2). \tag{1}$$

The estimated R^2 of Eq. (1) represents the hedging effectiveness of the minimum-variance hedge. However, the fact that many asset prices follow time-varying distributions suggests that the minimum variance hedge ratio should be time-varying (Kroner and Sultan, 1993) which in turn raises concerns regarding the risk reduction properties of hedge ratios based on Eq. (1). To address this issue, a number of studies apply multivariate generalised autoregressive conditional heteroscedasticity (GARCH) (Engle and Kroner, 1995) models and derive time-varying hedge ratios directly from the estimated second moments (see for instance, Kroner and Sultan (1993) and Kavussanos and Nomikos (2000)). The consensus from these studies is that GARCH hedge ratios change as new information arrives and, on average, tend to outperform, in terms of risk reduction, constant hedge ratios derived from Eq. (1). However, these gains are market specific and vary across different contracts while, occasionally, the benefits in terms of risk reduction seem to be minimal (Lien and Tse, 2002).

Empirically, a common feature of GARCH models is that they tend to impute a high degree of persistence to the conditional volatility i.e. shocks to the conditional

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variance that occurred in the distant past continue to have a nontrivial impact in the current estimate of volatility. Lamoureux and Lastrapes (1990) associate these high levels of volatility persistence with structural breaks in the volatility process. Another study by Wilson et al. (1996) shows evidence of sudden changes in the unconditional volatility of oil futures contracts. During the period 1984–1992, three major shifts in volatility are detected and are attributed to the nature and magnitude of exogenous shocks (OPEC policy changes, Iran-Iraq conflict, Gulf War and extreme weather conditions). Fong and See (2002, 2003) also report significant regime shifts in the conditional volatility of crude oil futures contracts, which tend to dominate the GARCH effects. In addition, they find that in a high variance regime a negative basis is more likely to increase the regime persistence than a positive basis and associate volatility regimes with specific market events. Sarno and Valente (2000) provide a further dimension to the literature using a multivariate extension of the markov regime switching (MRS) model proposed by Hamilton (1989) and Krolzig (1999). They find that the relationship between spot and futures is regime dependent and MRS models can explain this relationship better than simple linear models.

The evidence presented above suggests that by allowing the volatility to switch stochastically between different processes under different market conditions, one may obtain more robust estimates of the conditional second moments and, as a result, more efficient hedge ratios compared to other methods such as GARCH models or OLS. For instance, Alizadeh and Nomikos (2004) examined the hedging effectiveness of FTSE-100 and S&P 500 stock index futures contracts, using MRS models for the estimation of dynamic hedge ratios. Allowing Eq. (1) to switch between two state processes, they provided evidence in favour of those models in terms of variance reduction and increase in utility both in- and out-of-sample. Similarly, Lee and Yoder (2007a) extend the univariate MRS–GARCH model of Gray (1996), to a state dependent multivariate GARCH model. They apply their model to the corn and nickel futures markets and they report higher, yet insignificant, variance reduction compared to OLS and single regime GARCH hedging strategies. Similar results are obtained from the Lee and Yoder (2007b) MRS model of time-varying correlation (MR–TVC–GARCH) as applied to the Nikkei 225 and Hang Seng index futures.

This paper investigates the hedging effectiveness of the MRS models for the WTI crude oil, unleaded gasoline and heating oil futures contracts traded on NYMEX. In doing so, it contributes to the existing literature in a number of ways. First, we extend the univariate MRS model in the hedging literature by introducing, for the first time, a regime switching vector error correction model (VECM) with GARCH error structure, which includes in the mean equation the cointegrating relationship between spot and futures prices. Empirical evidence suggests that if spot and futures prices are cointegrated, omitting the equilibrium relationship will lead to misspecification problems by underestimating the true optimal hedge ratio (see for instance Kroner and Sultan, 1993; Ghosh, 1993; Lien, 1996).

The inclusion of the error correction mechanism in the regime switching framework will thus enable us to examine whether the speed of adjustment of spot and futures prices to the long-run relationship changes across different regimes. The motivation for this stems from the fact that since the relationship between spot and futures prices changes over time, the adjustment to the equilibrium process should also be time-dependent. This in turn introduces an informative link between volatility and cointegration allowing for both time dependency and asymmetric behaviour across different states in the market. Our paper therefore is different from the Lee and Yoder (2007a) Switching BEKK study in the sense that our model also allows for switching in the error correction coefficients.

In addition, we evaluate the hedging effectiveness of the proposed model using both in- and out-of-sample tests. The performance of the MRS hedge ratios is compared to that of alternative hedge ratios generated from a variety of models that have been proposed in the literature and is assessed in terms of variance reduction, increase in utility and reduction in the value-at-risk for a given position. This way we provide robust evidence on the performance of the proposed hedging strategy. Finally, in addition to providing evidence on the statistical significance of the hedging performance from the competing models using White's (2000) Reality Check, we also address the issue of downside risk by examining whether the effects of mean-variance hedge ratios differ between long and short hedges.

The structure of this paper is as follows. Section 2 presents the minimum-variance hedge ratio methodology and demonstrates the MRS-BEKK model estimation procedure. In Section 3, the data and their properties are described. Section 4 discusses the empirical results. This is followed by an evaluation of the hedging effectiveness of the proposed strategies in Section 5; Section 6 describes the reality check for data snooping bias. Section 7 provides a note on downside risk and finally, conclusions are given in the last section.

2. Markov regime switching garch models and hedging

Market participants in futures markets choose a hedging strategy that reflects their individual goals and attitudes towards risk. The degree of hedging effectiveness in futures markets depends on the relative variation of spot and futures price changes as well as the hedge ratio. The hedge ratio that minimises the variance of the hedge portfolio is derived as the slope coefficient of spot price changes on futures price changes, as in Eq. (1). This can also be expressed as

$$\gamma_1 = \frac{\mathrm{Cov}(\Delta S_t, \Delta F_t)}{\mathrm{Var}(\Delta F_t)}. \tag{2}$$