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Optimal hedging in the US natural gas market: The effect of maturity and cointegration

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ABSTRACT

We use the US natural gas market as the rich experimental context to test multiple features of hedging performances. First, we compare the hedging effectiveness of a single futures contract (i.e. Henry Hub) used for hedging six different physical price positions. Second, we examine the performance of hedging, when one uses a futures contract with time-to-maturity beyond the hedging horizon (i.e. a non-matching hedging strategy). Finally, we quantify the effect of accounting for cointegration and also the time varying volatility in the calculation of optimal hedge ratios. As a robustness check we conduct our analysis using both ex-ante (out of sample) and ex-post (in sample) methods. Our findings suggest that using longer maturity contracts may improve the hedging effectiveness. We also find that accounting for cointegration and time varying prices has minimal effect on the hedge ratio and hedging effectiveness for almost all physical prices. Our findings can inform businesses exposed to commodity price risks in on making better risk-management decisions.

1. Introduction

The US natural gas market introduces an interesting context for testing multiple properties of the conventional and modified optimal hedge ratio calculations. The widely traded futures contract in this market (with the ticker NG) is based on the upstream prices of the Henry Hub (HH) market. The users of natural gas, on the other hand, are located in many states and are exposed to various types of physical prices. There are at least six different physical prices in this market, namely wellhead, industrial, power, citygate, commercial, and residential. Although over the counter contracts may exist for some of these specialized markets, a larger number of users may prefer to hedge their exposure using standard, exchange-traded futures contracts. Since the base commodity of the NG contract differs from the physical prices, optimizing risk management in the US natural gas market requires cross-hedging decisions.

Cross-hedging refers to when an exact futures contract for the actual commodity does not exist and the user needs to hedge using closely-related (but not perfectly correlated) futures contracts. The famous example is to use heating oil futures for hedging jet fuel prices risks. The correlation of changes in the spot and futures price in the cross-hedging context is smaller than one, in other words because there exists a basis risk[1]. Therefore, the naïve one-to-one opposite positions on the spot and futures market may be suboptimal. The literature of hedging has introduced the concept of the *optimal hedge ratio* to estimate the number of futures positions that minimizes the overall risk of the hedged position.

We contribute to the literature of optimal hedging and also to the understanding of the price dynamics in the US natural gas market by examining a wide range of hedging results in this market. In particular, we are focusing on the following four main research questions: 1) How does the hedging effectiveness change across different physical prices?, 2) How does the hedging effectiveness change if one uses a futures contract with a maturity different than the hedge

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[1] The basis measures the expected change of the spot price, considering the futures prices as unbiased estimates of the future spot price and is calculated as the difference between the spot price of asset to be hedged and price of futures contract used for hedging. Basis risk results from the uncertainty regarding the basis at the time of setting the hedge.

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horizon?, 3) What is the impact of accounting for cointegration and time varying prices in the calculation of the optimal hedge ratios?, and 4) How does the hedging effectiveness change across different hedging horizons, for the same physical price?

Despite the critical role of natural gas in the recent era of the US energy systems (in particular in the post-shale-revolution years), the literature on the risk management properties of natural gas futures contracts is limited. The closely-related paper to our work is Brinkmann and Rabinovitch (1995), which examines the effectiveness of NYMEX futures contracts for gas sold in different geographical regions. Except for Brinkmann and Rabinovitch (1995), we are not aware of any other paper that directly deals with the questions we are investigating in this paper. Therefore, we believe that our paper can have a useful contribution to the current literature.

The literature of hedging considers a wide range of approaches and strategies to calculate the optimal hedge ratio as well as the effectiveness of these optimal hedging positions. In the prevailing risk management literature introduced by Johnson (1960), Stein (1961) and Ederington (1979), the optimal ratio of a cross-hedge is typically found using a linear regression estimation of the minimum variance hedge ratio. The portfolio approach builds on the basis risk and defines the optimal hedge ratio as the number of futures contracts that minimizes the variance of the spot/futures portfolio. Benet (1992), Ederington (1979) and Malliaris et al. (1991) use the ordinary least-squares (OLS); Baillie and Myers (1991) and Sephton (1993) use the conditional heteroscadestic (ARCH or GARCH) method, and Chou et al. (1996), Geppert (1995), Ghosh et al. (1993), Lien and Luo (1993) and Kroner and Sultan (1993) use the more advanced cointegration method for estimating the optimal hedge ratio. Butterworth and Holmes (2001) and Lien et al. (2002) compare hedging effectiveness between alternative contracts and between alternative estimation techniques.

The impact of the hedge horizon on hedging effectiveness has been studied by several papers. Ripple and Moosa (2007) estimate the hedging effectiveness of crude oil futures contracts of different maturities. They use 1-period and k-period differences of the futures price changes. Lien and Shrestha (2007), Ederington (1979), Hill and Schneeweis (1981), Hill and Schneeweis (1982) and Benet (1992) relate the higher hedging effectiveness with longer hedge horizons. For instance monthly differencing yields in higher R^2 than weekly differencing. Geppert (1995) uses k-period differencing for long hedge horizons and shows that hedging effectiveness is higher for longer hedge horizons.

One important modification proposed for the conventional optimal hedge ratio is to consider the cointegration between spot and futures prices. As Stock and Watson (1988) and Hylleberg and Mizon (1989) show, the cointegrated series share a similar stochastic trend along with similar long-term and transitory components. Cointegrated spot and futures prices tend to return toward their equilibrium relation, even in cases of temporary substantial deviations; therefore, *modified* hedging methodologies based on cointegrated financial assets may result in an improved hedge ratio.

Garbade and Silber (1983) show that the optimal hedge ratio increases after accounting for cointegration. On the other hand, Ghosh et al. (1993), Moosa et al. (2003) and Lien (2004) find that the hedge ratio may increase but the hedging performance is not different after accounting for cointegration. Juhl et al. (2012) account for cointegration between physical and futures prices and show that using an alternative ECM model does not change the results achieved from the simple OLS model. Finally, Lien et al. (2015) also find that the hedge ratio estimation using the error correction model in which the cointegration relationship is accounted for underperforms the OLS hedge ratio. We contribute to this literature by showing new evidence from the US natural gas market. Our findings also suggest that accounting for cointegration does not have a major effect on the hedging effectiveness.

We also consider the effect of the hedge horizon on hedging effectiveness. Geppert (1995) introduces a model based on cointegrated spot and futures prices. He shows that in case of accounting for cointegration, the hedge ratio and hedging effectiveness depend on the hedge horizon and typically improves as the horizon increases. The improved effectiveness is explained by considering the fact that when two prices are cointegrated, they will not depart from each other in the long-run; therefore, there is an additional equilibrating force (beyond the simple correlation), which needs to be considered for the optimal hedging calculations. The effect of this force is more pronounced over longer horizons. Lien and Luo (1993) also assume the spot and futures price series to be cointegrated. They use the error-correction representation (EC) implied by cointegration to derive multi-period hedge ratios. Natural gas futures contract prices are found to be cointegrated with physical market prices (Ghoddusi, 2016).

The hedge ratio estimated by the OLS method, does not account for variation of the spot and futures prices over time (Cecchetti et al., 1988). Bollerslev et al. (1988) develop the multivariate GARCH method for time variate hedge ratio estimation, which accounts for the conditional variance and covariance of spot and futures prices. A large body of literature focuses on comparing the hedging effectiveness associated with the hedge ratios estimated by these two methods (Holmes, 1995; Park and Switzer, 1996; Yang and Allen, 2005). We also include the time varying characteristics of spot and futures prices in the analysis and report the optimal time varying hedge ratio and hedging effectiveness utilizing the GARCH model.

The paper is organized as follows. First, we describe mathematical methods used for optimal hedging ratios in Section 2. Second, Section 3 introduces the data and describes the empirical considerations of the study. Third, Section 4 provides the results of our estimations. Forth, Section 5 offers the results generated through alternative econometrics setups. Finally, we conclude by summarizing our results and offering directions for future research in Section 6.

2. Methodology

For the purpose of this paper, hedging is defined as the elimination or alleviation of the price volatility of a spot position through including a proper number of futures contracts in the portfolio. Consider a portfolio V with Q_S units of long spot positions and Q_F units of short futures positions. The hedge ratio is defined by the number of futures positions needed to hedge one unit of the spot position.

$$h = \frac{Q_F}{Q_S}.$$

The value of the portfolio, including Q_S units of spot and Q_F units of futures, will be given by:

$$V_h = Q_S S - Q_F F. \tag{1}$$

It follows that the changes in the value of the hedged portfolio is given by:

$$\Delta V_h = Q_S \Delta S - Q_F \Delta F.$$

The Minimum Variance (MV) hedge ratio is calculated by choosing the number of futures contracts that minimizes the conditional variance of the changes in the portfolio value. The optimal hedge ratio of the MV model is given by:

$$h^* = \frac{Q_F}{Q_S} = \frac{Cov(\Delta S, \Delta F|I)}{Var(\Delta F|I)} \tag{2}$$

where I is considered to be the information set at time t and h^* the optimal hedge ratio. Note that when there is a perfect match