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Dynamic hedging strategy in incomplete market: Evidence from Shanghai fuel oil futures market

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ABSTRACT

This paper introduces a new incomplete index and establishes a new optimal hedging model. We find that when the market micro-noise is perfectly negatively correlated with the return of futures market, market incompleteness depends on the relative level of noise volatility. Especially when noise volatility is less than the futures market yield, noise volatility will be offset by return volatility. As a result, complete optimal hedging model emerges. As an aside, it is interesting to note that as different conditional variances derived from different volatility models being applied, the hedge performance tends to be basically consistent with subtle difference: DCC–GARCH model is more likely to execute the hedging with 1:1 ratio, while other multivariate GARCH models would give a hedging ratio with greater probability less than 1:1 and is less likely to be a perfect hedge. Therefore, we believe that a simpler econometric model might produce better empirical results.

1. Introduction

The launch of stock index futures traded on Chinese Financial Futures Exchange On April 16th, 2010, opened a new era for China's financial industry, offering a new derivative product for hedging, given current insufficient investment and financing channel in Chinese capital market. The chairman of CSRC, Guo Shu-qing has remarked that crude oil futures is likely going to be launched within 2012, and expected to be the third global crude oil trading center after the USA and the UK, in order to gain pricing power. China's futures market has developed for more than twenty years, with twenty seven futures products, however, there is still a huge gap between the development of derivative products and the needs of real economy; especially for fossil oil, as China consumes huge quantity of fossil oil, nevertheless without pricing power, which constrains the economic development; given recent volatile crude oil price movement, the market urgently needs new financial derivative for crude oil to mitigate investment risk. With only fuel oil futures currently available in the market, the lack of hedging tools and strong speculative sentiment is the major concern among many concerns by Chairman Guo. The launch of stock index futures makes certain hedging activities possible. However, there are many institutional constrains in China's market, for instance, information asymmetry between buyers and sellers, short-sale constrains, margin system, price-movement limits; thus the market is incomplete, resulting in the discrepancy between futures market price and theoretical price (Buhler and Kempf, 1995; Lafuente and Novales, 2003; Miller et al., 1994; Wang, 2008; Wang and Hsu, 2006; Yadav and Pope, 1990), which constitutes market micro-noise, and compromises the effectiveness of hedging with stock index futures.

In previous literatures, Chen et al. (2003) summarized optimal hedging theory. Lafuente and Novales (2003) pioneered with the noise volatility factor to analyze the optimal hedging ratio with the discrepancy between market futures price and theoretical futures price, which largely improved hedging strategy. To solve the market noise problem, Andani and Lafuente (2009), based on the model by Lafuente and Novales (2003), conducted empirical studies on number of countries with different liquidities, and found that the hedging ratio proposed by the model shows no significant improvement over a fixed 1:1 hedging strategy. We believe that the empirical results might be caused by different data, and unique traits of each market, such as institutional factors, incompleteness, etc.

Market incompleteness is the starting point of this paper. It is noteworthy that market incompleteness includes the incompleteness within the market and the incompleteness between markets (Hsu and Wu, 2010). Early measurement to market incompleteness is accomplished by measuring the incompleteness of a single market through some indicator (e.g. transaction cost (Hsu and Wang, 2004)). By establishing a pricing model for stock index futures in an incomplete market, a more comprehensive indicator can be put forward, providing a more reliable method to evaluate inter-market incompleteness. On the

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premise of market incompleteness, this paper introduces a new incompleteness measurement and considers market micro-noise to build optimal hedging model. Based on continuous time diffusion model, this paper also analyzes the optimal hedging strategy with market micro-noise. To better examine the operability of the model, we utilized the trading data of fuel oil futures contracts traded on SHFE, due to the short history of Chinese futures market and the underdevelopment of the derivative market. Because China's fuel oil futures market is far from perfect, the impact of market noise on hedging with stock index futures deserves our attention. As a result, this paper employs multivariate GARCH model to examine the reasonability of the theoretical model, and attempts to discuss the characteristics of the incompleteness exhibited in China's fuel oil and stock index futures markets with estimations and simulated results.

The paper is laid out as follows: the second section discusses the theoretical analysis of the optimal hedging strategy in an incomplete market considering market micro-noise; the third section discusses the optimal hedging model and evaluation; the fourth section gives the analysis of multivariate GARCH model; the fifth section shows the empirical analysis, including in-sample ex post analysis and out-of-sample ex ante analysis; and conclusion.

2. The theory model

Cornell and French (1983a,b) had shown that in the perfect market, the price $F_{t,T}^*$ at time t (contract maturing at time T) of the index futures had following relationship with spot price S_t :

$$F_{t,T}^* = S_t e^{(r-d)(T-t)} \tag{1}$$

where, $r_{f^*,t} = \ln(F_{t,T}^*/F_{t-1,T}^*)$ and $r_{o,t} = \ln(S_t/S_{t-1})$.

When the markets are perfect, the volatility models are displaying the same process, however, the market are usually are imperfect because of the noise, the process between the markets are quite different. In order to characterize the difference of volatility models, following the method of Lafuente and Novales (2003), we introduce a second noise specific to the future market. Therefore, we can decompose the volatility model into two different parts, and depict as following.

$$dr_{f,t} = \mu_f\left(r_{f,t}\right)dt + \sigma_f\left(r_{f,t}\right)dw_{f,t} = \mu_f\left(r_{f,t}\right)dt + \sigma_o\left(r_{o,t}\right)dw_{o,t} + \sigma_n(n_t)dw_{n,t}. \tag{2}$$

Here, $w_{f,t}$ is a Wiener process which affects the index future volatility, and $w_{n,t}$ is defined as new Wiener process which is related to noise.

Considering the two period generation model, an investor hold one unit long position of fuel oil future; however, in order to hedge the risk, the investor short sell h_t unit index future in anther market. Then we can obtain the hedge ratio h_t. Therefore, the investor can make choice the properly hedge ratio h_t to minimize the portfolio variance.

$$\begin{aligned} &\min_{h_t} Var_t\left(\frac{dr_{o,t}}{dt} - h_t\frac{dr_{f,t}}{dt}\right) \\ &s.t. dr_{o,t} = \mu_o\left(r_{o,t}\right)dt + \sigma_o\left(r_{o,t}\right)dw_{o,t} \\ &\quad dr_{f,t} = \mu_f\left(r_{f,t}\right)dt + \sigma_o\left(r_{o,t}\right)dw_{o,t} + \sigma_n(n_t)dw_{n,t} + dw \end{aligned} \tag{3}$$

Following the method introduced by Lafuente and Novales (2003), we obtain the optimal hedge ratio (Chen et al., 2013):

$$h_t^* = \frac{1+\rho_{on,t}\delta_t}{1+\delta_t^2+\rho_{on,t}\delta_t}. \tag{4}$$

Here, $Corr(\varepsilon_{ot}, \varepsilon_{nt}) = \rho_{on,t}$ and $\delta_t = \sigma_n(n_t)/\sigma_o(r_{o,t})$ denote the relative ratio of the specific market noise. Consequently, we can easily make conclusion that there exist some relationship between optimal hedge ratio and market noise from Eq. (4).

It suggests a nonlinear relationship between the optimal hedging ratio and market micro-noise. The consideration of market noise will naturally lead to market incompleteness. Regarding market incompleteness, Hsu and Wang (2004) provides an explicit explanation, which built a mathematical theory model with noise and market incompleteness.

Based on the model proposed by Hsu and Wang (2004), the invest portfolio ratio $h_t = \sigma_o(r_{o,t})/\sigma_f(r_{f,t})$ can be applied repeatedly to make the return of the hedging portfolio free of risk ($\sigma_{p,t} = 0$). However, with market incompleteness, perfect hedge is unlikely, because of which, Hsu and Wang (2004) proposed $\sigma_{p,t}/\sigma_{o,t}$ as a measurement for market incompleteness. Also, the more the incompleteness in the market, the bigger the $\sigma_{p,t}$ becomes; by selecting the optimal hedging ratio, we can minimize the volatility variance of the hedging portfolio, and furthermore, obtain market incompleteness measurement *MI*.

$$MI = 1 - \frac{1+\rho_{on,t}\delta_t}{\sqrt{1+\delta_t^2+\rho_{on,t}\delta_t}}. \tag{5}$$

Thus, we can see that market incompleteness increases as market micro-noise increases (Eq. (5)), which may be a result of frequent trading noise that makes hedging portfolio partially ineffective. Risk diversification won't be achieved easily if hedging performance is not ideal.

3. Evaluate the performance of the optimal hedge model

There have been many assessment and theoretical discussion of various hedge strategies (Johnson, 1960; Ederington, 1979; Myers, 1991; Baillie and Myers, 1991; Kroner and Sultan, 1993; Park and Switzer, 1995; Thomas and Brooks, 2001; Meneu and Torro, 2003; Lee et al., 2006; Chang et al., 2010a,b). A common method is to use the ratio of the minimum conditional variance of hedge position and the variance of non-hedge position (*VIF*), as a measurement.

If the minimum conditional variance of the hedge portfolio is $V_{\min}$, then we can express *VIF* as below (see Appendix A)

$$VIF = 2MI - MI^2. \tag{6}$$

This equation does a better job illustrating how the effectiveness of the optimal hedge strategy with micro-noise changes along with the change of the market incompleteness.

By analyzing proposition Eq. (6), we can find that when market incompleteness reaches 1, the optimal hedge strategy with noise becomes ineffective, because the underlying asset is entirely unrelated with stock index futures, which enables the building of an effective hedge portfolio. Also, we found that when the market incompleteness is either too low or too high, the optimal hedge strategy with noise displaces excellent effectiveness. As matter of fact, when $MI \geq 1$, which means a high degree of market incompleteness, a simple fixed 1:1 hedge strategy is not only unable to effectively hedge, but also amplify the risk of the hedge portfolio.

4. Volatility model framework

In this section, we only briefly introduce a simple GARCH model, and univariate GARCH model, such as CCC, DCC, Diag-BEKK, Full-BEKK, Scalar-BEKK, etc. Given the constrain of the length, we will not list all of them here. The main purpose of these models is to obtain the conditional volatility, of course, with consideration of historical volatility that is used in the process of estimating the optimal hedge ratio. Different variances estimated by different models differ greatly, thus we reconsidered these models to make comparison of optimal hedge ratios from in and out-of-sample data. These variances play important role in optimal estimation, especially the computation of optimal ratio itself.