Skewness, basis risk, and optimal futures demand

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ABSTRACT

We propose a maximum-expected utility hedging model with futures where cash and futures returns follow a bivariate skew-normal distribution, such to consider the effect of skewness on the optimal futures demand. Relative to the benchmark of bivariate normality, skewness has a material impact when the agent is significantly risk averse. Pure hedging demand is either greater or smaller than minimum-variance demand, depending on the relative skewness of cash and futures positions. The difference between pure hedging and minimum-variance demand increases with basis risk, i.e. the imperfect correlation between cash and futures returns. When the agent is moderately but not infinitely risk averse, there is room for speculative positions, and the optimal futures demand is driven by both basis risk and the expected return on the futures market.

1. Introduction

The literature on hedging a cash position with futures is vast. Since the early contributions of Johnson (1960), Stein (1961), and Ederington (1979), and in spite of a number of papers proposing alternative approaches (see Chen, Lee, & Shrestha, 2003, for a review), minimum-variance hedging is by far the most common technique in practice, as it is fairly simple to understand and implement. Minimum-variance hedging is a particular case of the general maximum expected utility framework (Cecchetti, Cumby, & Figlewski, 1988), in which the optimal hedge is based on the maximisation of the agent's expected utility at the time the hedge is lifted. Contrary to the minimum-variance approach, the maximum-expected utility hedging position considers the subjective preferences of the agent via his/her utility function. Under restrictive assumptions on the distribution of cash and futures returns, and the subjective preferences of the hedger, the maximum-expected utility hedge reduces to the minimum-variance position (Benninga, Eldor, & Zilcha, 1983, 1984).

From an empirical standpoint, it is well known that such assumptions do not hold and, as a consequence, the maximum-expected utility hedge diverges from the minimum-variance position. In the very special case of jointly normally distributed cash and futures returns the separation between maximum-expected utility and minimum-variance hedge has a closed form, and it is accomplished via Stein's lemma (Stein, 1981). When cash and futures returns do not follow a bivariate normal distribution it is a matter of empirical estimation to disentangle the one from the other, and the literature on this regard is sparse. Cotter and Hanly (2012) estimate and compare the optimal hedging position in the oil and gas market using a number of different utility functions, finding that material differences exist, and depend on the agent's risk aversion. Cotter and Hanly (2015) focus on the effectiveness of utility-based hedging strategies in the oil market, when different hedging horizons are considered. Their results show that the differences between maximum-expected utility and minimum-variance hedge depend on the agent's hedging horizon. A recent paper by Hanly (2017) estimates the optimal hedging strategy for the largest and most actively traded energy products using a number of objective functions, including expected utility. His results confirm the great variability among the optimal hedge (and their effectiveness) yielded by different

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approaches.

In this paper we set up a hedging model with futures contracts where the bivariate distribution of cash and futures returns is skew-normal, thus incorporating the effect of (usually negative, but also possibly positive) skewness on the agent's optimal futures demand. The skew-normal distribution has been thoroughly applied in finance (see Adcock, Eling, & Loperfido, 2015, for an extensive review), since it preserves the simplicity of its normal counterparty, but it is far more flexible in terms of skewness. Negative skewness, in particular, is a persistent characteristic affecting almost any financial asset. Choosing such probability distribution allows us to explicitly solve the hedging problem for a general utility-maximising agent through a generalisation of Stein's lemma applied to the problem first order conditions, similar to the covariance decomposition which holds for the bivariate normal case (Adcock, 2007). Our paper contributes to the literature on maximum-expected utility hedging in the two following important aspects.

First, we explicitly disentangle the speculative component of the optimal futures demand from the pure hedging component, and we analyse the sensitivity of the hedging strategy to the model parameters, mainly the agent's risk aversion and the skewness of cash and futures returns. Second, and most important, since our model starts from the joint distribution of cash and futures returns, it naturally embeds basis risk, that is the imperfect correlation between cash and futures positions at the time the hedge is lifted. In reality, basis risk can hardly be neglected in any risk management strategy. It may originate from the mismatch between the maturity of the futures contract used for hedging and the hedging horizon, or the mismatch between the asset being hedged and the asset underlying the futures contract employed for hedging, or both these situations. It is also amplified by potential liquidity differences between the cash and the futures market, frictions such as transaction costs, or credit risk differences. Basis risk can also originate from a stacked hedge, when a strip hedge is not possible (Figlewski, 1988; Smithson, 1998). In all these cases, the hedger with futures contracts always trades off price risk with basis risk. Modelling the joint distribution of cash and futures returns allows us to study the optimal hedge for a variety of correlation structures, representing the more or less pronounced basis risk borne by the hedger.

In anticipation of our results, we find that skewness has a material effect on the optimal futures demand when the agent is significantly risk averse. While in the bivariate normal case, as the agent becomes infinitely risk averse, the limiting position is the minimum-variance hedge, under skew-normally distributed returns this limit is represented by a skewness-corrected position. When the agent is sufficiently risk averse, he/she weighs more the impact of skewness than that of variance on the expected utility generated by his/her overall position. As a result, a pure hedger aims at reducing the skewness of his/her hedged position, even at the cost of retaining some additional variance. The difference between the pure hedging demand when returns are skewed and the minimum-variance hedge depends on the relative skewness of cash and futures positions. Interestingly, the intensity of this difference is driven by basis risk, as it increases as the correlation coefficient between cash and futures returns decreases. When the agent is moderately but not infinitely risk averse, there is room for a speculative futures demand. In such case, the optimal futures position is driven by both basis risk and the expected return on the futures market.

The remainder of the paper is organised as follows. In the next section we review the relevant literature on minimum-variance and maximum-expected utility hedging, and the assumptions under which the two approaches converge. In section 3 we set up our hedging model of optimal futures demand, we solve it for skew-normally distributed cash and futures returns, and we compare the solution to the benchmark case of bivariate normality. Section 4 is devoted to simulating and discussing the practical implications for hedging when returns are skew-normally distributed. This section also covers some robustness exercises, and finally it studies the sensitivities of the optimal futures demand to the relevant parameters, i.e. the agent's risk aversion and the degree of skewness. Finally, section 5 concludes the study.

2. Review of the literature

When dealing with hedging a cash position with futures contracts, the “optimality” of the hedge depends on the choice of the objective function to be optimised. Apart from the variance, a number of papers have dealt with the minimisation of a risk measure. However, despite unattractive from a theoretical point of view due to the pitfalls of variance as a risk measure, minimum-variance hedging is still widely employed in practice, most likely because of its simplicity, both to understand and to estimate, as it is a slope of a linear regression (see Chen et al., 2003). Minimum-variance hedging is a particular case of the general maximum-expected utility framework (Cecchetti et al., 1988; Lence, 1995, 1996), in which the optimal hedge is based on the maximisation of the agent's expected utility at the time the hedge is lifted. Under some restrictive assumptions, the maximum-expected utility hedge reduces to the minimum-variance position (Bennenga et al., 1983; 1984; Heaney & Poitras, 1991; Lence, 1995). These assumptions are: (1) the probability distribution for cash and futures returns belongs to the elliptical class (of which bivariate normal is a noteworthy member), and either (2a) the futures market is unbiased, meaning that the futures price follows a pure martingale, or (2b) the agent is infinitely risk averse. If either of the assumptions (2a) and (2b) does not hold, there is room for speculative positions. In this case, it is customary to disentangle the speculative futures demand from the pure hedging demand, corresponding to the minimum-variance position in the elliptical case (Anderson & Danthine, 1981). This separation can be accomplished via Stein's lemma (Stein, 1981), which requires that cash and futures returns jointly follow a normal distribution.

These theoretical considerations do not hold in practice. There is strong evidence that futures prices do not follow a pure martingale.

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1 Noteworthy examples are the Sharpe ratio (Howard & D’Antonio, 1984, 1987), the mean-Gini coefficient (Kolb & Okunev, 1992; Shalit, 1995), the generalised semi-variance or lower partial moments (De Jong, De Roon, & Veld, 1997; Lien & Tse, 1998, 2000), the value-at-risk and the expected shortfall (Barbi & Romagnoli, 2014; Cao, Harris, & Shen, 2010; Harris & Shen, 2006), and recently the economic index of riskiness introduced by Aumann and Serrano (2008) (Chen, Ho, & Tzeng, 2014), and a general spectral risk measure (Barbi & Romagnoli, 2016).
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