Journal of Empirical Finance xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Journal of Empirical Finance

journal homepage: www.elsevier.com/locate/jempfin

Risk-adjusted implied volatility and its performance in forecasting realized volatility in corn futures prices

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ARTICLE INFO

Article history:
Received 26 April 2013
Received in revised form 10 March 2015
Accepted 21 July 2015
Available online xxxx

JEL classification:
G13
G17
C53
C51

Keywords:
Volatility risk premium
Model-free implied volatility
Diffusion jump
GMM estimation

ABSTRACT

We propose a methodology for constructing a risk-adjusted implied volatility measure that removes the forecast bias of model-free implied volatility that is typically believed to be related to risk premiums. The risk adjustment is based on a generalized, closed-form relationship between the expectation of future volatility and the model-free implied volatility assuming a jump-diffusion model. We also develop a GMM framework to estimate key model parameters. An empirical application using corn futures and option prices is used to illustrate the methodology and demonstrate differences between our approach and the standard model-free implied volatility. We compare the risk-adjusted forecast with the unadjusted forecast as well as other alternatives. Results suggest that the risk-adjusted volatility is unbiased, informationally efficient, and has superior predictive power over the alternatives considered.
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1. Introduction

The question of whether implied volatility provides unbiased and informationally efficient forecasts of future realized volatility has been studied extensively in the finance and time series econometrics literature. Tests are typically based on the regression:

$$v_{t,t+\Delta} = \gamma_0 + \gamma_{IM}\sigma^{IM}_{t,t+\Delta} + \gamma_{AV}\sigma^{AV}_{t,t+\Delta} + \epsilon_{t+\Delta}, \quad (1)$$

where $v_{t,t+\Delta}$ is realized volatility over the period t to $t+\Delta$, $\sigma^{IM}_{t,t+\Delta}$ is implied volatility over the same period, and $\sigma^{AV}_{t,t+\Delta}$ is an alternative predictor typically generated from historical information. Tests then evaluate whether implied volatility is unbiased ($\gamma_0 = 0$ and $\gamma_{IM} = 1$) and subsumes all information contained in historical volatility ($\gamma_{AV} = 0$). The general result from previous studies is that the Black–Scholes (*BS*) implied volatility, a frequently used measure in the literature, is an informationally efficient but biased forecast of future realized volatility, in the sense that estimated γ_0 is different from zero, estimated γ_{IM} is significantly less than unity, and estimated γ_{AV} is insignificantly different from zero (see, e.g., Szakmary et al., 2003; Jiang and Tian, 2005).

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http://dx.doi.org/10.1016/j.jempfin.2015.07.003
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Please cite this article as: Wu, F., et al., Risk-adjusted implied volatility and its performance in forecasting realized volatility in corn futures prices, J. Empir. Finance (2015), http://dx.doi.org/10.1016/j.jempfin.2015.07.003

In view of limitations of *BS* implied volatility, a model-free (*MF*) implied volatility measure that does not depend on any particular option-pricing model has been proposed in the literature (Britten-Jones and Neuberger, 2000). The *MF* implied volatility is computed from a set of options with different strike prices instead of only at-the-money options. This measure seems more likely to generate an unbiased estimate of realized volatility because, unlike the *BS* implied volatility, it does not depend on a particular option pricing model. But Jiang and Tian (2005) found that the *MF* implied volatility is also biased.

Lamoureux and Lastrapes (1993) were the first to suggest that a risk premium could be responsible for the bias in implied volatility forecasts. More recently, Chernov (2007) argued that even *MF* implied volatility is derived under a risk-neutrality assumption while realized volatility is based on observed market outcomes. Risk premiums can therefore cause a disparity between observed and risk-neutral probability measures and produce bias in *MF* implied volatility forecasts (Carr and Wu, 2009).

Becker et al. (2009) have recently proposed correcting bias in the *MF* implied volatility forecast by incorporating a risk premium. However, their risk adjustment procedure was developed assuming a diffusion process for the underlying asset returns. In this study we develop a new risk-adjusted *MF* implied volatility forecast assuming a jump-diffusion model for the underlying asset returns. The jump-diffusion model is more general and capable of better capturing empirically relevant features of observed asset return dynamics. Our approach therefore is a more general way of adjusting *MF* implied volatility for a risk premium. We derive a generalized model linking the expectation of future volatility under an observed jump-diffusion probability measure with the *MF* implied volatility. The jump-diffusion risk-adjusted model immediately explains the typical finding of a downward bias in forecasts from unadjusted *MF* implied volatility. Our new model indicates that the volatility risk premium contributes to the forecast bias in *MF* implied volatility. But, more importantly, jump risk premiums are also shown to play a role in the forecast bias. We also develop a generalized method of moments (GMM) estimation procedure to operationalize our jump-diffusion risk-adjusted *MF* implied volatility measure. Compared to the even more sophisticated asset return model with jumps in volatility and prices (Duffie et al., 2000; Pan, 2002), our model provides virtually identical option pricing performance.

We apply our new model to forecast corn futures price volatility. In recent years, agricultural commodity prices have experienced increases in volatility due to increased biofuel production and other factors. Faced with volatility risk and lack of an instrument for hedging volatility, stakeholders in agricultural commodity markets have urged regulators to consider position and trading limits. Against this backdrop, this application has implications for improved forecasting of corn futures volatility.

Because there is currently no hedging instrument for corn price volatility, we use Jiang and Tian's (2005) method to construct the *MF* implied volatility for the empirical application. Then we correct the *MF* implied volatility using the estimated volatility risk premium. Although the risk premium has been pointed out to follow a rather complex process (Chabi-Yo et al., 2008; Pan, 2002), we assume a simple constant correction factor. After constructing the risk-adjusted *MF* implied volatility, we investigate its ability to forecast corn futures realized volatility using three criteria: unbiasedness, informational efficiency relative to alternative forecasts, and superiority in predictive power. Evaluations are conducted against three alternative predictors of volatility: a) the historical volatility *HV*, b) the *BS* implied volatility, and c) the risk-neutral *MF* implied volatility. Our results support that the risk-adjusted implied volatility under jump-diffusion is unbiased while the unadjusted *MF* implied volatility is biased. The results also provide evidence supporting informational efficiency of the risk-adjusted implied volatility. More importantly, we find that the risk-adjusted implied volatility provides a more precise forecast compared to alternative forecasts.

The rest of the paper is organized as follows. In Section 2, we propose a stochastic-volatility jump-diffusion model and derive the explicit expression between the expectation of future volatility and the *MF* implied volatility for this case. In Section 3, we outline basic moment conditions, calculate volatility measures, construct the GMM framework to estimate the parameters of interest, and provide finite sample simulation evidence on the performance of the estimator. Section 4 discusses the corn dataset used for the application, reports empirical results, and evaluates the robustness of estimates. In Section 5, forecast performance of the new implied volatility measure is evaluated. Section 6 provides concluding comments.

2. Model specification and volatility forecast

2.1. Price dynamics

Following Bates (1996), asset prices *S* under the observed probability measure *P* are assumed to follow a jump-diffusion process with stochastic volatility, commonly referred to as the SVJ model:

$$dlnS_t = udt + \sqrt{V_t}dB_{1t} + \ln(1+J_t)dN_t - \lambda\mu dt, \tag{2}$$

$$dV_t = k(\theta - V_t)dt + \sigma(V_t)dB_{2t}, \tag{3}$$

where u denotes the drift; k is the speed of volatility mean reversion; θ is the long-term volatility mean; $\sigma(V_t)$ is the volatility of volatility; B_{1t} and B_{2t} are two correlated Wiener processes with correlation coefficient ρ;N_t is a Poisson process with intensity λ and distributed independently of B_{1t} and B_{2t}; and $\ln(1+J_t)$ is a normally distributed random variable with mean $\mu = \ln(1+\mu_J) - \sigma_J^2/2$ and variance σ_J^2. Consequently, the expected percentage jump size is $E(J_t) = \mu_J$. The term $\lambda\mu dt$ is the compensation for the instantaneous change as a result of a jump so that $\ln(1+J_t)dN_t - \lambda\mu dt$ has zero mean.

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