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Spurious long memory, uncommon breaks and the implied–realized volatility puzzle☆

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One of the puzzles in international finance is the frequent finding that implied volatility is a biased predictor of realized volatility. However, given asset price volatility is often characterized as possessing long memory, the recent literature has shown that allowing for long-range dependence removes this bias. Of course, the appearance of long memory can be generated by the presence of structural breaks. This paper discusses the effect of structural breaks on the implied–realized volatility relation. Simulations show that if significant structural breaks are omitted, testing can spuriously show the typical patterns of fractional cointegration found in the literature. Next, empirical results show that foreign exchange implied and realized volatility contains structural breaks. The breaks in the implied series never closely anticipate or co-occur with those of the realized series, suggesting that the market has no ability to forecast structural change. When breaks are accounted for in the bi-variate framework, the point estimate of the slope parameter falls and the null of unbiasedness can be rejected. Allowing for structural breaks suggests that the implied–realized volatility puzzle might not be solved after all.

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1. Introduction

Optimal modelling and forecasting of volatility is essential for a variety of risk assessment and trading purposes. However, standard market efficiency tests in the extant literature (see, *inter alia*, Christensen and Prabhala, 1998; Poteshman, 2000) have routinely led to the conclusion that option implied volatility (IV) is a biased forecast of realized volatility (RV). Specifically, given the regression below

$$\sigma^{R}_{t+\tau} = \alpha + \beta\sigma^{IV}_{t} + u_{t+\tau} \tag{1}$$

where σ^{IV}_{t} is IV over a time period τ and $\sigma^{R}_{t+\tau}$ represents RV over that same period, least squares estimation typically finds $\widehat{\beta} < 1$, violating the joint unbiasedness restrictions of $\alpha = 0$, $\beta = 1$ and $u_{t+\tau}$ being serially uncorrelated. This *bias* occurs across a number of asset markets (see Neely, 2009) and has therefore inspired the search for an appropriate rationale. Common suggestions include that volatility risk is not priced (Chernov, 2007), computing RV with low-frequency data (Poteshman, 2000) and that the standard estimation with overlapping observations produces inconsistent parameter estimates (Christensen et al., 2001). However, Neely (2009), shows that the conditional bias in IV is robust to these potential solutions.

The optimality of the approach applied to the estimation of (1) relies crucially on the order of integration (d) of the covariates. Given the extant literature suggests that individual volatility series are appropriately represented as long memory, fractionally integrated processes with $0 < d < 1$ (Anderson et al., 2001a,b), least squares estimates of (1) will be inconsistent when $d < 0.5$, and although consistent when $d > 0.5 > 1$, converges slowly[1] at the rate $O_p(T^{1-d-d_{\min}})$ where T represents number of observations.

Employing either foreign exchange or stock market data, Kellard et al. (2010), hereafter KDS, Nielsen (2007), Bandi and Perron (2006), Christensen and Nielsen (2006) show that IV and RV are fractionally cointegrated series wherein equation (1), $u_{t+\tau} \sim I(d-b)$ and $b \le d$. Moreover, this literature suggests that estimators, such as narrow band least squares[2] (NBLS), account for the fractional character of volatility and find a unity slope parameter in equation (1) cannot be rejected. In other words, the traditional slope bias disappears. However, KDS also show that the frequency of data used for measuring RV within a fractionally cointegrating framework is important for the results of unbiasedness tests. Specifically, for some popular exchange rates, the use of less noisy intra-day rather than daily data reveals the possibility a different bias, as evidence of a latent fractionally integrated risk premium is detected.

For the sake of clarity, consider augmenting regression (1) with a time-varying risk premium term rp_t

$$\sigma^{RV}_{t+\tau} = \alpha + \beta\sigma^{IV}_{t} + \delta rp_t + u_{t+\tau} \tag{2}$$

A corollary of finding fractional cointegration between RV and IV is that any risk premium will be of a lower order of (fractional) integration than the original volatilities. In this context (see Bandi and Perron, 2006), spectral methods like NBLS will still estimate regression (1) consistently. Re-arranging (2) leads to

$$\sigma^{RV}_{t+\tau} - \alpha - \beta\sigma^{IV}_{t} = \delta rp_t + u_{t+\tau} \tag{3}$$

If daily data is relatively noisy, KDS posit any long memory behaviour of the risk premium[3] is swamped[4] and therefore hidden by $u_{t+\tau}$ in finite samples. Contrastingly, the use of a less noisy intra-

[1] See Marinucci and Robinson (2001, p.231).
[2] See Robinson and Marinucci (2003).
[3] Evidence for a fractionally integrated risk premium in forward foreign exchange markets is provided by Kellard and Sarantis (2008). Further discussion of volatility risk premia in other markets can be found in Almeida and Vicente (2009) and Doran and Ronn (2008).
[4] See Maynard and Phillips (2001), Kellard (2006) and Kellard and Sarantis (2008) for other discussions of swamping and its effect in finite time series.