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Modeling the joint dynamics of risk-neutral stock index and bond yield volatilities

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A B S T R A C T

This study examines the joint evolution of risk-neutral stock index and bond yield volatilities by using the Chicago Board Option Exchange S&P500 volatility index (VIX) and the Bank of America Merrill Lynch Treasury Option Volatility Estimate Index (MOVE). I use bivariate regime-switching models to investigate the alternation of "high-risk" and "low-risk" markets, where the high-risk regime is characterized by higher and more volatilities with weaker cross-market linkages. Common information about economic and financial conditions appears to drive VIX and MOVE fluctuations between the two risk regimes. Two-regime specifications also distinguish between information spillover and common information effects. Ignoring regime shifts leads to spurious extreme persistence and incomplete inferences about asymmetric volatility. The findings carry important implications for asset allocation.

1. Introduction

Volatility is one of the most important determinants of asset value for stocks and bonds, the two most important asset classes. Expectations of future market volatility and their linkages have important implications for asset pricing, portfolio management and hedging effectiveness. If volatility is directly related to the rate of information flow (Ross, 1989), volatility expectations may persist over time due to the gradual incorporation of information (Anderson and Bollerslev, 1997) or incomplete information from traders and subsequent revisions in beliefs after a structural break (Timmerman, 2001). Investors can also react differently to positive and negative information of the same magnitude. Therefore, asymmetric volatility is documented both for stocks (Black, 1976a; Campbell and Hentschel, 1992) and interest rates (Chan et al., 1992). Furthermore, the linkages between the stock and bond markets reflect common information (Ederington and Lee, 1993) and cross-market information spillover effects (Fleming et al., 1998).

Typically, researchers estimate volatility from the time series of historical price changes.[1] However, such volatility estimates are *ex post* measures and reflect only part of the impact of information arrival on perceptions of volatility. Information not only causes asset price changes but also induces revisions of investor beliefs about the future volatility of asset prices and macro-economic variables (Stulz, 1986). Although not directly observable, implied volatility estimates derived from prices of options or other derivatives represent investor beliefs about the underlying asset price volatility (Patell and Wolfson, 1979). Recently, implied volatility has gained more popularity in the literature and among practitioners. In contrast to *ex post* physical volatility measures, implied volatility is the *ex ante* risk-neutral expectation of future volatility and it reflects both immediate and longer-term effects of information flow. Another problem of volatility is its high persistence, a sign of structural

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[1] Two approaches for measuring volatility are parametric estimation and more direct non-parametric measures. Among parametric methods, the ARCH class of models formulates volatility as a function of past returns and other directly observable variables whereas stochastic volatility in discrete-time models incorporates past returns as well as latent state variables. In contrast, non-parametric volatility measurements are generally data-driven and model-free, including ARCH filters and smoothers designed to measure volatility over infinitesimally short horizons, and realized volatility measures for (non-trivial) fixed-length time intervals.

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change in variance which can be better characterized empirically by regime-switching models.[2]

There is substantial time-variation and regime-dependence in the relation between stock and bond returns. Multivariate regime-switching models have become increasingly popular in investigating asset allocation between stock and bonds (Guidolin and Timmermann, 2005, 2006, 2007; Baele et al., 2010; Yang et al., 2010; Chan et al., 2011). Also, regime-switching models have been used to study asymmetric correlations across asset returns and to draw implications for asset allocation (Ang and Bekaert, 2002a; Ang and Chen, 2002; Guidolin and Timmermann, 2008). Ang and Timmermann (2012) conduct a good survey of regime switching and financial markets. All these studies have demonstrated that the regime-switching model is better than the single-state model at capturing the joint return distribution. However, very few studies have explored the regime shifts for joint distribution of risk-neutral stock and bond volatilities. My paper fills this gap and makes several contributions to the literature.

Firstly, with implied volatility indices for the S&P500 stock index and US Treasury bond yields from 1990 to 2010, I find that bivariate two-state regime-switching models fit the data much better than a single-regime model would, thereby suggesting substantial regime-dependence in the relationship between risk-neutral stock index and bond yield volatilities. These models are particularly appealing for implied volatilities because news about business cycles and financial conditions can simultaneously alter investor expectations both in stock and bond markets, as indicated in Timmermann (2001). In particular, the two regimes in my model can be characterized as "high-risk" and "low-risk" regimes.[3] During the high-risk markets, both stock and bond risk neutral volatilities are higher and more volatile. Moreover, these *ex ante* stock and bond volatilities have a lower correlation in the high-risk regime, which is consistent with the stock–bond return correlation pattern found in Yang et al. (2009). By contrast, the low-risk regime is associated with lower volatility expectations, lower volatility of volatilities and stronger cross-market linkages between *ex ante* volatilities.

Secondly, allowing for regime shifts can empirically distinguish between information spillover and common information effects. I report strong evidence that macro-economic and financial variables commonly used in the literature predict the transition probability of regime switches. Thus, common information about economic and financial conditions, especially the default spread, causes regime shifts in the joint evolution of volatility expectations of stock and bond markets. There is also evidence that VIX and MOVE can predict each other, indicating a bi-directional information spillover effect. At a short (weekly) horizon, higher bond yield volatility tends to follow higher stock volatility in the previous period more significantly in the high-risk regime, suggesting increased information flow from the stock market to the Treasury bond market when investors flight to safety in the bad time. However, such stronger information spillover effect becomes insignificant in a longer (monthly) horizon, implying that flying to safety is a short-term phenomenon.

Thirdly, I document additional new evidence on volatility clustering and asymmetry. Volatility expectation forms clusters in each regime, suggesting the gradual incorporation of information. Moreover, high-volatility expectation persists for 4.44 weeks whereas low-volatility expectation persists for 17.54 weeks. Ignoring regime shifts leads to the spurious appearance of extreme persistence. Also, a very significant and robust negative relation between innovations in stock returns and expected stock volatility exists and it is consistent with the asymmetric volatility literature using implied volatilities (for example, Dennis et al., 2006). A notable new finding is that the asymmetric volatility effect is much larger in the high-risk regime. This suggests that non-diversifiable stock market volatility as an asset class[4] should be very appealing for stock portfolio diversification, especially in bad times. Moreover, the relation between bond yield implied volatility and the level of the long-term interest rate is regime-dependent, negative in the high-risk regime but positive in the low-risk regime. This adds to the literature on interest rate volatility that typically examines volatility of the short-term interest rate and finds mixed relationships (Trolle and Schwartz, 2009).

Finally, this study features two very prominent volatility indicators, the Chicago Board Option Exchange's S&P500 volatility index (VIX) and the Bank of America Merrill Lynch's Treasury Option Volatility Estimate Index (MOVE). VIX is widely covered by the financial media, and is even included on the ticker of the CNBC financial news cable television network. Investors view the VIX index as reflecting both fear and the demand for portfolio insurance (Whaley, 2000, 2008) whereas academics find VIX an increasingly useful and interesting measure of the market's expected future stock index volatility. MOVE is a widely-followed measure of government bond yield volatility.[5] MOVE is also included by the IMF in a statistical appendix of Global Financial Stability Reports together with VIX. However, MOVE is seldom studied in the literature, either by itself or in relation to VIX.[6] My study fills this gap.

The rest of the paper is organized as follows. Section 2 describes the data. Section 3 discusses the regime-switching models and develops testable hypotheses. Section 4 presents the empirical results. Finally, Section 5 gives concluding remarks.

2. Data

The VIX index is the square root of the market price average for selected out-of-the-money call and put options written on the S&P500 index at two of the nearest maturities.[7] The squared VIX approximates the model-free implied variance of Britten-Jones and Neuberger (2000) and the risk-neutral expected value of return variance of Carr and Wu (2009) over a 30-day horizon. The MOVE index is a weighted average of the normalized implied yield volatility for 1-month Treasury options on the two-year (20% weight), five-year (20% weight), 10-year (40% weight), and 30-year (20% weight) US Treasury bonds. The implied volatility of the MOVE index is not a model-free measure but estimated from at-the-money Treasury options by using Black's (1976b) model. The weights on implied volatility are based on estimates of option trading volumes in each maturity. The options underlying the MOVE Index have expiration dates of approximately one month; thus, the MOVE index measures the implied volatility of long-term yields over a relatively short horizon. Also note that VIX is quoted in percentages while MOVE is expressed in basis points.

[2] See Lamoureux and Lastrapes (1990), Cai (1994), and Hamilton and Susmel (1994).

[3] Strictly speaking, the VIX and other implied volatility indices add higher order cumulants beyond risk-neutral volatility when there are jumps in the underlying returns (Carr and Lee, 2009; Martin, 2013). They should be interpreted more broadly as risk or uncertainty. Therefore, I name the two regimes as "high-risk" and "low-risk" rather than "high-volatility" and "low-volatility".

[4] Stock market volatility is now traded in the USA and Europe. In particular, VIX futures and options saw a dramatic increase in volume in the past few years.

[5] For example, a recent story in the Wall Street Journal (Blumberg, 2010) attributes a rise in MOVE from 75 basis points in August 2010 to 109 basis points in December 2010 to concerns about the fiscal health of Euro-zone nations.

[6] See Cieslak and Povala (2013), Markellos and Psychoyios (2013), and Mueller et al. (2013) for the relevant studies on MOVE. But they do not model the joint dynamics of VIX and MOVE.

[7] See Carr and Wu (2006) and Chicago Board Options Exchange (2009) for detailed construction of VIX index.