International Review of Financial Analysis xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Review of Financial Analysis

Asymmetries of the intraday return-volatility relation

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ARTICLE INFO

Article history:
Received 26 January 2016
Received in revised form 20 September 2016
Accepted 23 September 2016
Available online xxxx

JEL classification:
C21
G12
G13

Keywords:
Asymmetric return-volatility relation
Implied volatility
Index options
Intraday
Quantile regression
VIX

ABSTRACT

This study investigates the asymmetry of the intraday return-volatility relation at different return horizons ranging from 1, 5, 10, 15, up to 60 min and compares the empirical results with results for the daily return horizon. Using data on the S&P 500 (SPX) and the VIX from September 25, 2003 to December 30, 2011 and a Quantile-Regression approach, we observe strong negative return-volatility relation over all return horizons. However, this negative relation is asymmetric in three different aspects. First, the effects of positive and negative returns on volatility are different and more pronounced for negative returns. Second, for both positive and negative returns, the effect is conditional on the distribution of volatility changes. The absolute effect is up to five times larger in the extreme tails of the distribution. Third, at the intraday level, there is evidence of both autocorrelation in volatility changes and cross-autocorrelation with returns. This lead-lag relation with returns is also very asymmetric and more pronounced in the tails of the distribution. These effects are, however, not observed at the daily return horizon.

1. Introduction

The relation between risk and return is a fundamental principle in finance and has extensively been examined in the past four decades (Markowitz & Blay, 2013). Moreover, the relation between volatility and equity returns has commonly been documented to be asymmetric. Returns and volatility are negatively related and this relation is more prominent for negative returns (Bekaert & Wu, 2000; Black, 1976; Christie, 1982; French, Schwert, & Stambaugh, 1987).

In this paper, we take a new look at the risk and return relation by examining the intra-daily effects of negative and positive stock index returns over various parts of the conditional volatility index (VIX) distribution. Our approach allows us to investigate the cases of extreme asymmetric volatility in more depth. As the level of volatility increases, e.g. during financial crises, it is expected that the negative asymmetric return-volatility relation will be significantly more pronounced in the extreme parts of the conditional VIX distribution than what traditional models, e.g., the Ordinary Least Squares (OLS), will predict. Our methodology, Quantile Regression analysis, allows modelling of the return-volatility relation with emphasis on different parts of the conditional volatility distribution, including the extreme tails. By using a combination of the robust Quantile Regression approach and a data set of varying high-frequency returns and VIX, our study is able to monitor the strong contemporaneous negative asymmetric return-volatility relation across the conditional VIX distribution. Well-known hypotheses put forward in the literature for this relation, such as the *leverage effect* and the *volatility feedback effect*, have not been able to completely characterize such a strong contemporaneous relation at stock index level. Additional investigation of the asymmetric relationship between equity returns and volatility is vital as it has important implications for asset pricing models, option pricing and risk management practices.

The use of high frequency data, which we believe is the first time used in the literature to investigate the relation between index return and implied volatility, has enabled us to reveal several aspects of this relation that are not discernable using daily data as in the existing literature. Overall, we observe that the strength of the asymmetric return-volatility relation increases with the return horizon and is strongest for daily returns. We further note that the asymmetry increases monotonically from the median to the tails of the distribution. As a consequence, OLS analysis will underestimate the asymmetry of this relation beyond the median. Moreover, results based on OLS reveals no asymmetry in the relation at higher frequencies, e.g., 1 m interval, whereas results using Quantile Regression shows that there is a strong asymmetric return-volatility relation in the tails of the conditional VIX

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http://dx.doi.org/10.1016/j.irfa.2016.09.016
1057-5219/

Please cite this article as: Badshah, I., et al., Asymmetries of the intraday return-volatility relation, *International Review of Financial Analysis* (2016), http://dx.doi.org/10.1016/j.irfa.2016.09.016

distribution. At higher frequencies lagged effects also become more pronounced. Finally, across all frequencies, we find that OLS analysis underestimates the stronger relation in the tails of the distribution.

The remainder of the paper is structured as follows. Section 2 briefly reviews the literature on the return-volatility relation. Section 3 discusses the data used in the study and Section 4 presents the methodology applied. Section 5 reports on the results and Section 6 finally summarizes and concludes.

2. The asymmetric return-volatility relation

2.1. The leverage and volatility feedback explanations

Black (1976) and Christie (1982) attribute the asymmetric return-volatility relation to the financial leverage of a firm. The hypothesis they put forward is *the leverage effect*: a decline in the value of the stock increases a firm's leverage, as a result the firm's debt/equity ratio increases, which increases firm's risk level. As the risk level increases, the volatility of the equity is also expected to increase. In contrast, French et al. (1987), Campbell and Hentschel (1992), and Bekaert and Wu (2000), attribute the asymmetric return-volatility relation to the volatility feedback effect.[1] The hypothesis they put forward is that if volatility is priced, an expected increase in volatility raises the expected returns on equity leading to an immediate stock price decline to reflect the increase in risk. It states that increases in volatility imply that required future returns will increase and, as a result, current stock prices decline. These firm's fundamental-based explanations for the asymmetric volatility fail to characterize the strong negative asymmetric return-volatility relation at stock index level at high frequencies such as daily or higher frequencies.[2]

There is an abundance of studies that examine the return-volatility relation. However, empirical studies on the asymmetric return-implied volatility relation are relatively recent and fewer in number (including Fleming, Ostdiek, & Whaley, 1995; Whaley, 2000; Low, 2004; Giot, 2005; Dennis, Mayhew, & Stivers, 2006; Hibbert, Daigler, & Dupoyet, 2008; Frijns, Tallau, & Tourani-Rad, 2010; Allen et al., 2012; Badshah, 2013; Agbeyegbe, 2016). Fleming et al. (1995) are the first to investigate the relation between S&P 100 (OEX) returns and VXO (the predecessor of VIX) changes, they document a strong negative contemporaneous relation between implied volatility changes and returns. However, they find other lags to be insignificant or marginally significant.[3] Low (2004) attempts to explain this strong negative contemporaneous asymmetric return-implied volatility relation between OEX returns and VXO changes by the behavioral theory of loss-aversion (Kahneman & Tversky, 1979), in which the impact of losses is higher than gains. He confirms the strong negative contemporaneous asymmetric return-implied volatility relation and finds the relation to be nonlinear, its shape can be best described as a downward sloping reclined S-curve. The negative (positive) returns have convex (concave) profiles. Convexity (concavity) implies accelerating increases (decreases) in the VXO. Hibbert et al. (2008) examine the negative asymmetric return- implied volatility relation between the SPX (NASDAQ-100 index, NDX) returns and changes in the VIX (VXN) at intraday and daily frequencies. They find a stronger negative asymmetric return-implied volatility relation contemporaneously than at lags, and conclude that explanations such as leverage and volatility feedback hypotheses cannot explain this strong relation as the effect of return on volatility, and vice versa, should involve longer lags at lower frequencies than at higher frequencies.[4] Dennis et al. (2006) provide evidence that the negative asymmetric return-implied volatility relation is a market-wide phenomenon rather than an individual stock-level characteristic. Badshah (2013), using Quantile Regression models, examines the asymmetric return-volatility relation at the daily frequency for several stock market indexes. He observes strong negative asymmetric return-volatility relation in the tails of the conditional volatility changes distribution, and finds that OLS underestimates (overestimates) this relation in the positive (negative) tail of the conditional volatility changes distribution.

In this paper, we explore the intraday asymmetric return-volatility relation at high frequencies using Quantile Regressions. Agbeyegbe (2016) examines the return implied volatility relation for the US stock market indices (Dow Jones 30, S&P 500, and NASDAQ100) using linear quantile regression and copula quantile regression methods, and finds that the return-volatility relation depends on the quantile being examined, and this relation is found to be of inverted U-shape.[5]

2.2. Investor heterogeneity and the return-volatility relation

The new VIX uses a cross-section of strike prices, and therefore captures market-wide investor sentiment (errors in investors' beliefs) of fear and exuberance. In the stock market, usually investors have different beliefs about fundamentals of a firm and as a result we observe different stock price forecasts. Differences in beliefs are usually higher in down-market than in up-market conditions.[6] Shefrin (2008), for example, through survey data, finds that investors have heterogeneous beliefs which play an important role in asset pricing. He shows that the expected returns in the US stock market are not uni-modal, but bimodal and fat-tailed. He attributes these clusters to the two types of extreme beliefs that manifest themselves in the tails of the distributions. The right-end tail of the distribution represents the extreme beliefs of optimistic investors and the left-end tail represents the extreme beliefs of pessimistic investors. The optimistic investors (pessimistic investors) overestimate (underestimate) expected returns and underestimate (overestimate) volatility. These survey results are consistent with the view that institutional investors, being pessimists, would buy out of the money (OTM) put options to hedge their underlying portfolios. This buying pressure for OTM put options increases their prices beyond the efficient level. This finding is consistent with Bollen and Whaley's (2004) and Han (2008) who find skewed volatilities across the strike prices are purely caused by the demand for OTM put options. Earlier, Jackwerth and Rubinstein (1996) observe a skew in the implied volatility across different strike prices, which they attribute to the fear of crashes. Shiller (2000) confirms this fear of crashes through survey results in which investors predict more than a 10% probability of market crash within the next six months.

Based on Shefrin's (2001, 2008) observations that investor heterogeneity leads to a bi-model and fat-tailed stock index return distribution, we note that OLS regression estimates (using the conditional mean function) only focuses on the central part of the distribution. OLS

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[1] Poterba and Summers (1986), and French et al. (1987), argue that asymmetric volatility reflects the time varying risk premium that induces the volatility feedback effect.

[2] Schwert (1990) and Bollerslev, Litvinova, and Tauchen (2006), among others, argue that the asymmetry in volatility is too strong to be explained by the leverage effect. Also previous empirical studies show that the volatility feedback hypothesis is not always consistent. Furthermore, some studies find that there is not always a positive relation between current volatility and expected future returns (e.g., Breen, Glosten, & Jagannathan, 1989). However, other studies support the hypothesis (e.g., French et al., 1987; Campbell & Hentschel, 1992; Bali and Bali & Peng, 2006).

[3] Later Giot (2005) investigates the negative contemporaneous return-implied volatility relation in both SPX and NDX stock market indexes. He confirms the strong negative asymmetric contemporaneous return-volatility relation of Fleming et al. (1995).

[4] Other studies such as Bollerslev et al. (2006) examine the asymmetric return-volatility relationship for stock market index using intraday data; however, they use realized volatility instead. They conclude that the magnitude of the effect of price drop on volatility is too strong to be explained by financial leverage fluctuations. Bali and Bali and Peng (2006) also use intraday data in their study however their focus is not asymmetry rather they tests for risk-return trade in the intertemporal CAPM framework, they find significant and positive relationship between risk and return for each of the volatility measure such as realized, GARCH and implied volatility.

[5] Other studies who investigate return implied volatility relation using quantile regression methods, for example Agbeyegbe (2015) for Oil ETF, and Daigler et al. (2014) and Kaurijoki et al. (2015) for currencies.

[6] Li (2007), and Buraschi and Jiltsov (2006) highlight the role of heterogeneous beliefs in asset prices and options prices, respectively.