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Extreme asymmetric volatility: Stress and aggregate asset prices☆

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ABSTRACT

Asymmetric volatility in equity markets has been widely documented in finance (Bekaert and Wu, 2000)). We study asymmetric volatility for daily S&P 500 index returns and VIX index changes, thereby examining the relation between extreme changes in risk-neutral volatility expectations, i.e. market stress, and aggregate asset prices. To this aim, we model market returns, implied VIX market volatility and volatility of volatility, showing that the latter is asymmetric in that past positive volatility shocks drive positive shocks to volatility of volatility. Our main result documents the existence of a significant extreme asymmetric volatility effect as we find contemporaneous volatility-return tail dependence for crashes but not for booms. We then outline aggregate market price implications of extreme asymmetric volatility, indicating that under volatility feedback a one-in-a-hundred trading day innovation to average VIX implied volatility, for example, relates to an expected market drop of more than 4 percent.

Asymmetric volatility in equity markets has been widely documented in finance, stating that returns and volatility are negatively related and that this relation is more pronounced for negative returns. In other words, large volatility increases and large market declines tend to coincide. Asymmetric equity market volatility is important for at least three reasons. First, it is an important characteristic of the market volatility dynamics has asset pricing implications and is a characteristic of priced risk factors. Second, it plays an important role in risk prediction, hedging and option pricing. Finally, asymmetric volatility implies negatively skewed return distributions, i.e. it can help to explain some of the probability of large losses.

In this paper we address the points above, namely how forward looking volatility expectations as measured by large jumps in, or shocks to, implied market volatility relate to large aggregate asset price drops. The topic is relevant to the

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occurrence of periods of market stress. As financial institutions are typically adversely affected by global volatility shocks, it also relates to overall financial stability, which in turn may affect economic performance.[1] Systemic risk is a recognized concept in financial stability, which is sensitive with respect to equity market volatility. As such Bekaert and Hoerova (2014) show that conditional equity market volatility is inversely related to contemporaneous financial stability. Bianconi et al. (2014) further find that implied volatility is significantly related to the systemic risk of distressed financial firms. Therefore, the degree to which volatility relates to aggregate asset prices is also central to the question how global volatility relates to the systemic risk of international financial institutions.

How do forward looking market volatility expectations relate to aggregate asset prices? In the present paper, we address the effect of asymmetric volatility when markets face extreme movements. As market prices are determined by expectations, we use the VIX index as a forward looking risk-neutral implied volatility expectation in our analysis.[2] Two prominent economic hypotheses, which aim at an explanation of the asymmetric volatility phenomenon, are the so-called “leverage effect” hypothesis (i.e. decreasing equity values imply higher financial leverage and risk) and the “volatility feedback effect” hypothesis (i.e. higher expected market risk implies higher expected market return and lower prices); see Black (1976), Campbell and Hentschel (1992) and Bekaert and Wu (2000). While it is known that volatility changes behave asymmetrically with security price changes, it is not yet documented whether such behavior may also be considered as a driver of periods of market stress.[3] Based on the VIX as a measure of relevant future volatility expectations, we examine whether the asymmetric price-volatility relation prevails or weakens when markets face extreme price shocks. In case it prevails, the phenomenon can help to explain the severity of large market declines.

Our paper covers two novel areas. First, we propose a model of the distribution of market returns and observable VIX implied volatility. As in the work by Bollerslev et al. (2009a), we propose an ARCH-type specification for the volatility of volatility daily market returns. While the latter use a symmetric model based on realized variation, our VIX-based model allows for asymmetric responses of volatility of volatility to innovations in volatility. Considering the bivariate distribution of returns and volatility, central to our model is return and volatility shocks, which may exhibit cross-sectional dependence. Under normal periods, this dependence is captured within the dynamic conditional correlation (DCC) approach of Engle (2002) and Engle and Sheppard (2001). The focus of our paper is second on periods of market stress, where we consider extreme shock dependence in the context of extreme value theory (EVT). The feedback hypothesis predicts that periods of pronounced volatility increases jointly with large negative returns are not simply outlying observations. In contrast, feedback can systematically amplify large negative return shocks and lead to a situation where the market would be predicted to decline heavily given an initial large positive shock to volatility. We empirically examine the magnitude of such an event, which is a component to systemic market risk. Assuming that market volatility is a priced risk factor, our test of extreme asymmetric volatility can also be seen as a test of whether the risk of large implied volatility shocks is priced.[4]

Based on our sample of daily U.S. market returns and VIX implied volatility during the period 1990–2012 we document a statistically significant contemporaneous asymmetry effect which is time-varying but consistent. We further show that volatility of volatility is asymmetric in that past positive volatility shocks drive positive shocks to volatility of volatility. Turning to the examination of the tails of the joint return and volatility shocks, we test for the effect of asymmetric volatility under market stress based on a set of hypotheses. We thereby confirm asymmetric behavior in the tails by a strict test of tail independence. While we do not find return-volatility causality in either direction, the contemporaneous asymmetric relation between expected market risk and return is found to be strong during periods of market stress. Our findings thereby underline that the risk of large positive shocks to VIX implied volatility is priced. We finally illustrate the asset pricing implications of extreme asymmetric volatility. Our results for example predict that, under extreme feedback, a one-in-a-hundred trading day 3-sigma innovation to the average VIX level—which occurs two to three times a year on average—relates to an aggregate market drop of more than 4 percent.

The remainder of the paper is organized as follows. Asymmetric volatility is briefly reviewed in Section 1. Our model of market returns and implied volatility is outlined in Section 2, which also includes our methodology for the study of the dependence between volatility and returns. In Section 3, we present the data set and the empirical results. The paper concludes with Section 4.

[1] See for example IMF (2003). One may also add the following foresighted statement: “*Members of the Federal Reserve’s policy-setting committee worried at their most recent meeting that housing and financial market stress could trigger a nasty slide in the economy.* (Reuters, April 8, 2008)”

[2] Other papers that use of the VIX index in an analysis of asymmetric volatility include Wu and Xiao (2002), Carr and Wu (2006) and Hibbert et al. (2008). None of these studies considers extreme asymmetric volatility effects. Wu and Xiao (2002) note that the impact of large shocks may be of interest, however, they conclude that “*we do not have enough sample points in the tail to be able to make a prediction at a very high confidence level.*” (Wu and Xiao (2002), p. 302). Our approach uses theoretical results from extreme value statistics to overcome this problem.

[3] Note that Campbell and Hentschel (1992) suggest that volatility feedback is presumably more important during periods of market stress.

[4] As pointed out in Li (2004) and Engle and Mistry (2007), intertemporal asset pricing models predict volatility asymmetry once market volatility is a priced risk factor. Bollerslev et al. (2009b) find evidence that the difference between implied and realized market volatility, i.e. the variance risk premium, is able to explain variation in aggregate equity market returns. Bekaert and Hoerova (2014) show that while the variance risk premium predicts equity returns, the conditional equity market variance is related to contemporaneous financial instability.