News Impact on Variance Term Structure and Jumps

Ye Yue

Tampere University of Technology

ye.yue@tut.fi

March 14, 2016

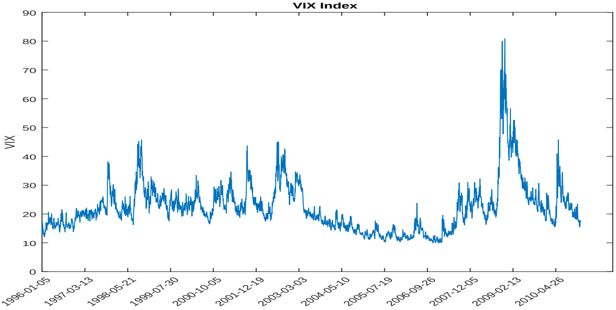
Overview

1. Introduction
2. News Impact on Variance Term Structure
3. News Impact on Jumps: Duration Analysis

Variance, Jumps and News in Financial Markets

- Variance is a measure of risk in financial markets
- Jumps are large changes in asset prices
- Different market news as valuable information to investors are available
- Are variance and jumps associated with important market news?
- In what way does the market news impact on variance and jumps?

VIX and Its Construction



$$VIX = 100\sqrt{\frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Opt(K_i) - \frac{1}{T}\left[\frac{F}{K_0} - 1\right]^2}$$

- What is the shape of daily VIX term structure curve?

VIX Term Structure Estimated Using Option Prices

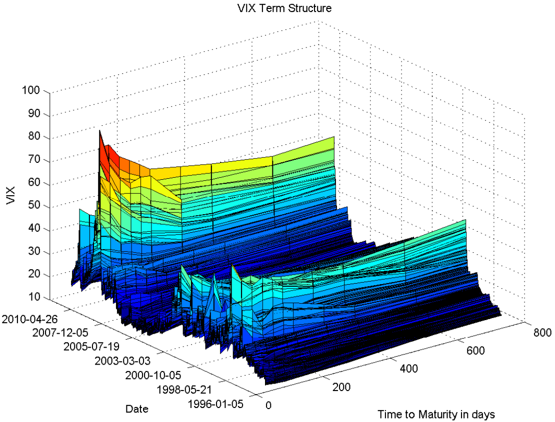


Figure: VIX Term Structure

Typical VIX Term Structure Curves

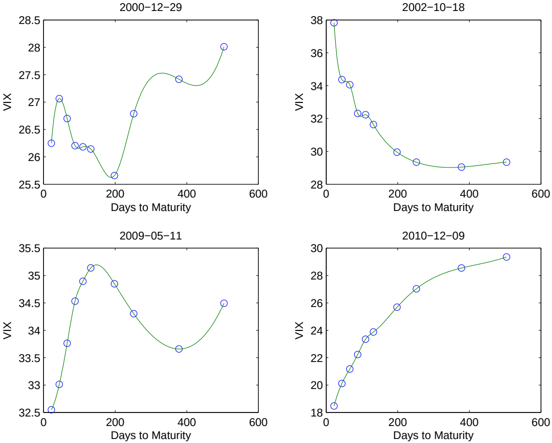


Figure: Typical VIX Term Structure Curves

A Good Start: GARCH(1,1)

Under physical measure

$$\ln(S_t/S_{t-1}) \equiv R_t = r + \lambda\sqrt{h_t} - \frac{1}{2}h_t + \sqrt{h_t}\epsilon_t$$

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-1} f(\epsilon_{t-1})$$

Under risk-neutral measure (Duan 1995)

$$\ln(S_t/S_{t-1}) \equiv R_t = r - \frac{1}{2}h_t + \sqrt{h_t}\epsilon_t^*$$

$$h_t = \beta_0 + \beta_1 h_{t-1} + \beta_2 h_{t-1} f(\epsilon_{t-1}^* - \lambda)$$

VIX Formula Implied by GARCH(1,1)

Let $M = \beta_1 + \beta_2 \mathbb{E}^{\mathbb{Q}}[f(\epsilon^* - \lambda)]$, and under stationary condition, the unconditional variance is $\sigma^2 = \frac{\beta_0}{1-M}$

$$\begin{aligned} \mathbb{E}_t^{\mathbb{Q}}[h_{t+k}] &= \beta_0 \sum_{j=0}^{k-1} M^j + M^{k-1}(\beta_1 h_t + \beta_2 f(\epsilon^* - \lambda)) \\ &= \sigma^2 + (h_{t+1} - \sigma^2) M^{k-1} \end{aligned}$$

The annualized VIX term structure formula is given by

$$VIX_t(\tau) = 100 \sqrt{\frac{252}{\tau} \mathbb{E}_t^{\mathbb{Q}}(\sum_{k=1}^{\tau} h_{t+k})} \quad (1)$$

$$= 100 \sqrt{252\sigma^2 + \frac{252}{\tau}(h_{t+1} - \sigma^2)\frac{1 - M^\tau}{1 - M}}, \quad \tau \geq 1 \quad (2)$$

Time-varying GARCH(1,1) driven by Market News

$$\ln(S_{t+1}/S_t) \equiv R_{t+1} = r + \lambda\sigma_{t+1} - \frac{1}{2}\sigma_{t+1}^2 + \sigma_{t+1}\epsilon_{t+1} \quad (3)$$

$$\sigma_{t+1}^2 = g_t(News_t, 1)h_{t+1} \quad (4)$$

$$h_{t+1} = \beta_0 + \beta_1 h_t + \beta_2 h_t f(\epsilon_t) \quad (5)$$

where g_t is a deterministic function with respect to time t.
Under risk neutral measure

$$\ln(S_{t+1}/S_t) \equiv R_{t+1} = r - \frac{1}{2}\sigma_{t+1}^2 + \sigma_{t+1}\epsilon_{t+1}^* \quad (6)$$

$$\sigma_{t+1}^2 = g_t(News_t, 1)h_{t+1} \quad (7)$$

$$h_{t+1} = \beta_0 + \beta_1 h_t + \beta_2 h_t f(\epsilon_t^* - \lambda) \quad (8)$$

Where $\epsilon_t^* = \epsilon_t + \lambda$, is a standard normal innovation under risk-neutral measure.

VIX Formula Implied by News TV GARCH(1,1)

Let $M = \beta_1 + \beta_2 \mathbb{E}^{\mathbb{Q}}[f(\epsilon^* - \lambda)]$. Under stationary condition, $0 < M < 1$, and the unconditional variance σ^2 is $\frac{\beta_0}{1-M}$.

The annualized VIX term structure formula is given by

$$VIX_t(\tau) = 100\sqrt{\frac{252}{\tau}\mathbb{E}_t^{\mathbb{Q}}(\sum_{k=1}^{\tau} g_t(News_t, k)h_{t+k})} \quad (9)$$

$$= 100\sqrt{\frac{252}{\tau}\sum_{k=1}^{\tau} g_t(News_t, k)\big(\sigma^2 + (h_{t+1} - \sigma^2)M^{k-1}\big)}, \quad \tau \geq 1 \quad (10)$$

Conclusion: It is observed that the shape of VIX term structure curve $VIX_t(\tau)$ is determined by the multiplier $g_t(News_t, k)$.

News Indicator

- News Indicator

$$\mathbb{I}_t^{News} = \omega \frac{|\sum_{i \in N_t} \#\mathbb{N}_t^i - \sum_{i \in N_{t-1}} \#\mathbb{N}_{t-1}^i|}{\sum_{i \in N_{t-1}} \#\mathbb{N}_{t-1}^i} + (1-\omega) \frac{\sum_{i \in N_t} D_i^{KS}}{\sum_{i=1}^n D_i^{KS}} \quad (11)$$

- n classes of important news, $\mathbb{N}^i$, $i = 1, 2, ..., n$, time horizon $\mathbb{T} = \{1, 2, ..., T\}$.
- $N_t \subseteq \{1, 2, .., n\}$ is the news index set on day t.
- $\#\mathbb{N}_t^i$ is the number of pieces of news in class i on day t.
- $\mathbb{T}^i \subseteq \mathbb{T}$ is a set of trading days when news $\mathbb{N}^i$ arrives on.
- $$D_i^{KS} = KS(\hat{F}_{RV}^i, \hat{F}_{RV}^{-i})$$
- Kolmogorov-Smirnov Distance between empirical distributions of realized variance on days in $\mathbb{T}^i$ and on days in $\mathbb{T} \setminus \mathbb{T}^i$.

Macroeconomic News Data

- Data Source: Bloomberg World Economic Calendar
- Time horizon: 29-Jan-2001 to 03-Jan-2011
- 420 types of macroeconomic announcements,e.g.
  - Industrial Production
  - Trade balance
  - Consumer Price Index
  - National Employment report

Specification of News Impact Curve $g_t(News_t, k)$

We specify the time varying news impact curve as a squared three degree polynomial with time varying coefficients driven by news indicator $\mathbb{I}_t^{News}$.

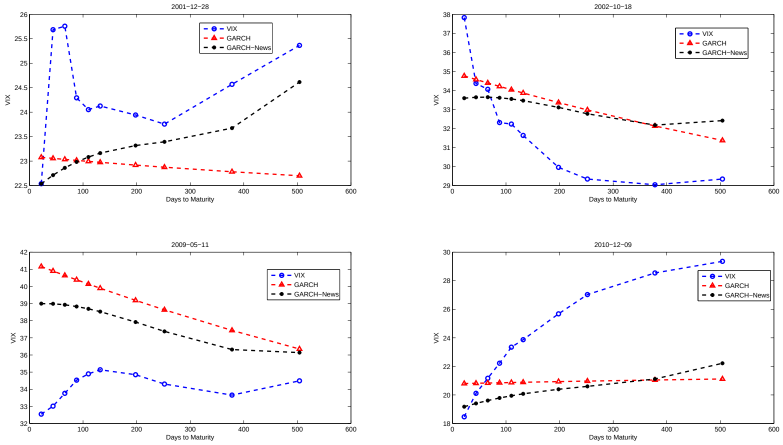
$$g_t(News_t, k) = \left([a_1 + a_5\mathbb{I}_t^{News}]k^3 + [a_2 + a_5\mathbb{I}_t^{News}]k^2 + [a_3 + a_5\mathbb{I}_t^{News}]k + a_4 + a_5\mathbb{I}_t^{News}\right)^2$$

where $a_i,\ i = 1, 2, 3, 4$ are constant parameters determining the "fundamental shape" of VIX term structure, the shape of VIX term structure curves is time varying due to the impulse of daily changing news indicator $\mathbb{I}_t^{News}$.

$$VIX_t(\tau) = 100\sqrt{\frac{252}{\tau}\mathbb{E}^{\mathbb{Q}}\left(\sum_{k=1}^{\tau} g_t(News_t, k)h_{t+k}\right)} \qquad (12)$$

$$= 100\sqrt{\frac{252}{\tau}\sum_{k=1}^{\tau} g_t(News_t, k)\left(\sigma^2 + (h_{t+1} - \sigma^2)M^{k-1}\right)}, \quad \tau \geq 1 \qquad (13)$$

VIX Term Structures Implied by GARCH Models



News Impact on Jumps: Duration Analysis

- Is there an association between Jumps and Company Announcements?
- How to test this association statistically?
- Data
  - 69 large cap Finnish stocks quote prices from 2006 to 2009
  - Firm-specific announcements delivered by Nasdaq Nordic, e.g. earning announcements, news about an acquisition and so on, are classified into scheduled and non-scheduled announcements.

Jump Detection Method (Mykland&Lee 2009)

$$d \log S(t) = \mu(t)dt + \sigma(t)dB(t) + Y(t)dJ(t)$$

- The jump detection statistics

$$\mathcal{L}(k) \equiv \frac{\log[S(t_k)/S(t_{k-1})]}{\widehat{\sigma}(t_k)},$$

- Test Criteria

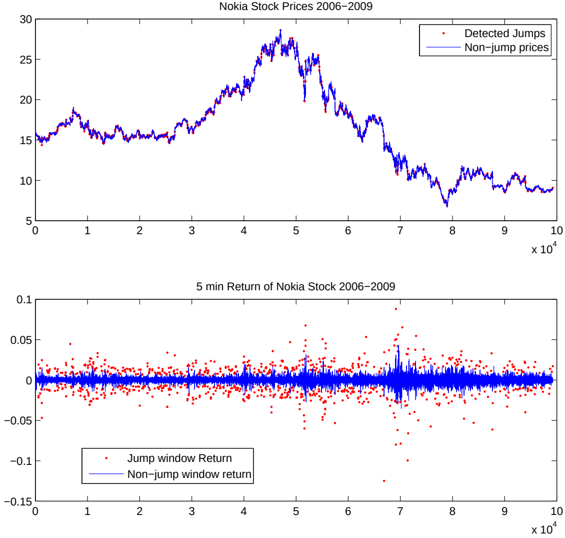
$$\frac{|\mathcal{L}(k)| - C_n}{T_n} > -\log(-\log(1-\alpha)),$$

where

$$C_n = \frac{(2\log n)^{1/2}}{\sqrt{2/\pi}} - \frac{\log \pi + \log(\log n)}{2\sqrt{2/\pi}(2\log n)^{1/2}}, \quad T_n = \frac{1}{\sqrt{2/\pi}(2\log n)^{1/2}},$$

n is the sample size and α is a level of significance

Detected Jumps in Norkia Stock Prices and Returns



Histogram of Detected Jump Time Stamps

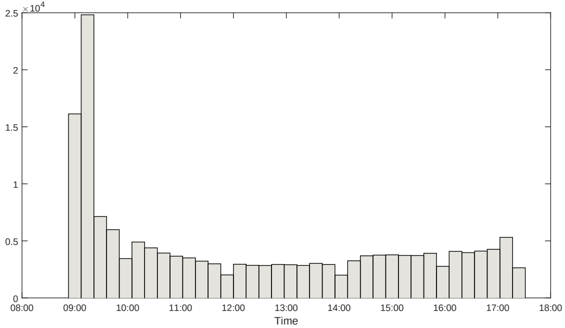


Figure: The histogram of detected jumps time stamps for Finnish companies. The jumps are detected using a Mykland&Lee's methodology with the sampling interval of 5 minutes.

Histogram of Announcement Time Stamps

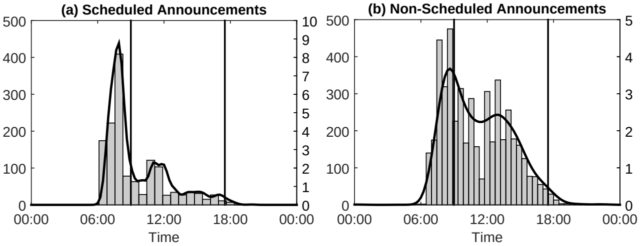


Figure: Histogram and empirical distribution for announcements' time stamps. The vertical lines represent opening time 7:00am and closing time 5:30pm. The total numbers of scheduled and non-scheduled announcements are 1,411 and 4,803, respectively.

Simulation of Reference Announcement Time Stamps

- Intuition: if jumps associated with announcements, the time between them should be short.
- Simulation for Reference Announcement Time Stamps
  - In the first step, for company i, we simulate the number of daily announcements, $\{n_{i,1}, n_{i,2}, \ldots, n_{i,m_i}\}$, which is the series of non-negative integer random numbers. Given that n_i is the number of announcements observed empirically for company i, we set $\sum_{j=1}^{m_i} n_{i,j} = n_i$.
  - In the second step, we randomly generate time stamps according to an *empirical distribution* to take the intraday seasonality into account.

Empirical Distributions of Waiting Time for Scheduled Annoucements

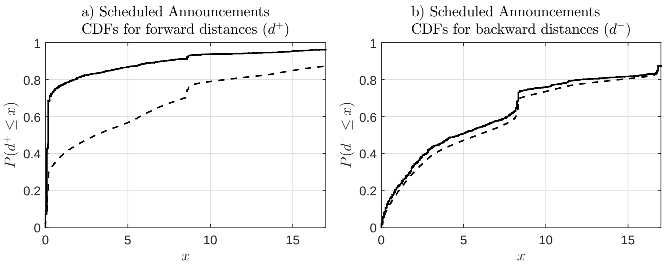


Figure: Cumulative distribution functions for distances between *scheduled* announcements and detected jumps using Finnish data. d^+ denotes a forward distance between an announcement and a first detected jump that follows and d^- denotes a backward distance (between a latest detected jump that precedes and an announcement). Solid line plots distances based on time stamps from empirical data (real announcements) and dashed line is generated by simulating time stamps .

Empirical Distributions of Waiting Time for Non-Scheduled Annoucements

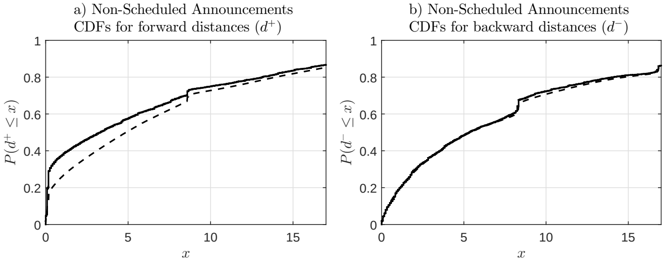


Figure: Cumulative distribution functions for distances between *non-scheduled* announcements and detected jumps Finnish data. d^+ denotes a forward distance between an announcement and a first detected jump that follows and d^- denotes a backward distance (between a latest detected jump that precedes and an announcement). Solid line plots distances based on time stamps from empirical data (real announcements) and dashed line is generated by simulating time stamps.

Conclusions

- Important macroeconomic announcements may change the shape of VIX term structure curves.
- Jumps in company stock prices are associated to both scheduled and non-scheduled company announcements.
- Important market news can be incorporated into classical financial models to improve performance of risk management.

Thank you for your attention!