Risk, Uncertainty and Monetary Policy

Geert Bekaert  
Columbia GSB

Marie Hoerova  
ECB

Marco Lo Duca  
ECB

The views expressed are solely those of the authors.
The “fear index” and MP

<table>
<thead>
<tr>
<th>LVIX,RERA(-i)</th>
<th>LVIX,RERA(+i)</th>
<th>i</th>
<th>lag</th>
<th>lead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0.1716</td>
<td>0.1716</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>0.2169</td>
<td>0.1391</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>0.2651</td>
<td>0.1119</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>0.3119</td>
<td>0.0846</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.3547</td>
<td>0.0586</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>0.3988</td>
<td>0.0300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>0.4225</td>
<td>-0.0039</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>0.4401</td>
<td>-0.0283</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>0.4473</td>
<td>-0.0350</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>0.4560</td>
<td>-0.0513</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.4684</td>
<td>-0.0759</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>0.4912</td>
<td>-0.0935</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>0.5057</td>
<td>-0.1193</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>0.5150</td>
<td>-0.1628</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>0.5314</td>
<td>-0.2032</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>0.5485</td>
<td>-0.2321</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>0.5634</td>
<td>-0.2719</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>0.5731</td>
<td>-0.2947</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>0.5846</td>
<td>-0.3107</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td>0.5979</td>
<td>-0.3344</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>0.6151</td>
<td>-0.3614</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21</td>
<td>0.6329</td>
<td>-0.3979</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>0.6438</td>
<td>-0.4308</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>0.6491</td>
<td>-0.4544</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>0.6515</td>
<td>-0.4686</td>
</tr>
</tbody>
</table>
Research questions / Related research

Does monetary policy (MP) affect stock market risk appetite?

- Evidence for risk appetite of banks (loans); see Altunbas et al. (2010), Ioannidou et al. (2009), Jiménez et al. (2009), Maddaloni and Peydró (2010)
- Role of broad liquidity and credit (Adrian and Shin, 2008; Borio and Zhu, 2004)

What is the relation between MP and stock market volatility?

- Heightened “uncertainty” decreases employment and output (Bloom, 2009)

MP and the stock market – what is the channel?

- Expansionary MP affects the stock market positively and vice versa; see Thorbecke (1997), Rigobon and Sack (2003, 2004), Bernanke and Kuttner (2005)
Empirical challenges

♦ Endogeneity
  - use structural VAR framework, different identifying restrictions
    → robust relations

♦ Measuring monetary policy stance/shocks
  - try various measures for robustness
    In particular: also identification using high frequency Fed funds futures changes

♦ Omitted variables
  - include a business cycle variable

♦ The VIX: indicator of risk aversion but also “uncertainty”
  - split into the two components
Data


- Risk aversion RA and uncertainty UC

- Monetary policy stance: real rate RERA [Fed funds end of month target rate minus CPI annual inflation rate]
  - robustness: Fed Funds rate FED, Taylor rule deviations, M1 growth

- Business cycle: industrial production (IPI)
  - robustness: non-farm employment, ISM index

- Price level(s): CPI, PPI
The VIX!

Physical and Risk-Neutral Conditional Return Volatility

percent, annual rate


physical
risk-neutral
The VIX: risk aversion and uncertainty

- A simple discrete-state, one-period economy
- Return distribution with 3 states $x_i$, occur with prob. $\pi_i$:

<table>
<thead>
<tr>
<th>State</th>
<th>Return $x_i$</th>
<th>Prob. $\pi_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>$x_g = \mu + a$</td>
<td>$\pi_g = \frac{1-p}{2}$</td>
</tr>
<tr>
<td>Bad</td>
<td>$x_b = \mu - a$</td>
<td>$\pi_b = \frac{1-p}{2}$</td>
</tr>
<tr>
<td>Crash</td>
<td>$x_c = c &lt; 0$</td>
<td>$\pi_c = p$</td>
</tr>
</tbody>
</table>

- Investor has all wealth in the stock market:

$$U(\tilde{W}) = E \left[ \frac{(W_0\tilde{R})^{1-\gamma}}{1-\gamma} \right]$$

where $\tilde{R}$ – gross return, $W_0$ – initial wealth, $\gamma$ - CRRA

- “Pricing kernel”: marginal utility $m$, proportional to $\tilde{R}^{-\gamma}$
  - Stock market down, $m$ relatively high and vice versa
“Physical” stock market variance measured using actual probabilities:

\[ V = \pi_g (x_g - \bar{x})^2 + \pi_b (x_b - \bar{x})^2 + \pi_c (x_c - \bar{x})^2 \]

The VIX measures the risk-neutral variance, using probabilities adjusted for risk \( \pi_{j}^{RN} \):

\[ VIX^2 = \pi_g^{RN} (x_g - \bar{x})^2 + \pi_b^{RN} (x_b - \bar{x})^2 + \pi_c^{RN} (x_c - \bar{x})^2 \]

where

\[ \pi_{j}^{RN} = \pi_j \frac{m_j}{E[m]} = \pi_j \frac{(1 + x_j)^{-\gamma}}{E[m]} \]

The variance premium is given by:

\[ VP \equiv VIX^2 - V = \sum_{j=g,b,c} (\pi_{j}^{RN} - \pi_j) (x_j - \bar{x})^2 \]
The VIX: risk aversion and uncertainty

Since $\pi_c^{RN} \gg \pi_c$ and the crash state induces lots of variance, $VP > 0$

- if $\gamma \uparrow \rightarrow$ weight on the crash state $\uparrow \rightarrow VP \uparrow$

With a Campbell-Cochrane (1999)-like external habit:

- the “pricing kernel” is given by $(\tilde{R} - W_{bm})^{-\gamma}$, where $W_{bm}$ is benchmark wealth
- the coefficient of relative risk aversion is $\frac{\gamma \tilde{R}}{\tilde{R} - W_{bm}}$
The VIX: risk aversion and uncertainty

- Suppose statistics to match are: $\bar{x} = 10\%$, $\sigma = 15\%$, skewness $Sk = -1$ and $c = -25\%$

- The implied crash probability is $p = 0.5\%$

- The VIX and VP as a function of $\gamma$ or $W_{bm}$:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>VIX</th>
<th>VP</th>
<th>Parameters</th>
<th>VIX</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma = 2, W_{bm} = 0$</td>
<td>15.9871</td>
<td>0.0031</td>
<td>$\gamma = 4, W_{bm} = 0.05$</td>
<td>17.8677</td>
<td>0.0094</td>
</tr>
<tr>
<td>$\gamma = 4, W_{bm} = 0$</td>
<td>17.6115</td>
<td>0.0085</td>
<td>$\gamma = 4, W_{bm} = 0.25$</td>
<td>19.5977</td>
<td>0.0159</td>
</tr>
<tr>
<td>$\gamma = 6, W_{bm} = 0$</td>
<td>20.1388</td>
<td>0.0181</td>
<td>$\gamma = 4, W_{bm} = 0.50$</td>
<td>27.9344</td>
<td>0.0556</td>
</tr>
</tbody>
</table>

- VP ↑ as effective risk aversion ↑
The VIX: risk aversion and uncertainty

- Two components of the VIX (risk-neutral expected stock market volatility):
  - Actual expected stock market variance $V$, (log=“uncertainty”)
    - fitted values from regressing realized variance on lagged VIX and lagged realized variance
      → best model in horse race
  - Variance premium, $VIX^2 - V$, (log = “risk aversion”)
    - increases monotonically with effective risk aversion in the economy
VIX decomposed: UC (green)
Empirical strategy

♦ Structural VAR: $AZ_t = \Phi Z_{t-1} + \varepsilon_t$

♦ Reduced-form VAR: $Z_t = A^{-1} \Phi Z_{t-1} + A^{-1} \varepsilon_t$

♦ Structural identification: restrictions on contemporaneous responses (Cholesky)
  • A is lower triangular
  • order of variables: price and business cycle first (slow-moving); MP; RA and UC last (fast-moving)
Results: monetary policy shocks

♦ Model with RERA: DIPI RERA RA UC

♦ Model with FED: CPI IPI FED PPI RA UC
  (See Christiano, Eichenbaum, Evans, 1999)

♦ A contractionary MP shock:
  • an increase in the real / Fed Funds rate of 35 / 15 b.p.
  • industrial production decreases in medium run (insignificant)
  • price level decreases (significant)

Results with employment stronger.
Results: monetary policy shocks

Impulse MP, response RA

Model with RERA

Model with FED
Results: monetary policy shocks

Impulse MP, response UC

Model with RERA

Model with FED
Results: Variance decomposition

% of variance explained by MP shocks

- RA
- RERA
- DIPI
- UC
Results: RA/UC shocks

- Impulse: RA; Response: MP

[Graph showing the response of MP to RA shocks at different time intervals]
Results: RA/UC shocks

Impulse: UC; Response: MP
Robustness

♦ Measuring monetary policy:
  • Fed funds rate
  • Taylor rule residuals
  • Growth rate M1

♦ Business cycle measures:
  • Employment, ISM index

♦ Identification of monetary policy shocks:
  • long-run neutrality of money restrictions
Robustness: High frequency identification

♦ Can a monthly VAR really identify MP shocks?

♦ Two alternatives:

  • Bernanke-Kuttner (2005) exogenous monthly MP shocks using Federal funds futures contracts

  • New procedure using high-frequency data (inspired by D’Amico and Farka, 2011)
Robustness: High frequency identification

- Step 1: MP shocks = high frequency change in Fed futures rate around the FOMC announcement (Gürkaynak, Sack, and Swanson, 2005)

- Step 2: Run high frequency “response” regressions

\[
\Delta R_A_t = -0.039 + 0.047 \Delta MP_t - 0.005 \Delta IP_t - 0.004 \Delta ISM_t - 0.004 \Delta EMP_t
\]

(0.007) (0.020) (0.014) (0.016) (0.017)

\[
\Delta U_C_t = -0.009 + 0.013 \Delta MP_t + 0.002 \Delta IP_t - 0.002 \Delta ISM_t - 0.008 \Delta EMP_t
\]

(0.003) (0.010) (0.005) (0.005) (0.011)

- Step 3: Use these coefficients as the estimates of $A^{-1}$ in the VAR! [delivers 4 restrictions]
Robustness: High frequency identification

Impulse MP, Response RA

Note: BC and MP do not respond instantaneously to UC
Robustness: High frequency identification

Impulse MP, Response UC
Concluding remarks

<table>
<thead>
<tr>
<th>LVIX, RERA(-i)</th>
<th>LVIX, RERA(+i)</th>
<th>i</th>
<th>lag</th>
<th>lead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0.1716</td>
<td>0.1716</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>0.2169</td>
<td>0.1391</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>0.2651</td>
<td>0.1119</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>0.3119</td>
<td>0.0846</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.3547</td>
<td>0.0586</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>0.3988</td>
<td>0.0300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>0.4225</td>
<td>-0.0039</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>0.4401</td>
<td>-0.0283</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>0.4473</td>
<td>-0.0350</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>0.4560</td>
<td>-0.0513</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.4684</td>
<td>-0.0759</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>0.4912</td>
<td>-0.0935</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>0.5057</td>
<td>-0.1193</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>0.5150</td>
<td>-0.1628</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>0.5314</td>
<td>-0.2032</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>0.5485</td>
<td>-0.2321</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>0.5634</td>
<td>-0.2719</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>0.5731</td>
<td>-0.2947</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>0.5846</td>
<td>-0.3107</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td>0.5979</td>
<td>-0.3344</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>0.6151</td>
<td>-0.3614</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21</td>
<td>0.6329</td>
<td>-0.3979</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>0.6438</td>
<td>-0.4308</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>0.6491</td>
<td>-0.4544</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>0.6515</td>
<td>-0.4686</td>
</tr>
</tbody>
</table>
Concluding remarks

♦ VAR analysis to characterize links between RA, UC and MP

♦ Provide an interpretation of the VIX ↔ MP relations:
  • co-movement between past MP and current VIX: channel is both RA and UC but RA effect stronger
  • co-movement between current VIX and future MP: MP accommodates but not statistically significant

♦ Monetary easing increases risk appetite
  • Effect significant after 8 months, lasts for 3 years
Concluding remarks

♦ What are the theoretical links between monetary policy and risk-taking behavior in asset markets?

♦ Structural sources of the VIX dynamics in consumption-based asset pricing models: Bekaert and Engstrom (2010), Bollerslev et al. (2008), Drechsler and Yaron (2011), but no MP equation

♦ Possible channels include (excessive) risk-taking in asset management (Rajan, 2006); balance sheets of financial intermediaries (Adrian and Shin, 2010); . . .
Asset Return Dynamics under Bad Environment - Good Environment Fundamentals

Geert Bekaert
Columbia University and NBER

Eric Engstrom
Federal Reserve Board of Governors