Financial Stress and Macroeconomic Dynamics
the transmission of crises

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This paper is a work in progress.
Aim: Investigate the joint determination of financial stress and macro dynamics

- Question 1: How does financial stress affect the real economy?
- Question 2: Are there nonlinearities in the relationship?
- Question 3: What is the role of monetary policy?
- Question 4: Whence the nonlinear dynamics, if any?
Our approach:

- Employ a Financial Stress Index (FSI) for the United States
Methodology

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  - Should encompass a range of financial market phenomena
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- **Allow for time variation (non-linear)**
  1. Use multivariate Markov-Switching VAR model
  2. State-of-the-art Bayesian estimation [Sims-Wagonner-Zha (2008)]
  3. Use model data densities and other criteria to investigate our questions
Financial stress: channels of transmission

1. Raises costs of funds for purchasers of durable goods
2. Impedes borrower-lender relationships inducing credit rationing
3. Increases option value of waiting
4. Resulting disruption to real activity feeds back on financial variables
Related research
A shamefully incomplete listing.

- **Non-structural models**: Lown and Morgan (2006); Davig and Hakkio (2010), others
- **Surveys**: Kashyup and Stein (1994); Hubbard (1998)
- **Markov switching**: Hamilton (1978); Kim and Nelson (1999); Sims, Wagonner and Zha (2008)
Table 1
U.S. Financial Stress Index*

<table>
<thead>
<tr>
<th>#</th>
<th>Component description**</th>
<th>Std.dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>AA bond rate-Treasury spread, const. maturity</td>
<td>67.4</td>
</tr>
<tr>
<td>2.</td>
<td>BBB bond rate-Treasury spread, const. maturity</td>
<td>96.7</td>
</tr>
<tr>
<td>3.</td>
<td>Federal funds rate less 2-yr Treasury yield</td>
<td>0.72</td>
</tr>
<tr>
<td>4.</td>
<td>10-year Treasury bond implied volatility</td>
<td>1.50</td>
</tr>
<tr>
<td>5.</td>
<td>Private long-term bond implied volatility</td>
<td>2.34</td>
</tr>
<tr>
<td>6.</td>
<td>10-year Treasury on-the-run premium</td>
<td>9.80</td>
</tr>
<tr>
<td>7.</td>
<td>2-year Treasury on-the-run premium</td>
<td>4.13</td>
</tr>
<tr>
<td>8.</td>
<td>S&amp;P 500 earnings/price less 10-year Treasury</td>
<td>1.61</td>
</tr>
<tr>
<td>9.</td>
<td>S&amp;P 100 implied volatility (VIX)</td>
<td>8.96</td>
</tr>
</tbody>
</table>

* Source: Federal Reserve Board staff. Available on request.

**Weighted as a function of the inverse of their sample std. dev’s.
The FSI (continued)

How does it look?

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The model

A Multivariate MS-VAR model:

\[ y_t' A_0(s_t) = \sum_{l=1}^{p} y_{t-l}' A_l(s_t) + z_t' C(s_t) + \varepsilon_t', \quad (1) \]

with \( y = [u, \pi, R, S] \). Here we have rolled intercept terms into \( z \). The value of \( s_t \) is an element of \( \{1, 2, ..., h\} \) and evolves according to a first-order Markov process:

\[ \Pr(s_t = i | s_{t-1} = k) = p_{ik}, \quad i, k = 1, 2, ..., h. \quad (2) \]

Let

\[ A'_+ = [A_1(k)', A_2(k)', ..., A_p(k)', C(k)'] \quad \text{and} \quad x'_t = [y'_{t-1}, ..., y'_{t-p}, z'_t] \]

The model can be rewritten as:

\[ y_t' A_0(s_t) = x'_t A'_+(s_t) + \varepsilon', \quad t = 1, 2, ..., T \quad (3) \]
The reduced form system is then:

\[ y_t' = x_t' B(s_t) + u_t'(s_t), \quad t = 1, 2, \ldots T \]  \hspace{1cm} (4)

with

\[ B(s_t) = A_+(s_t)A_0^{-1}(s_t) \]  \hspace{1cm} (5)

\[ u_t'(s_t) = A'_0^{-1}(s_t)\varepsilon_t' \]  \hspace{1cm} (6)

\[ E(u_t(s_t)u_t(s_t)') = (A_0(s_t)A'_0(s_t))^{-1}. \]  \hspace{1cm} (7)

As written here, the **stochastic volatility** and **parameter shifting** have common sources, but we will relax this assumption in estimation.
Bayesian estimation
Multivariate MS-VAR methods based on Sims-Waggoner-Zha (2008)

<table>
<thead>
<tr>
<th>Prior values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu_1 ) overall ( A_0 ) and ( A_+ )</td>
</tr>
<tr>
<td>( \mu_2 ) relative for ( A_+ )</td>
</tr>
<tr>
<td>( \mu_3 ) lag decay</td>
</tr>
<tr>
<td>( \mu_4 ) dummies (unit roots)</td>
</tr>
<tr>
<td>( \mu_5 ) dummies (other)</td>
</tr>
<tr>
<td>( P(p_{ik}) ) Dirchlet</td>
</tr>
<tr>
<td>duration of a regime</td>
</tr>
</tbody>
</table>

Notes: priors are all normal except variances which are gamma.

- **Bottom line**: weaker priors than Sims-Zha recommendations for monthly data.
monthly data, seasonally adjusted, expressed at annual rates, 1988:m12 to 2009:m9

\[ y_t = [u, \pi, R, S] \]
where \( u \) is the unemployment rate; \( \pi \) is core CPI inflation; \( R \) is the targeted federal funds rate; \( S \) is financial stress.

None of these series is ever revised (except for changing seasonal factors)

Choleski decomposition, ordered as shown. Thus only stress responds instantaneously to policy innovations and nothing responds instantaneously to stress.

Further work to come using other identification schemes

Further work to come using banking sector information
Model specification

- Interested in whether stochastic volatility \((v)\) alone does the trick, or whether parameter shifting \((m)\) is also helpful.
- Interested in the number of latent states, \(h\).
- Can we restrict the switching to certain equations?
- Example of notation for tables: \(2vR2m\) means 2 \(sv\) states\((v)\), and two parameter shifting states, \((m)\), with the latter restricted to the funds rate equation, \(R\). No \(R\), (or \(S\) or \(RS\)), no restriction.
Stochastic volatility alone?

Table 3
Selected econometric results from MS-VAR model

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1v log(mdd)</td>
<td>-190.29</td>
<td>-115.02</td>
<td>-110.82</td>
<td>-104.48</td>
<td>-99.75</td>
</tr>
<tr>
<td>2v log(L)</td>
<td>-44.25</td>
<td>31.29</td>
<td>87.39</td>
<td>35.09</td>
<td>12.16</td>
</tr>
</tbody>
</table>

- *Marginal data densities* favor more elaborate models, but....
- ...the contribution of the data to that outcome is small
Whence the parameter switching?

Table 4
Econometric results from MS-VAR model

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>log(mdd)</td>
<td>-115.02</td>
<td>-110.82</td>
<td>-112.32</td>
<td>-115.19</td>
<td>-107.94</td>
</tr>
<tr>
<td>log(L)</td>
<td>31.29</td>
<td>87.39</td>
<td>-34.96</td>
<td>8.38</td>
<td>59.60</td>
</tr>
</tbody>
</table>

- Among 2v models, the data favor *parameter shifting*
- Among models that restrict the location of parameter shifting, switching in $R$ and $S$ together is preferred to either alone.
### Table 5
Estimated state transition probabilities
(posterior mode)

| model       | volatility | parameters |  |  |
|-------------|------------|------------|  |  |
|             | $q_{11}$   | $q_{22}$   | $q_{11}$ | $q_{22}$ |  |  |
| 2v          | 0.96       | 0.89       | -         | -         |  |  |
| 2v2m        | 0.95       | 0.96       | 0.91      | 0.97      |  |  |
| 2vRS2m      | 0.85       | 0.91       | 0.99      | 0.92      |  |  |
| 2vR2m       | 0.99       | 0.99       | 0.99      | 0.99      |  |  |
| 2vS2m       | 0.99       | 0.99       | 0.99      | 0.97      |  |  |

Note: priors for $q_{ii}$ are 0.85 in all cases.

- $q_{11}$ for the 2vRS2m model does not budge from its prior. Hmm...
Switching probabilities II
The 2v2m model

Probability of high-stress state, 2v2m MS-VAR model

Slope and intercept coefficients

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Switching probabilities III

The 2vRS2m model

![Probability of high-stress state, 2vRS2m MS-VAR model](chart1)

![Slope and intercept coefficients](chart2)
## Table 6

### RFF impact coefficients by state

<table>
<thead>
<tr>
<th>State</th>
<th>RS</th>
<th>RR</th>
<th>RS</th>
<th>RR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1v</td>
<td>-1.04</td>
<td>6.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2v2m</td>
<td>-1.11</td>
<td>3.30</td>
<td>-0.31</td>
<td>6.74</td>
</tr>
<tr>
<td>2vRS2m</td>
<td>0.32</td>
<td>6.33</td>
<td>0.97</td>
<td>11.55</td>
</tr>
</tbody>
</table>

**Notes:** RS is the R response to S shock.

- Both models: R own-shock responses are *weaker* in high-stress states.
- 2v2m: responses to S shocks are *stronger*.
- 2vRS2m: responses to S shocks are perverse. Hmm...
Conclusions

- It is a challenge to find MS in a short sample with supposedly few events: but we found some.
- The data suggest that switching is probably in more than just volatilities.
- The timing in jumps to high-stress states lines up well with known events.
- Real-time performance appears to be quite good as well (in progress).
- Monetary policy does appear to transmit differently in high-stress periods.
Appendix
The FSI and unemployment
Correlation of FSI with leads and lags of IP growth
Table A1
Econometric results for \( j2vkm \) MS-VAR models

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>log(mdd)</td>
<td>-110.82</td>
<td>-115.19</td>
<td>-140.33</td>
<td>-107.94</td>
<td>-140.32</td>
</tr>
<tr>
<td>ESS</td>
<td>n/a</td>
<td>93</td>
<td>827</td>
<td>319</td>
<td>797</td>
</tr>
<tr>
<td>log(L)</td>
<td>87.39</td>
<td>8.38</td>
<td>7.78</td>
<td>59.60</td>
<td>6.57</td>
</tr>
</tbody>
</table>

* \( j, k = [], S, R, RS \) where \( R = \) policy rate; \( S = \) stress; \( [] = \) all.

- The data *hate* constraining stochastic volatility to a subset of variables
**Table A2**

Results for $3v_{j2m}$ MS-VAR models*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>log(mdd)</td>
<td>-95.14</td>
<td>-82.00</td>
<td>-109.22</td>
<td>-99.05</td>
</tr>
<tr>
<td>ESS</td>
<td>n/a</td>
<td>334</td>
<td>9</td>
<td>202</td>
</tr>
<tr>
<td>log(L)</td>
<td>87.89</td>
<td>80.26</td>
<td>6.87</td>
<td>64.36</td>
</tr>
</tbody>
</table>

* $j = [], R, S$ where $R =$ policy rate; $S =$ stress.
Directory: Results/1m_inflation/new_0310/2v2m_4var_3lag_wprior
P(s1)=1 and P(s2)=1

P(s1)=1 and P(s2)=2

P(s1)=2 and P(s2)=1

P(s1)=2 and P(s2)=2

P(s1)=2

P(s1)=1

P(s2)=2

P(s2)=1

Directory: Results/1m_inflation/new_0310/2v2m_4var_3lag_wprior