Contributions to Financial Stability
Measuring and Forecasting Financial Stress

SAFE: An early warning system for systemic banking risk

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Financial Stability Analysis: Using the Tools, Finding the Data
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Agenda

1. **Early warning of systemic stress**
   - Measure of systemic conditions
     - Identifying systemic stress
   - Set of factors to explain this measure
     - Forecasting systemic stress

2. **Data**
   - Confidential supervisory data adds value to public data

3. **Uses in supervisory process**
   - Across time
     - Identification of stress
     - Monitoring of stress
     - Alerting of stress
   - Across institutions
     - Contributions to stress
     - Adverse exposures
     - Macroprudential vs. microprudential issues
Introduction

• Systemic risk leading to financial crisis
  • Economic imbalances
  • Shock
  • Adverse feedback loop
  • No self-correcting mechanism
  • Financial market fails to function normally
  • Spillover to the real economy

Group of Ten, 2001, BIS

• Develop an early-warning system for systemic risk identification that provides supervisors time to prevent or mitigate a potential financial crisis
Conceptual model

- Explanatory factors in literature (See Table 1)
- Feedback (Krishnamurthy, 2009)

- Explanatory factors (This paper)
- Institutional imbalances (This paper)
- Liquidity feedback (This paper)

Liquidity transformation imbalances
Risk transformation imbalances
Return transformation imbalances
Structural imbalances

FINANCIAL STRESS
—positive
—negative
Observations

- Accumulated imbalances above long term means are highly correlated to stress episodes across time.

- Structurally, financial system is highly heterogeneous by exposure concentrations across institutions.
CFSI — measure of US financial stress

Available daily from http://www.clevelandfed.org/research/data/financial_stress_index/
Early warning

**CFSI — measure of US financial stress**

Components of the CFSI - Summary

This chart shows the contribution of four financial sectors to the Cleveland Financial Stress Index (CFSI). The CFSI is a coincident indicator of systemic stress, where a high value of CFSI indicates high stress in the financial system. A value of 0 indicates the least possible stress, and a value of 100 indicates the most possible stress.

Early warning

US Financial stress indexes in 2008... and in 2010

Sources: Oet, Bianco, Gramlich, and Ong (2012); Federal Reserve Bank of St. Louis

Sources: Oet, Bianco, Gramlich, and Ong (2012); Federal Reserve Bank of Kansas City

Sources: Oet, Bianco, Gramlich, and Ong (2012); Federal Reserve Bank of Chicago

Sources: Oet, Bianco, Gramlich, and Ong (2012); Bloomberg

Sources: Oet, Bianco, Gramlich, and Ong (2012); Bloomberg

Sources: Oet, Bianco, Gramlich, and Ong (2012); Hatzius, Hooper, Mishkin, Schoenholtz, and Watson (2010)

Note: Values are quarterly averages.
CFSI comparison with alternative indexes - quarterly

Source: Federal Reserve Bank of Cleveland; Federal Reserve Bank of Chicago; Federal Reserve Bank of Kansas City; Federal Reserve Bank of St. Louis
Development of dependent variable series

- Quarterly financial stress series (CFSIqt)
  - what is the precedent set by the indicator’s value
  - how much that precedent matters

- Mathematically:

\[ Y_t = CFSIqt = \sum_j \left[ w_{jt} \ast \int_{-\infty}^{z_{jt}} f(z_{jt}) \, dz_{jt} \right] \ast 100 \]

  - where the Zjt term is the value of indicator j at time t,
  - the integration term is the CDF of indicator j,
  - the Wjt term is the weight given to indicator j in the FSI at time t.

- A key technical challenge is the potential for false alarms
  - Overcome by appropriate choice of the weighting methodology
Imbalances

- Methodology uses Z-scores to express imbalances
  - Imbalance $X_t$ is defined as deviation of explanatory variable $X_t$ from its mean
  - $X_t$ is constructed as standardized imbalance of $X_t$

$$X_t = \frac{X_t - \mu^x_t}{\sigma^x_t}$$

- where $X_t$ is a deflated explanatory variable
- $\mu^x_t$ is cumulative mean of the explanatory indicator known as of time $t$, and $\sigma^x_t$ is its cumulative standard deviation

- The $X_t$ imbalance shows potential for stress
Early warning

Model

- Each SAFE model is an optimal lag linear regression model

\[ Y_t = \beta_0 + \beta_{RET}X_{RET,t-n_{RSK}} + \beta_{RSK}X_{RSK,t-n_{RSK}} \]
\[ + \beta_{LIQ}X_{LIQ,t-n_{LIQ}} + \beta_{STR}X_{STR,t-n_{STR}} + u_t \]

where the dependent variable \( Y_t \) is constructed separately as a series of systemic stress in the U.S. financial markets, and the independent variables \( X_{i,\text{lagged}t} \) are return, risk, liquidity, and structural characteristics of the asset class exposures of the top twenty-five US BHCs.
Design

• A hazard inherent for all ex ante models is that the model uncertainty may lead to wrong policy choices

• To mitigate this risk, SAFE develops two perspectives
  - medium term advanced warning specifications, suitable for ex ante policy action
    • long-lag models: lags 6-12
  - short term model specifications for verification and adjustment of supervisory actions
    • short-lag models: lags 2-12

• Model Checks and Balances
  - LL models provide a minimum of 6 quarters warning
  - SL models provide a minimum of 2 quarters warning
Benchmark model

- Expect stress to be related to past stress

\[ \hat{FSI} = 7.85 + 0.60FSI_{-1} + 0.24FSI_{-4} \]
Simple candidate base model

**RETURN**
- Equity +

**RISK**
- Credit Risk Capital –

**LIQUIDITY**
- AL Mismatch +

**STRUCTURE**
- Leverage +
Early warning

From simple to complex: short- and long-lag

Form Benchmark Model
\[
FSI = 7.85 + 0.60FSL_{-1} + 0.24FSL_{-4}
\]

Form Candidate Base Model
\[
FSI = 36.58 + 0.35FSL_{-1} + 1.70GT\_AL3_{-5} + 7.04GT\_LEVN_{-5} + 2.34\Delta PMKTCP_{-5} - 12.62\Delta CRCAP\_NV_{-11}
\]

Form Short-Lag Benchmark Model
\[
FSI = 38.77 + 0.40FSL_{-1} + 2.06\Delta HFX4_{-6} + 8.65\Delta EQ5_{-8} + 8.15GT\_LEVN_{-5} - 2.94\Delta EQLGDW3_{-7} - 4.55CR\_EVS\_V_{-8}
\]

Form Long-Lag Benchmark Model
\[
FSI = 37.85 - 9.88GT\_ALG3_{-9} + 2.29EDF_{-11} - 2.24CR\_EVNV_{-6} + 4.55GT\_HIB_{-8} + 11.20GT\_LEVN_{-7}
\]
### Results: short-lag and long-lag

#### Short-lag models

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<thead>
<tr>
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<td><strong>OBSERVATIONS</strong></td>
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<tr>
<td><strong>R-SQUARED</strong></td>
<td>0.733</td>
<td>0.824</td>
<td>0.817</td>
<td>0.803</td>
<td>0.784</td>
<td>0.783</td>
<td>0.774</td>
<td>0.780</td>
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**Combination**

- **In-sample**

- **Out-of-sample**

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<td><strong>MAPE</strong></td>
<td>18.68</td>
<td>26.36</td>
<td>16.87</td>
<td>21.96</td>
<td>19.17</td>
<td>27.37</td>
<td>18.82</td>
<td>21.09</td>
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<td><strong>Theil U</strong></td>
<td>0.150</td>
<td>0.231</td>
<td>0.138</td>
<td>0.178</td>
<td>0.173</td>
<td>0.246</td>
<td>0.117</td>
<td>0.185</td>
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</table>

**Combination**

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<tr>
<td><strong>RMSE</strong></td>
<td>27.99</td>
<td>30.36</td>
<td>23.04</td>
<td>24.68</td>
<td>28.47</td>
<td>27.21</td>
<td>29.28</td>
<td>30.20</td>
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<tr>
<td><strong>MAPE</strong></td>
<td>29.89</td>
<td>33.57</td>
<td>25.20</td>
<td>24.88</td>
<td>29.94</td>
<td>29.35</td>
<td>31.91</td>
<td>33.08</td>
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<tr>
<td><strong>Theil U</strong></td>
<td>0.231</td>
<td>0.256</td>
<td>0.178</td>
<td>0.197</td>
<td>0.235</td>
<td>0.223</td>
<td>0.244</td>
<td>0.254</td>
</tr>
</tbody>
</table>

**Combination**

- **In-sample**

- **Out-of-sample**

#### Long-lag models
Forecast combinations

- Employ regression to resolve relative importance of each model
- Clarify significance of variables out-of-sample

- Short-lag forecast combination

\[ CFSI_t = w_1 SL1_t + w_2 SL2_t + w_3 SL3_t + w_4 SL4_t + w_5 SL5_t + w_6 SL6_t \\
+ w_7 SL7_t + (1 - w_1 - w_2 - w_3 - w_4 - w_5 - w_6 - w_7) SL8_t + \varepsilon_t \]

- Long-lag forecast combination

\[ CFSI_t = w_1 LL1_t + w_2 LL2_t + w_3 LL3_t + w_4 LL4_t + w_5 LL5_t + w_6 LL6_t \\
+ w_7 LL7_t + (1 - w_1 - w_2 - w_3 - w_4 - w_5 - w_6 - w_7) LL8_t + \varepsilon_t \]
How accurate were SAFE forecasts in real time?

- Actual CFSI
- Long Lag Forecast
- Short Lag Forecast
## Early warning

### Data

**Short-lag stress drivers — 2Q: 2007**

<table>
<thead>
<tr>
<th>Units of CFSI</th>
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<td>-6</td>
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### Uses

- A-L Gap (3 to 12 mos.)
- A-L Gap (> 3 mos.)
- Currency Markets - Interbank Exposure
- Securitization
- IRR Indicator
- Credit Risk
- Bank Capital-at-Risk
- Delta CoVaR at 5%
- Capital Market concentration
- FX Concentration
- FX Concentration
- Interbank Concentration
- Risk Transfer Concentration

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Long-lag stress drivers — 2Q: 2007

Units of CFSI

AL Gap Indicator - '0 to 3 months' maturity band
AL Gap Indicator - '3 to 12 months' maturity band
Liquidity Index Indicator - immediate fire sale
Capital Markets - Equity
Capital Markets - Bonds
Capital Markets - commercial property
Interbank Exposures
Interbank Exposures
Securitization
Economic Value: 12 call report loan portfolios
CoVaR at 5%
FX concentration
Interbank concentration
Leverage
Explanatory data sources

- Explanatory Data - 86 quarterly data panels from March 1991 to March 2013, top Tier top 100 BHCs, aggregated top 25 BHCs, specified using 62 in-sample quarters

<table>
<thead>
<tr>
<th>Return Imbalances</th>
<th>Liquidity Imbalances</th>
<th>Risk Imbalances</th>
<th>Structure Imbalances</th>
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<tbody>
<tr>
<td>- CRSP</td>
<td>- Moody’s</td>
<td>- Moody’s</td>
<td>- CRSP</td>
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<tr>
<td>- S&amp;P Case-Schiller data</td>
<td>- FRS – FDR micro data</td>
<td>- FRS – FDR micro data</td>
<td>- FRS - CoVaR model</td>
</tr>
<tr>
<td>- MIT CRE data</td>
<td>- Moody’s</td>
<td>- Moody’s</td>
<td>- FRS - Flow of Funds</td>
</tr>
<tr>
<td>† FRS – X-Country data</td>
<td>†† FRS – IRR FOCUS</td>
<td>†† FRS – IRR FOCUS</td>
<td>† FRS – X-Country data</td>
</tr>
<tr>
<td>†† FRS – BankCaR</td>
<td>†† FRS – IRR FOCUS</td>
<td>†† FRS – BankCaR</td>
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<tr>
<td>†† FRS – SABR/SEER</td>
<td>†† FRS – IRR FOCUS</td>
<td>†† FRS – CAMELS</td>
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<tr>
<td>†† FRBC – SCAP-haircut</td>
<td>†† FRS – SABR/SEER</td>
<td>†† FRBC – CAMELS</td>
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<td>†† FRBC – LFM</td>
<td>†† FRBC – SCAP-haircut</td>
<td>†† FRBC – LFM</td>
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Clear row indicates public data.
Shaded row indicates supervisory data.
† - Confidential supervisory data (category 1).
†† - Constructed supervisory data (category 2).
Confidential supervisory and public data

- There are three broad categories of explanatory data.
  - Institution-specific data internal to the Federal Reserve System
  - Undisclosed Federal Reserve models and their output
    - These models may use either publicly available data or FRS data
  - Data from the public domain
    - These include raw data from the public domain as well as output from publicly available models that utilizes data from the public domain.
- Our approach defines confidential supervisory data as FRS internal data and the undisclosed output of FRS models.

<table>
<thead>
<tr>
<th>Measures</th>
<th>FRS Series</th>
<th>Proportion FRS</th>
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<tbody>
<tr>
<td>Total</td>
<td>33</td>
<td>50.0%</td>
</tr>
<tr>
<td>RET Measures</td>
<td>1</td>
<td>10.0%</td>
</tr>
<tr>
<td>RSK Measures</td>
<td>28</td>
<td>82.4%</td>
</tr>
<tr>
<td>LIQ Measures</td>
<td>3</td>
<td>42.9%</td>
</tr>
<tr>
<td>STR Measures</td>
<td>1</td>
<td>7.1%</td>
</tr>
</tbody>
</table>
Does confidential supervisory data add value?

• To test, we remove all FRS variables from the model suggestion stage and re-specify the optimal model.
  - Many of the public series from our original model are preserved
  - Risk series are most depleted by loss of confidential data

• Summary of Findings
  • FRS models fit the in-sample period more tightly
  • FRS models provides a more accurate forecast by all observed metrics

• Conclusions
  • Both model sets catch the increase in stress during 2Q 2007. Confidential models do better in explaining the ongoing crisis. Public models miss the subprime episode all together.
  • This demonstrates the importance and usefulness of confidential data in the creation of an Early Warning System.
Using the tools: the challenges

**OBJECTIVES**
- T| Time dimension of policy objectives
- X| Cross-sectional dimension of policy objectives

**FUNCTIONS**
- Identification of systemic conditions
- Forward-looking
- Forecasting
- Identification of systemic imbalances
- Distinguish excessive exposures
- Sensitivity to systemic risk posed

**EVALUATION**
- Expected loss calculations
- Model uncertainty aversion
- Local robustness analysis
- Robustness with multiple models

**FORMS**
- Early warning systems
- Asset price models
- Stress testing
- Microprudential feeds
Uses in supervisory process

- Uses across time
  - Forecast thresholds
  - Stress alerts
  - Migration matrices

- Uses across institutions
  - Stress contributions
  - Targets and limits
  - Tiered parity
  - Macroprudential / microprudential issues
Time dimension

Policymakers’ decision is assisted by establishing

- stress thresholds and
- decision rules

- When forecast of stress exceeds the target level of stress, the policymakers can weigh the economic costs of regulatory action against economic costs of a shock
- When forecasts of stress fall short of target action level, EWS supports markets’ ability to self-resolve the particular level of stress
Forecast thresholds across time

LTCM →
Dot-Com Crisis →
Early 2000s Recession →
Lehman Brothers Failure →
Bear Stearns Collapse →
Stock Market Downturn →


Grade 4
Grade 3
Grade 2
Grade 1

Source: Federal Reserve Bank of Cleveland.
Stress alerts across time

Source: Oet, Bianco, Gramlich, and Ong (2012).
Migration matrices across time

- Leverage change (std) needed for stress migration

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<tr>
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<th>Grade 3</th>
<th>Grade 4</th>
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<tbody>
<tr>
<td>Grade 1</td>
<td>0</td>
<td>2.3</td>
<td>5.1</td>
<td>7.4</td>
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<td>Grade 2</td>
<td>(2.3)</td>
<td>0</td>
<td>2.3</td>
<td>4.6</td>
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<tr>
<td>Grade 3</td>
<td>(5.1)</td>
<td>(2.3)</td>
<td>0</td>
<td>2.3</td>
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<tr>
<td>Grade 4</td>
<td>(7.4)</td>
<td>(4.6)</td>
<td>(2.3)</td>
<td>0</td>
</tr>
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</table>
Stress contributions across top 5 institutions
Stress contributions across top 25 institutions
Potential targets and limits across institutions

- Loan portfolio (cpi)
- Interbank currency (cpi)
- Securitizations (cpi)
- Securitizations (ta)
- IR derivatives
- Liq index 1 yr fwd
- Liq index 3 mo fwd
- Liq index fire sale
- Solvency through the cycle
- Solvency in stress
- EDF
- IR distance to crisis
- CR distance to crisis
- Solvency distance to crisis
- FX mark concentration
- Interbank concentration
- Leverage

TARGET

LIMIT

1Q ahead
2Q ahead
3Q ahead
4Q ahead
5Q ahead
6Q ahead

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Tiered parity supervision across institutions

LISCC add 1.30 units to stress

LBO add 0.31 units to stress

FEDERAL RESERVE BANK OF CLEVELAND
Macroprudential and microprudential issues across institutions

Macroprudential
Concentration - Currency Market (interbank)

Microprudential
Credit Risk - normal distance-to-systemic stress
Conclusion: SAFE Early Warning System

- Three main contributions
  - significant association between institutional imbalances, system structure, and financial market stress
  - evidence of value of confidential supervisory data from comparisons of public and confidential SAFE models
  - supervisory uses in two dimensions
    - across time: improved identification of emerging systemic stress
    - across institutions: improved identification of adverse common exposures

- SAFE substantiates macroprudential policy choices to supplement the fundamental institution-specific microprudential practices
Discussion

• Q&A

Thank you for your attention

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