A Framework for Assessing the Systemic Risk of Major Financial Institutions

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Importance of financial stability

Macro-prudential perspective: focus on the stability of the financial system as a whole

- How to measure the systemic risk of a banking system?
- How to assess the vulnerability of a banking system?
Introduction

Methodology

Empirical Work

Related studies

- Measuring systemic risk
  - Balance sheet information: NPL, profitability, etc
  - Market data: CDS spreads (Avesani et al, 2006)
    - More timely
    - Forward-looking

- Vulnerability assessment: stress testing
  - CGFS (2000, 2005), Drehmann (2008a, 2008b)
Contributions of this paper

To propose a methodological framework with an illustrative example
- A new indicator of systemic risk: price of insurance against distressed losses
  - Based on market data: CDS and equity prices
  - Economically intuitive
  - Increase in both PD and correlations
- A novel approach to estimating / forecasting asset return correlations: high-frequency technique
- Vulnerability assessment: an integrated micro-macro model that allows for two-way linkages between the health of the banking system and the general economy
Outlines of the presentation

- Methodology
- Data
- An illustrative example
- Conclusion
Methodology: an overview

- CDS spreads
- Step 1
- PD
- Step 3
- Indicator

- Equity prices
- Step 2
- Correlation

- Step 4
- Model
- Shocks

- Step 5
- Stress test outcomes

Huang, Zhou and Zhu  Systemic Risk of Financial Institutions  5/28
Methodology

- Step 1: estimating PDs from CDS spreads \((s_{i,t})\) (Duffie (1999) and Tarashev and Zhu (2008))

\[ PD_{i,t} = \frac{a_t s_{i,t}}{a_t LGD_{i,t} + b_t s_{i,t}} \] (1)

- PDs are risk-neutral: physical PD + risk premium
- PDs are forward-looking

- Step 2: estimating asset return correlations
  - Use equity return correlations as a proxy (Hull & White): short time horizon
  - Use the realized correlation based on high-frequency equity data
  - Use forecasted correlations

Intraday equity return

\[ r_{ij} = p((i-1)h + \frac{h_j}{M}) - p((i-1)h + \frac{h(j-1)}{M}), \quad j = 1, 2, ..., M. \]  \hspace{1cm} (2)

Define realized correlation

\[ \hat{\rho}_{(kl),j} = \frac{\sum_{j=1}^{M} r_{(k),j} r_{(l),j}}{\sqrt{\sum_{j=1}^{M} r_{(k),j}^2} \sqrt{\sum_{j=1}^{M} r_{(l),j}^2}} \]  \hspace{1cm} (3)

Property: asymptotical convergence

\[ \hat{\rho}_{(kl),j} \xrightarrow{P} \rho_{(kl),j}, \quad M \to \infty \]  \hspace{1cm} (4)
Major advantages of using realized correlations

- A much more reliable estimate of correlation in the short-term (weekly time horizon): validity of the proxy correlation
- Short-term realized correlations turn out to have significant and additional predicting power on future correlations

\[
\rho_{t, t+12} = c + k_1 \rho_{t-12, t} + \sum_{i=1}^{I} k_{2i} \cdot \rho_{t-i, t-i+1} + \eta X_t + \nu_t \tag{5}
\]
Step 3: Construct an indicator of systemic risk
- Price of insurance against distressed losses ("distress insurance premium")
- A hypothetical weighted portfolio of debt instruments of all banks, weighted by bank liabilities
- Monte Carlo simulation
  - Simulate (risk-neutral) portfolio loss distribution \( L \)
  - Indicator: \( \sum_{L} L \cdot P(L) \) for all \( L \geq L_0 \).
Alternative measures
- nth-to-default probability: IMF
- Credit VaR, expected shortfall

Why using this indicator?
- Economically meaningful: PDs are risk-neutral (alternative measures are more appropriate when physical PDs are used)
- Desirable property: it increases in both PDs and correlations
Step 4: stress testing model

- A “macro” part: VAR analysis (X includes default risk parameters and financial market variables)

\[
X_t = c_1 + \sum_{i=1}^{\rho} b_i \cdot X_{t-i} + \epsilon_t
\]  

(6)

- A “micro” part: determination of PDs of individual banks

\[
PD_{i,t} = c_{2i} + a_i \cdot PD_{i,t-1} + \gamma X_t + \mu_i
\]  

(7)

\[
\rho_{t,t+12} = c + k_1 \rho_{t-12,t} + \sum_{i=1}^{l} k_{2i} \cdot \rho_{t-i,t-i+1} + \eta X_t + \nu_t
\]  

(8)

- The model allows for two-way linkages between the banking sector and the general market
- Step 5: stress testing exercise
  - Historical or hypothetical shock scenarios in VAR system 
    \((\mu, \nu, \epsilon)\)
  - Feed into the model to affect individual PDs and forecasted correlations
  - Impact the indicator of systemic risk
Data

- 12 major financial institutions in the US
  - Bank of America, Bank of New York, Bear Stearns, Citi, Goldman Sachs, JPMorgan Chase, Lehman Brothers, Merrill Lynch, Morgan Stanley, State Street, Wachovia, Wells Fargo
- Sample period: January 2001 to May 2008
- CDS data: Markit
- Equity data: TAQ
- Macro-financial variables: fed fund rate, term spread, S&P500 return, VIX
- The time horizon of the indicator: one quarter
### Table 1: Regression: forecasting correlations

<table>
<thead>
<tr>
<th></th>
<th>Regression 1</th>
<th>Regression 2</th>
<th>Regression 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{\rho}_{t-12,t}$</td>
<td>0.52**</td>
<td>0.63**</td>
<td>0.52**</td>
</tr>
<tr>
<td>$\hat{\rho}_{t-1,t}$</td>
<td>0.18**</td>
<td></td>
<td>0.12**</td>
</tr>
<tr>
<td>FFR$_t$</td>
<td></td>
<td>-0.030</td>
<td>-0.026</td>
</tr>
<tr>
<td>TERM$_t$</td>
<td></td>
<td>-0.038</td>
<td>-0.033</td>
</tr>
<tr>
<td>SP500 ret$_t$</td>
<td>-0.0046**</td>
<td>-0.0036**</td>
<td></td>
</tr>
<tr>
<td>VIX$_t$</td>
<td>0.0015</td>
<td>0.0012</td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>0.19**</td>
<td>0.36**</td>
<td>0.33**</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.54</td>
<td>0.55</td>
<td>0.56</td>
</tr>
</tbody>
</table>

- PDs, correlations transformed $[-\infty, +\infty]$  
- $X_t$ includes fed fund rate, term spread, S&P500 return, VIX
Construct the indicator of systemic risk: price of insurance against distressed losses ($\geq 15\%$ of total liabilities)

- Tarashev and Zhu (2008): Monte Carlo simulation
- Heterogeneous PD
- Heterogeneous weight: size of bank liability
- Random LGD: symmetric triangular distribution $[0.1, 1]$
- LGD independent of PD
## Table 2: What determines the level of the indicator?

<table>
<thead>
<tr>
<th></th>
<th>Price of insurance</th>
<th>$n = 1$</th>
<th>$n = 2$</th>
<th>$n \geq 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PD_t$</td>
<td>$0.2077^{**}$</td>
<td>$1.0994^{**}$</td>
<td>$0.3085^{**}$</td>
<td>$1.6952^{**}$</td>
</tr>
<tr>
<td>$\bar{r}_t$</td>
<td>$0.0029^{**}$</td>
<td>$-0.0204^{**}$</td>
<td>$0.0008^{**}$</td>
<td>$-0.0157^{**}$</td>
</tr>
<tr>
<td>constant</td>
<td>$-0.0021^{**}$</td>
<td>$0.0145^{**}$</td>
<td>$-0.0005^{**}$</td>
<td>$0.0110^{**}$</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>$0.97$</td>
<td>$0.96$</td>
<td>$0.99$</td>
<td>$0.99$</td>
</tr>
</tbody>
</table>
“Macro” part of the model: VAR analysis

- Serial-correlated
- Financial factors affect PD and correlations
- The reverse impact is very weak

<table>
<thead>
<tr>
<th></th>
<th>$\hat{PD}$</th>
<th>$\hat{PW}$</th>
<th>FFR</th>
<th>Term</th>
<th>SP500 ret</th>
<th>VIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{PD}(-1)$</td>
<td>0.98**</td>
<td>0.055**</td>
<td>-0.037*</td>
<td>0.033</td>
<td>-0.34</td>
<td>0.66*</td>
</tr>
<tr>
<td>$\hat{PW}(-1)$</td>
<td>0.083**</td>
<td>0.49**</td>
<td>-0.031</td>
<td>0.026</td>
<td>0.11</td>
<td>-0.22</td>
</tr>
<tr>
<td>FFR(-1)</td>
<td>0.010</td>
<td>-0.054**</td>
<td>0.94**</td>
<td>-0.012</td>
<td>-0.38</td>
<td>0.084</td>
</tr>
<tr>
<td>Term(-1)</td>
<td>0.012</td>
<td>-0.071**</td>
<td>-0.064**</td>
<td>0.97**</td>
<td>-0.47</td>
<td>0.097</td>
</tr>
<tr>
<td>SP500 ret(-1)</td>
<td>-0.0025**</td>
<td>-0.0029*</td>
<td>-0.0063</td>
<td>-0.0047</td>
<td>0.73**</td>
<td>0.0048</td>
</tr>
<tr>
<td>VIX(-1)</td>
<td>-0.00084</td>
<td>0.0012</td>
<td>-0.0011</td>
<td>0.0024</td>
<td>0.030</td>
<td>0.92**</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.18</td>
<td>0.85**</td>
<td>0.14</td>
<td>0.20</td>
<td>-0.44</td>
<td>4.70</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.97</td>
<td>0.43</td>
<td>0.99</td>
<td>0.99</td>
<td>0.53</td>
<td>0.91</td>
</tr>
</tbody>
</table>
- Serial-correlated
- Positive effect of average PD
- Mixed effects of macro-financial factors

<table>
<thead>
<tr>
<th>Factors</th>
<th>Bank 1</th>
<th>Bank 2</th>
<th>Bank 3</th>
<th>Bank 4</th>
<th>Bank 5</th>
<th>Bank 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PD_{j-1}$</td>
<td>0.70**</td>
<td>0.63**</td>
<td>0.68**</td>
<td>0.51**</td>
<td>0.38**</td>
<td>0.71**</td>
</tr>
<tr>
<td>$PD_j$</td>
<td>0.25**</td>
<td>0.39**</td>
<td>0.36**</td>
<td>0.63**</td>
<td>0.50**</td>
<td>0.23**</td>
</tr>
<tr>
<td>$\rho_W$</td>
<td>-0.04</td>
<td>-0.004</td>
<td>0.15**</td>
<td>0.01</td>
<td>0.11**</td>
<td>0.13**</td>
</tr>
<tr>
<td>FFR</td>
<td>-0.02</td>
<td>0.03**</td>
<td>0.10**</td>
<td>-0.03**</td>
<td>0.003</td>
<td>-0.03**</td>
</tr>
<tr>
<td>TERM</td>
<td>-0.02</td>
<td>0.04</td>
<td>0.08</td>
<td>-0.04</td>
<td>-0.01</td>
<td>-0.02*</td>
</tr>
<tr>
<td>SP500 ret</td>
<td>0.0004</td>
<td>-0.005**</td>
<td>-0.006**</td>
<td>-0.006**</td>
<td>0.001</td>
<td>-0.005**</td>
</tr>
<tr>
<td>VIX</td>
<td>0.0002</td>
<td>-0.003**</td>
<td>-0.004**</td>
<td>-0.004**</td>
<td>0.002**</td>
<td>0.001</td>
</tr>
<tr>
<td>constant</td>
<td>-0.27</td>
<td>-0.09</td>
<td>-0.17</td>
<td>0.78**</td>
<td>-0.64**</td>
<td>-0.31**</td>
</tr>
</tbody>
</table>

| Adjusted $R^2$ | 0.99  | 0.99  | 0.99  | 0.91  | 0.98  | 0.97  |

<table>
<thead>
<tr>
<th>Factors</th>
<th>Bank 7</th>
<th>Bank 8</th>
<th>Bank 9</th>
<th>Bank 10</th>
<th>Bank 11</th>
<th>Bank 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PD_{j-1}$</td>
<td>0.45**</td>
<td>0.57**</td>
<td>0.38**</td>
<td>0.81**</td>
<td>0.79**</td>
<td>0.68**</td>
</tr>
<tr>
<td>$PD_j$</td>
<td>0.63**</td>
<td>0.50**</td>
<td>0.61**</td>
<td>0.10**</td>
<td>0.29**</td>
<td>0.35**</td>
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<tr>
<td>$\rho_W$</td>
<td>0.10**</td>
<td>0.15**</td>
<td>0.17**</td>
<td>0.02</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>FFR</td>
<td>0.08**</td>
<td>-0.02</td>
<td>-0.03**</td>
<td>-0.003</td>
<td>0.02**</td>
<td>0.0000</td>
</tr>
<tr>
<td>TERM</td>
<td>0.05</td>
<td>-0.03</td>
<td>-0.06</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>SP500 ret</td>
<td>-0.003</td>
<td>-0.004**</td>
<td>-0.001</td>
<td>0.002</td>
<td>-0.003**</td>
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<td>-0.004**</td>
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<td>0.20**</td>
<td>-0.57**</td>
<td>0.33**</td>
<td>0.006</td>
</tr>
</tbody>
</table>

| Adjusted $R^2$ | 0.99  | 0.99  | 0.97  | 0.91  | 0.98  | 0.97  |
Stress testing exercise

- Design stress-testing scenarios
  - Hypothetical shocks
  - Shocks fed into default risk parameters and affect the systemic risk indicator
- Exercise 1: statistical shocks
  - Use bootstrapping techniques, simulate $(\mu, \nu, \epsilon)$ $N$ times $\rightarrow$ distribution of future systemic risk indicators
Huang, Zhou and Zhu  Systemic Risk of Financial Institutions  22/26
Exercise 2: historical scenarios — use shocks in macro-financial variables during major historical events

![Stress testing: historical scenarios](image-url)
The bootstrapping technique can also be used as a forecasting tool

- The same exercise at each period in the sample
- Plot the mean and distribution of 12-week-ahead systemic risk indicators
- Results: located within the 95% confidence interval band most of the sample period, except the 2007.07-09 and 2008.03 (3.5% of sample weeks) → validation of the model used in the analysis
Price of insurance against distresses (>=15% losses)

- In-sample
- Predicted mean
- Predicted 95% interval
The methodology intends to be general
- Only a first step toward improving our understanding of financial stability issues
- Other dimensions to measure financial stability
- Policy issues: how to prevent / deal with financial instability, interaction with monetary policies, etc