System-wide stress simulation

2019 EBA Policy Research Workshop
27 November 2019

Views expressed are those of the authors and do not necessarily reflect those of the Bank of England or its policy committees.

David Aikman, Pavel Chichkanov, Graeme Douglas, Yordan Georgiev, James Howat, Benjamin King
Motivation

• Non-bank, ‘market-based’, finance has grown rapidly, changing the structure of the financial system
• It’s not yet clear how this new structure will affect the system’s response to stress
• And historical data only tell us how stress played out in the past

➢ Develop models to try to understand how stress could propagate across the whole financial system
Goals of system-wide analysis

- Account for changes in financial system structure
- Incorporate banks and non-banks
- Simulate stress events before they occur
- Consider feedback and amplification from interaction between sectors
- Look for tipping points and non-linear responses
- Test regulations and other changes in constraints
Our model

*Equilibrium pricing, representative agent model of short term stress in the UK financial system*

- *Equilibrium prices* of traded assets and quantities of funding are determined within the model
- *Key financial sectors* are aggregated and represented as different agents
- Model is designed to simulate *short term market stress* events
- We focus on *UK financial assets and sectors*
Model structure
Model structure
Model structure

Secondary Asset Markets: Government bonds, corporate bonds and equities

- Dealer Bank
- Comm. Bank
- Inv. Fund
- Hedge Fund
- Pension Fund
- Insurer

MMF
Model structure

Secondary Asset Markets: Government bonds, corporate bonds and equities

- Dealer Bank
- Comm. Bank
- Inv. Fund
- Hedge Fund
- Pension Fund
- Insurer

Securities financing markets: Repo

MMF
Model structure

Secondary Asset Markets: Government bonds, corporate bonds and equities

- Dealer Bank
- Comm. Bank
- Inv. Fund
- Hedge Fund
- Pension Fund
- Insurer

Securities financing markets: Repo

- MMF

Derivatives markets: IRS
Model structure

Secondary Asset Markets: Government bonds, corporate bonds and equities

- Dealer Bank
- Comm. Bank
- Inv. Fund
- Hedge Fund
- Pension Fund
- Insurer

Securities financing markets: Repo

Derivatives markets: IRS

MMF
Agents’ objectives and constraints
Agents’ objectives and constraints

<table>
<thead>
<tr>
<th>Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pension fund</td>
</tr>
<tr>
<td>Insurer</td>
</tr>
<tr>
<td>Investment fund</td>
</tr>
<tr>
<td>Hedge fund</td>
</tr>
<tr>
<td>Dealer</td>
</tr>
<tr>
<td>Commercial Bank</td>
</tr>
<tr>
<td>MMF</td>
</tr>
</tbody>
</table>
## Agents’ objectives and constraints

<table>
<thead>
<tr>
<th>Agent</th>
<th>Objectives / role in the model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pension fund</td>
<td>Choose asset allocation to maximise expected risk-adjusted returns</td>
</tr>
<tr>
<td>Insurer</td>
<td></td>
</tr>
<tr>
<td>Investment fund</td>
<td></td>
</tr>
<tr>
<td>Hedge fund</td>
<td>Arbitrageur</td>
</tr>
<tr>
<td>Dealer</td>
<td>Intermediate Repo and IRS markets</td>
</tr>
<tr>
<td>Commercial Bank</td>
<td>Funding provider into Repo market</td>
</tr>
<tr>
<td>MMF</td>
<td></td>
</tr>
</tbody>
</table>
## Agents’ objectives and constraints

<table>
<thead>
<tr>
<th>Agent</th>
<th>Objectives / role in the model</th>
<th>Leverage / solvency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pension fund</td>
<td>Choose asset allocation to maximise expected risk-adjusted returns</td>
<td>✓</td>
</tr>
<tr>
<td>Insurer</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Investment fund</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hedge fund</td>
<td>Arbitrageur</td>
<td>✓</td>
</tr>
<tr>
<td>Dealer</td>
<td>Intermediate Repo and IRS markets</td>
<td>✓</td>
</tr>
<tr>
<td>Commercial Bank</td>
<td>Funding provider into Repo market</td>
<td>✓</td>
</tr>
<tr>
<td>MMF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Agents’ objectives and constraints

<table>
<thead>
<tr>
<th>Agent</th>
<th>Objectives / role in the model</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pension fund</td>
<td>Choose asset allocation to maximise expected risk-adjusted returns</td>
<td>✔</td>
</tr>
<tr>
<td>Insurer</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Investment fund</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>Hedge fund</td>
<td>Arbitrageur</td>
<td>✔</td>
</tr>
<tr>
<td>Dealer</td>
<td>Intermediate Repo and IRS markets</td>
<td>✔</td>
</tr>
<tr>
<td>Commercial Bank</td>
<td>Funding provider into Repo market</td>
<td>✔</td>
</tr>
<tr>
<td>MMF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Agents’ objectives and constraints

<table>
<thead>
<tr>
<th>Agent</th>
<th>Objectives / role in the model</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pension fund</td>
<td>Choose asset allocation to maximise expected risk-adjusted returns</td>
<td></td>
</tr>
<tr>
<td>Insurer</td>
<td></td>
<td>Leverage / solvency: ✔</td>
</tr>
<tr>
<td>Investment fund</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hedge fund</td>
<td>Arbitrageur</td>
<td></td>
</tr>
<tr>
<td>Dealer</td>
<td>Intermediate Repo and IRS markets</td>
<td></td>
</tr>
<tr>
<td>Commercial Bank</td>
<td>Funding provider into Repo market</td>
<td></td>
</tr>
<tr>
<td>MMF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Model process
Model process

Initial equilibrium
Model process

Exogenous shock

Initial equilibrium
Model process

Exogenous shock

Agents react to shock

Initial equilibrium
Model process

Exogenous shock

Initial equilibrium

Agents react to shock

Compute D&S across funding and asset markets
Model process

Exogenous shock

Agents react to shock

Compute D&S across funding and asset markets

Iterate prices until all markets clear

Initial equilibrium
Exogenous shock

Agents react to shock

Compute D&S across funding and asset markets

Iterate prices until all markets clear

New equilibrium

Initial equilibrium
Model process

Exogenous shock

Agents react to shock

Compute D&S across funding and asset markets

Iterate prices until all markets clear

New equilibrium

Initial equilibrium

1 month
Model process

Exogenous shock

Agents react to shock

Compute D&S across funding and asset markets

Iterate prices until all markets clear

New equilibrium

Initial equilibrium

1 month

Four categories of exogenous shock:

1) Determinants of traded asset prices
   e.g. expected credit loss

2) Price of non-traded assets
   e.g. commercial bank’s banking book

3) Household behaviours
   e.g. investment fund redemptions

4) Constraints
   e.g. insurer solvency ratio
Results: layered stress scenario

• We illustrate some properties of the model through a layered stress scenario:

<table>
<thead>
<tr>
<th>Layer 1</th>
<th>Shock to ‘corporate outlook’: lower expected returns on corporate bonds and equities.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 2</td>
<td>Corporate shock</td>
</tr>
<tr>
<td></td>
<td>+ binding dealer leverage ratio</td>
</tr>
<tr>
<td>Layer 3</td>
<td>Corporate shock</td>
</tr>
<tr>
<td></td>
<td>+ binding dealer leverage ratio</td>
</tr>
<tr>
<td></td>
<td>+ binding commercial bank risk-based capital ratio</td>
</tr>
</tbody>
</table>
Results: layered stress scenario (1)

Investors reassess asset allocations

Selling pressure from **hedge fund** & **investment fund** partly offset by the countercyclical behaviour of **insurer** & **pension fund**.
Dealer deleverages to meet constraint:
- Sells traded assets
- Reduces funding to hedge fund
Results: layered stress scenario (3)

Commercial bank deleverages / de-risks:
- Focuses sales in equities
- Further funding squeeze for other agents

Constraints tighten as asset prices fall:
- Reducing funding provision
- Redemptions from funds
- Forced sales
Results: effect of alleviating constraints

• We can use the model to look at the impact of alleviating specific constraints in a stress scenario
• One way to measure the benefits is to look at how much value destruction is avoided
• In the final layer of our stress scenario UK traded assets fall in value by £221bn
• How could a social planner most effectively reduce this number?
Results: effect of alleviating constraints

Absolute £bn impact on value of traded securities
Results: effect of alleviating constraints

Absolute £bn impact on value of traded securities

- Inv. fund liquidity
- Comm. bank capital
- Hedge fund liquidity
- Dealer capital
Results: effect of alleviating constraints

Absolute £bn impact on value of traded securities

<table>
<thead>
<tr>
<th>Size of improvement (£bn)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. fund liquidity</td>
<td>18</td>
<td>34</td>
<td>56</td>
<td>75</td>
<td>92</td>
<td>105</td>
<td>117</td>
<td>127</td>
<td>156</td>
<td>175</td>
</tr>
<tr>
<td>Comm. bank capital</td>
<td>0</td>
<td>0</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>Hedge fund liquidity</td>
<td>18</td>
<td>35</td>
<td>48</td>
<td>60</td>
<td>69</td>
<td>78</td>
<td>85</td>
<td>92</td>
<td>98</td>
<td>104</td>
</tr>
<tr>
<td>Dealer capital</td>
<td>13</td>
<td>69</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>75</td>
<td>75</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
</tbody>
</table>
## Results: effect of alleviating constraints

### Absolute £bn impact on value of traded securities

<table>
<thead>
<tr>
<th>Size of improvement (£bn)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. fund liquidity</td>
<td>18</td>
<td>34</td>
<td>56</td>
<td>75</td>
<td>92</td>
<td>105</td>
<td>117</td>
<td>127</td>
<td>156</td>
<td>175</td>
</tr>
<tr>
<td>Comm. bank capital</td>
<td>0</td>
<td>0</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>Hedge fund liquidity</td>
<td>18</td>
<td>35</td>
<td>48</td>
<td>60</td>
<td>69</td>
<td>78</td>
<td>85</td>
<td>92</td>
<td>98</td>
<td>104</td>
</tr>
<tr>
<td>Dealer capital</td>
<td>13</td>
<td>69</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>75</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
</tbody>
</table>

### ‘Bang-for-buck’ ratios

<table>
<thead>
<tr>
<th>Size of improvement (£bn)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inv. fund liquidity</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Comm. bank capital</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Hedge fund liquidity</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Dealer capital</td>
<td>3</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Future work

- Take account of non-UK sectors
- Application to policy-relevant questions
- Dynamic model
System-wide stress simulation

https://www.bankofengland.co.uk/working-paper/2019/system-wide-stress-simulation

benjamin.king@bankofengland.co.uk