Taking regulation seriously: Fire sales under solvency and liquidity constraints

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Disclaimer

The views expressed are those of the authors only and do not necessarily reflect those of the Bank of England or Norges Bank.
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2 Model

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   Asset shock: variants of 2017 stress test
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Motivation

“During the early ‘liquidity phase’ of the financial crisis that began in 2007, many credit institutions, despite maintaining adequate capital levels, experienced significant difficulties because they had failed to manage their liquidity risk prudently... (Such) credit institutions were then forced to liquidate assets in a fire-sale which created a self-reinforcing downward price spiral and lack of market confidence triggering a solvency crisis."

(European Commission, 2015)
Motivation

- Liquidity issues during the crisis
- Multiple regulatory constraints
- Macroprudential stress tests
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- Liquidity issues during the crisis
- Multiple regulatory constraints
- Macroprudential stress tests
- Objectives:
  - Build a quantitative model of fire sales to assess the interaction between liquidity and solvency constraints that banks simultaneously face.
  - Which types of financial shocks and regulatory requirements combine to produce fire sales?
  - How do banks optimally liquidate their portfolios when they are forced to do so?
Literature review

- **Fire-sale models:**
  [Greenwood et al., 2015], [Cont and Schaanning, 2017],
  [Duarte and Eisenbach, 2013]

- **Constraints and optimal deleveraging:**
  [Cecchetti and Kashyap, 2016],
  [Braouezec and Wagalath, 2016]

- **Liquidity:**
  [Hellwig, 2009], [Gorton and Metrick, 2012], [Pierret, 2015],
  [Acharya and Merrouche, 2012]

- **Macro-stress tests:**
  [Dees and Henry, 2017], [Bank of England, 2017],
  [Bardoscia et al., 2017], [Fique, 2017],
  [Puhr and Schmitz, 2014], [Calimani et al., 2017]
Model overview

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Bank balance sheets

- **Marketable securities** $M_{i,k}$, $k = 1 \ldots 310$ and $i = 1 \ldots 7$ 
  Bonds and equity holdings that are available for sale and suffer a price impact.

- **Other assets** $O_{i,k}$, $k = 1, 2$: loans, intangible goods, and off-balance sheet items, which are **not** available for deleveraging.

- **Cash** or cash-like assets $C_{i,k}$, $k = 1, 2$. 

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- **Cash** or cash-like assets $C_{i,k}$, $k = 1, 2$.

- **Liabilities** $L_{i,k}$, $k = 1...12$. These include classic retail customer deposits, institutional deposits, short-term whole-sale funding, and issued debt.

- **Capital** $E_i$. 
Regulatory constraints

- Risk-weighted Capital Ratio:

\[ CAP^i(A, E) := \frac{E^i}{\rho^\top A^i} \geq REG_{CAP}. \]
Regulatory constraints

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CAP^i(A, E) := \frac{E_i}{\rho^\top A_i} \geq REG_{CAP}.
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LEV^i(A, C, E) := \frac{E_i}{1^\top A_i + 1^\top C_i} \geq REG_{LEV},
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Regulatory constraints

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- **Liquidity Coverage Ratio:**

  \[ \text{LCR}^i(A, C, L) := \frac{\lambda^\top M^i + 1^\top C^i}{\omega^\top_{\text{out}} L^i - \omega^\top_{\text{in}} A^i} \geq \text{REG}_{\text{LCR}}. \]
Shocks

We consider three type of shocks:

1. Asset shock ($\epsilon_A$): $A_{0, k}^i = A_{i, k}^i (1 - \epsilon_{A}^k)$. (k = 1...314)
2. Funding shock ($\epsilon_L$): $L_{0, k}^i = L_{i, k}^i (1 - \epsilon_{L}^k)$. (k = 1..12)
3. Combined asset and funding shock.
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3. Combined asset and funding shock.

\[
E_{0}^{i} = (E^{i} - \epsilon_{A}^{T} A^{i})^+. \\
C_{0}^{i} = (C^{i} - \epsilon_{L}^{T} L^{i})^+. 
\]
Bank deleveraging

Figure: Shrinking a bank’s balance sheet
Fire-sale losses

Price evolution under fire sales

\[ P_{t+1}^k = P_t^k \left( 1 - \delta_k^{-1} \sum_{i=1}^{N} S_{t}^{i,k} \right), \]
Fire-sale losses

Price evolution under fire sales

\[ P_{t+1}^k = P_t^k \left( 1 - \delta_k^{-1} \sum_{i=1}^{N} S_{i,k}^t \right), \]

Two forms of loss:

- Mark-to-market losses

\[ \sum_{k=1}^{K} \underbrace{(M_{i,k}^t - S_{i,k}^t)}_{\text{Remaining holdings}} \times \underbrace{\delta_k^{-1} \sum_{i=1}^{N} S_{i,k}^t}_{\text{Price impact (above)}}. \]
Fire-sale losses

Price evolution under fire sales

\[ P_{t+1}^k = P_t^k \left( 1 - \delta_k^{-1} \sum_{i=1}^{N} S_t^{i,k} \right), \]

Two forms of loss:

• Mark-to-market losses

\[ \sum_{k=1}^{K} \left( M_t^{i,k} - S_t^{i,k} \right) \times \delta_k^{-1} \sum_{i=1}^{N} S_t^{i,k} \]

Remaining holdings

Price impact (above)

• Implementation shortfall

\[ \frac{1}{2} \sum_{k=1}^{K} S_t^{i,k} \sum_{j=1}^{N} \delta_k^{-1} S_t^{j,k}. \]
Bank optimisation problem: Minimize liquidation losses

\[
\min_{S^i, R^i} \left( M^i - \frac{1}{2} S^i \right) \top \left( \frac{S^i}{\delta} \right),
\]
Bank optimisation problem: Minimize liquidation losses

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\min_{S^i, R^i} \left( M^i - \frac{1}{2} S^i \right) \top \left( \frac{S^i}{\delta} \right),
\]

subject to the constraints

\[
CAP^i(A, E; S) \geq REG_{CAP}
\]
\[
LEV^i(A, C, E; S, R) \geq REG_{LEV}
\]
\[
LCR^i(A, C, L; S, R) \geq REG_{LCR}
\]
\[
CASH^i(A, C; S, R) \geq 0.
\]
Bank optimisation problem: Minimize liquidation losses

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\]

subject to the constraints

\[
\begin{align*}
CAP^i(A, E; S) & \geq REG_{CAP} \\
LEV^i(A, C, E; S, R) & \geq REG_{LEV} \\
LCR^i(A, C, L; S, R) & \geq REG_{LCR} \\
CASH^i(A, C; S, R) & \geq 0.
\end{align*}
\]

Note: banks only internalise the effects of their own sales, and not the spillover effects of sales by other banks.
Calibration

- **Balance sheet data** taken from regulatory returns (COREP and FINREP) and Bank of England stress test data.
- **Regulatory weights** based on Basel guidance, European legislation and firms’ annual statements.
- **Regulatory ratios & constraints** taken from regulatory returns.
- **Market depths** based on national authorities’ published statistics on average trading volumes and S&P price indices for government bonds, and BoAML prices and outstanding volumes for corporate bonds.
Stress scenarios

We consider three scenarios:

1. **Asset shock** ($\epsilon_A$): Bank of England 2017 Stress scenario and shocks of increased intensity.
2. **Funding shock** ($\epsilon_L$): Depositor run (20%, 40% and 60% deposit outflows).
Asset shock

- Risk-weighted capital requirements tend to be more tightly binding than leverage constraints.
- Banks constrained by risk-weighted capital constraints sell on average more illiquid assets, and in larger amounts, than when constrained by the leverage ratio.
- The size of unexpected losses, which are not internalized by banks, can be as important as the size of expected losses.
Asset sales: leverage ratio only

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Asset shock: variants of 2017 stress test

Asset sales: capital ratio only

![Graph showing market depth (£tn) for different scenarios: 2017 BoE, 2017 BoEx 1.1, and 2017 BoEx 1.25. The graph compares the mean market depth of initial holdings under Leverage only, All constraints, and Risk-weighted only constraints.]
Asset shock: variants of 2017 stress test

Asset sales: all constraints

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Asset shock: variants of 2017 stress test

**Fire-sale losses**

![Graph showing fire-sale losses and initial shock (multiples of 2017 stress test)]

- 2017BoE
- 2017BoEx1.1
- 2017BoEx1.25

- Initial shock (multiples of 2017 stress test)
- Fire-sale losses (£bn)
- All constraints
- Risk-weighted only
- Leverage only

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Fire-sale losses: decomposition

![Graph showing fire-sale losses decomposition](image)

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Funding shock: deposit outflows

- Banks prefer to use cash and sell highly liquid assets first to minimise losses.
- However, as the shock becomes larger, banks are forced to sell less liquid assets.
- When banks defend their LCRs to keep them above 100%, they need to sell less liquid assets in larger amounts.
- Hence fire-sale losses are significantly larger relative to the case when banks do not defend their LCRs.
Asset sales

![Graph showing the relationship between initial deposit outflows and market depth for different LCR strategies. The graph includes a line indicating the mean market depth of initial holdings.]

- Don’t defend LCR
- Defend LCR

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Funding shock

Fire-sale losses

![Graph showing fire-sale losses vs initial deposit outflows. The graph includes points labeled 'Defend LCR' and 'Don't defend LCR'.]
Fire-sale losses: decomposition

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Asset and Funding shocks

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Conclusions

• Both risk-weighted capital and liquidity constraints can become binding and generate significant fire sales losses, by incentivising sales of larger amounts of less liquid assets.

• Models that only account for a leverage constraint might then under-estimate fire sale losses.
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- Both risk-weighted capital and liquidity constraints can become binding and generate significant fire sales losses, by incentivising sales of larger amounts of less liquid assets.
- Models that only account for a leverage constraint might then under-estimate fire sale losses.
- Unexpected fire sales losses, e.g. losses due to deleveraging by other banks, can be larger than banks’ expected losses from their own sales.
- Relaxing banks’ regulatory constraints during stress may be a possible mitigating action to avoid fire sales. For example, allowing banks to draw down their LCR.
Next steps

- Run more rounds of fire sales.
- Explore solvency-liquidity nexus by running asset and funding shocks (both at the same time and sequentially).
- Sensitivity analysis: market depths, price function, targeting vs threshold.
- Constraints: UK leverage framework, LCR with limits to reserves usability.
Thank you


[SATELLITE MODELS, page 13.]

[Federal Reserve Bank of New York Staff Report, 645.]

[Bank of Canada.]


