Banks’ Risk Exposures

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Matching models to data:

- Consumption: easy
  - model: specify set of goods
    ("all nondurables & services", "housing" vs "other")
  - data: go to NIPA & download aggregated price and quantity measures
    → with many agents: get allocations from expenditure data

- Credit market positions: messy
  - model: specify set of assets
  - data: raw accounting measures on lots of fixed income instruments ("bonds")
    → how to aggregate? how to compare across agents?

- When modeling banks, want to
  - aggregate positions: risk in derivatives vs other business
  - compare institutions: systemic risk?

- This paper:
  - portfolio approach to aggregate & compare positions
  - application to large US banks
Background: what banks do

- historically, banks provide an alternative to markets
  - issue deposits, make loans
- modern banks participate more in markets
  - hold more tradable securities (e.g., MBS)
  - trade in derivatives
  - make markets in bonds, derivatives
## Modern Bank Balance Sheet, JP Morgan Chase 2011

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash 6%</td>
<td>Deposits 50%</td>
</tr>
<tr>
<td>Securities 16%</td>
<td>Other borrowed money 15%</td>
</tr>
<tr>
<td>Trading assets 20%</td>
<td>Trading liabilities 6%</td>
</tr>
<tr>
<td>Fed funds + Repos 17%</td>
<td>Fed funds + Repos 10%</td>
</tr>
<tr>
<td>Loans 31%</td>
<td>Other liabilities 11%</td>
</tr>
<tr>
<td>Other assets 10%</td>
<td>Equity 8%</td>
</tr>
</tbody>
</table>

Total assets/liabilities: $2.3 Trillion  
Derivatives: $60 Trillion Notionals of Swaps
## Schedule HC-B—Securities

### Dollar Amounts in Thousands

<table>
<thead>
<tr>
<th>Description</th>
<th>Held-to-Maturity (Column A)</th>
<th>Available-for-Sale (Column D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Amortized Cost)</td>
<td>BHCK Bil Mil Thou</td>
<td>BHCK Bil Mil Thou</td>
</tr>
<tr>
<td>(Fair Value)</td>
<td>BHCK Bil Mil Thou</td>
<td>BHCK Bil Mil Thou</td>
</tr>
<tr>
<td>1. U.S. Treasury securities ..................................................................</td>
<td>0211 0213</td>
<td>1286 1287</td>
</tr>
<tr>
<td>2. U.S. government agency obligations (exclude mortgage-backed securities):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Issued by U.S. government agencies1 ...............................................</td>
<td>1289 1290</td>
<td>1291 1293</td>
</tr>
<tr>
<td>b. Issued by U.S. government-sponsored agencies2 ..................................</td>
<td>1294 1295</td>
<td>1297 1298</td>
</tr>
<tr>
<td>3. Securities issued by states and political subdivisions in the U.S. ....</td>
<td>8496 8497</td>
<td>8498 8499</td>
</tr>
<tr>
<td>4. Mortgage-backed securities (MBS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Residential pass-through securities:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Guaranteed by GNMA</td>
<td>G300 G301 G302 G303</td>
<td></td>
</tr>
<tr>
<td>(2) Issued by FNMA and FHLMC ................................................................</td>
<td>G304 G305 G306 G307</td>
<td></td>
</tr>
<tr>
<td>(3) Other pass-through securities</td>
<td>G308 G309 G310 G311</td>
<td></td>
</tr>
<tr>
<td>b. Other residential mortgage-backed securities (include CMOs, REMICs, and stripped MBS):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Issued or guaranteed by FNMA, FHLMC, or GNMA</td>
<td>G312 G313 G314 G315</td>
<td></td>
</tr>
<tr>
<td>(2) Collateralized by MBS issued or guaranteed by FNMA, FHLMC, or GNMA</td>
<td>G316 G317 G318 G319</td>
<td></td>
</tr>
<tr>
<td>(3) All other residential mortgage-backed securities</td>
<td>G320 G321 G322 G323</td>
<td></td>
</tr>
<tr>
<td>c. Commercial MBS:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Commercial pass-through securities</td>
<td>G324 G325 G326 G327</td>
<td></td>
</tr>
<tr>
<td>(2) Other commercial MBS</td>
<td>G328 G329 G330 G331</td>
<td></td>
</tr>
<tr>
<td>5. Asset-backed securities and structured financial products:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Asset-backed Securities (ABS)</td>
<td>C026 C988 C989 C027</td>
<td></td>
</tr>
<tr>
<td>b. Structured financial products:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Cash</td>
<td>G336 G337 G338 G339</td>
<td></td>
</tr>
<tr>
<td>(2) Synthetic</td>
<td>G340 G341 G342 G343</td>
<td></td>
</tr>
<tr>
<td>(3) Hybrid</td>
<td>G344 G345 G346 G347</td>
<td></td>
</tr>
<tr>
<td>6. Other debt securities:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Other domestic debt securities</td>
<td>1737 1738 1739 1741</td>
<td></td>
</tr>
<tr>
<td>b. Foreign debt securities</td>
<td>1742 1743 1744 1746</td>
<td></td>
</tr>
<tr>
<td>7. Investments in mutual funds and other equity securities with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>readily determinable fair values</td>
<td>A510 A511</td>
<td></td>
</tr>
<tr>
<td>8. Total (sum of 1 through 7) (total of column A must equal)</td>
<td>bhtc</td>
<td></td>
</tr>
<tr>
<td>Schedule HC, item 2.a (total of column D must equal)</td>
<td>1754 1771 1772 1773</td>
<td></td>
</tr>
</tbody>
</table>

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1. Includes Small Business Administration "Guaranteed Loan Pool Certificates," U.S. Maritime Administration obligations, and Export–Import Bank participation certificates.
2. Includes obligations (other than mortgage-backed securities) issued by the Farm Credit System, the Federal Home Loan Bank System, the Federal Home Loan Mortgage Corporation, the Federal National Mortgage Association, the Financing Corporation, Resolution Funding Corporation, the Student Loan Marketing Association, and the Tennessee Valley Authority.
Inferring risk from accounting data

- many securities: how to compress & compare?
- consider model with aggregate risk & many assets
  - any portfolio = collection of contingent claims on aggregate shocks
  - few aggregate states $\Rightarrow$ simple portfolios
- can we think about a bank the same way?
  - statistical evidence:
    - cross section of bond values driven by few shocks
  - anecdotal evidence: problems from bets on aggregate events
    - house prices (Goldman – MBS)
    - credit risk indices (AIG, London Whale)
    - sovereign default (German & French banks — Greek bonds)
- “few shocks” works like “few states” $\Rightarrow$ simple portfolios
Portfolio approach to measuring risk exposure

- represent credit market positions as simple portfolios
  - readily comparable across positions, banks
  - conditional distribution of bank’s portfolio = risk measure
  - enables measuring the risk exposure in derivatives

- application to large US banks
  - interest rate derivatives often do not hedge other bank business
  - similar exposures to aggregate risk
Related literature

- Bank regulation (Basel II):
  - separately considers credit & market risk
  - credit risk: compute default probabilities using credit ratings or internal statistical models
  - capital requirements for different positions
  - look at positions one by one

- Measures of exposure
  - regress stock returns on risk factor, e.g. interest rates
    Flannery-James 84, Venkatachalam 96, Hirtle 97,...
  - stress tests: Brunnermeier-Gorton-Krishnamurthy 12, Duffie 12

- Measures of institutional risk
  - measures of tail risk, VaR: Acharya-Pederson-Philippon-Richardson 10,
    Kelly-Lustig-van Nieuwerburgh 11

- Bank position data
  - derivatives: Gorton-Rosen 95, Stulz et al. 08, Hirtle 08
  - crisis: Adrian & Shin 08, Shin 11, He & Krishnamurthy 11
Outline

1. Bond values described by statistical model with few shocks
2. Bond/debt positions = simple portfolios in a few bonds
3. From regulatory data to simple portfolios: loans, securities, deposits
4. Swaps – definitions and data
5. From regulatory data to simple portfolios: swaps
1. Bond values described by stat. model with few shocks

- low dimensional factor models for cross section of bonds
  \[ \text{bond value } = p(f_t, t) \]
  \[ f_t = \phi f_{t-1} + \sigma(f_t) \varepsilon_t \quad \varepsilon_t \sim N(0, \# \text{ factors}) \]

- bond pricing models
  - w/o credit risk: interest rate is function of factors
  - with credit risk: default prob, loss in default are functions of factors

- here: quarterly model with one factor
  - estimated on cross section of Treasury, LIBOR & swap rates
  - fitting errors low (\(<25 \text{ bp}\)) for maturities up to 15 years
Riskless (solid) zero coupon bond yields

Piazzesi ( )

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Riskless (solid) & risky (dotted) zero coupon bond yields

[Graph showing yield curves for various durations and LIBOR rates over the years 1995 to 2010]
Riskless (solid) & risky (dotted) zero coupon bond yields
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2. Bond/debt positions = simple portfolios in a few bonds

- Change in bond value $p_t = p(f_t, t)$

  $p_{t+1} - p_t \approx p_t \left( \mu_t + \sigma_t \epsilon_{t+1} \right)$

  - $\mu_t$ = expected return
  - $\sigma_t$ = volatility

- cash

  $\mu_t = i_t, \quad \sigma_t = 0$

- represent other bond $\tilde{p}_t = \tilde{p}(f_t, t)$ as simple portfolio

  $\tilde{p}_t (\tilde{\mu}_t + \tilde{\sigma}_t \epsilon_{t+1}) = \omega_t \ p_t \ (\mu_t + \sigma_t \epsilon_{t+1}) + \text{cash}_t \ i_t$

- say, $p$ is value of 5-year riskless bond
- simple portfolios are holdings $\omega_t$ of 5-year riskless bonds & cash
- portfolio weight on 5-year bond increasing in maturity, risk of $\tilde{p}$
  - 2 year Treasury: 40% 5-year bond, 60% cash
  - 10 year Treasury: 150% 5-year bond, $-50\%$ cash
  - 10 year risky bond: 160% 5-year bond, $-60\%$ cash
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- Quarterly Call report data on bank balance sheets
  - loans: book value, maturity, credit quality
  - securities: fair values, maturity, credit quality
  - cash, deposits & fed funds

- Represent as simple portfolios in 5-year bond & cash
JP Morgan Chase: simple portfolio holdings

![Graph showing portfolio holdings over time](image-url)
Outline

1. Bond values described by statistical model with few shocks
2. Bond/debt positions $\Rightarrow$ simple portfolios in a few bonds
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5. From regulatory data to simple portfolios: swaps
Notionals of Interest Rate Derivatives of US Banks

- Trillions $US
- All contracts
- Swaps

- 1995
- 2000
- 2005
- 2010

- 20
- 40
- 60
- 80
- 100
- 120
- 140
- 160
Concentrated Holdings of Interest Rate Derivatives

- Trillions $US
- for trading
- not for trading
- top 3 dealers

Net fair values of derivatives

Billions $US

net fixed income

net fair value, int. rate deriv.
4. Swaps – definitions and data

- most derivatives are swaps – bets on direction of rates

- pay-fixed swap vs. pay-floating swap — what holder does
- value of pay-fixed swap goes up when rates go up,
  standard valuation formulas
- zero-sum: value of pay-fixed swap = − value of pay-floating swap
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- Call Report data on interest rate swaps
  - notionals
  - fair values

- Call Reports do not contain
  - sign: pay-fixed or pay-floating swap?
  - what fixed-rate was locked in?
  - maturity of swaps

- approach: *estimate* positions in the simple portfolio for swaps
  - consists of cash & 5-year pay-fixed swap with some locked-in rate
Estimation of net swap position

- \( \{\omega_t\} = \text{net position in 5-year pay-fixed swaps, rel. to gross notionals} \)
  - \( \omega_t \) negative if pay-floating swap
  - \( |\omega_t| \) small if lots of netting in gross notionals

- infer sequence \( \{\omega_t\} \) from

\[
\frac{\text{net value}_t}{\text{notionals}_t} = \omega_t \text{ (value of 5 yr swap)} + \text{cash}_t + u_t
\]

value of 5 yr swap = \( f(\text{current rates, locked in swap rate}) \)
transition equation: updates cash & locked-in swap rate given \( \omega_t \)

- Bayesian estimation using MCMC
JP Morgan Chase: swap position

Notionals

Net fair value / notional (%)

5 year swap rate (% p.a.)
JP Morgan Chase: swap position

- **Notionals ($ trillions)**
- **Net Fair Value / Notional (%)**
- **Omega (%)**
- **5 Year Swap Rate (% p.a.)**

Graphs showing trends from 1995 to 2010.
JPMorgan Chase (blue) & BofA (green): swap positions

- **notionals**
  - $ trillions
  - 1995-2010

- **net fair value / notional (%)**
  - 1995-2010

- **omega (%)**
  - 1995-2010

- **5 year swap rate (%) p.a.**
  - 1995-2010
  - current, locked in
JP Morgan Chase: replicating portfolios

The diagram illustrates the trend of cash and 5-year-old financial instruments (FI) from 1995 to 2010. The x-axis represents the years from 1995 to 2010, while the y-axis represents trillions of US dollars. The red line represents cash, and the green line represents 5-year-old FI. The data shows a decrease in cash and an increase in 5-year-old FI over the years.
JP Morgan Chase: replicating portfolios

Trillions $US

-0.5
0
0.5
1
1.5

1995
2000
2005
2010

-0.5
0
0.5
1
1.5

Trillions $US

Cash, old FI
5 year, old FI
Cash, deriv
5 year, deriv
JP Morgan Chase, one quarter ahead exposures

derivatives

net fair value
+ std dev (factor)
- std dev (factor)

net fixed income

$ billions

2000
2010

2000
2010
Summary

- Methodology to measure exposures in bank positions
- Results for top dealer banks
  Derivatives often increase exposure to interest rate risk, some hedging after the crisis
- Possible models for banks:
  - risk averse agents that use derivatives to insure (no!)
  - agents who double up with derivatives
  - agents who provide insurance to others
- Need models with heterogeneous agents, position data will inform these models