Financial Stability and the Capital Adequacy of Large U.S. Banking Organizations: A VAR in VaR Approach

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[Ψ] The views expressed are those of the authors and do not necessarily reflect those of the Board of Governors of the Federal Reserve System or its staff.

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Basel II : A Risk-Bucketing System

- Bank assets will be partitioned by various characteristics.
  - For example, by loan type and borrower credit rating.
- Capital charge on a given asset will depend only on its own characteristics.
- In particular, the capital charge does not depend on the characteristics of the portfolio.

$\therefore$ Basel II is a “bottom-up” approach for determining capital adequacy.

U.S. Capital-to-Asset Ratio Requirements

- Banks with less than 5 percent (tier 1) capital-to-asset ratios have restrictions or conditions on certain activities and may also be subject to mandatory or discretionary supervisory actions.
- Under Regulation Y, most bank holding companies must hold a minimum ratio of tier 1 capital-to-total assets of 4 percent.
  - In some circumstances, the minimum for bank holding companies is as low as 3 percent.
- Remains unchanged whether or not a U.S. banking organization is subject to the Basel II framework.

Three Common Rationales for a Minimum Capital-to-Asset Ratio...

1. Provide a base of capital to absorb losses that could arise as a result of risks not accounted for by risk-based capital requirements.

   - Banks should desire to protect themselves from insolvency, and voluntarily hold sufficient capital to absorb losses.
   - Mispricing of liabilities due to conjectural government guarantees or deposit insurance.
   - Unaccounted social costs associated with illiquidity and insolvency of depositories.

Three Common Rationales for a Minimum Capital-to-Asset Ratio

2. The uniform risk-weights for a minimum capital-to-asset ratio may be less distortionary than imperfect risk-weights for a risk-bucketing system.

3. The use of the single systematic risk factor assumption that underpins the Basel II risk-based capital adequacy framework is a concern.

- Portfolio-invariant capital charges may be inappropriate.
- May also result in a significant understatement of the capital needed to protect against insolvency (Gordy, 2002).
- Costly for banks to account for more than one systematic factor, limiting the ability of bottom-up approaches to account for systematic risks.

Preview of the Four Steps of our "Top Down" Framework

- Step 1: We use a vector-autoregression (VAR) investors' expectation model.
  - Translates shocks in the benchmark risk-free rate, systematic risk factors and macroeconomic outlook variables into subordinated debt return surprises.
- Step 2: We use a Merton-style contingent claims model to translate changes in the value of debt into changes in the market value of a banking organization.
  - Capital adequacy is determined by having enough capital to cover the change in market value of the firm generated by an extremely severe systematic shock.

Preview of the Four Steps of our "Top Down" Framework

- Step 3: We construct a Value-at-Risk measure using the change in banks' market value in response to large shocks of systematic risk factors.

- Step 4: We adjust our Value-at-Risk measure for market liquidity conditions and conjectural government guarantees.

Preliminary Finding

- Our capital adequacy estimate, adjusted for liquidity conditions, averaged 2.1 percent of market value of three large, systemically important BHCs over 1999:Q3 - 2008:Q1.

- It ranged from a high of 6 percent in 2004 to a low of 0.4% in 2008.

Why Subordinated Debt?

- Subordinated debt holders are likely to be particularly sensitive to bank risks.
  - Unlike stock holders, they are exposed to loss but do not benefit from upside gains that accrue due to excessive risk-taking.
  - The long maturity of subordinated debt means that these debt holders are not able to “run the bank.”
  - To the extent that subordinated debt is issued in place of insured deposits, it provides an extra “cushion” for the Federal Deposit Insurance Corporation in the event of bank failure.

Modeling Subordinated Bond Yields

- Extend the analyses of Campbell and Shiller (1988), Campbell and Ammer (1993), Campbell, Lo, and MacKinlay (1997), Bernanke and Kuttner (2005) and Cochrane (2005).

- Following the notation of Campbell, Lo and MacKinlay, the return on a long-maturity, coupon-bond can be written as a weighted-average of price changes and fixed, nominal, coupons (c) or:

$$\underbrace{r_{c,\,n,\,t+1}}_{\text{return on bond}} \approx k + \underbrace{\rho\, p_{c,\,n-1,\,t+1} - p_{cnt}}_{\text{change in price}} - \underbrace{(1-\rho)c}_{\text{change in value of coupon}} \quad ,$$

where k and ρ are linearization parameters and n denotes a bond's remaining period to maturity.

- This is based on a present value accounting identity.

Subordinated Debt and Investor Expectations

- For long-maturity bonds held for short-periods of time, the unexpected change in a bond's (log) yield-to-maturity is directly related to changes in the expectations of bond returns, or:

$$\underbrace{y_{c,\,n-1,\,t+1} - E_t y_{c,\,n-1,\,t+1}}_{\text{change in yield on subordinated debt}} = \underbrace{(E_{t+1} - E_t)\sum_{i=1}^{n-1} \rho^i r_{n-i,\,t+1+i}}_{\text{change in outlook for bond returns}} .$$

The Relationship between Yields-to-Maturity and Systematic or Macroeconomic Risks

- The unexpected changes in (log) yield-to-maturity for a bond over the holding period can be directly related to:

$$y_{n-1,\,t+1} - E_t y_{c,n-1,t+1} = (E_{t+1} - E_t)\left[\sum_{i=0}^{n-1} \underbrace{\rho^i r_{0,\,t+1+i}}_{\text{Benchmark risk-free rate}} + \sum_{j=1}^{k}\sum_{i=0}^{n-1} \underbrace{\rho^i \beta_{t+1}^j RF_{n-i,\,t+1+i}}_{\text{Systematic and Macroeconomic Risk Factors}} + \sum_{i=0}^{n-1} \underbrace{\rho^i \upsilon_{n-1,\,t+1+i}}_{\text{Uncertainty Premium}}\right]$$

Measuring the Sensitivities of Subordinated Debt Yields to Shocks in Risk Factors

- We estimated a second-order VAR system for each banking organization that included seven variables:
- A bank-specific (log) yield-to-maturity, y_{it}
- Two Fama – French factors:
  - Excess market return, EMR
  - Risk factor in returns related to firm size, SMB
- Four elements of a small, macroeconomic forecasting model:
  - One-month Treasury rate, $Rate$
  - Slope of the yield curve, $Term$
  - Corporate debt risk premium, $CorpRisk$
  - Industrial Production Index (weekly), IP

Calculating Impulse Response Functions

- Impulse-response functions describe the reaction of one variable in the VAR system to innovations (i.e., shocks) in another variable in the system.
- We are interested in the shocks to the systematic risk factors and macroeconomic forecasting variables.
- We use a VAR system with variables entered in the following order: *IP*, *Term*, *CorpRisk*, *Rate*, *SMB*, *EMR* and *y*.
- The variables that appear earlier in this ordering influence other variables contemporaneously, as well as with a lag.
  - Later variables in the ordering only influence previous variables with a lag.

$\therefore$ The bond yield is the "most endogenous" variable in the system.

Individual Bank VAR Systems

- Separate VAR systems were estimated for the three largest U.S. bank holding companies (BHCs):
  - Bank of America, Citigroup, and JPMorgan Chase.
- Each of these institutions hold almost $1.5 trillion on-balance sheet assets and more than $1.5 trillion off-balance sheet managed assets.
- Each VAR system was estimated over periods for which the BHC had a liquid (i.e., frequently traded) market for its subordinated debt.
- During these periods, each BHC had at least three outstanding subordinated debt issues with maturities of five years or more.
- In addition, the aggregate amount of such subordinated debt at each BHC was at least $500 million and accounted for at least one percent of its liabilities.

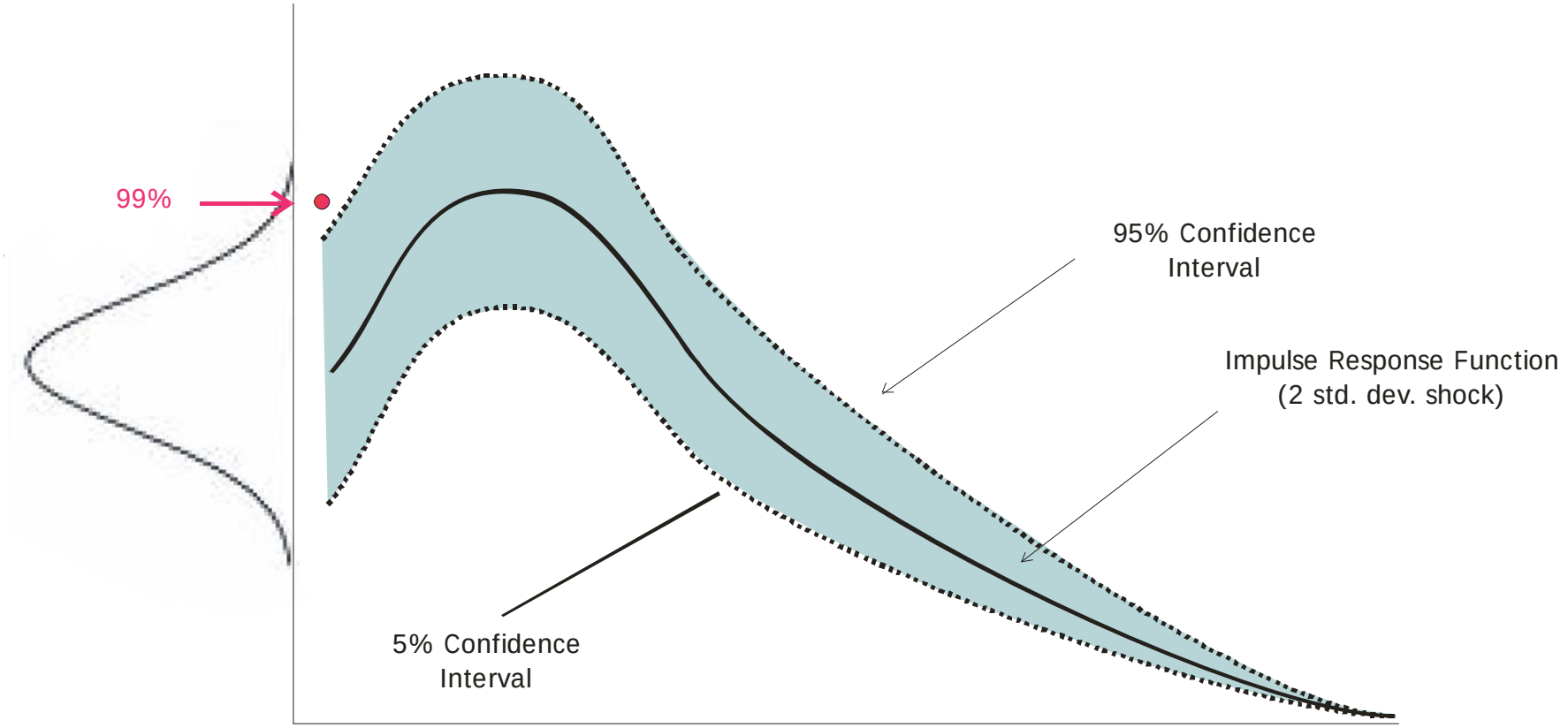
The "Rolling VAR"

- A "rolling VAR model" was estimated for each BHC.
- The first estimation period begins when time-series data became available and ends two and one-half years later.
- The next estimation period drops the first week of the previous period, and then adds another week at the end.
- The length of the window used – two and one-half years – represents the trade-off between embedding timely information in the VAR system versus maintaining sufficient degrees of freedom to estimate a fairly parsimonious VAR.

Measuring the Systematic Risks Posed by Large Banking Organizations

- For our VAR systems, the impulse response functions of interest are the responses in the yield-to-maturity to a two standard-deviation shock.
- The first impulse is the contemporaneous response in the yield-to-maturity to the shock.
  - It is often, but not always, the largest response.
- Our focus on the contemporaneous response reflects our desire to develop capital adequacy measures consistent with financial stability.

A Picture Worth a Thousand Words: VAR in Value-at-Risk Measure

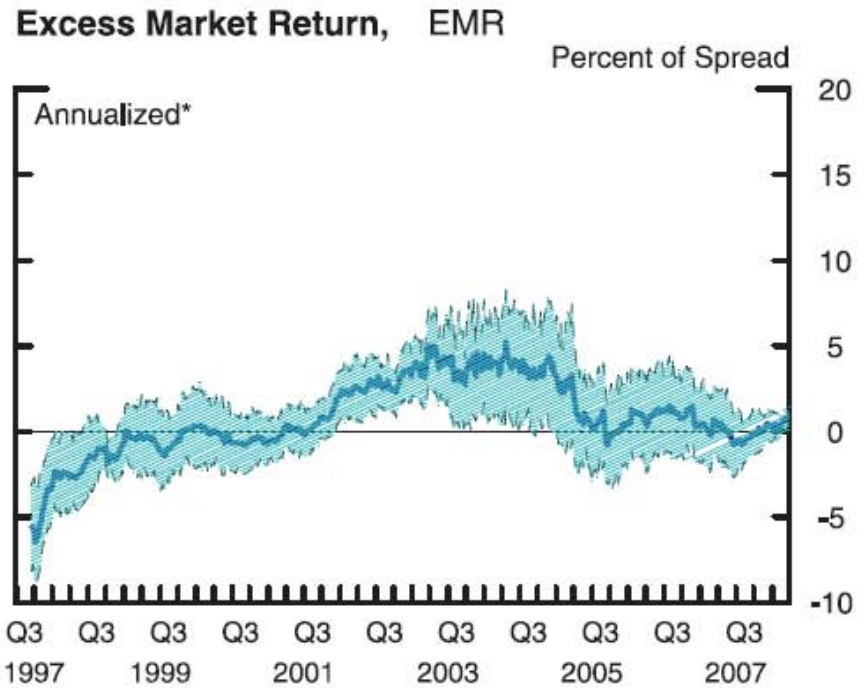


Results of Shocks to Individual Bank VAR Systems

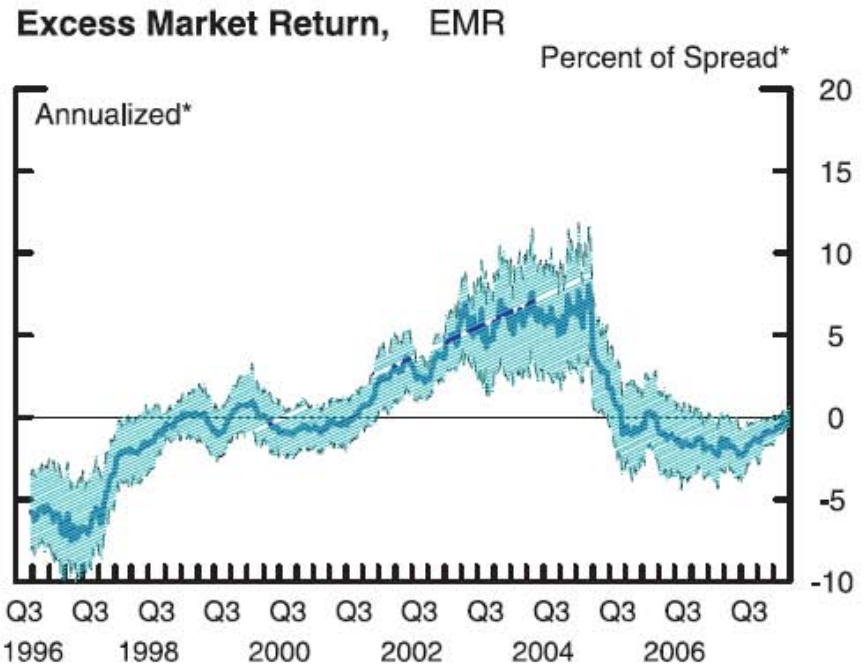
- For each of our three BHCs, we examine the time-series of the contemporaneous responses to a shock.
- The time-series patterns for contemporaneous responses across BHCs are very similar.
- This similarity in the time-series patterns indicates that investors generally perceive that the three largest U.S. BHCs present similar systematic risks.
- In the following slide, each BHC's contemporaneous responses (estimated for each 2.5 year window) are provided together with shaded regions that indicate the 5 percent and 95 percent confidence intervals. Each observation is dated using the last week of each estimation period.

Time-series of Contemporaneous Responses to Shocks in Excess Market Returns

Bank of America



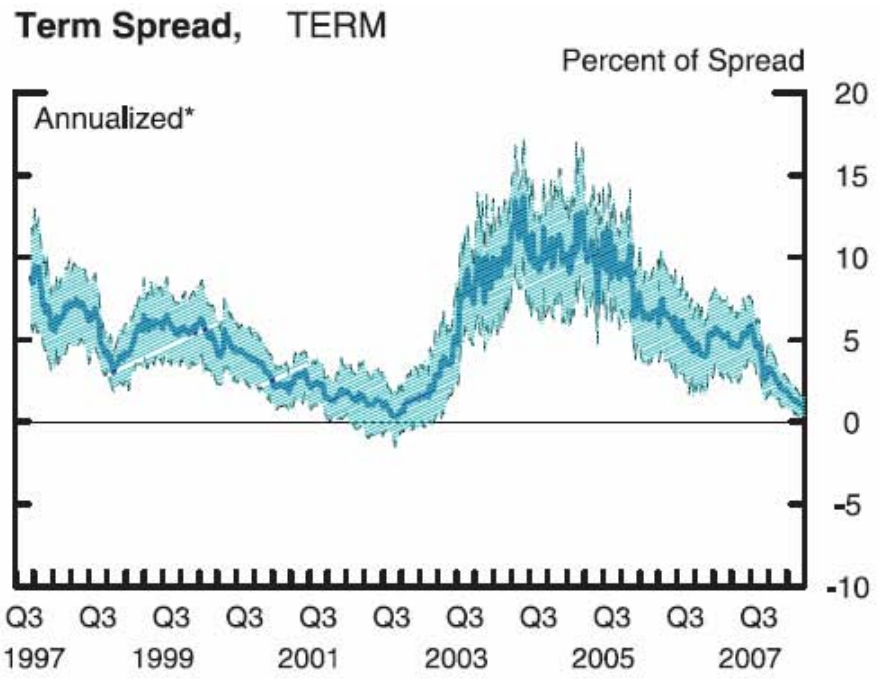
Citigroup



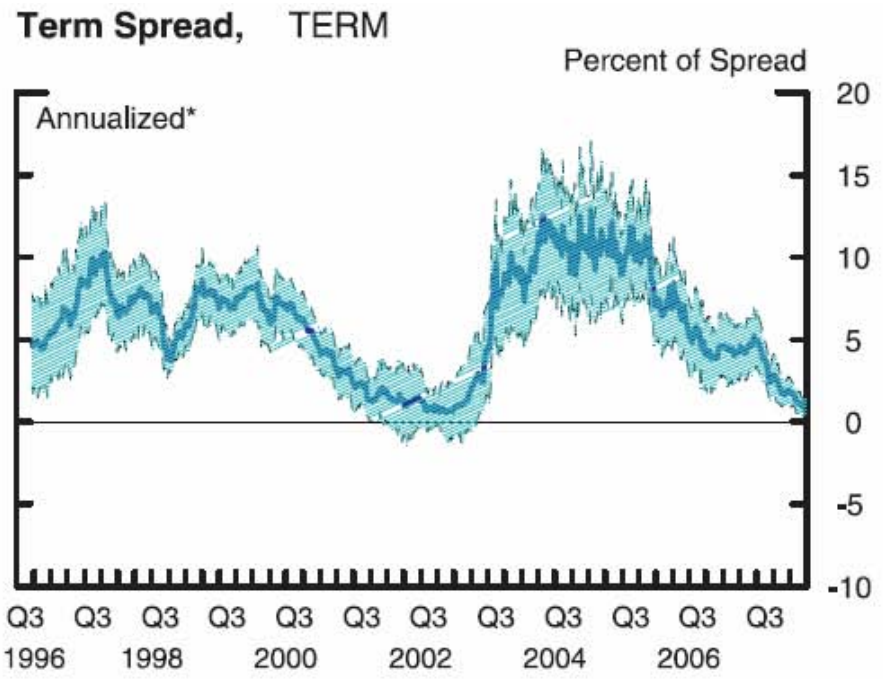
***Observations are weekly data. Spread is calculated as mean subordinated debt yield minus treasury debt yield over 2.5 year window.**

Time-series of Contemporaneous Responses to Shocks in Term Spreads

Bank of America



Citigroup



***Observations are weekly data. Spread is calculated as mean subordinated debt yield minus treasury debt yield over 2.5 year window.**

Discussion of Individual BHC VAR Models

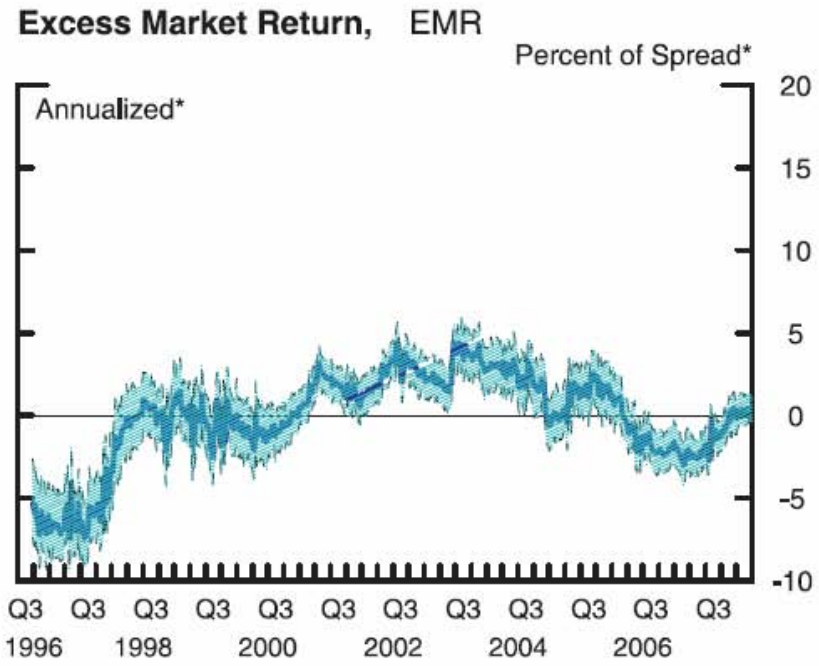
- The differences over time in the first responses are due to differences (across BHCs) in the coefficients of the VAR systems.
  - The differences are not due to differences in the size of the shocks across time (i.e. differences across time in the size of the residuals of the VAR systems).
- The correlations of the residuals for each equation (in the VAR system) separately across BHCs are generally greater than 95 percent.
  - This suggests that the differences in contemporaneous responses across BHCs is almost exclusively due to the differences in their response to similar shocks that are embedded in each BHC's VAR system.

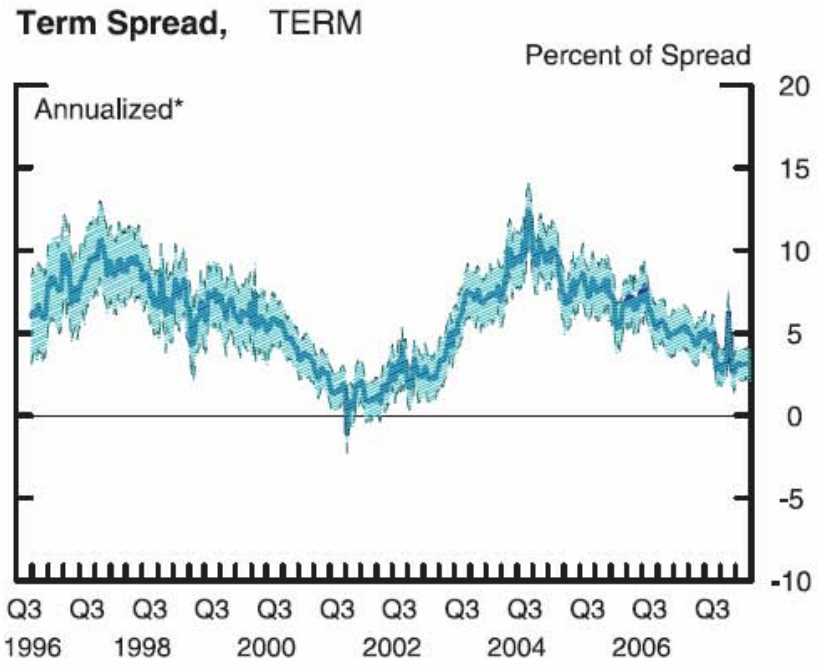
Using Panel-VAR to Extract Common Factors from a Group of Banks

- Beyond the systematic risks associated with individual BHCs, our technique can be used to measure the financial system's robustness in response to a systematic shock.
- Greater co-movement of financial firm subordinated bond returns to systematic risk factors may portend greater risks to the macro-economy.
  - Such institutions may be more likely to amplify macroeconomic shocks, perhaps by curtailing credit to many firms simultaneously.
- We use a panel-VAR to create a common portfolio of the subordinated debt issued by the three largest U.S. BHCs.

Results from the Panel-VAR Estimation

- Not surprisingly, our Panel-VAR results are similar to the individual BHC VAR results.





***Observations are weekly data. Spread is calculated as mean subordinated debt yield minus treasury debt yield over 2.5 year window.**

Valuing the Bank

- The price decline, in response to the rise in yield associated with a shock, is the loss (in present value) in the market value of the subordinated debt held by investors.

- This decline can be directly related to the change in the value of the financial institution (V) as follows:

$$\partial V_{t+1} = \frac{\partial V_{t+1}}{\partial SD_{t+1}} \frac{\partial SD_{t+1}}{\partial RF_t^{\,j}} \partial RF_t^{\,j}$$

where SD_t is the value of subordinated debt and RF denotes a risk factor.

Gorton and Santomero's Contingent Claims Model

- To derive a change in the value of the firm, we use a contingent claims model that accounts for subordinated debt (SD_t).
- Gorton and Santomero (1990) demonstrate that the market value of subordinated debt is a function of the:
  - value of the firm (V)
  - volatility of equity returns (σ)
  - debt maturity (τ)
  - risk-free rate (r_f)
  - book value of senior debt (X_1)
  - book value of subordinated debt (X_2).

Calculating the Changes in Firm Value...

- Using the standard arguments concerning option pricing formulas, we calculate the percentage change in the value of the firm as:

$$\frac{\Delta V}{\Delta RF}\frac{1}{V} = \frac{100}{[N(d_1) - N(d_1')]}\frac{SD}{V}\frac{\left[\frac{\Delta SD}{SD}\right]}{\Delta RF}$$

- $N(\bullet)$ is the cumulative normal distribution evaluated using the variables in the contingent claims model.

- Following Gorton, Santomero (1990):

$$d_1 = \frac{\left[\ln(V/(X_1)) + (r_f + \sigma^2/2)\tau\right]}{\sigma\sqrt{\tau}}, d_1' = \frac{\left[\ln(V/(X_1 + X_2)) + (r_f + \sigma^2/2)\tau\right]}{\sigma\sqrt{\tau}}$$

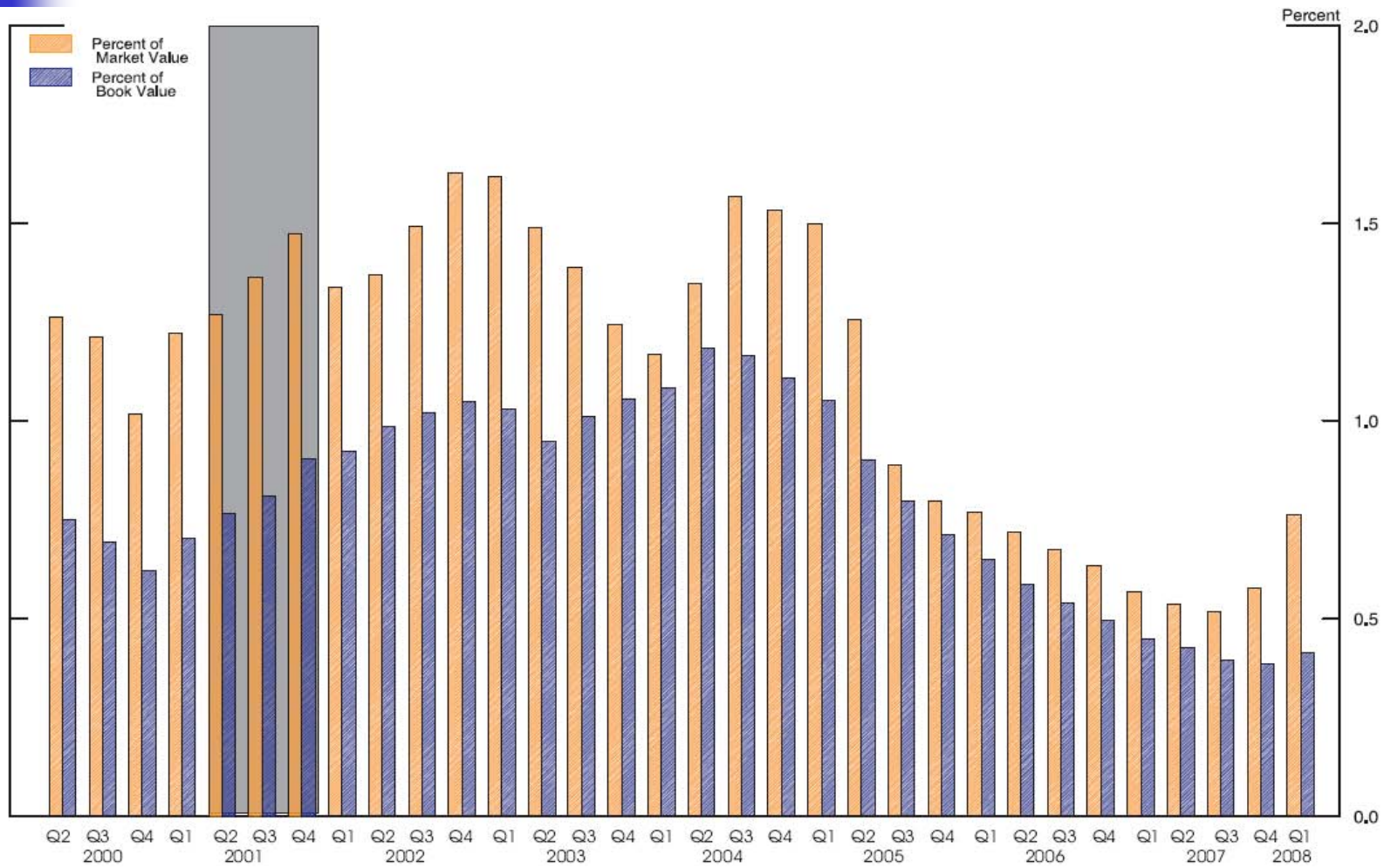
Calculating the Changes in Firm Value

- Book values of equity and debt are available from the Call Report Y9 data.
- CRSP stock data were used to calculate sigma and market value.
- Risk-free rates were obtained from the Federal Reserve H.15 statistical release.
- We use impulse response functions estimated from a vector-autoregression model to derive the change in the value of subordinated debt with respect to a shock.

Constructing "Value-at-Risk" Measures

- Changes in the value of a banking organization can be inferred from changes in the value of its subordinated debt.
- We calculate the value-at-risk (VaR) to systematic shocks where:
  - The holding period is one week.
  - The shock is a 99th percentile shock in a systematic risk factor.
  - The 99th percentile VAR model represents investors who are highly-sensitive to such shocks.
- The shock is the sum of "contemporaneous responses" to the systematic risk and macroeconomic outlook shocks.

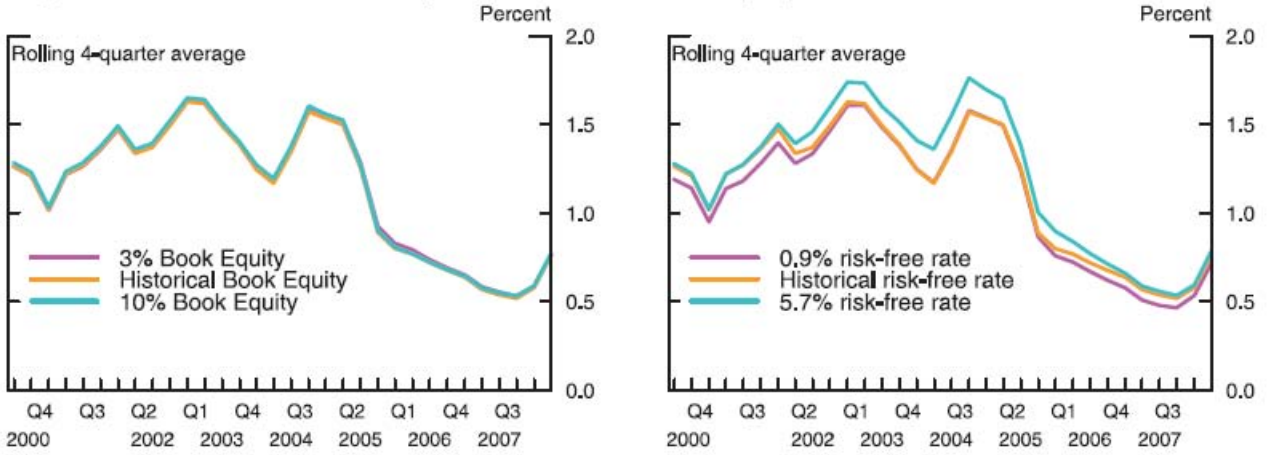
The VaR for the Group of the Three Largest U.S. Banks to Systematic Shocks



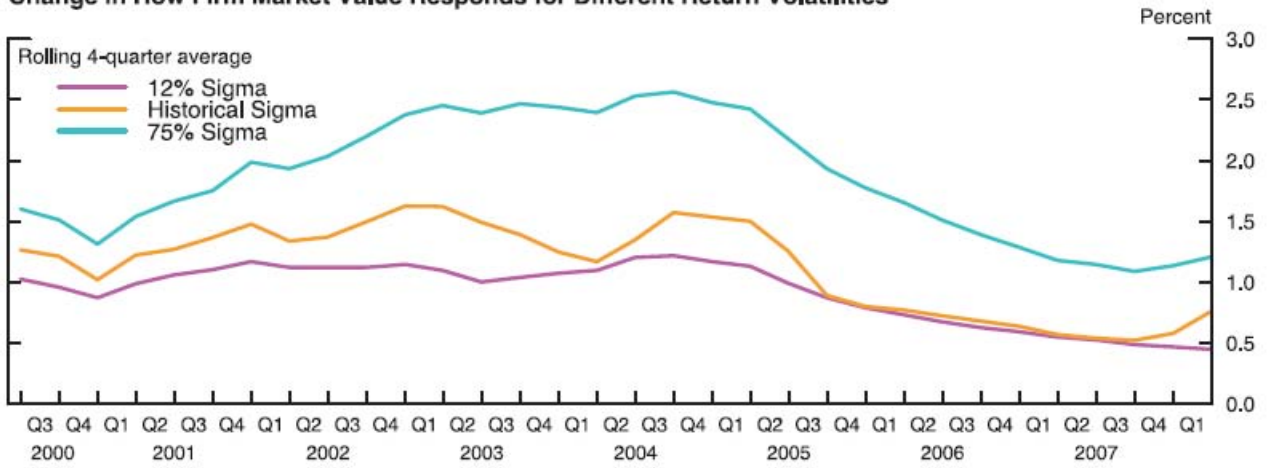
* Shading denotes period of recession, as defined by NBER. Observations are rolling 4-quarter average data.

Sensitivity of VaR Calculations

Change in How Firm Market Value Responds for Different Book Equity to Book Asset Ratios and Risk-free Rates



Change in How Firm Market Value Responds for Different Return Volatilities



The Confounding Role of Market Liquidity Conditions and Conjectural Government Guarantees

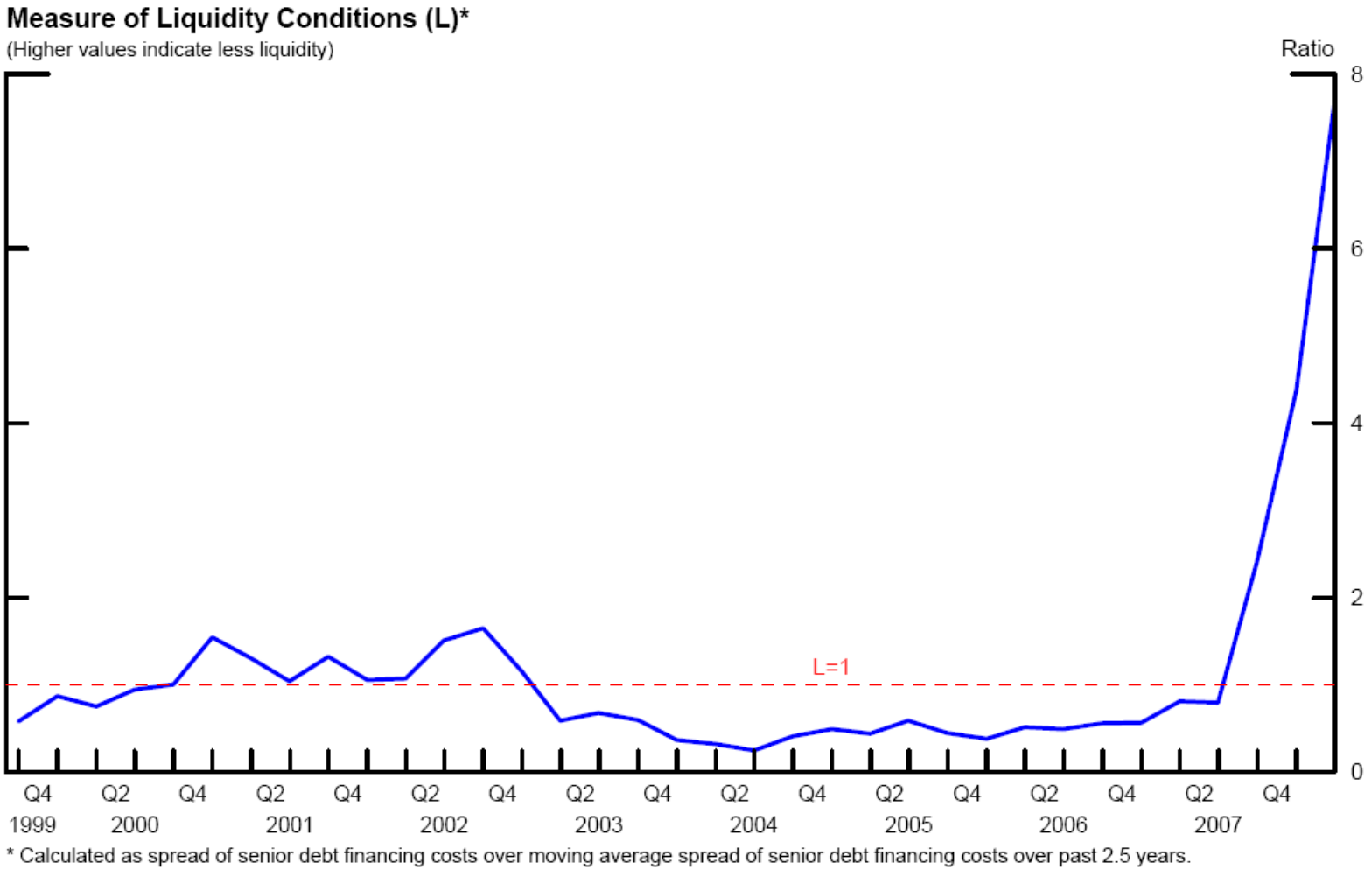
- For large financial firms, the observed credit risk premiums reflect investors' perceptions with respect to expected losses, *liquidity risk and conjectural government guarantees.*
- Let L represent investors' perceptions that there will be delays in their ability to sell a bond.
  - L=1: Defines normal liquidity, where no investor expects to suffer losses because of problems with selling the bond.
  - L>1: Bond investors suffer more than the expected loss due to illiquidity.
  - L<1: Large proportion of noise traders create excess liquidity.
- The risk sensitivity of the credit risk premium (δ) to each systematic risk or macroeconomic outlook factor (RF_j) depends on its risk fundamental (β^j) and on liquidity conditions (L) or:

$$\frac{\partial E_t(\delta_t^j)}{\partial RF_{t+1}} = L\beta_{t+1}^j.$$

An Estimate of L and the Influence of Conjectural Government Guarantees

- We propose a measure of relative market liquidity, which includes investors' conjectures about government backing (that might make the debt of some banks "super liquid.")
- The numerator of our liquidity conditions ratio is the spread between the large bank holding companies' senior debt yields and the yields on debt issued by the government-sponsored enterprises (GSEs).
- The denominator equals the moving average of the spread over a 2.5 year period.
- "Normal" liquidity conditions are defined as current liquidity being equal to the average spread between large BHCs and GSEs during the past two and half years (L=1).

Our Measure of Liquidity Conditions (L)



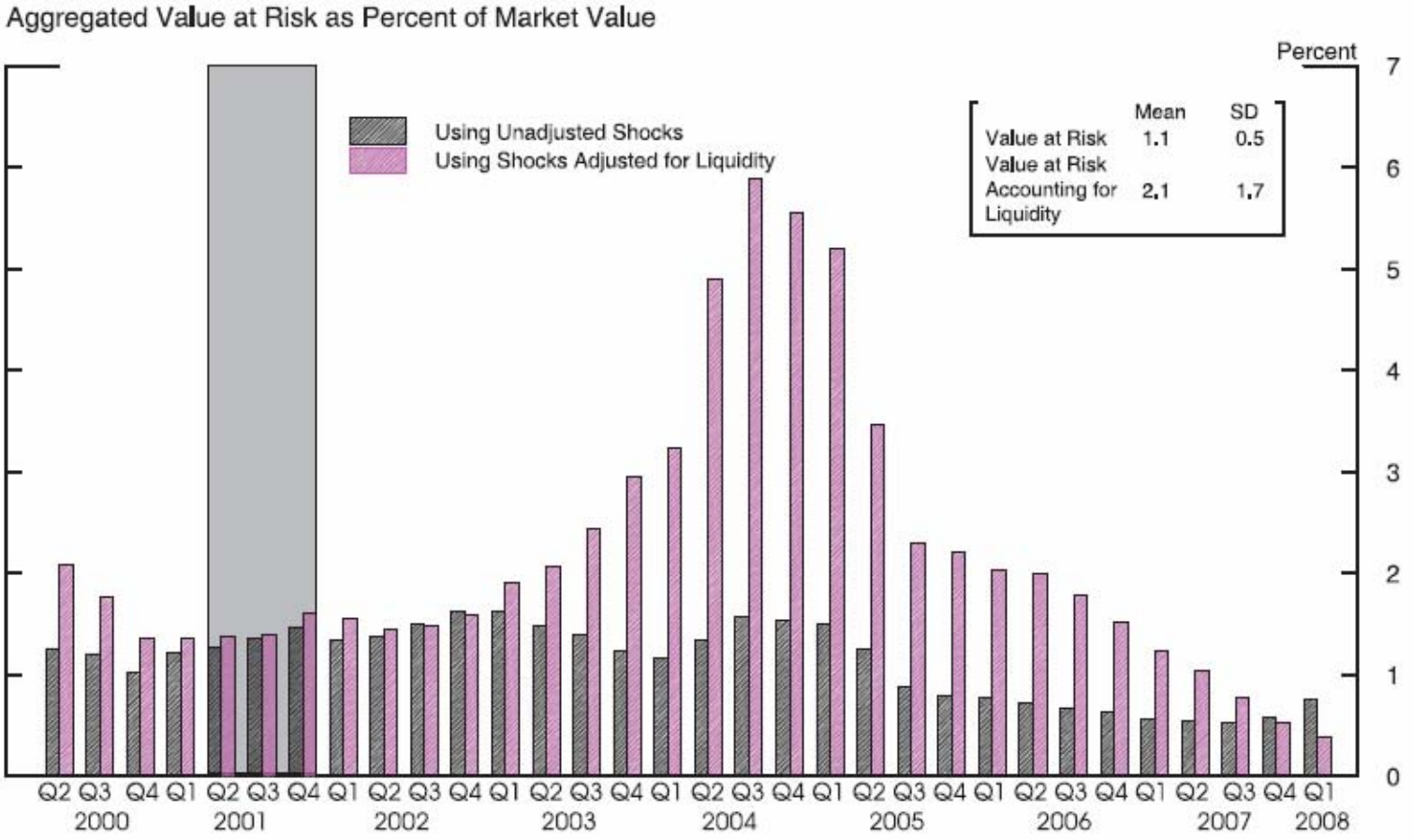
Adjustments for Excess Liquidity Conditions

- Our adjustment allows the leverage ratio to rise during times of high credit risk even when masked by “excess liquidity” or conjectural government guarantees.
- Our methodology suggests that market liquidity movements dominated credit risks in recent years.
- Responses to systematic shocks were understated during the period 2003-2005.
- During that time, our proposed minimum leverage ratio would have risen to 6 percent of market value in 2004 --- a time markets perceived minimal credit risks.

Adjustments for Market Illiquidity

- When credit risks are low but markets become extremely illiquid or perceptions of government guarantees are diminished, the leverage ratio would decline.
- During 2006-2007, our measure of capital needed to cover systematic risks suggests very low leverage ratios were warranted because investor responses to these shocks were heightened by the illiquid market conditions.
- By 2007, the minimum proposed leverage ratio fell to 0.5 percent.

The VaR for the Three Largest U.S. Banking Organizations to Shocks After Accounting for Market Liquidity and Conjectural Government Guarantees



* Shading denotes period of recession, as defined by NBER. Observations are rolling 4-quarter average data.

Quick Review of Our Technique...

- Despite their important role, relatively little research has been provided to determine minimum regulatory capital-to-asset ratios. This paper seeks to fill this gap.

- Our VAR in VaR approach translates time-series movements in subordinated debt yields-to-maturity arising from changes in systematic risk factors and changes in the macroeconomic outlook into time-series movements in bank market value.

Quick Review of Our Technique

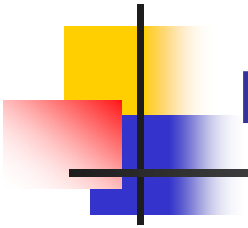
- These time-series movements are, in turn, used to compute the aggregate amount of capital needed to offset losses in bank market value that could occur in the face of several large systematic shocks.

- This “top down” approach provides time-varying and risk-adjusted minimum capital-to-asset ratios to protect against systematic and undiversifiable risks present in the macro-economy.

Quick Review of Our Findings

- Adjusting for market liquidity conditions and conjectural government guarantees, our market-based time-varying risk-adjusted leverage requirements averaged 2.1 percent of their market value of assets over 1999:Q3-2008:Q1.

- This is 1.6 percent of the book value of assets over 1999:Q3-2008:Q1.



Extending Our Technique

- The framework is general enough that it can be applied to different groups of banking organizations.

- For example, banking organizations could be stratified by whether they met specified criteria, such as having implemented risk-based capital measures for market risk, or whether they specialized in certain types of activities (e.g., the trading book, credit card lending or mortgage lending).

Extending our Technique to Account for Contagion

- Our technique also provides a straightforward way to measure “knock-on” effects associated with contagion.
- If we added the yield on the subordinated debt of one banking organization into the VAR system of another, we would be able to estimate the “knock-on” effect.
- Ordering matters where VAR systems are concerned.
  - Important to order the bank-specific yields so that the most contagious banking organization is the most endogenous in the VAR system.
- Implementing this approach, would require significant time-series information on subordinated debt yields for all of the banking organizations involved.