Robert Engle and Emil Siriwardane
Volatility Institute of NYU Stern
6/24/2014

STRUCTURAL GARCH AND A RISK BASED TOTAL LEVERAGE CAPITAL REQUIREMENT

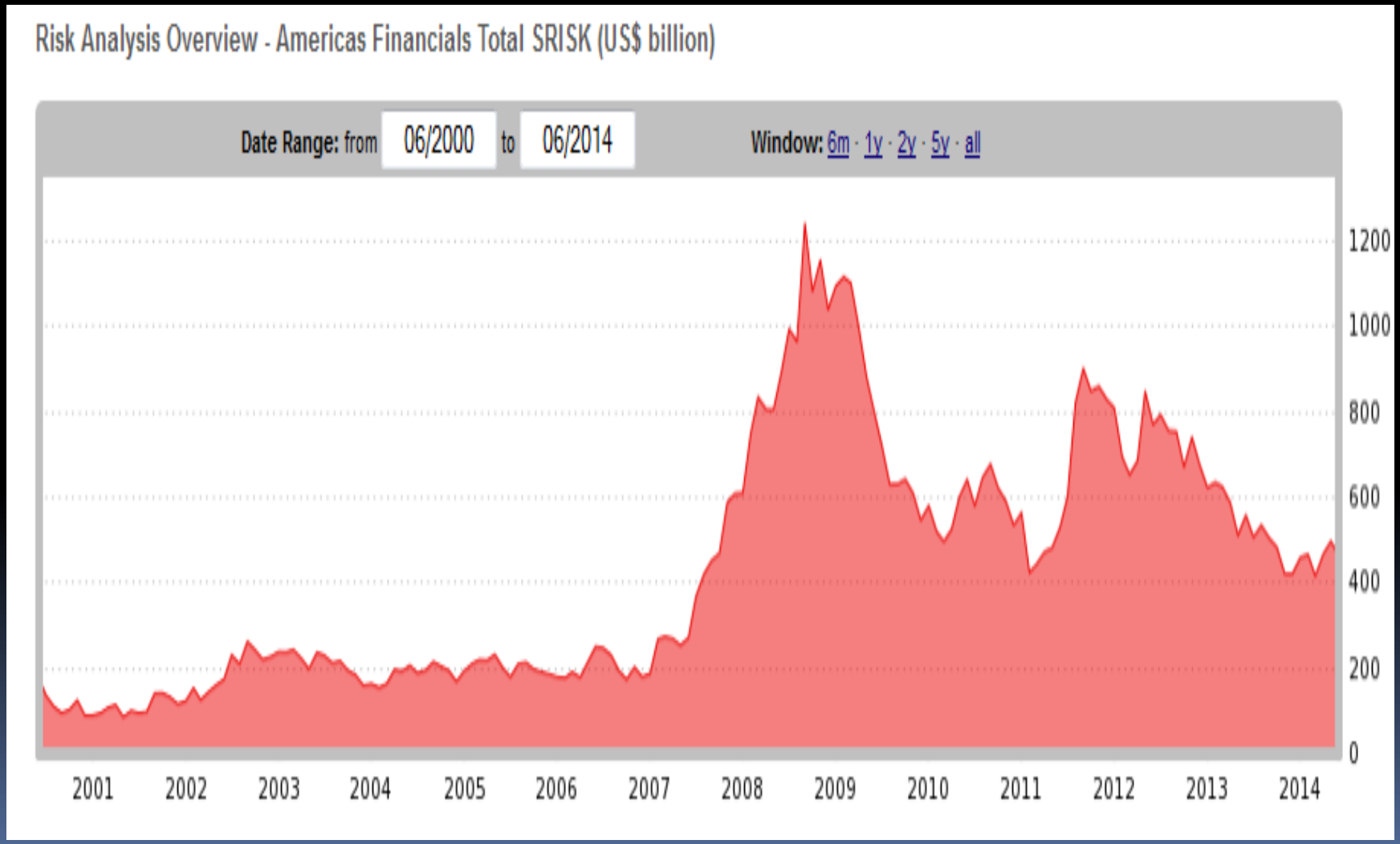
SRISK

- How much additional capital would a firm expect to need in order to function normally if we have another financial crisis? Functioning normally means a capital ratio of k.
- We estimate this econometrically weekly and post it on:
- VLAB.stern.nyu.edu
- It is a useful measure of systemic risk that is showing improvement today in US and much of Europe.

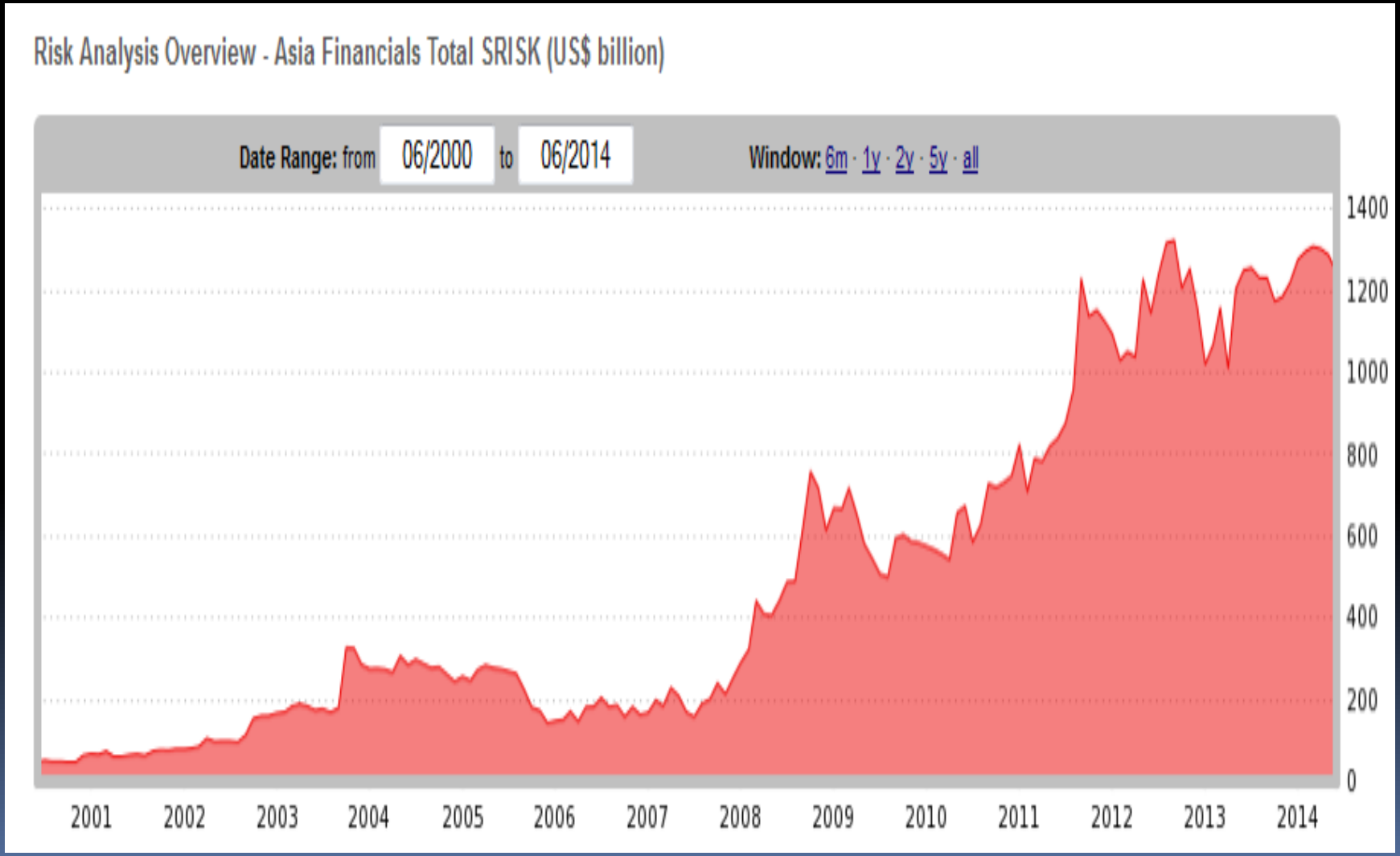
THE MODEL

- Simulate crisis paths for the global stock market with six month decline of 40%.
- For each path simulate market cap for each firm using dynamic conditional beta and bootstrapped residuals.
- Measure capital shortfall relative to book value of liabilities and average across crisis paths.
- Take stressed normal capital ratio to be 8% for GAAP and 5.5% for IFRS firms.
- Some approximations are made.

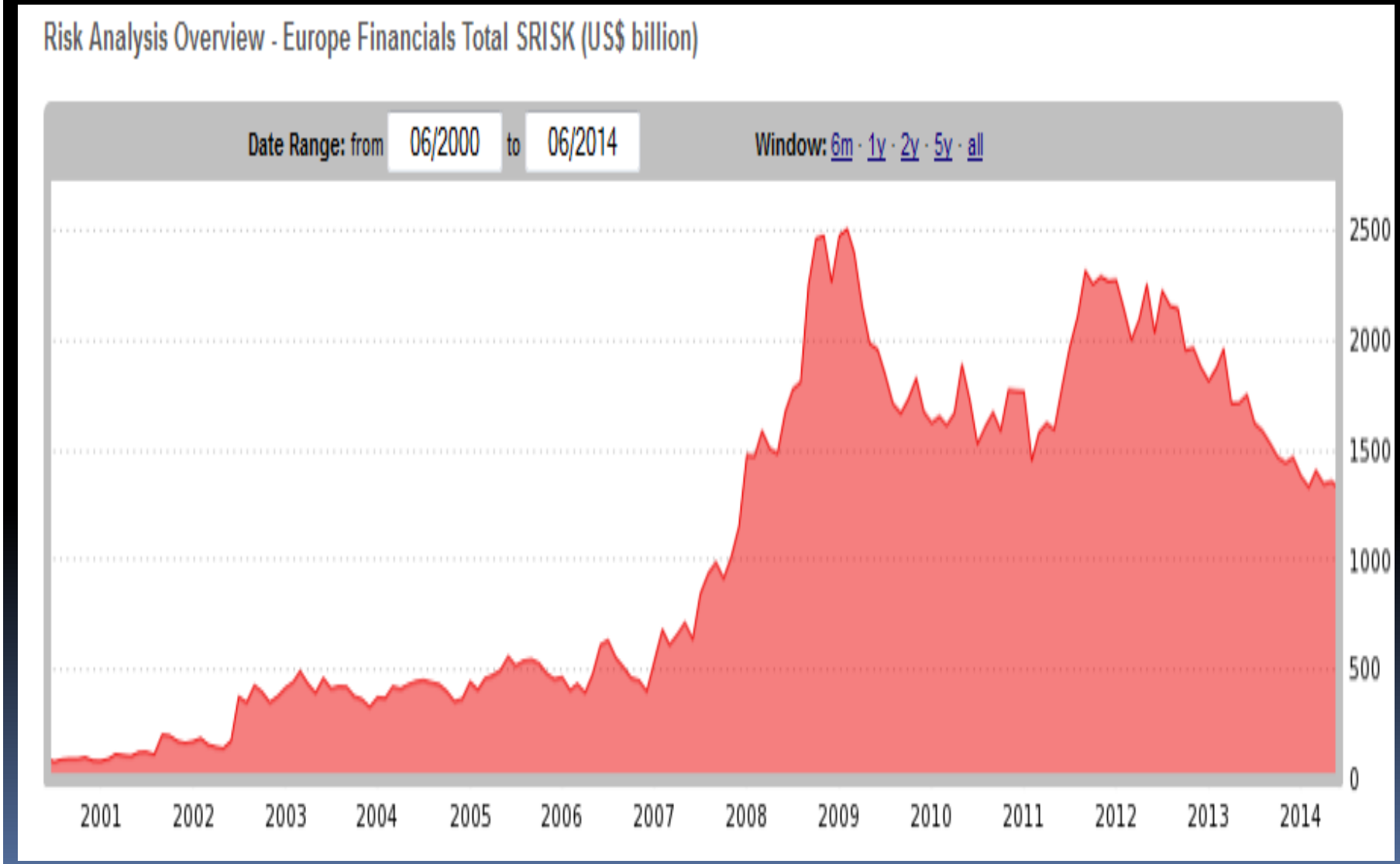
AMERICAS SINCE 2000



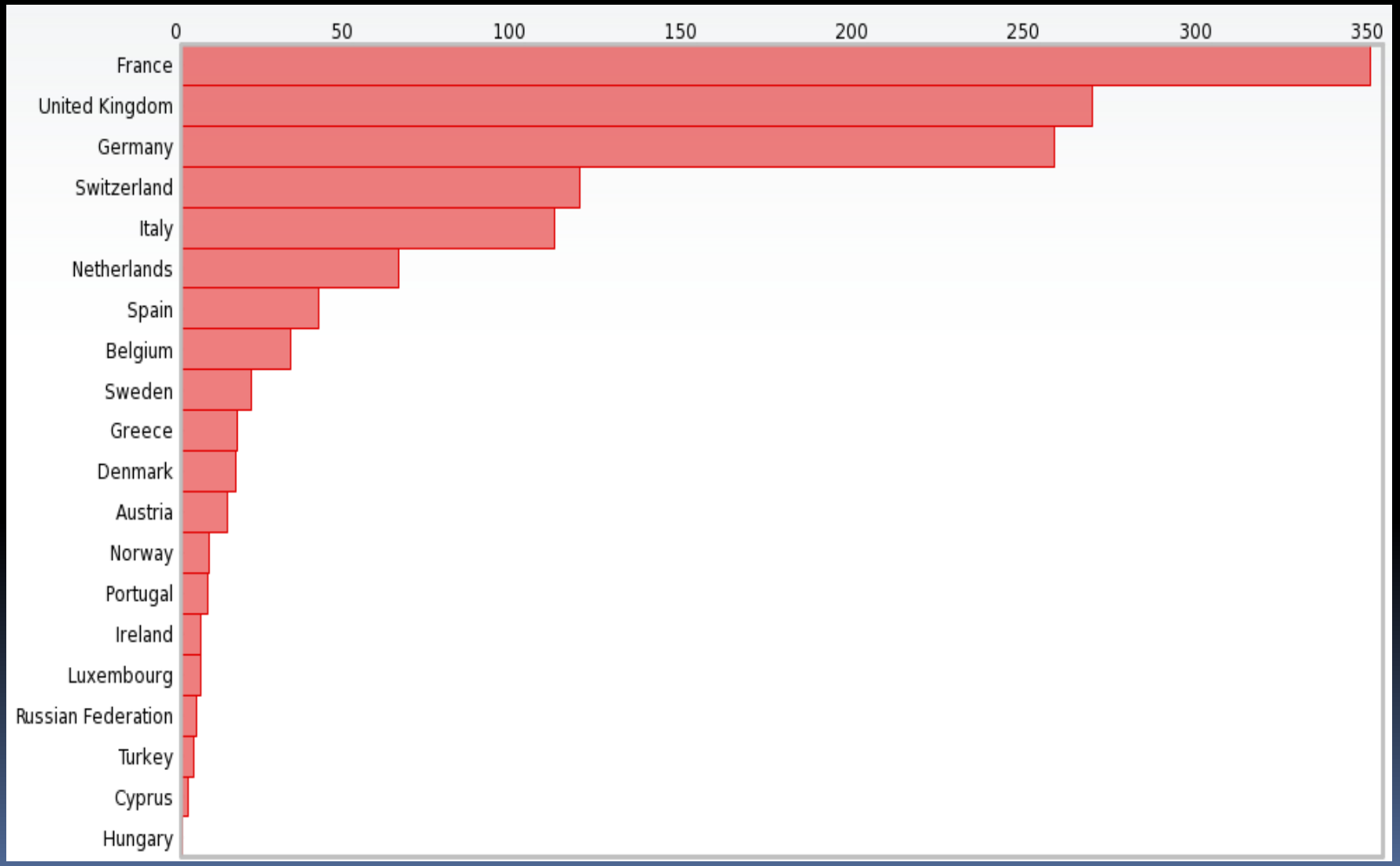
ASIA SINCE 2000



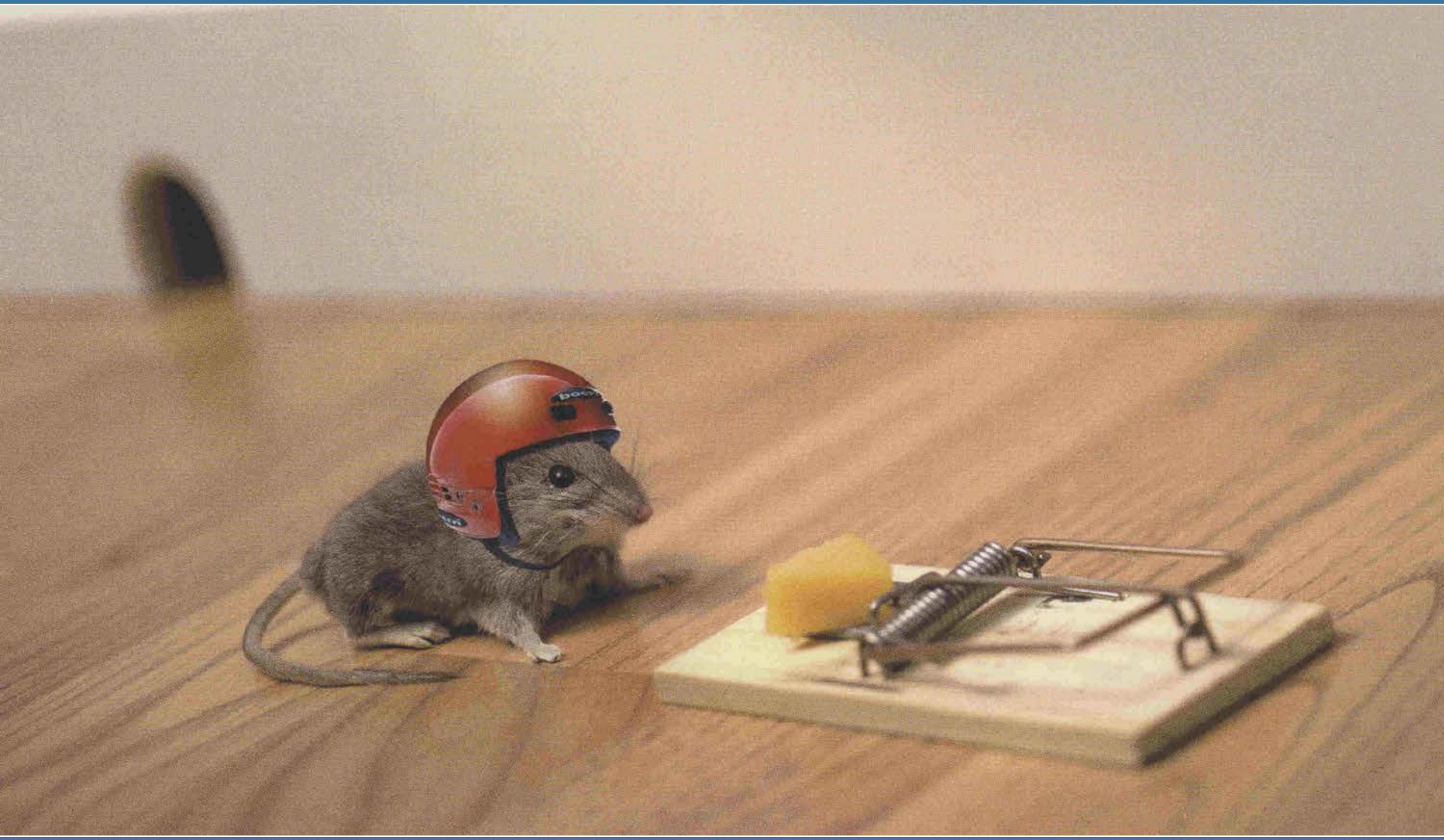
EUROPE SINCE 2000



WHERE IS THE RISK TODAY?



THE FINANCIAL CRISIS: WERE WE PREPARED?



PRECAUTIONARY CAPITAL: A NEW QUESTION

- How much additional capital should a firm have today so that with probability £ *l* its capital ratio will fall below *k* if we have another financial crisis?

- The parameters lambda and kappa define the capital ratio but it must be assessed with a probability model.

k

- When capital ratios become too low, financial firms cease to function effectively and ultimately fail. We sometimes call these zombie banks.
- Measure with market value of equity over book value of liabilities plus equity.
- Lehman failed with a capital ratio of 2% in Aug 08. FNMA and FMAC were less than 1% and WAMU was 2.5%. BSC was 2.5% in Feb 08 before it failed.
- Subsequently, big US banks and insurers had capital ratios even lower but by this time they were under Treasury protection.

DIFFERENCES BETWEEN PRECAUTIONARY CAPITAL AND SRISK

- Precautionary capital is needed today vs. bailout capital needed later
- Tail probability of low capital ratios vs. expected capital needs

- Precautionary capital corresponds better to the goals of a risk manager as well as to a prudential supervisor.

A CAPITAL CRITERION

- Why does this give a sensible capital criterion?
- Conditional on a crisis, the probability of firm undercapitalization is less than or equal to lambda.
- Conditional on a crisis, firm outcomes will be approximately independent, hence the expected failure rate is lambda and the probability of much higher rates is very small.
- The tolerance for financial firm failure in a crisis is a reasonable criterion for requiring capital.
- It does not however assess the cost of excess capital.

COUNTER CYCLICAL IMPLEMENTATION

- It would be desirable to implement any capital requirement so that it is counter-cyclical.
- Capital requirements would be raised in good times and reduced in bad times.
- Timing is complicated and optimality is very difficult to achieve in light of the Lucas critique.
- Should capital ratios ever be reduced below the minimum viewed as sustainable?

ECONOMETRICS

- Estimate the fall in market capitalization of a firm in a financial crisis. Calculate the distribution of capital ratios that result.
- If losses are unaffected by the initial capital of the firm, then it is easy to compute both SRISK and Precautionary Capital.
- *However, it is likely that a well capitalized firm will have lower volatility and suffer less in a crisis.* How can we estimate this effect?
- STRUCTURAL GARCH

STRUCTURAL GARCH

- Engle and Siriwardane (2014)
- Recognizing that equity is a call option on the asset value of a firm, the moneyness of this option will affect its volatility.
- The moneyness of the equity option is a monotonic function of the debt to equity ratio.
- We estimate a model of equity prices by inferring a GJR-GARCH for asset values and a leverage multiplier.

Structural Models of Credit

- Under relatively weak assumptions on the vol process, structural models say $E_t = f(A_t, D_t, \sigma_{A,t}, \tau, r_t)$
  - A_t = market value of assets
  - D_t = book value of debt
  - $\sigma_{A,t}$ = stochastic asset volatility
- Generic dynamics for assets and asset variance (allow for jumps later):

$$\frac{dA_t}{A_t} = \mu_A(t)dt + \sigma_{A,t}dB_A(t)$$
$$d\sigma^2_{A,t} = \mu_v(t, \sigma_{A,t})dt + \sigma_v(t, \sigma_{A,t})dB_v(t)$$

- $B_A(t)$ and $B_v(t)$ potentially correlated

Equity Returns and Equity Volatility

Introducing the Leverage Multiplier

- Apply Itō Lemma and ignore $\mathcal{O}(dt)$ terms (daily equity returns ≈ 0):

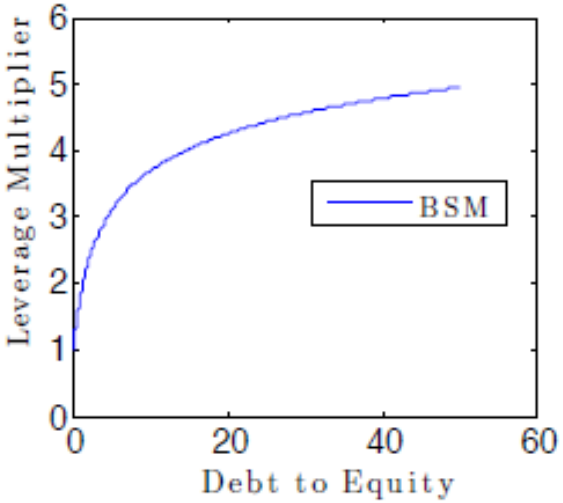
$$\begin{aligned}\frac{dE_t}{E_t} &= LM_t \sigma_{A,t} dB_A(t) + \frac{\nu_t}{E_t} \frac{\sigma_v(t, \sigma_{A,t})}{2\sigma_{A,t}} dB_v(t) \\ &\approx LM_t \times \sigma_{A,t} \times dB_A(t) \\ vol_t\left(\frac{dE_t}{E_t}\right) &\approx LM_t \times \sigma_{A,t}\end{aligned}$$

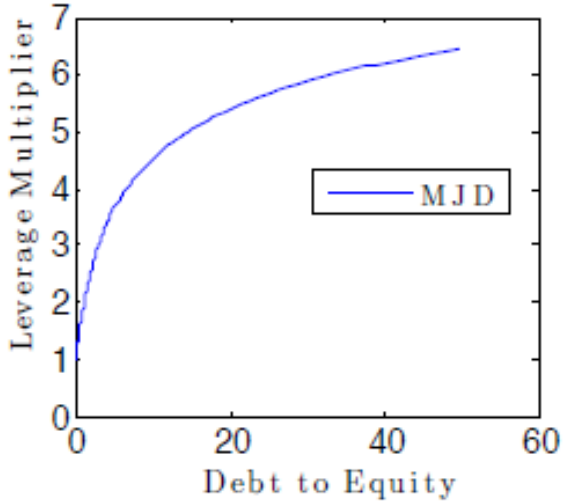
  where $LM_t = LM(E_t/D_t, 1, \sigma_{A,t}, \tau, r_t)$ is the "leverage multiplier"

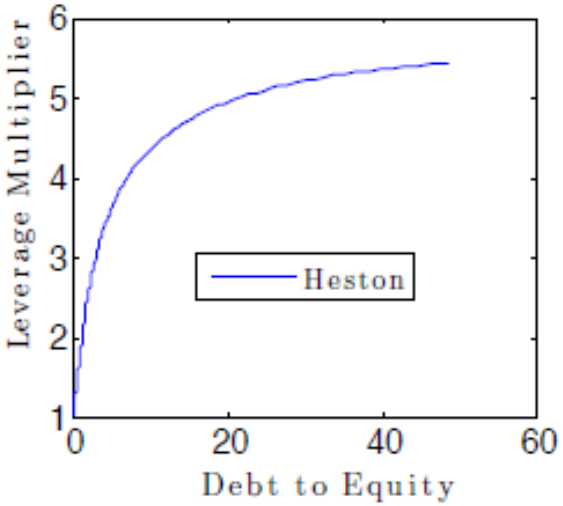
- LM_t amplifies asset shocks and volatility
- Two questions:
  1. How much does the higher order term contribute? Not Much
  2. What does LM_t look like? Robust shape across models

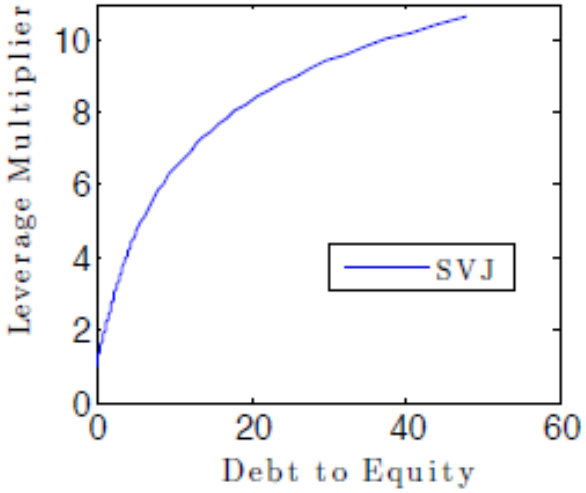
What Does the Leverage Multiplier Look Like?

Various Option Pricing Models



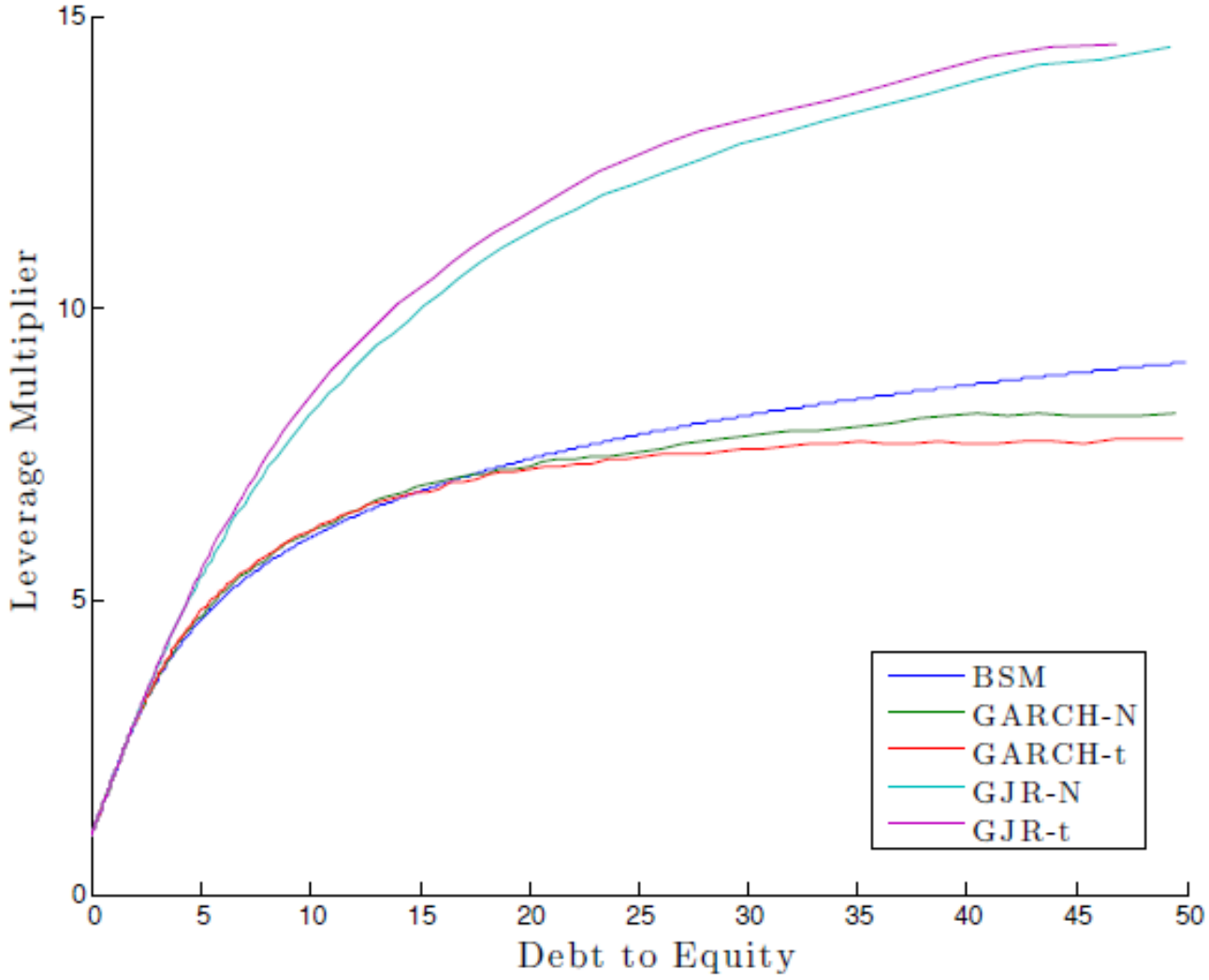






Leverage Multiplier with GARCH/Non-Normality

GARCH Parameters s.t. Unconditional Asset Volatility $= 0.15$. $\tau = 2, r = 0$



Our Specification

- The challenge is choosing the right functional form for LM_t
- We use simple transformations of Black-Scholes-Merton (BSM) functions:

$$LM_t(D_t/E_t, \sigma^f_{A,t}, \tau) = \left[\triangle^{BSM}_t \times g^{BSM}\left(E_t/D_t, 1, \sigma^f_{A,t}, \tau\right) \times \frac{D_t}{E_t} \right]^{\phi}$$

  $g^{BSM}(\cdot)$ is inverse BSM call function. Δ^{BSM}_t is BSM delta

- $\phi \neq$ specific option pricing model
- Our parametrization preserves necessary properties of LM, but stills retain some flexibility

The Full Recursive Model

Structural GARCH

$$r_{E,t} = LM_{t-1} \times \sqrt{h_{A,t}} \times \varepsilon_{A,t}$$

$$h_{A,t} \sim GJR(\omega, \alpha, \gamma, \beta)$$

$$LM_{t-1} = \left[\triangle_{t-1}^{BSM} \times g^{BSM} \left(E_{t-1}/D_{t-1}, 1, \sigma_{A,t-1}^{f}, \tau \right) \times \frac{D_{t-1}}{E_{t-1}} \right]^{\phi}$$

$$\sigma_{A,t-1}^{f} = \sqrt{\mathbb{E}_{t-1} \left[\sum_{s=t}^{t+\tau} h_{A,s} \right]}$$

So parameter set is $\Theta = (\omega, \alpha, \gamma, \beta, \phi)$

EMPIRICAL RESULTS

Estimation Details

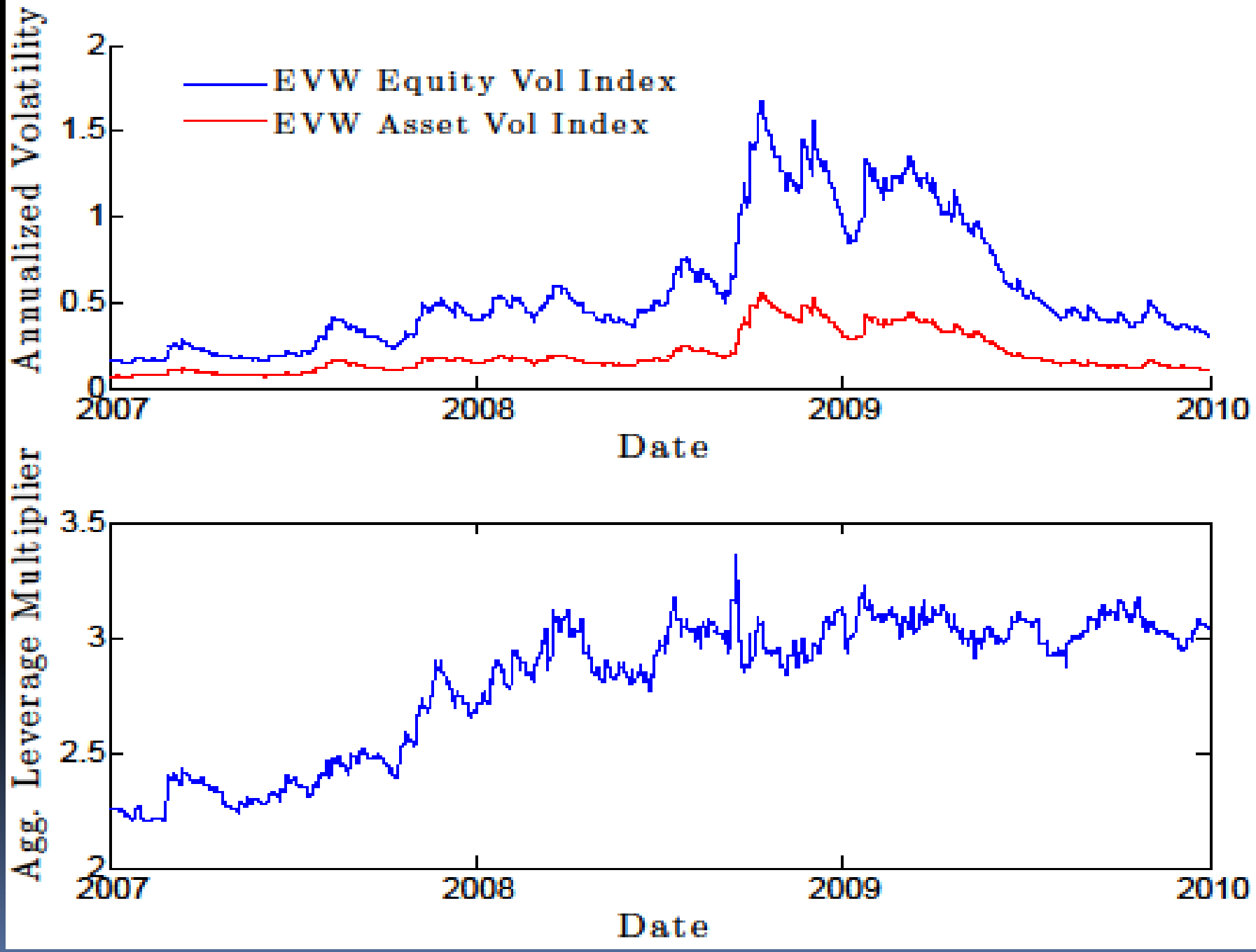
- Estimate for 82 financials via QMLE; iterate over $\tau \in [1, 30]$
- Equity returns and balance sheet information from Bloomberg
- D_t is exponentially smoothed book value of debt
  - smoothing parameter $= 0.01$, so half-life of weights ≈ 70 days
- We estimate the model using two approaches for $\sigma^f_{A,t-1}$, then use the highest likelihood:
  1. A dynamic forecast for asset volatility over life of the option
  2. The unconditional volatility of the asset GJR process

Parameter Values

Cross-Sectional Summary of Estimated Parameters

Parameter	Mean	Mean t-stat	% with $\lvert t \rvert > 1.64$
ω	2.7e-06	1.70	47.2
α	0.0458	3.07	86.1
γ	0.0721	2.91	80.6
β	0.9024	80.08	100
ϕ	0.9834	4.00	73.6

- Average $\tau = 8.34$
- Leverage matters


Annualized Volatility
EVW Equity Vol Index
EVW Asset Vol Index
2
1.5
1
0.5
0
2007
2008
2009
2010
Date
Agg. Leverage Multiplier
3.5
3
2.5
2
2007
2008
2009
2010
Date

Bank of America

Capital Shortfall: 2006-2011

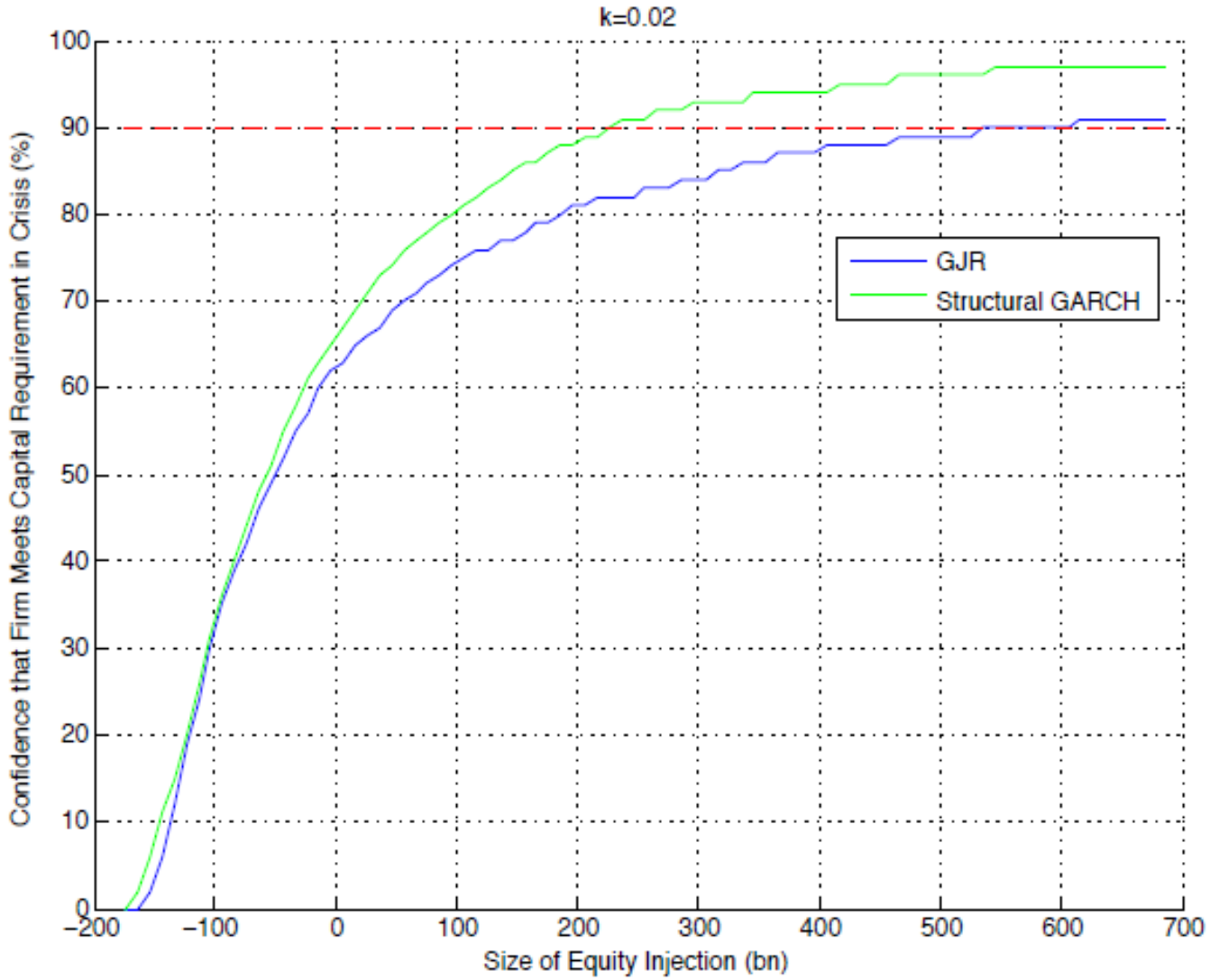
COMPUTE PRECAUTIONARY CAPITAL

BAC ON OCTOBER 1, 2008

- How much capital is needed today to be 90% certain that capital will not fall below 2% if the global market falls by 40%?

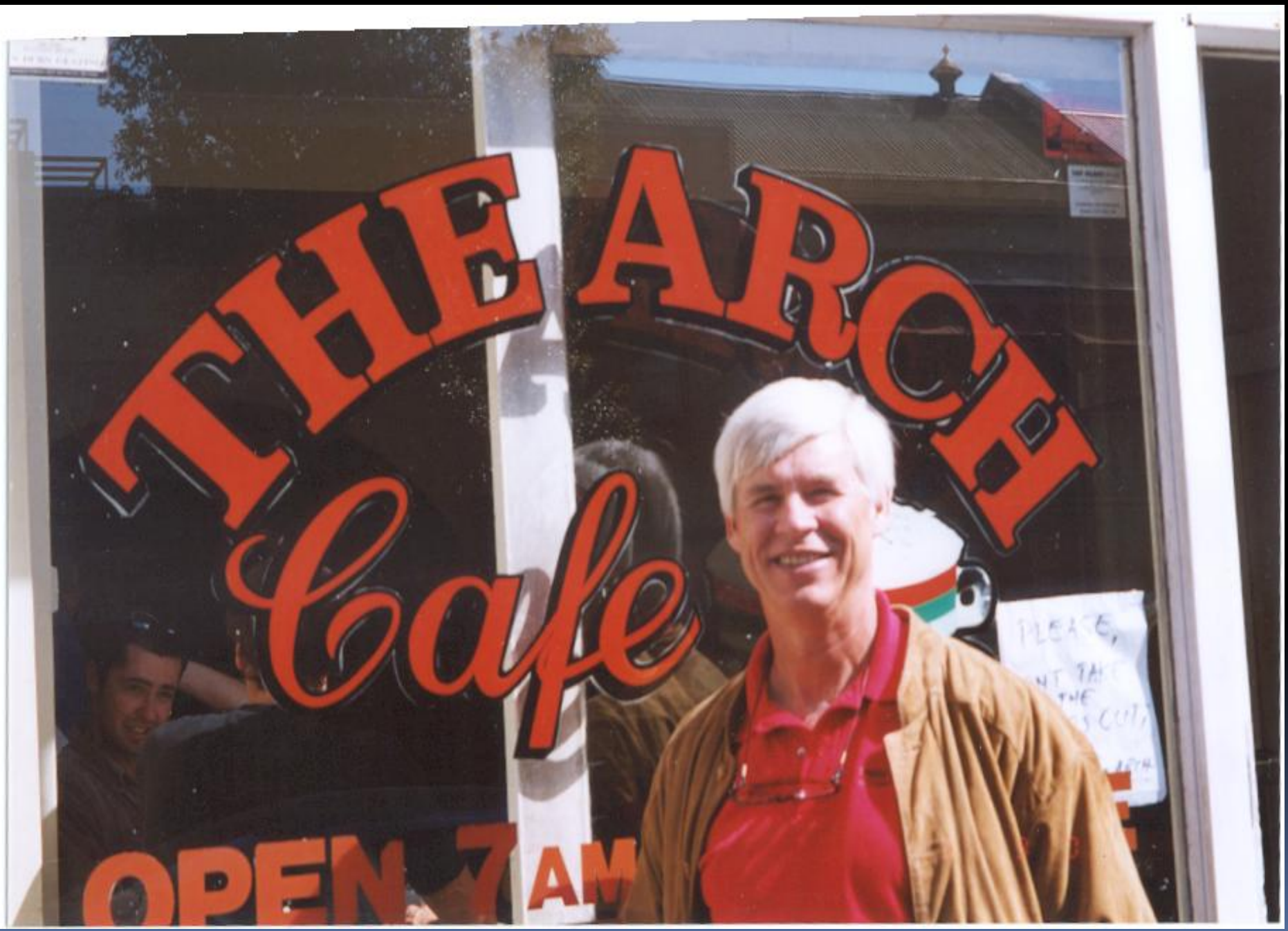
Precautionary Capital: BAC

BAC on 10/1/2008: $E_0 = 173.9$ bn; $D_0 = 1{,}670.1$ bn



WHAT THIS SHOWS

- Standard volatility models do not have a channel for leverage and therefore adding capital today does not reduce the volatility or beta.
- With Structural Garch, reducing leverage by increasing capital today will reduce risk in the future.


THE ARCH
Cafe
OPEN 7 AM