Aggregate and firm-level measures of systemic risk from a structural model of default

Alexander Reyngold, Moody's Analytics
Ksenia Shnyra, Moody's Analytics
Roger M. Stein, MIT LFE & Moody's Corp.

Consortium for Systemic Risk Analytics
Spring 2013 research meeting

Systemic Risk

- We define one type of systemic risk as:
  - Joint distress of SIFIs
  - Potential is high when there is tight coupling of firm credit fundamentals
  - *"A shock is more likely to propagate quickly and broadly when sources of risk are tightly coupled"* (Kritzman et al., 2010)
- We focus on credit risk but view systemic risk as distinct
  - Our measure highlights states of the world in which there is higher potential for a severe systemic event, but does not necessarily imply one will take place

Overview

- Aggregate measure (*Credit Absorption Ratio*):
  - We interpret this as a potential for a severe systemic event
  - Simple to calculate from publicly available data
  - Appears to provide some forward looking indication of systemic events
  - Can be estimated at regional (US, EU) or Global level

- Firm - level measure (*mean absolute loading*):
  - We interpret this as susceptibility of a firm to a systemic event *should one occur*
  - Forward looking – typically moves earlier than some other measures
  - NOT a measure as each bank's contributions to the risk of overall banking system
  - Can be scaled by CAR to transform to *absolute measure* of systemic risk

Motivation

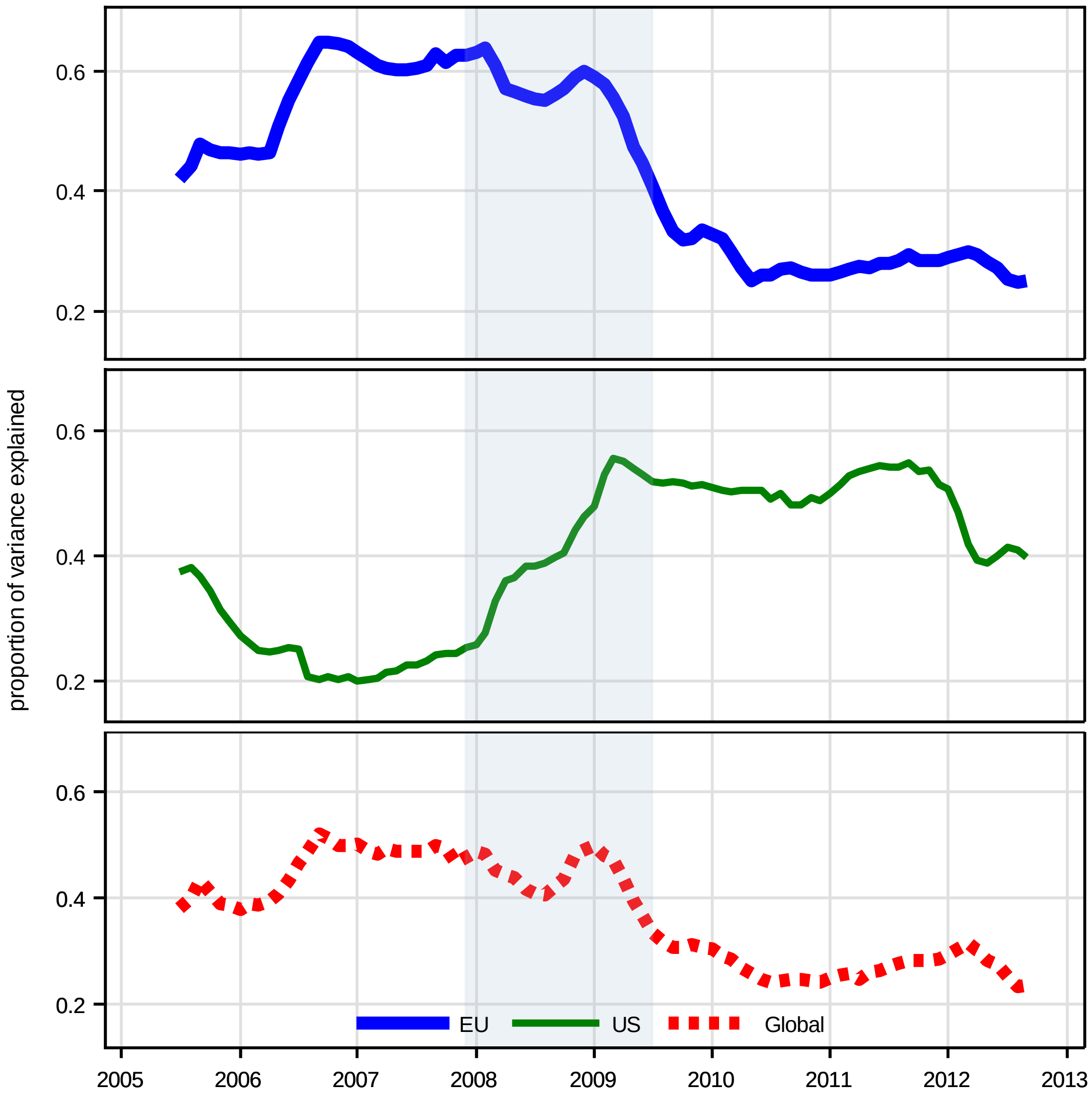
➤Credit Absorption Ratio (CAR)

- Extension of the Absorption Ratio (Kritzman et al. 2010)
- Time series of implied asset returns based on version of Merton's (1973) structural model of default
- Credit focus (only financial firms are considered)

➤Economic intuition

- A financial institution defaults when its asset value falls below the face value of its debt
- Over short horizon movements in assets cause changes in default probabilities
- Asset value movements are typically explained by a broad number of industry/geographic factors
- When this broad set of factors collapses into a much smaller set, the default probabilities become tightly coupled through common dependence

Regional CAR



Original Absorption Ratio (Kritzman, et al. 2010)

- Percentage of the total variance explained by several principal components

$$AR = \frac{\sum_{j=1}^{k} \lambda_j}{\sum_{j=1}^{m} \lambda_j}, \qquad \text{where}$$

$$\begin{aligned} AR &\equiv \text{absorption ratio} \\ m &\equiv \text{number of indices} \\ k &\equiv \text{number of eigenvectors used to calculate the AR} \\ \lambda_j &\equiv \text{variance of the } j^{th} \text{ principal component (the } j^{th} \text{ eigenvalue)} \end{aligned}$$

- The k is fixed at approximately at $m/5$, which in the empirical example corresponds to the $k = 10$ principal components

Credit Absorption Ratio

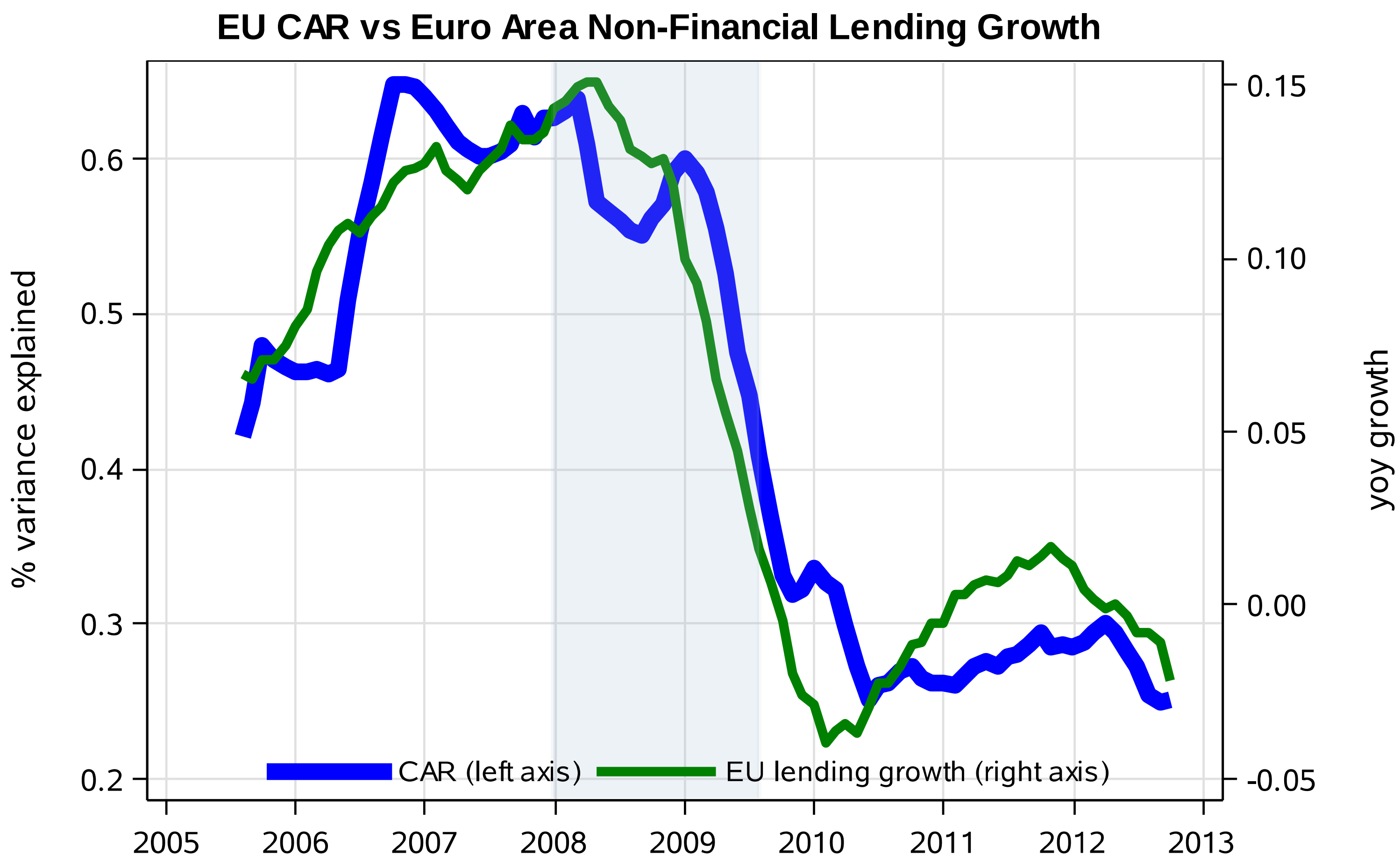
- The CAR utilizes Merton's structural model of default:
  - Market value of assets follows geometric Brownian motion where μ_A is the drift of the assets and σ_A is the asset volatility.

$$dA = \mu_A A dt + \sigma_A A dz,$$

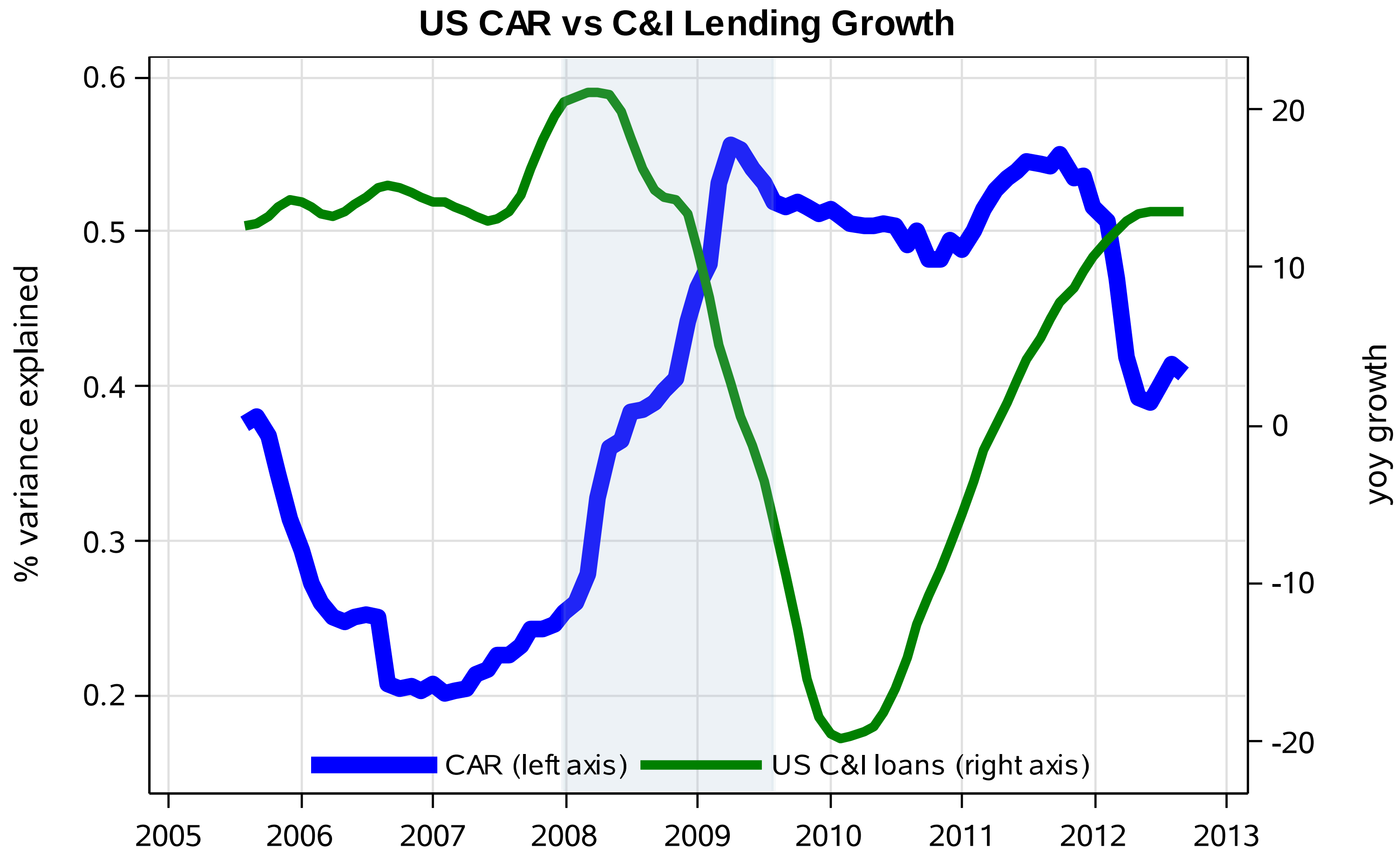
  - Default occurs when value of assets falls below the face value of debt.
  - Asset values are implied from equity prices and balance sheet information
- We perform PCA on the implied *asset returns of financial* firms, rather than on broad market indices
- CAR_t is defined as the percentage of the total variance explained by the first principal component at time t

$$CAR_t = \frac{\lambda_{1t}}{\sum_{j=1}^{m} \lambda_{jt}},$$

Case Study – EU CAR



Case Study – US CAR



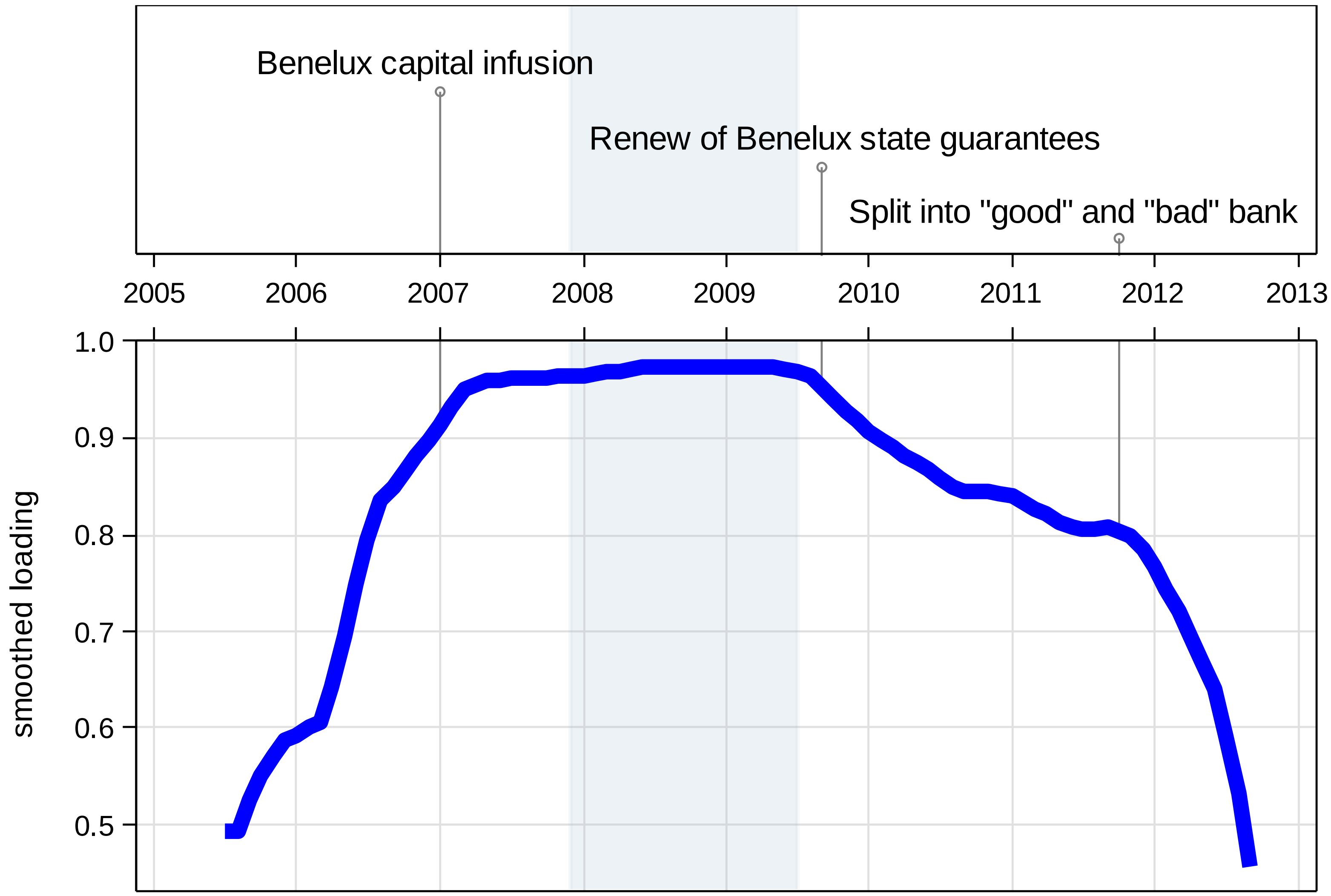
Firm Specific Measure

- We can also use PCA framework to measure the *susceptibility* of each bank to a systemic event
- We average the (absolute) loadings of firm *i* on the first PC over the 12 months ending at time *t* (λ_{it}):

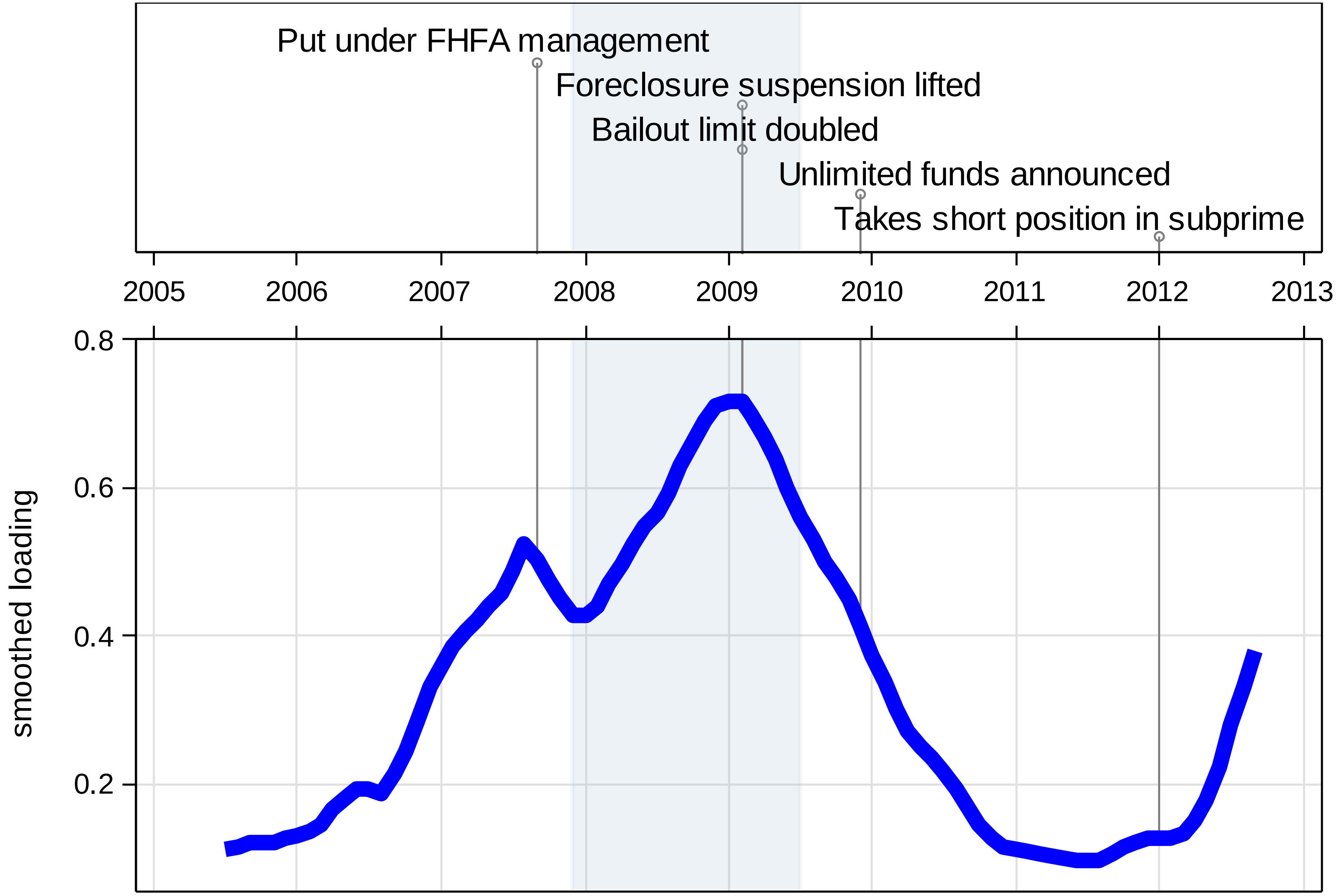
$$\tilde{\gamma}_{it} = \frac{1}{12} \sum_{\tau=t-11}^{t} |\gamma_{i\tau}|$$

- This measures the time *t* exposure of firm *i* to a systemic event *should one occur*
- This is a *conditional* measure
- An *absolute* measure may also be derived, though in the examples we show, the analysis was broadly similar in both cases

Case Study – Dexia



Case Study – Freddie Mac



Caveats

- There is a number of aspects of our work that suggest caution in interpreting our results:
  - *Time period examined:* Our data only cover the last decade
  - *Restatements of historical data:* Rare but sometimes occur as financial data are corrected
  - *Revision of asset value model by vendor*: may impact availability of the first portion of data series
  - *Focus on credit may (or may not) miss other risks:* E.g., impact of liquidity and how quickly it is incorporated is not known
  - Number of principal components used for CAR estimates (we provide analysis of $k=1..10$)
- We hope to explore some of these in future work

Conclusion

- Combination of original AR with economically motivated structural model of default gave rise to CAR
- Credit Absorption Ratio (CAR)
  - Measures coupling of the financial system
  - Increases when risk and correlation increase
  - Loadings on the CAR measure susceptibility of financial institutions to a systemic event
  - Economically motivated
- Empirically
  - *Ex ante* CAR appears to rise prior to the periods of financial distress
  - *Ex ante* loadings on CAR appear to rise prior to the distress of individual banks

Related Literature

- Monica Billio, Mila Getmansky, Andrew W. Lo, and Loriana Pelizzon. Measuring Systemic Risk in the Finance and Insurance Sectors. Social Science Research Network Working Paper Series, March 2010. URL http://ssrn.com/abstract=1571277.
- D. Bisias, M. Flood, A. Lo, and S. Valavanis. A survey of systemic risk analytics. Available at SSRN 1983602, 2012.
- J.R. Bohn and R.M. Stein. Active credit portfolio management in practice, volume 384. Wiley Online Library, 2009.
- M. Kritzman, Y. Li, S. Page, and R. Rigobon. Principal components as a measure of systemic risk. Available at SSRN 1582687, 2010.
- R.C. Merton. Theory of rational option pricing. The Bell Journal of Economics and Management Science, pages 141–183, 1973.