Are banks too big to fail

Measuring systemic importance of financial institutions

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Views expressed do not necessarily reflect the official positions of De Nederlandsche Bank

Quotation

Consolidated supervision of systemically important institutions, together with tougher capital, liquidity, and risk-management requirements for those firms, is needed not only to protect the firms' stability and the stability of the financial system as a whole, but also to reduce firms' incentive to grow very large in order to be perceived as too big to fail.

– Bernanke, Oct 23, 2009

Reading the quotation

- **Literally**
  - The stability of systemically important firms is crucial for the stability of the financial system.
  - Potential moral hazard problem
  - Call for strengthening regulatory policies on systemically important firms.

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- **Literally**
  - The stability of systemically important firms is crucial for the stability of the financial system.
  - Potential moral hazard problem
  - Call for strengthening regulatory policies on systemically important firms.
- **More...**
  - Financial system has to be viewed as a whole.
  - Still using ”too big to fail”?
  - Call for measures on ”systemic importance”.

Purpose of this study

- Provide systemic importance measures.
- Comparison among potential measures.
- Test the ”too big to fail” argument.

Literature

Contagion and systemic risks

- **Direct channel:** interbank market
  - Theoretical models on explaining crises contagion within TWO institutions.
  - From bilateral contagion to systemic risk – Models on networks.
- **Indirect channel:** similar portfolio holdings
  - Cifuentes et al. (2005) consider both channels, and show that the indirect channel dominates.
  - The indirect channel view does not provide causality.

Systemic importance measures

- **CoVaR** – Adrian and Brunnermeirer (2009)
  - Conditional VaR of the system (or bank B) given the crisis of bank A.
  - Comparing CoVaR with unconditional VaR gives the systemic importance of bank A.
  - Drawback: bilateral measure
  - Difficult to generalize into a systemic context

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  - Difficult to generalize into a systemic context
- **PAO** – Segoviano and Goodhart (2009)
  - The probability that at least one bank becomes distressed given the crisis of bank A.
  - It is in a systemic context (multivariate).
  - Potential drawback: less informative.

Methodology and data used in literature

- **CoVaR**
  - Data: equity returns; balance sheet data
  - Methodology: quantile regression
- **PAO**
  - Data: equity returns
  - Methodology: copula modeling

Modeling systemic risk

Copula and dependence

Copula

- A concept to decompose marginal information and dependence structure

$$F(x_1, \cdots, x_d) = C(F_1(x_1), \cdots, F_d(x_d))$$

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Drawback

- Statistical models on copula usually have no economic justification.
- Modeling full copula may misspecify tail dependence.

Extreme Value Theory and tail dependence

- **Fundamental assumption in MEVT**
  As $p \to 0$, for all $x_1, \cdots, x_d > 0$,

$$\frac{P\left(X_1 > VaR_1(x_1 p) \text{ or } \cdots \text{ or } X_d > VaR_d(x_d p)\right)}{p} \to L(x_1, x_2, \cdots, x_d).$$

- **In "Copula" language**

$$\frac{1 - C(1 - px_1, \cdots, 1 - px_d)}{p} \to L(x_1, x_2, \cdots, x_d).$$

Only an assumption on the extreme co-movements!

Why MEVT is relevant for modeling systemic risk?

- Characterizing extreme co-movements.
- Measuring systemic linkage

$$L(1,1,\cdots,1) \approx \frac{P\left(X_1 > VaR_1(p) \text{ or } \cdots \text{ or } X_d > VaR_d(p)\right)}{p}.$$

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Models on L

- From economic model
- From empirical estimation

Systemic importance measures

PAO in MEVT framework

Explicit definition of PAO

$$PAO_i(p) := P(\{\exists j \neq i, \text{ s.t. } X_j > VaR_j(p)\} \,|X_i > VaR_i(p)).$$

Taking $p \to 0$,

$$PAO_i := \lim_{p \to 0} PAO_i(p) = L_{\neq i}(1, 1, \cdots, 1) + 1 - L(1, 1, \cdots, 1),$$

with $L_{\neq i}(1, 1, \cdots, 1) = L(1, 1, \cdots, 1, 0, 1, \cdots, 1)$.

- Having L function is sufficient for calculating PAO_i.
- PAO_i is an approximation of $PAO_i(p)$ with low p.

An example on the limitation of PAO

Setup of the example

- A banking system consisting of 10 banks.
- 10 Banks are separated into two groups.
- Group A contains Bank 1 and 2; Group B contains the other eight (3-10).
- Banks within the same group are strongly linked.
- Banks from different groups are independent.

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PAO stays high and constant, across banks, and across time!

Our measure: systemic importance index

- **Definition:** The expected number of crises given the crisis of Bank A
- **Explicit expression**

$$SII_i(p) := E(\sum_{j=1}^{d} 1_{X_j > VaR_j(p)} | X_i > VaR_i(p))$$

- **Calculation under MEVT**

$$SII_i := \lim_{p \to 0} SII_i(p) = \sum_{j=1}^{d} (2 - L_{i,j}(1,1))$$

Comparison between PAO and SII

- **Differences**
  - PAO considers the probability of having an impact
  - SII considers the magnitude of the systemic impact
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- **Common points**
  - The limits of both measures can be calculated from the L function
  - Both measures consider the impact of the crisis of one bank to the systemic risk
- **Question**
  How to quantify the impact of the system stress to one bank?

Vulnerability Index

- **Definition:** The probability of Bank A being in crisis given the distress of the system defined by that at least one other banks is in crisis
- **Explicit expression**

$$VI_i(p) := P(X_i > VaR_i(p) | \{\exists j \neq i, \text{ s.t. } X_j > VaR_j(p)\}).$$

- **Connection to PAO**
  Swapping the two items in the conditional probability
- **Calculation under MEVT**

$$VI_i := \lim_{p \to 0} VI_i(p) = \frac{L_{\neq i}(1, 1, \cdots, 1) + 1 - L(1, 1, \cdots, 1)}{L_{\neq i}(1, 1, \cdots, 1)}$$

Comparison among PAO, SII, and VI

- **Common points:**
  - They are all in a systemic context (multivariate).
  - Their limit can be calculated from the L function under MEVT.
- **Connections**
  - PAO and SII consider the impact from the crisis of one bank to the systemic risk; VI considers the opposite.
  - PAO and VI are equally informative (MEVT calculation)
- **Potential difference**
  SII might be more volatile across banks and across time.

”Too big to fail”

Testing strategy

- **General question**
  Are larger banks more systemically important?
- **Detailed plan**
  - **Theoretically**
    - Build a simple economic model: both size and the L function can be easily calculated out.
    - Compare the order of the size and the systemic importance measures
  - **Empirically**
    - Estimate the L function and thus the systemic importance measures.
    - Test the correlation between the size measures and the systemic importance measures.

Theoretical model – idea

- Consider indirect channel models
- The model contains at least 3 banks
- Banks should differ in size
- Heavy-tailed distributions for modeling loss returns

Model setup (1)

- Three banks (X) hold three independent projects (Y).
- X_1 holds capital 2, while X_2 and X_3 hold capital 1 each. Hence, the size (total investment) of X_1 is larger.
- Y_1 demands capital 2, while Y_2 and Y_3 demand capital 1 each.

- The capital market is cleared by an affine portfolio model

$$\begin{cases} X_1 &= (2-2\gamma)Y_1 + \gamma Y_2 + \gamma Y_3 \\ X_2 &= \gamma Y_1 + (1-\gamma-\mu)Y_2 + \mu Y_3, \\ X_3 &= \gamma Y_1 + \mu Y_2 + (1-\gamma-\mu)Y_3, \end{cases}$$

with $0 < \gamma, \mu < 1$ and $\gamma + \mu < 1$.

Model setup (2)

- The loss returns of the three projects follow the same heavy-tailed distribution

$$\begin{cases} P(Y_i > s) & \sim As^{-\alpha}, \ i = 1, 2, \\ P(Y_i < -s) & = o(P(Y_i > s)), \end{cases}$$

where $\alpha > 0$ is the tail index.

Remark

- The affine portfolio model is very specific.
- Nevertheless, it is sufficient to demonstrate that "too big to fail" is not always valid.

Theoretical results

- **Equivalence among systemic importance measures:**
  In a three-bank model, SII follows the same order as PAO and VI. We only need to focus on SII.

Theoretical results

- **Equivalence among systemic importance measures:** In a three-bank model, SII follows the same order as PAO and VI. We only need to focus on SII.
- **Main results**
  - If $\frac{2}{3} < \gamma < 1$, $SII_1 < SII_2 = SII_3$. **"TBTF" fails**
  - If $\gamma = 1/2$, $SII_1 \geq SII_2 = SII_3$. **"TBTF" holds** The equality holds if and only if $\mu = 1/4$.
  - If $0 < \gamma < \frac{1}{3}$, there exists a $\mu^* < \frac{1-\gamma}{2}$, such that
    - For any $\mu \in (\mu^*, 1-\gamma-\mu^*)$, $SII_1 < SII_2 = SII_3$. **"TBTF" fails**
    - For any $\mu \in (0, \mu^*) \cup (1-\gamma-\mu^*, 1-\gamma)$, $SII_1 > SII_2 = SII_3$. **"TBTF" holds**
    - For $\mu = \mu^*$ or $\mu = 1-\gamma-\mu^*$, $SII_1 = SII_2 = SII_3$.

The model

$$\begin{cases} X_1 &= (2-2\gamma)Y_1 + \gamma Y_2 + \gamma Y_3 \\ X_2 &= \gamma Y_1 + (1-\gamma-\mu)Y_2 + \mu Y_3, \\ X_3 &= \gamma Y_1 + \mu Y_2 + (1-\gamma-\mu)Y_3, \end{cases}$$

When γ is close to 1,

- Large bank X_1 focuses on two small projects.
- Two small banks focus on the large projects.
- X_1 is quite different from the others.
- Two small banks are quite similar.

The large bank is not ”too big to fail”!

Interpreting the results: $\gamma = \frac{1}{2}$

The model

$$\begin{cases} X_1 &= (2-2\gamma)Y_1 + \gamma Y_2 + \gamma Y_3 \\ X_2 &= \gamma Y_1 + (1-\gamma-\mu)Y_2 + \mu Y_3, \\ X_3 &= \gamma Y_1 + \mu Y_2 + (1-\gamma-\mu)Y_3, \end{cases}$$

When $\gamma = \frac{1}{2}$,

- Large bank X_1 invests (1,1/2,1/2) at three projects.
- That creates linkages with the other two small banks.

The large bank is "too big to fail"!

Interpreting the results: $0 < \gamma < \frac{1}{3}$

The model

$$\begin{cases} X_1 &= (2-2\gamma)Y_1 + \gamma Y_2 + \gamma Y_3 \\ X_2 &= \gamma Y_1 + (1-\gamma-\mu)Y_2 + \mu Y_3, \\ X_3 &= \gamma Y_1 + \mu Y_2 + (1-\gamma-\mu)Y_3, \end{cases}$$

When γ is close to 0, $\mu \in (0, 1-\gamma)$,

- Large bank X_1 focuses on the large project.
- Two small banks focus on two small projects.
- When μ is close to the corners, two small banks differ.
- When μ lies in the middle, two small banks are similar.

The systemic importance of a bank may depend on the others.

Conclusion from the theoretical model

- ”Too big” is not necessarily the reason for being too systemically important.
- Having a balance sheet exposing to more risky projects would corresponds to high systemic importance.
- The systemic importance of a bank depends on its own strategies as well as what others do.

Conclusion from the theoretical model

- ”Too big” is not necessarily the reason for being too systemically important.
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More discussion:

Regarding ”projects” as ”banking activities”:

- Diversified activities help reduce individual risk
- However, it creates linkages, thus systemic importance
- Growing with speciality may avoid ”too big to fail”

There is a tradeoff between managing individual risk and keeping independency from the systemic risk.

Empirical analysis

- **Data**
  - Daily equity returns
  - 28 US financial institutions (including large and small)
  - Listed on NYSE from 1987 to 2009 (23 years)
  - Measures on size: TA, TE, TD (yearly)
- **Methodology**
  - L function: Multivariate Extreme Value Statistics
  - Calculating PAO, SII, VI
  - Pearson Correlation between the size measures and the systemic importance measures across different banks

Estimated systemic importance measures

BANKS	SII	PAO	VI
BANK OF AMERICA	10.84	94.44%	10.28%
CITIGROUP	10.59	90.56%	9.90%
CMTY.BK.SY.	6.53	59.44%	6.73%
JP MORGAN CHASE & CO.	9.76	86.67%	9.52%
KEYCORP	12.44	93.33%	10.18%
SUNTRUST BANKS	12.11	92.78%	10.12%

Observations:

- PAO measures are all around 80% except CMTY.BK.SY.
- SII measures vary more than PAO and VI.
- Banks with top three PAO are different from banks with top three SII.

Correlations

		SII	PAO	VI
	Total Asset	0.1790	0.3968**	0.3943**
		(0.3622)	(0.0366)	(0.0379)
End of 2009	Total Equity	0.1954	0.4085**	0.4061**
		(0.3191)	(0.0309)	(0.0320)
	Total Debt	0.1399	0.3640*	0.3615
		(0.4777)	(0.0569)	(0.0588)*
	Total Asset	0.1733	0.3746**	0.3723*
		(0.3779)	(0.0495)	(0.0510)
Average	Total Equity	0.1811	0.3824**	0.3802**
		(0.3565)	(0.0446)	(0.0460)
	Total Debt	0.1542	0.3546*	0.3523*
		(0.4334)	(0.0641)	(0.0660)

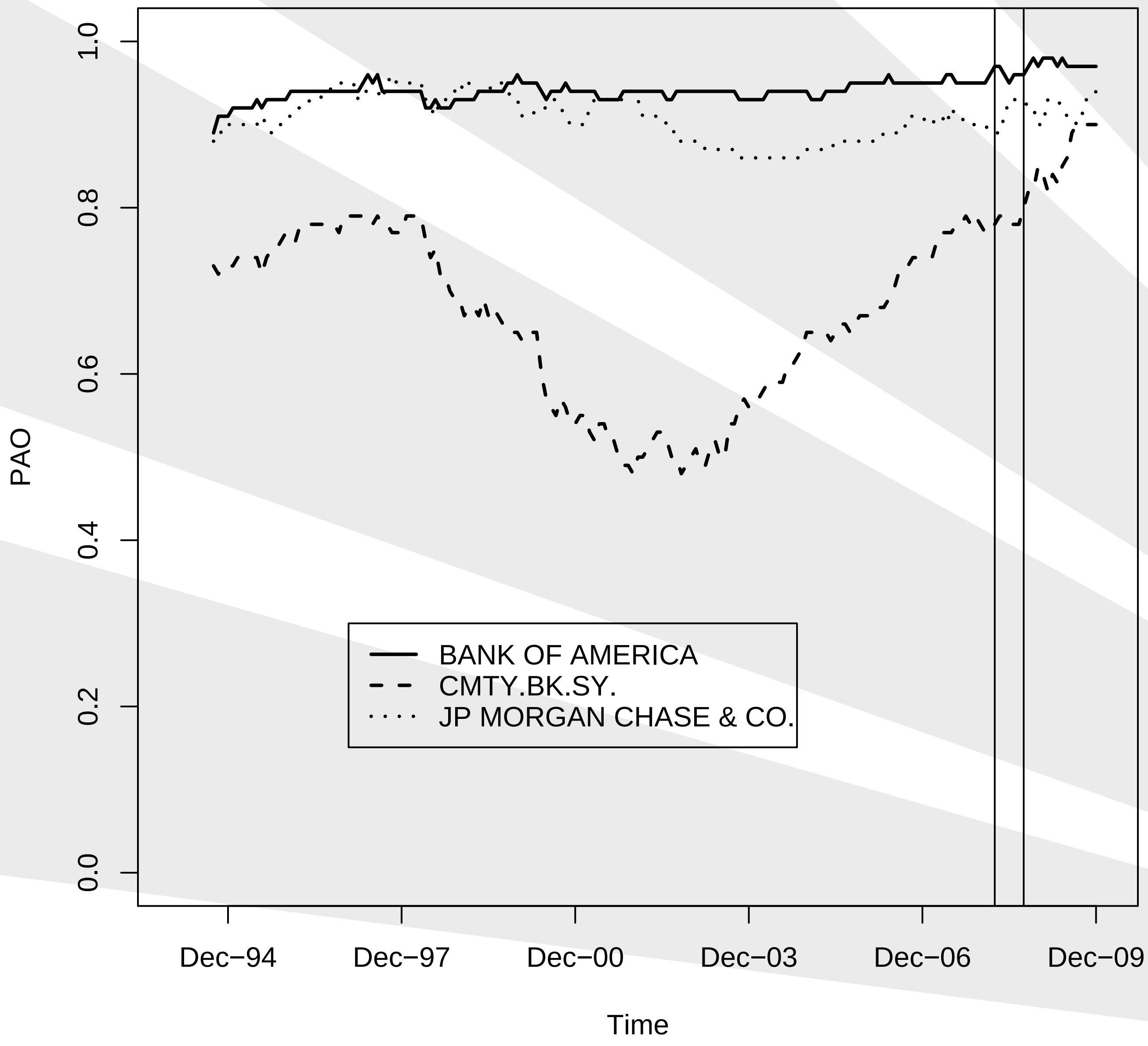
SII is different from PAO and VI.

Systemic importance measures across time

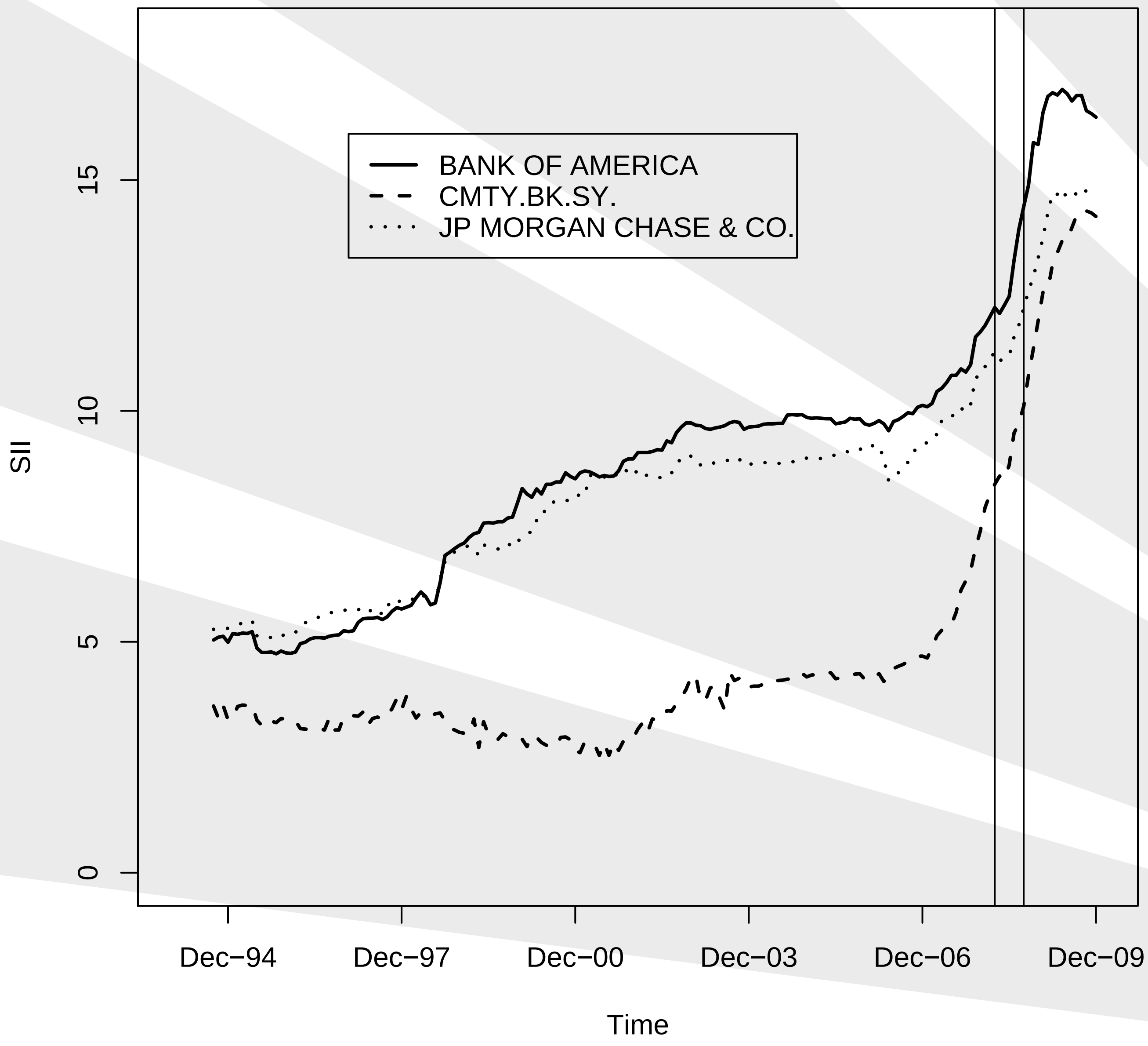
Moving window analysis

- Systemic importance measures are estimated from data in a 2000-day window.
- Estimation windows end with end of each months starting from Sept. 1994.
- Results in monthly-frequency time series on the systemic importance measures.

Moving window results on PAO



Moving window results on SII



Observations from moving window results

- SII measures have a sharp rising in recent crises for all banks.
- PAO measures lie in a stable (and high) level across time

SII measure seems to be more informative. However, all three measures should be considered in identifying systemically important bank.

Robustness check from moving window results

		SII	PAO	VI
Full sample	Total Asset	0.0263	0.2073	0.2069
	Total Equity	0.0418	0.2242	0.2236
	Total Debt	-0.0080	0.1665	0.1667
Period 1: 1994-1999	Total Asset	0.4541**	0.4950***	0.4911***
	Total Equity	0.4490**	0.4913***	0.4875***
	Total Debt	0.4648**	0.5014***	0.4973***
Period 2: 2000-2009	Total Asset	0.0263	0.2073	0.2069
	Total Equity	0.0418	0.2242	0.2236
	Total Debt	-0.0080	0.1665	0.1667

"TBTF" fails in more recent years.

Conclusion, discussion and more...

Conclusions

- **Systemic importance measures**
  - Three measures: PAO and SII measure the impact of one bank on the system, VI measures the opposite.
  - Comparison: SII is more informative. The other two measures are stable, both across banks and across time.
- **Testing ”too big to fail”**
  - Not always valid! (both theoretical and empirical)
  - Empirical results show that ”TBTF” is not valid in recent years.
- **Discussion**
  – Diversification tradeoff, macro-prudential, ...