BANK FOR INTERNATIONAL SETTLEMENTS

Allocating systemic risk across institutions: Methodology and Policy Applications

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Focus on the system

- Key lesson from crisis:
  - Emphasis on the system
  - Policy objective to mitigate systemic risk
  - “Macroprudential” approach
- Many prudential tools are institution-specific
- Instruments need to be calibrated on the basis of individual firm’s contribution to system-wide risk

Disclaimer

The views expressed here are my own and not necessarily those of the Bank for International Settlements or the Basel Committee on Banking Supervision

Contributions of this paper

- Propose an allocation procedure of systemic risk to individual institutions based on the “Shapley Value”
  - Efficient, fair, general and robust
- Use the procedure to illustrate the relative importance of different drivers of system-wide risk
  - Size, individual risk and interconnectedness
- Use it to demonstrate how policy tools can be designed to deal with the externalities of systemic importance
  - Macroprudential tools

Allocating systemic risk: Shapley value

- The Shapley value methodology has one requirement:
  - a characteristic function, which …
  - … maps any subgroup of institutions into a measure of risk

- The *Shapley value* of an institution = its *average contribution to the risk of all subgroups of institutions in the system*.

$$ShV_i(\Sigma) = \frac{1}{n}\sum_{n_S=1}^{n}\frac{1}{c(n_s)}\sum_{\substack{S\supset i\\ |S|=n_s}}\left(\vartheta(S)-\vartheta(S-\{i\})\right)$$

- Degree of systemic importance = Shapley value

Simple example with the Shapley value

- Three players: A, B and C

Subgroup	Subgroup output	Marginal contribution of A	Marginal contribution of B	Marginal contribution of C
A	4	4	.	.
B	4	.	4	.
C	4	.	.	4
A, B	9	5	5	.
A, C	10	6	.	6
B, C	11	.	7	7
A, B, C	15	4	5	6
Shapley value	.	4.5	5	5.5

Why Shapley value?

- Efficient: allocates total quantity of risk exactly
- Fair: allocates risk according to contributions
  - Includes all bilateral links
- Flexible: can be applied to any portfolio measure of system-wide risk
- Robust to model uncertainty: allocations corresponding to different models can be combined in a straight forward (linear) way to produce robust estimate of systemic contribution

Application using Expected Shortfall

- Define system-wide risk as the credit risk on the combined portfolio of liabilities of “banks” in the system
  - Think of the deposit insurer’s problem
- Expected Shortfall as the risk metric
  - Expected loss in the tail
- Used single-factor default mode model
  - A bank pays back or defaults and pays 1-LGD

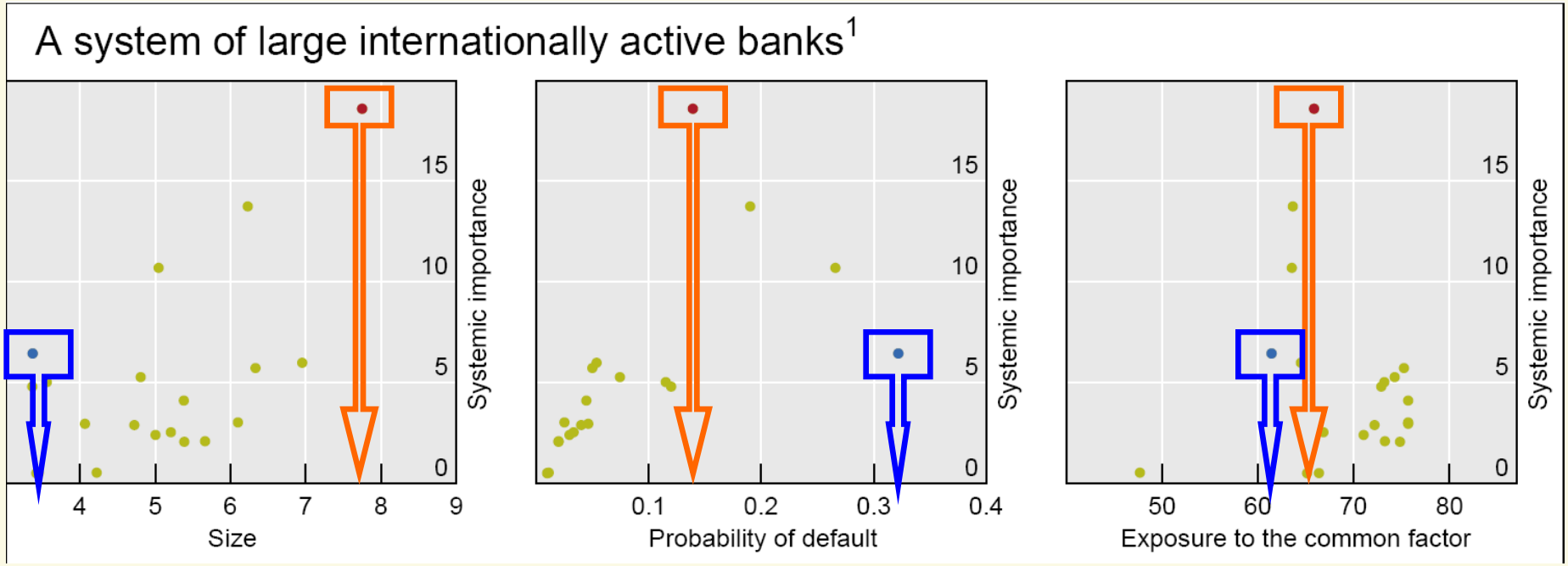
Application using Expected Shortfall

- Use two different value functions
  - Constant conditioning event, like in *Acharya et al (2009) and Huang, Zhao, Zhu (2009)*
  - Conditioning event dependent on the identity of the coalition

- Results are not identical but technology is equally applicable

Different drivers of systemic importance

- Drivers considered: size, PD, exposure to common factor



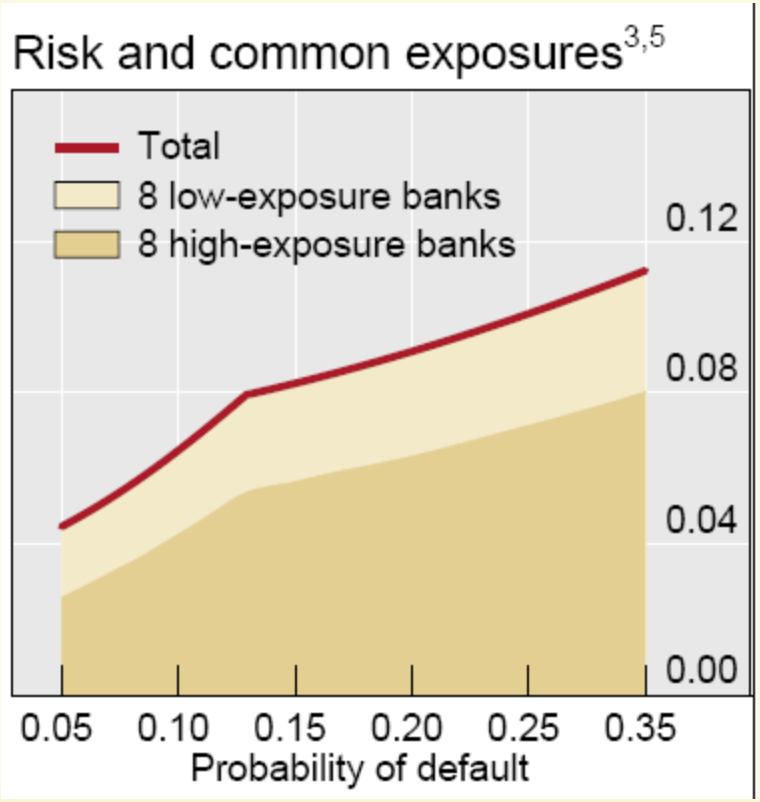
- No single driver explains satisfactorily systemic importance …

The impact of PD and common-factor exposure

- Intuitive results
- An increase in the PD raises systemic importance
- Higher exposure to the common factor …
  - … implies that the bank is more likely to fail with others
  - raises systemic importance

Interaction between different drivers

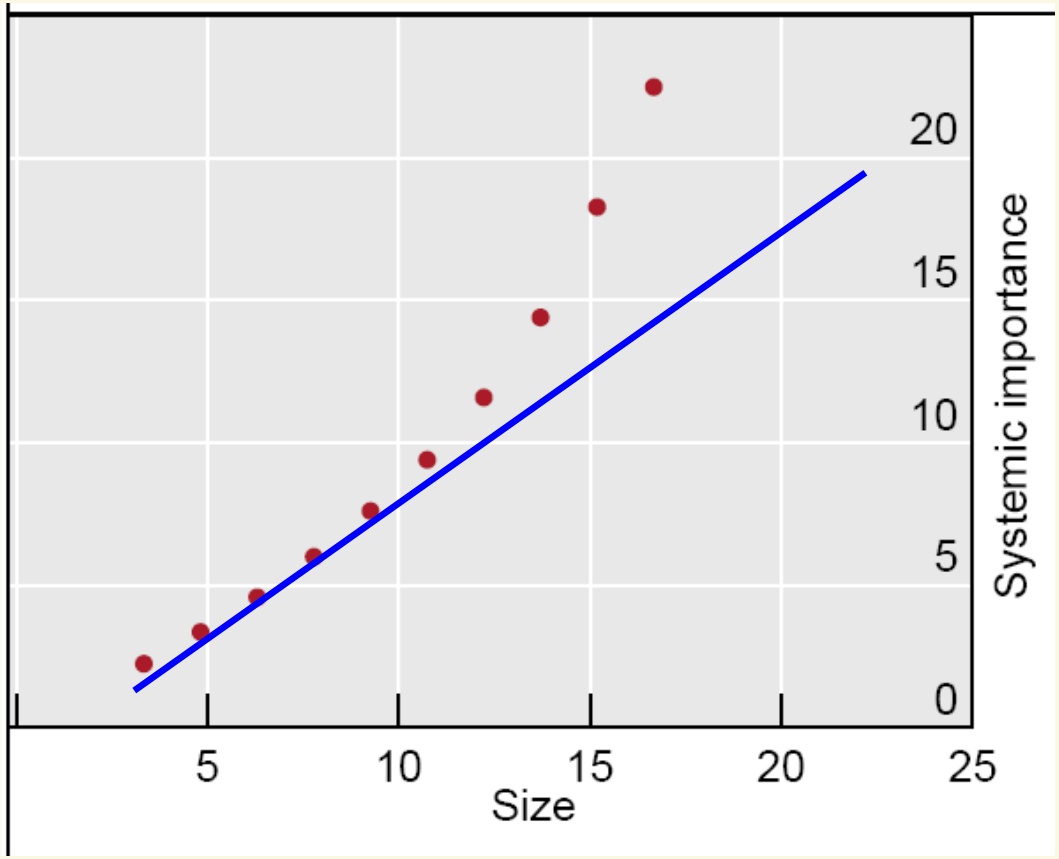
- Changes in PD have a greater impact on the systemic importance of institutions that are more exposed to the common factor …



Impact of size

- Ceteris paribus systemic importance increases at least proportionately with size of the institution

Size: a convex impact on systemic importance



Impact of size

- Ceteris paribus systemic importance increases at least proportionately with size of the institution

- Theorem:
  - Two banks {B,S} that are identical except for size
  - B is larger than *S*
  - ShV(*B*) / ShV(*S*) > size of (*B)* / size of *(S*)

Impact of size

- Ceteris paribus systemic importance increases at least proportionately with size of the institution

- Intuition: larger banks appear more often in tail events
  - ES is the expected loss conditional on being at the tail
  - For each tail event that includes S there must be another that includes the same group of banks and B instead of S

- Proof is possible because of Shapley Value structure

Policy intervention: “macro” vs “micro”

- Objective of the intervention
  - Attain a given level of systemic risk
  - Equalise systemic importance across institutions, controlling for institutions’ sizes
- Stylised system (mechanical application)
  - Higher capital → lower PD

Policy intervention: concrete example

	0. Initial system		1. Attain target level of systemic risk (ES =10) with equal PDs		2. Equalise contributions to systemic risk (keeping ES = 10)	
	Share in total ES	**PD (Capital)**	**Share in total ES**	**PD (Capital)**	**Share in total ES**	**PD (Capital)**
Five banks with a **low** exposure to the common factor (ρ_{low} = *0.30*)	34%	0.31% (4.0%)	37%	0.2% (4.47%)	50%	0.40% (3.7%)
Five banks with a **high** exposure to the common factor (ρ_{high} = *0.70*)	66%	0.31% (4.0%)	63%	0.2% (4.47%)	50%	0.15% (4.8%)
Memo: *Total ES and capital*	*12.5* (100%)	*(4.0%)*	*10* (100%)	*(4.47%)*	*10* (100%)	*(4.25%)*

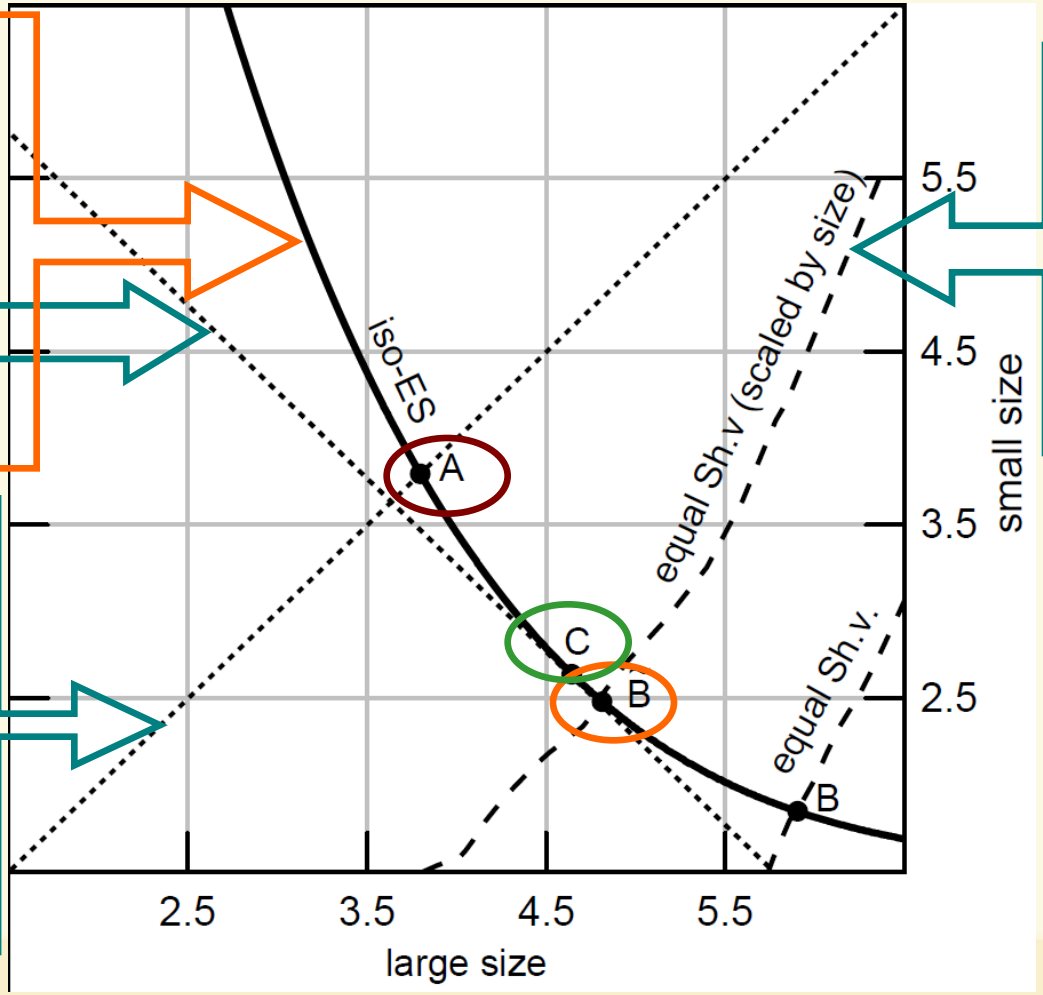
- "Efficiency" result: greater loading on systematic risk implies that a given change in capital (ie PD) has a greater impact on systemic importance
- Opposite outcome also possible, if there are more interactions …

Banks that differ only in size

Capital charge combinations that result in target level of system-wide risk

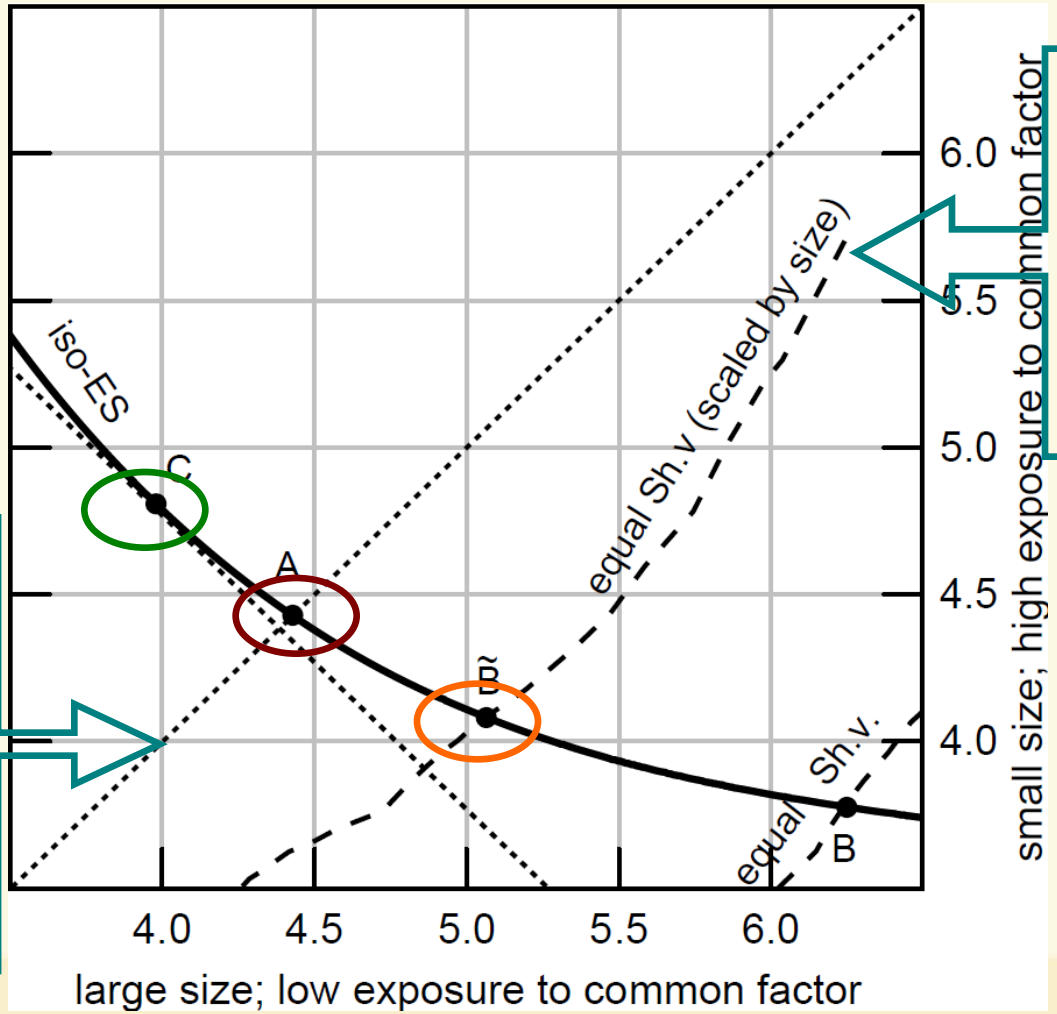
Minimum total capital combinations

Equal capital charges to both institutions



Capital charges that equate contributions to system-wide risk

Banks that differ in size and correlation



Capital charges that equate contributions to system-wide risk

Equal capital charges to both institutions

Conclusions

- Shapley methodology provides a neat way to allocate risk
  - Flexibility and robustness
- Attribution of risk needs to look at all drivers and interactions
  - Importance of models
  - Size has a non-linear effect
- Macroprudential policy can lead to re-allocation of capital

Thank you!

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