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

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?

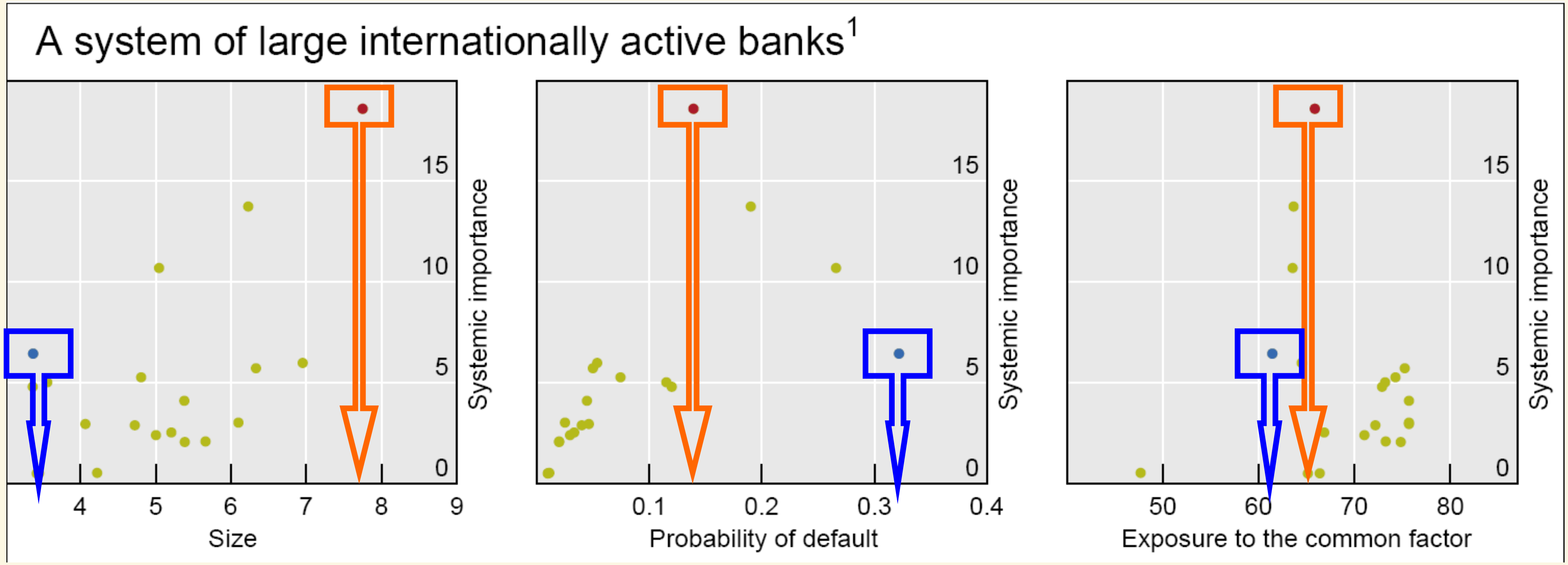
- Efficient: allocates total quantity of risk exactly
- Fair: allocates risk according to contributions
  - Includes all bilateral links
- Flexible: can be applied to <u>any</u> portfolio measure of system-wide risk
- Robust to model uncertainty: allocations corresponding to different models can be combined 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
- Use two different value functions (1) constant conditioning event [*Acharya et al (2009) and Huang, Zhao, Zhu (2009)]* (2) conditioning event dependent on coalition

Different drivers of systemic importance

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



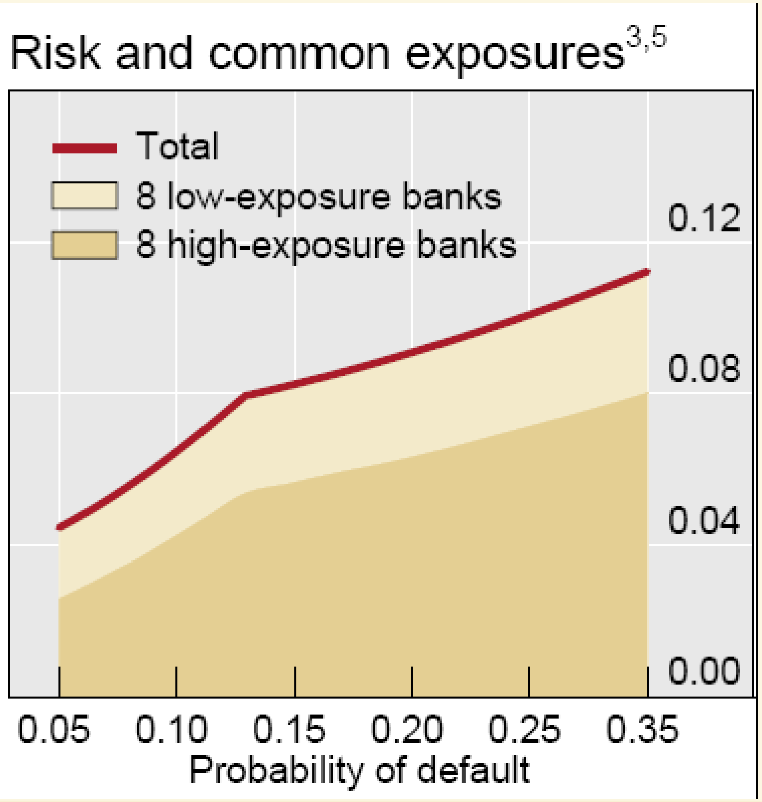
- No single driver explains satisfactorily systemic importance …

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

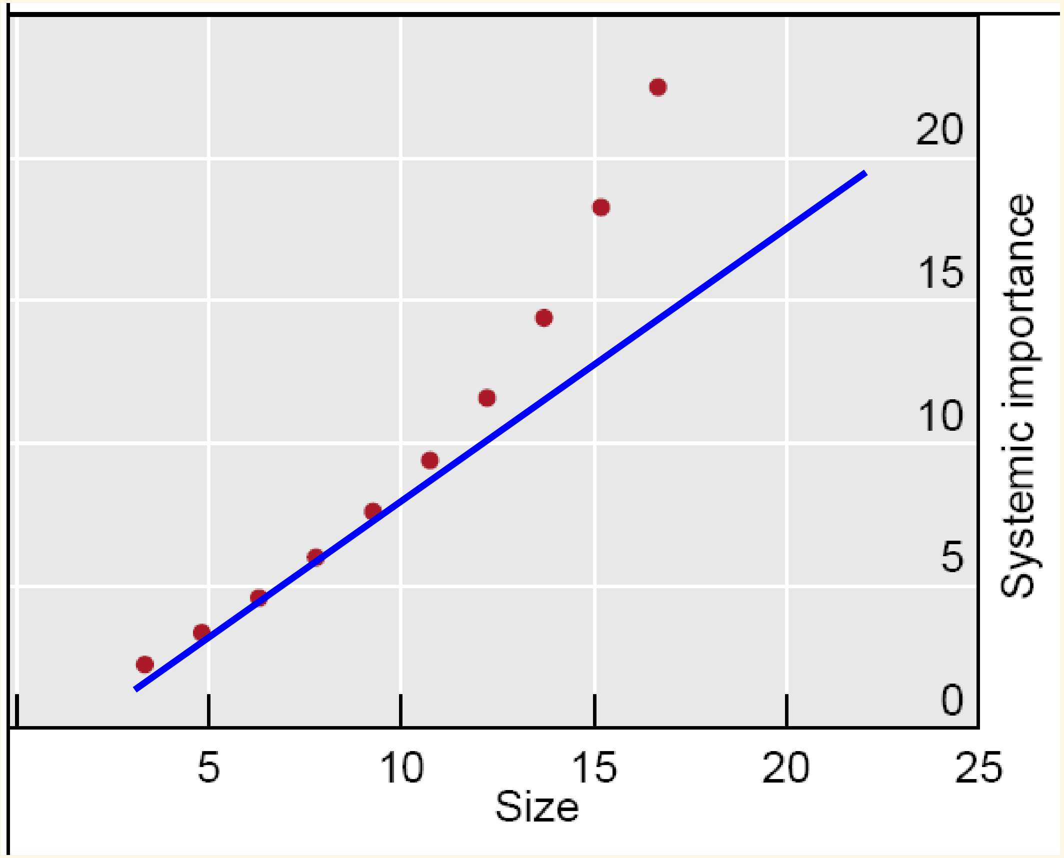
- Changes in PD have a greater impact on the systemic importance of institutions that are more exposed to the common factor …



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*)
- Intuition: larger banks appear more often in tail events

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 ($\rho_{low} = 0.30$)	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 ($\rho_{high} = 0.70$)	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%)*

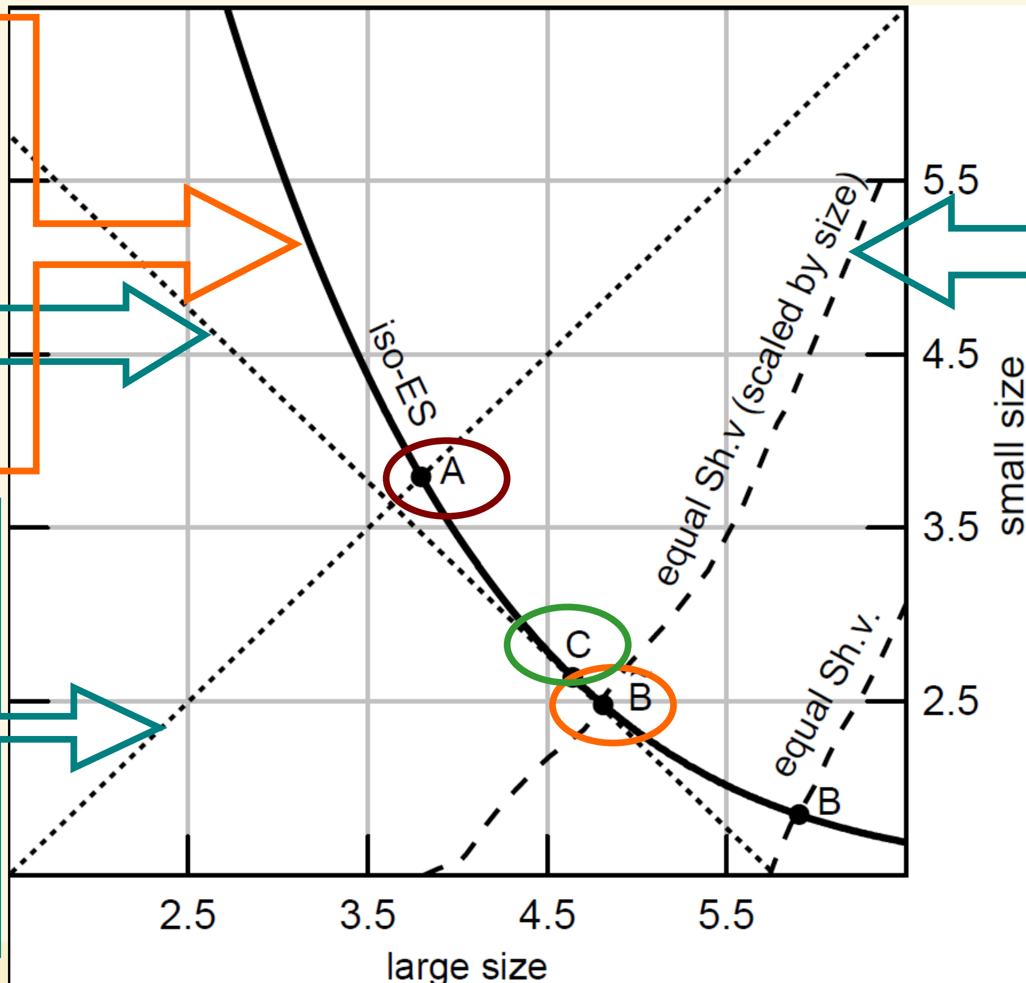
- "Efficiency" result: greater loading on systematic risk implies that a given change in capital (ie PD) has a greater impact on systemic importance
- Opposite outcome also possible, if there are more interactions …

Banks that differ only in size

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

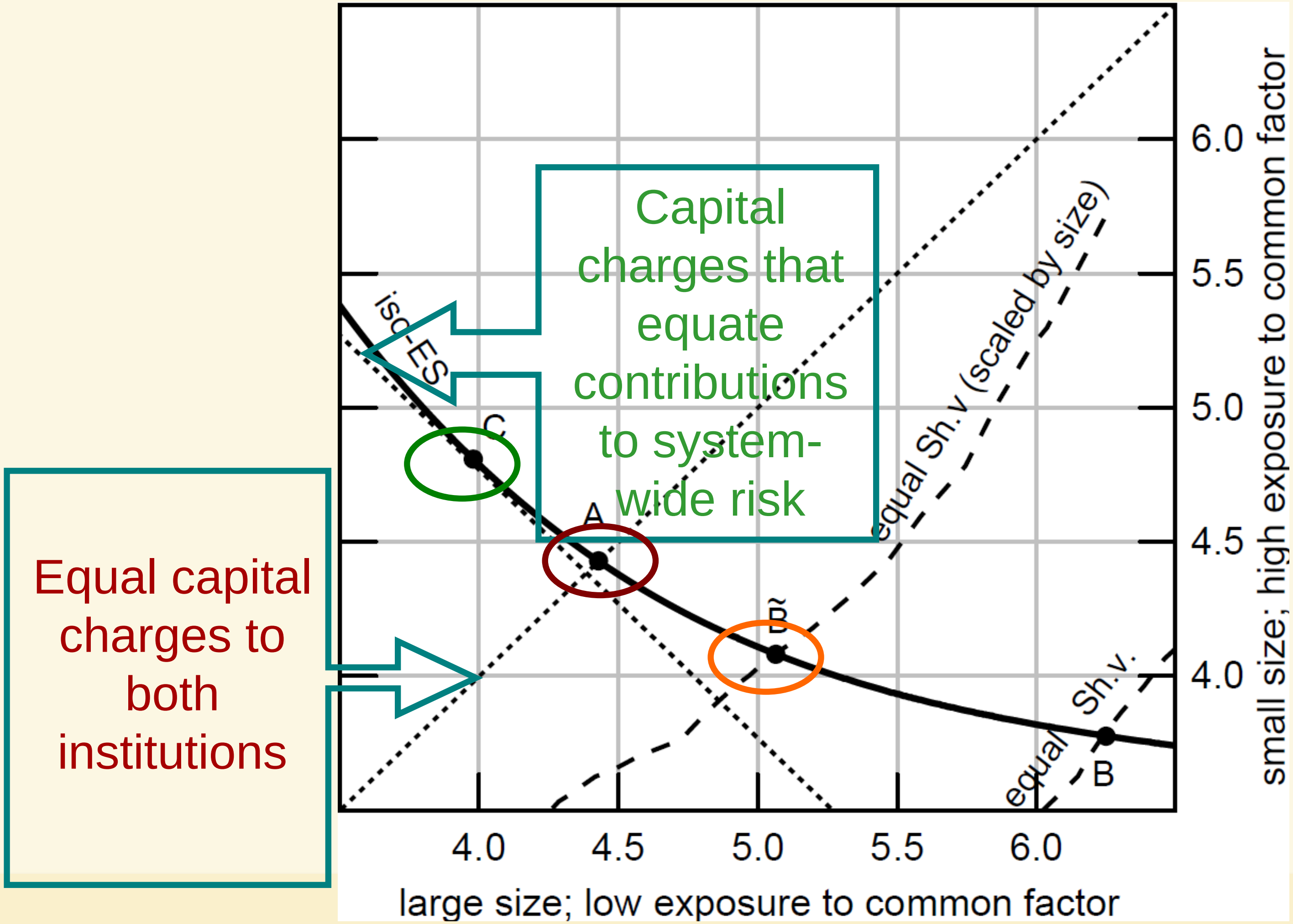
Minimum total capital combinations

Equal capital charges to both institutions



Capital charges that equate contributions to system-wide risk

Banks that differ in size and correlation



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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