Robustness and informativeness of systemic risk measures

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The views herein do not necessarily reflect those of the Deutsche Bundesbank.
What the paper is about

• Various proposals how to measure contributions of financial institutions ("banks") to system (in)stability

Do these *systemic risk measures* (SRM) set the right incentives?
• Sensitivities to risk parameters controlled by banks

How informative are they?
• SRM focus on – usually unobserved – extreme losses in the system, e.g. the 0.1% tail of aggregate returns
• For estimation, less extreme losses have to be used instead, e.g. the 5% tail
• Do risk measures based on moderate tails behave like those on extreme tails?
• Do they, at least, rank banks similarly?
• Estimation errors for realistic data?

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Systemic risk measures 1

- We only consider measures of *contributions* of financial institutions to system (in-) stability.
- \( R_i \) …return of bank \( i \)
  \( R_s \) … market return, or „system“ return

\( \Delta \text{CoVaR} \) (Adrian, Brunnermeier, 2010):
- *Change of the system‘s VaR through bank \( i \) moving from a normal to a very bad state*; formally: \( Q_\alpha (\ldots) \) … \( \alpha \)-quantile
- \[ \Delta \text{CoVaR}^{i,s}_\alpha \equiv Q_\alpha \left( R_s \mid R_i = Q_\alpha \left( R_i \right) \right) - Q_\alpha \left( R_s \mid R_i = Q_{0.5} \left( R_i \right) \right) \]

*Exposure CoVaR:*
- *Change of bank \( i \)‘s VaR through the system moving from a normal to a very bad state*; formally:
- \[ \Delta \text{CoVaR}^{i,s}_\alpha \equiv Q_\alpha \left( R_i \mid R_s = Q_\alpha \left( R_s \right) \right) - Q_\alpha \left( R_i \mid R_s = Q_{0.5} \left( R_s \right) \right) \]
Systemic risk measures 2

Marginal expected shortfall (MES)
- (Acharya, Pedersen, Philippon, Richardson, 2010)
  \[ MES^i_\alpha = \mathbb{E}[R_i \mid R_S < Q_\alpha (R_S)] \]

Tail Risk Gamma (Knaup, Wagner, 2012)
- \( p_t \) ... price of a put option on the market index, deep out of the money
- Regression:
  \[ R^i_t = \alpha + \beta R^S_t - \gamma \frac{p_t - p_{t-1}}{p_{t-1}} + u_t \]
- \( \gamma \) measures the sensitivity of \( R^i_t \) to extreme losses beyond the sensitivity captured by \( \beta \)
- For systemic risk charges, \( \gamma + \beta \) may be preferrable.
Do these SRM set the right incentives?

Linear model

- Classic market model: \(N\) banks, returns:
  \[ R_i = \beta_i F + \varepsilon_i \]
- Bank sector index \( R_S = \sum_{j=1}^{N} w_j R_j \) represents „the system“

- Sensitivities for \(\Delta CoVaR\):
  - rising \(\beta_i\) \(\Rightarrow\) rising \(|\Delta CoVaR_{\alpha}^{S,i}|\) (OK)
  - rising \(\sigma(\varepsilon_i)\): ambiguous effect
    - moderate size, beta \(\Rightarrow\) falling \(|\Delta CoVaR_{\alpha}^{S,i}|\) (wrong incentive!)
    - huge size or beta \(\Rightarrow\) rising \(|\Delta CoVaR_{\alpha}^{S,i}|\) (OK)
  - rising \(w_i\) (~size): ambiguous effect (a matter of taste…)

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**Do these SRM set the right incentives?**

**Linear model**

Sensitivity of the SRM to:

<table>
<thead>
<tr>
<th></th>
<th>idiosyncratic risk $\sigma(\epsilon_i)$</th>
<th>systematic risk $\beta_i$</th>
<th>size</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta\text{CoVaR}$ (conditioning on $R_i$)</td>
<td>largely problematic</td>
<td>OK</td>
<td>ambiguous</td>
</tr>
<tr>
<td>Exposure $\Delta\text{CoVaR}$ (conditioning on $R_S$)</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>MES</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>(tail risk gamma): regression beta</td>
<td>OK</td>
<td>OK</td>
<td>largely problematic</td>
</tr>
</tbody>
</table>

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Do these SRM set the right incentives?
SRM in a model with contagion

- One infectious bank: \( R_1 = \beta_1 F + \varepsilon_1 \)
- Infected banks: \( R_j = \beta_j F + \varepsilon_2 + \lambda I_{\varepsilon_1 < \kappa} \varepsilon_1, \quad j = 2, \ldots, N \)
- Bank sector index \( R_s = \frac{1}{N} \sum_j R_j \)
- All banks have the same beta and return volatility
- Analysis by Monte Carlo simulation
  - varying impact parameter \( \lambda \) and „infection threshold“ \( \kappa \)
  - \( N = 50 \)
### Do these SRM set the right incentives?
SRM in a model with contagion

|       | $\Delta CoVaR_{0.01}^{S|R_i}$ | $\Delta CoVaR_{0.01}^{R|S}$ | MES    | Tail risk gamma |
|-------|--------------------------------|-----------------------------|--------|-----------------|
| $\lambda = 0.5$ | Infectious | −2.16% | −3.18% | −3.00% | 0.63% |
| $\kappa = -0.0208$ | Infected | −2.44% | −3.01% | −2.79% | −0.01% |
| $\lambda = 0.5$ | Infectious | −2.12% | −3.00% | −2.77% | 0.20% |
| $\kappa = -0.0294$ | Infected | −2.32% | −3.06% | −2.67% | −0.00% |
| $\lambda = 0.5$ | Infectious | −2.27% | −2.92% | −2.64% | 0.04% |
| $\kappa = -0.0391$ | Infected | −2.14% | −3.07% | −2.62% | 0.00% |
| $\lambda = 0.2$ | Infectious | −2.14% | −3.29% | −2.75% | 0.14% |
| $\kappa = -0.0208$ | Infected | −2.20% | −2.90% | −2.65% | −0.00% |
| $\lambda = 0.2$ | Infectious | −2.05% | −3.10% | −2.67% | 0.05% |
| $\kappa = -0.0294$ | Infected | −2.29% | −3.11% | −2.63% | −0.00% |
| $\lambda = 0.2$ | Infectious | −2.25% | −3.14% | −2.62% | 0.02% |
| $\kappa = -0.0391$ | Infected | −2.04% | −2.84% | −2.62% | 0.00% |

- [ ] wrong order;
- [ ] right order, small difference;
- [ ] right order
How informative are the SRM?
The problem: Inferring from moderate tails on extreme tails

- The very bad system state of interest is rarely observed, e.g. the 0.1% tail of index return
- When estimating SRM, less extreme states have to be used instead, e.g. the 5% tail.
How informative are the SRM?
Analysis framework

- Classic market model: \( R^i_t = R_f + \beta_i (R^M_t - R_f) + \varepsilon^i_t \)
- Bank \( i \) holds a baseline portfolio with return \( R^i_t \).
- In addition, put options on the market index with low strike can be held

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How informative are the SRM?

Test setup

• Sequences of portfolios 1…16, increasing order of their “true” risk on 0.1% level.

Analyses:

• Comparison of risk ordering from 1 to 16 at different confidence levels, for each SRM

• We simulate returns and (repeatedly) estimate risk measures from realistic amounts of data. We then compare true and estimated risks
How informative are the SRM?
Portfolio type A: “baseline”

• Portfolios A1…A16
• Rising risk only through Beta running from $\beta = 1$ (A1) to $\beta = 2$ (A16)
• No options
How informative are the SRM?
Portfolio type B: “large risk – concave”

- Portfolios B1…B16; constant Beta = 1
- Linearly growing weight of option positions
- For B16: Put with strike 0.8, weight = −0.45%
  Put with strike 1, weight = 3%

![Graph showing portfolio return vs. market return.](image-url)
How informative are the SRM?
Portfolio type C: “convex profile”

- Portfolios C1…C16; rising Beta from 1 to 2.15
- Linearly growing weight of option positions
- For B16: Put with strike 0.8, weight = 0.75%
How informative are the SRM?
Portfolio type D: “extreme risk – convex / concave”

- Portfolios D1…D16; rising Beta from 1 to 1.375
- Linearly growing weight of option positions
- For B16: Put with strike 0.7, weight = -4.5%
  Put with strike 0.725, weight = 5.7%

![Graph: Portfolio return vs. Market return](image)
How informative are the SRM?

Exact SRM for different tail probabilities

Portfolio type A: “baseline”

Portfolio type B: “large risk – concave”

Wrong order throughout throughout
How informative are the SRM?

**Exact SRM for different tail probabilities**

Portfolio type C: “convex profile”

Portfolio type D: “Extreme risk – convex / concave”

wrong order throughout
Choose portfolio setting A or D.

Simulate daily market return and the 16 portfolio returns.

Estimate the risk measures in line with literature:
- MES: 260 days, 5% confidence level
- ΔCoVaR: 1,300 weeks (each 5 daily returns), quantile regression on 1% confidence level
- Tail risk gamma: 260 days, put option with maturity 4 months and strike 70%

Repeat steps (2) to (3) 1,000 times.

For each simulation, calculate ranks 1…16 of the risk measures of the 16 portfolios.

For each portfolio type, evaluate sample of ranks (N=1000)

The exact 0.1% MES (ΔCoVaR) defines the „true“ risk rank...
Estimation under realistic conditions:
Portfolio type A: “baseline”

9th decile
1st decile

Average rank

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Estimation under realistic conditions:
Portfolio type D: “Extreme risk – convex / concave”

Average rank
9\textsuperscript{th} decile

1\textsuperscript{st} decile

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Conclusion

• Some SRM imply strange incentives w.r.t. idiosyncratic risk and size, even in a cosy linear model.
• Contagion model: no clear picture whether, when and by which SRM an infectious banks would be identified.
• No reliable link between SRM for moderate and extreme tails.
• Large risks in the extreme tail can be masked by derivatives.
• Large estimation errors.

⇒ A direct application of the proposed measures to regulatory capital surcharges for systemic risk could create a lot of noise and wrong incentives for banks.
Do these SRM set the right incentives? Why ΔCoVaR gives the wrong relationship:
Estimation under realistic conditions: Portfolio type B: “large risk – concave”

Average rank

9\textsuperscript{th} decile

1\textsuperscript{st} decile

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Estimation under realistic conditions:
Portfolio type C: “convex profile”

Average rank  9\textsuperscript{th} decile

\begin{itemize}
  \item MES
  \item \(\Delta\text{CoVaR}\)
  \item Exposure \(\Delta\text{CoVaR}\)
  \item Tail risk gamma
\end{itemize}

1\textsuperscript{st} decile

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