BANK OF ENGLAND

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On the Origin of Systemic Risk

A New Microstructural Approach

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1. Motivation

Motivation (1) – Stylized Fact

❖ **Series of Number of Bank Defaults** ⟶ Binary System

- ➢ Very high correlation among banks' default probabilities in the cross-section.
- ➢ Very high auto-correlation over time

Figure 1: Historical series of percentage of distressed banks in the United States

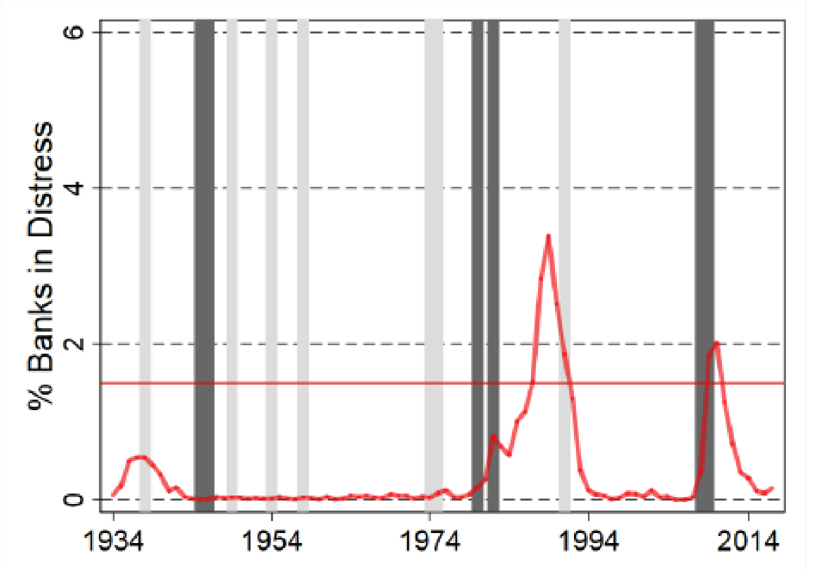
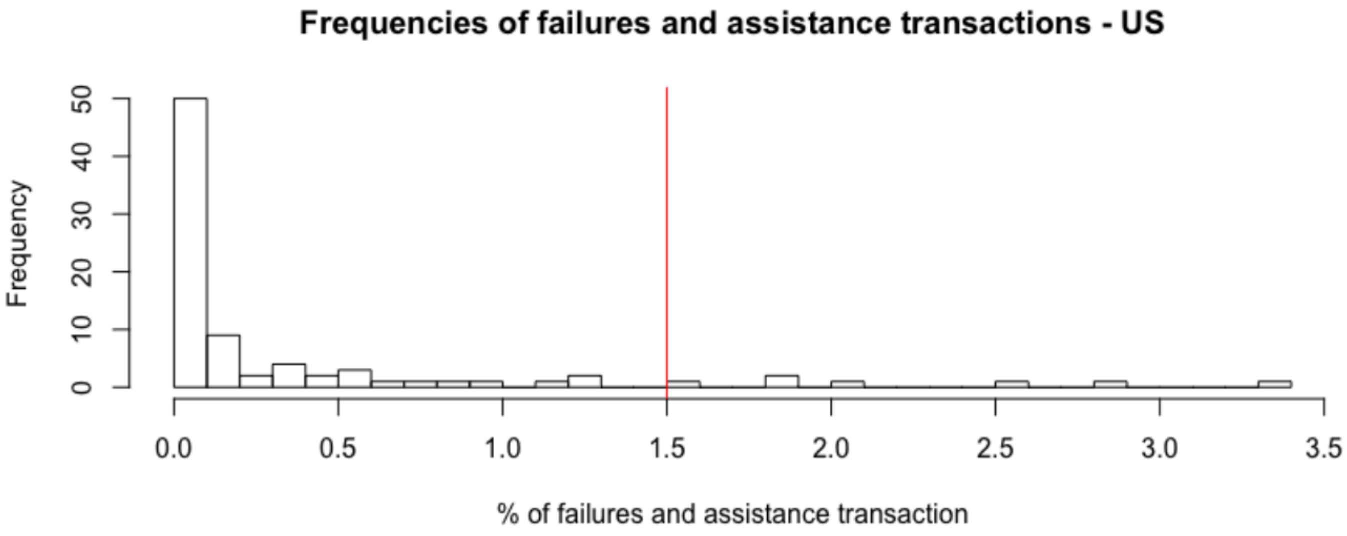


Figure 2: Distribution of the percentage of failures and assistance transactions per year in the US in the period 1934 - 2017.



Source: Federal Deposit Insurance Corporation. In red the threshold of 1.5% of defaulted or distressed banks per year to identify a systemic event.

Research-Policy Question

1. Definition of Systemic Event in Banking

- Time period (quarter or year) where a large number of banks goes simultaneously into distress or default (roughly 1.5% of total banks in the system).

2. Definition of Systemic Risk

- Probability that a systemic event takes place in a year (Historical Estimate 3.3% ~ 3 events over the last 90 years)

Why Do Systemic Events Happen?

- Strong Banks' Assets Correlation leading to very high cross-sectional correlation among banks default probabilities
  - What are the relevant sources/determinants of these events? *Systemic Risk and Bank PD Decomposition*
  - What is their probability to happen in the future? *Systemic Risk Measure*
  - How can we prevent them? *Policy Laboratory*

2. Literature

Literature

1. Market-based Data

- VAR Models: Alter and Bayer (2013); Diebold and Yilmaz (2009/11) Demirer et al. (2017) and Bassu et al. (2017)
- Price-based Systemic Risk rankings: Demirer et al. (2017) – **VaR**; Adrian and Brunnermeier (2014) – **CoVaR**; Acharya et al. (2010) - **MES**; Acharya et al. (2012) – **SRISK**.
- Price correlations (no actual linkages), reduced sample of banks, no policy exercise.

2. Bank-Balance Sheet Data -> Microstructure of the System

- **Seminal Work:** Allen and Gale (2000), Eisenberg and Noe (2001);
- **Simulated Networks or limited coverage:** Nier et al. (2007), Lu and Zhou (2010), Halaj and Kok (2013), Alter et al.(2014); (AT, DE, IT Interbank Market);
- **Risk Topology:** Battiston et al. (2012), Craig and von Peter (2015), Glasserman and Young (2016);
- **Multilayer:** Kok and Montagna (2013), Bargigli et al. (2015); Covi et al. (2019);
- **Liquidity Shock, Fire Sales:** Brunnermeier and Petersen (2009), Gai et al. (2011); Caballero and Simsek (2013); Caccioli et al. (2014); Cont and Schanning (2017);
- **Exogenous Shock:** level of systemic risk conditionally to an exogenous shock hitting the system.

3. Methodology

Methodology (1) - Systemic Risk Definition

❑Probability that a systemic event will take place in the next year, derived as the total number of systemic events over the number of simulations.

- N: Number of Banks in the System
- $\pi_{i,t}$: probability a bank i defaults in the period t
- D_t: total number of banks' default at time t
- $\bar{D}$: Systemic Event Threshold (1.5% of N)

$$\boldsymbol{SR} = Pr\left(\frac{D_t}{N} > \bar{D} \middle| \boldsymbol{I}_{t-\Delta t}\right).$$

Methodology (2) – Exogenous vs Endogenous Dynamics

❑ Standard Approach - Exogenous shock:

- Monitor the behaviours of a system in stressed conditions (banks' solvency and liquidity conditions given a bank default or asset-price shocks);
  - ➢ it fails to describe the phenomenon of systemic risk in relation to the economic system;
- The distribution of the initial shock is unknown, thereby not allowing a probabilistic assessment of the event
  - ➢ It doesn't deal with scenario uncertainty, results are point-estimates such as average loss, not a distribution of outcomes;

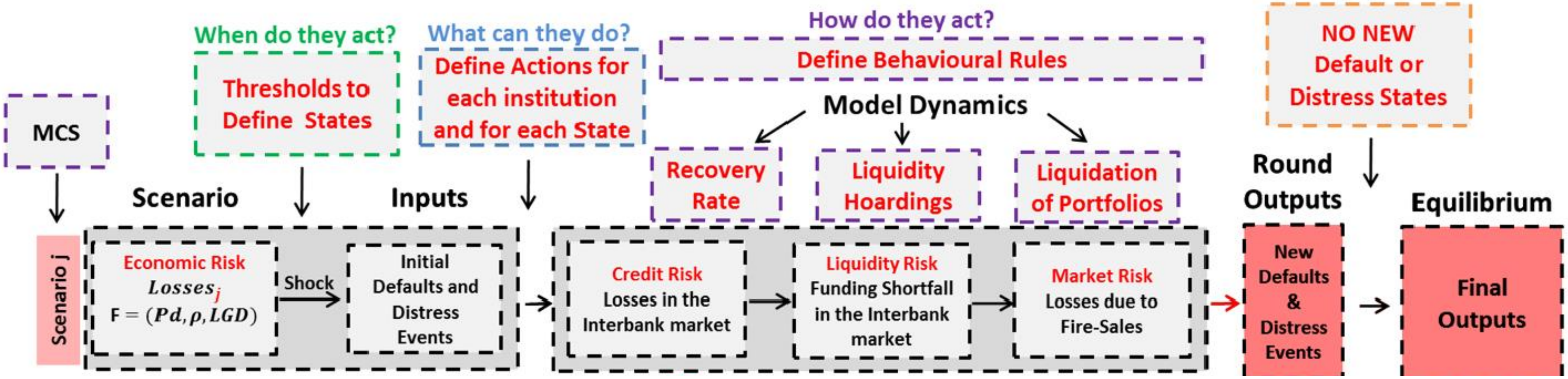
❑ Our Approach - Endogenous Systemic Risk:

1. **Stochasticity comes from the real economy**, i.e. by modelling the loss distribution of banks' exposures towards NFCs, HHs, and FCs (via entity-specific PDs, exposure-specific LGDs and Estimated Correlation Matrix of PDs);
2. **Interbank contagion is a deterministic process** acting as a highly non-linear map of the risks stemming from the real economy to the realization of systemic events.
3. Allows for probabilistic assessment of systemic events by mean of simulations;
4. It allows for a Decomposition of Banks' Asset Correlation into various determinants, respectively economic and financials.

Methodology (3) - Scenario Uncertainty + Financial Amplification

1. **Stochastic Process** determining the initial vector of banks in default or distress
   - Vector of defaults of economic entities (one for each scenario) derived via entity-specific PDs (Moodys) and a correlation matrix by country and sector (estimated using CDS spreads correlation);
   - Vector of banks' losses (one for each scenario) computed using exposure-specific LGD and the vector of economic defaults derived at point (1);
   - Vector of banks' default and distress events by checking whether losses stemming from the real economy have breached banks' minimum capital requirements or capital buffer requirements;
2. **Deterministic Map** of financial contagion and risk amplification in the banking sector by modelling:
   - Transmission of credit risk losses through long-term exposures: *Solvency Contagion*
   - Transmission of liquidity risk through short-term exposures: *Liquidity Contagion*
   - Transmission of Market risk through sales of securities: *Market Contagion*

Methodology (4) - Stochastic Microstructural Multilayer Model



STEP 1

Stochastic Process

STEP 2

Deterministic Process

STEP 3

Vector of Banks in Distress and Defaults

Methodology (5) – Output Measures

- ❑ For each scenario we store which bank is in distress and default, hence we can derive:

1. Systemic Risk Measure: How many scenarios can be classified as systemic over the total number of simulations? (Ex. 100 over 10.000 ~ 1% probability).
   - Systemic event: n. of banks in distress or in default > 1.5% of total n. of banks in the system
2. Average Bank Default Probability: How many banks do fail in each scenario over the total number of banks in the system? Then average across all scenarios.

- ❑ Decomposition of the Results according to the sources of risk by means of counterfactual exercises.

3. Bank-Specific Probability of Default: How many times each bank default across all scenarios.
4. Correlation across Bank-Specific Default Probabilities
5. Conditional Probability of Bank Defaults
   - Ex. 1 what's the probability of X defaulting given Y defaulting
   - Ex. 2 what's the probability of X defaulting given a Systemic Event

4. Dataset

Network Composition

Table 1. Summary Statistics for 2018-Q4. Values are reported in trillion euro for columns (3) to (6), while columns (8) and (9) report amounts in euro billion. Granular exposures refer to the exposure amount mapped with exposure-specific information, securities refer to the exposure amount mapped with ISIN information, while aggregate exposures refer to the exposure amount mapped on aggregate sector-country counterparty basis. LGD reports the share of total exposure amount used to impute credit risk losses. AVG edge refers to the average exposure amount per edge, while AVG node reports the average exposure amount per counterparty.

Sector	Edges	Nodes	Gran.	Sec.	Agg.	Tot.	LGD	Avg. edge	Avg. node
CI	8580	1175	3.0	0.6	-	3.6	14%	0.4	3.1
NFC	14497	5866	1.9	0.7	0.9	3.5	22%	0.2	0.6
FC	7762	4324	1.3	0.9	3.6	5.9	10%	0.8	1.4
GOV	4823	1257	2.9	2.0	-	4.8	24%	1.0	3.8
HH	820	297	0.04	-	5.3	5.3	17%	6.5	17.8
Total	36482	12919	9.1	4.3	9.8	23.2	18%	0.6	1.8

The Global Network of Euro Area Banks' Exposures

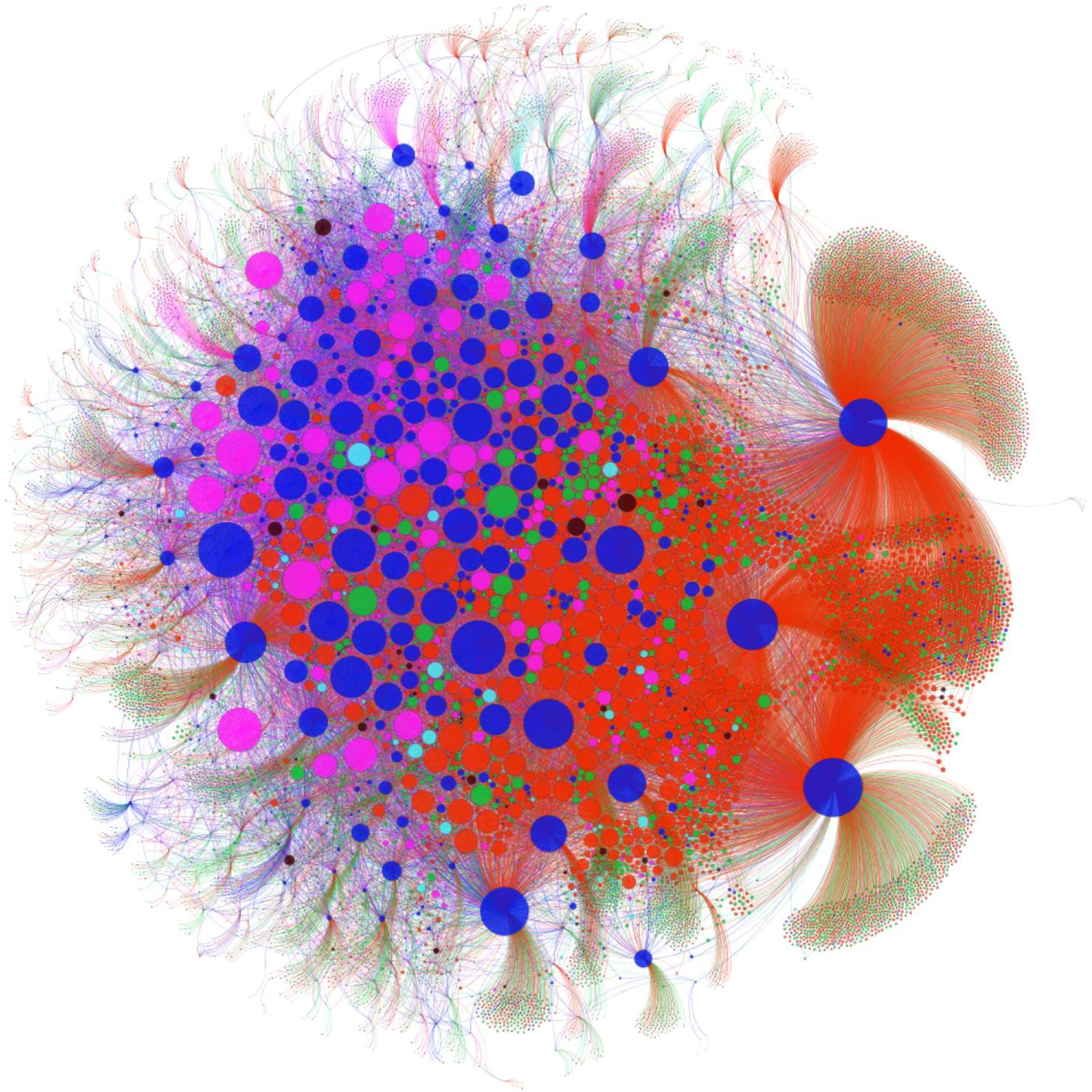
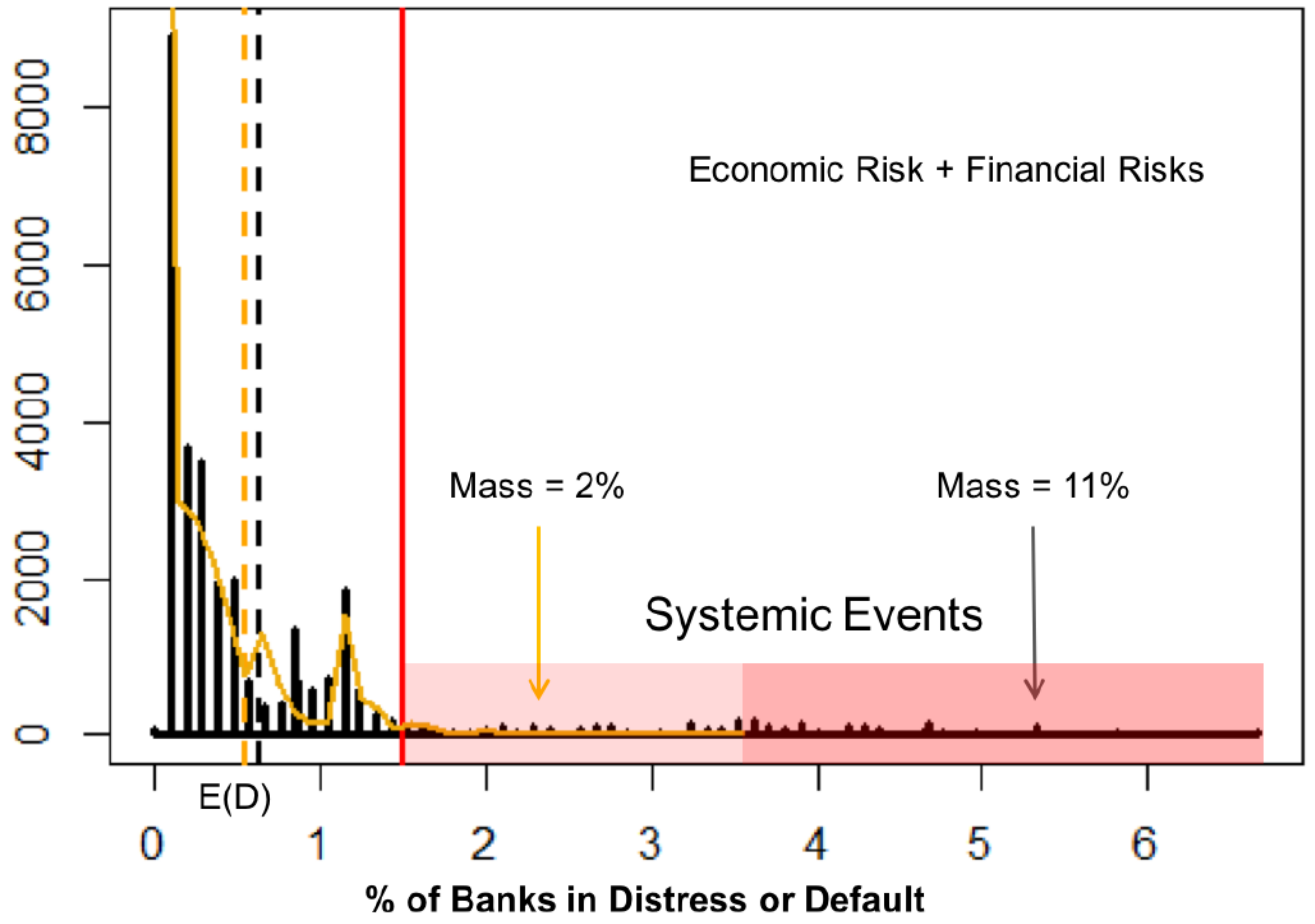


Figure 3. Network of the granular and aggregate exposures captured by our data. The total amount of exposures for 2018-Q4 is Euro 23.2 trillion. The network is built by assigning the eigenvector centrality metrics to the size of the nodes, while the colour of the edges to the node reporting the exposure on the asset side. Blue nodes represent the banking sector, red nodes non-financial corporates, purple nodes the government sector, green nodes the financial corporate sector, and finally the light blue nodes the household sector.

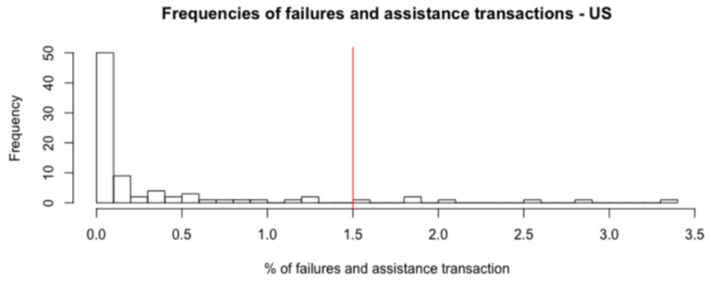
5. Results

Results (1) – Distribution of Systemic and Non-Systemic Events

Figure 4: Frequency of the % of banks in distress or in default across all scenarios



1. Systemic crises can be generated by economic shocks only;
2. Financial amplification mechanisms impact much more the tail of the distribution than the mean;
3. The number of defaults in the tail as % of total defaults across all simulations (CoVar) is amplified by a factor of 5 by financial amplification mechanisms.
4. Our Distribution seems to resemble the historical distribution



Results (2) – Risk Decomposition

Table 2: Decomposition of systemic risk, SR, and of the average default probability, for Q4-2018. Estimates are reported in basis points.

Sources	SR – Systemic risk	$\bar{\pi}_t$ – Avg. def. prob.
Economic Risk	**195.2**	**9.9**
Baseline	31.2	9.9
Correlation of shocks	164.0	0.0
Contagion Risk	**166.6**	**4.6**
Market contagion	83.4	0.7
Liquidity contagion	0.6	0.8
Solvency contagion	2.0	1.3
Interaction	77.0	1.8
Total	**358.2**	**14.5**

Note: the interaction term is approximated by the difference between total systemic risk and the sum across each single source of risk.

❖ SR Measure Quarterly Estimate is 358 basis points (3.6%);

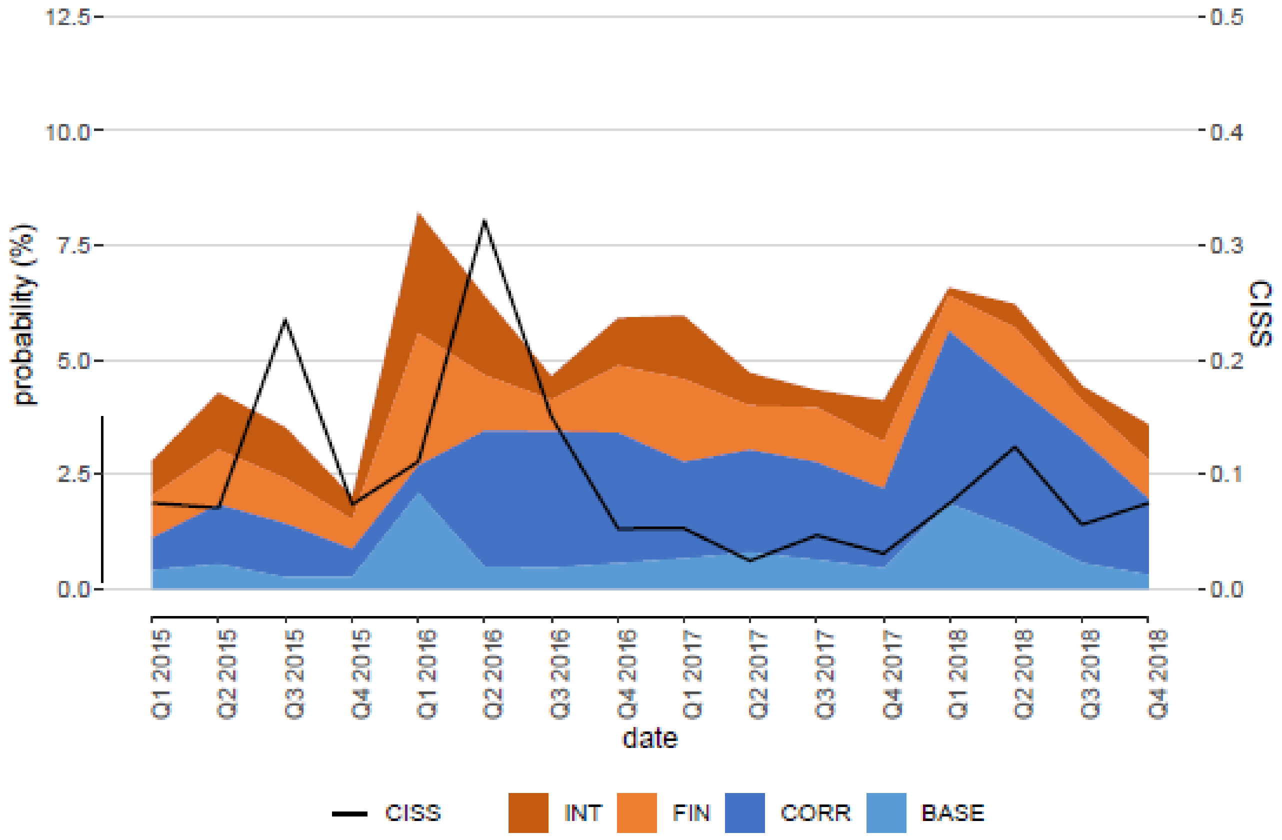
- Mostly due to Correlated Economic Shocks (164 bps)
- Market Contagion Fire-Sales (83 bps)
- Interaction among financial contagion channels (77 bps) - Multilayer Perspective.

❖ Average Default Probability is 14.5 basis points (0.14%).

- 2/3 of the contribution is due to losses stemming from real economy, correlated shocks do not matter in expectations.

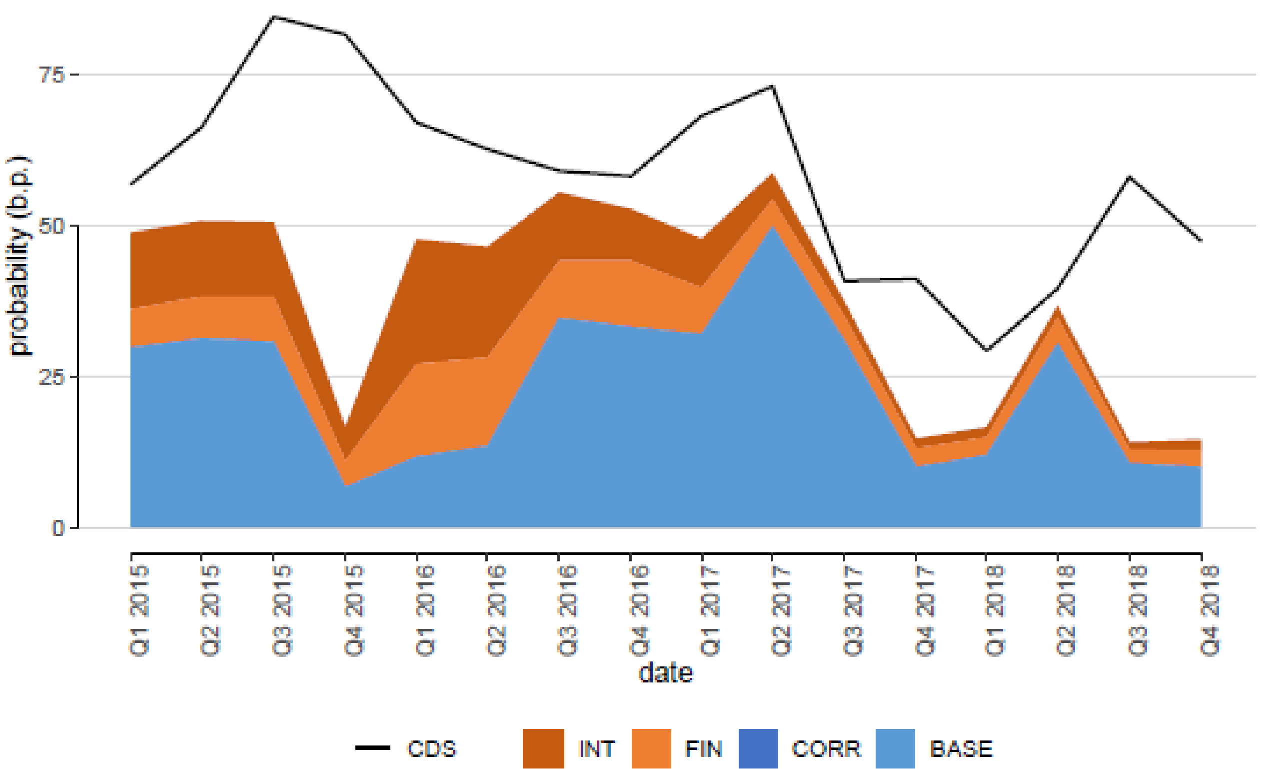
❖ Hence, a change in the intensity of the shocks (PDs of each individual real economic entity) may not have such a sizable effect on the level of systemic risk, contrary it should have it on the average bank default probability.

Results (3) – Systemic Risk Measure Over Time



- ❖ Systemic events are strongly affected by correlations among economic shocks (COR), financial amplification mechanisms (FIN) and by their interactions (INT);
- ❖ Even with low probabilities of default and during an expansionary cycle, systemic risk seems to be non-negligible;
- ❖ Our Systemic Risk Measure when it peaks seems to precede by one-quarter the Composite market-based systemic risk Index.

Results (4) – Average Bank Default Probability Over Time



- ❖ Economic losses are the main determinant of banks' default probabilities, while Financial conditions matter most in the tail of the distributions (Systemic Risk) as in Adrian et al. 2017;
- ❖ Average bank PD estimate resembles in trend and level the market estimate of average bank PD proxied by the average bank 5-year senior CDS spread;
- ❖ Correlation between SR and Avg PD is low ~ 0.25, and sometimes they show opposite trends, one increasing and the other decreasing.

- ❖ Policy Implication: targeting the reduction of banks' default probabilities may have very little effect in reducing the probability of experiencing a systemic crisis.

5. Conclusive Remarks

Conclusion

❑ Stochastic Microstructural Multilayer Stress Testing framework

1. Decompose systemic risk in its components as additive risks via analytical formulas or simulations
2. Able to replicate the event of a financial crisis using real data and a microstructural model.
3. Our estimates of the average banks’ PD resembles the pattern of EA banks CDS prices;
4. Systemic events are generated by amplification mechanisms in the financial sector (Adrian et al. 2017)
5. Flexible to perform counterfactual policy exercises and assess the role of each single institution in the system

❑ Policy implication – Take Away

With such high levels of interdependency among banks' economic and financial losses, targeting the reduction of banks' default probabilities may have very little effect in reducing the probability of experiencing a systemic crisis, that is, banks’ joint default probabilities.

Appendix

Results (6) – Correlation Matrix

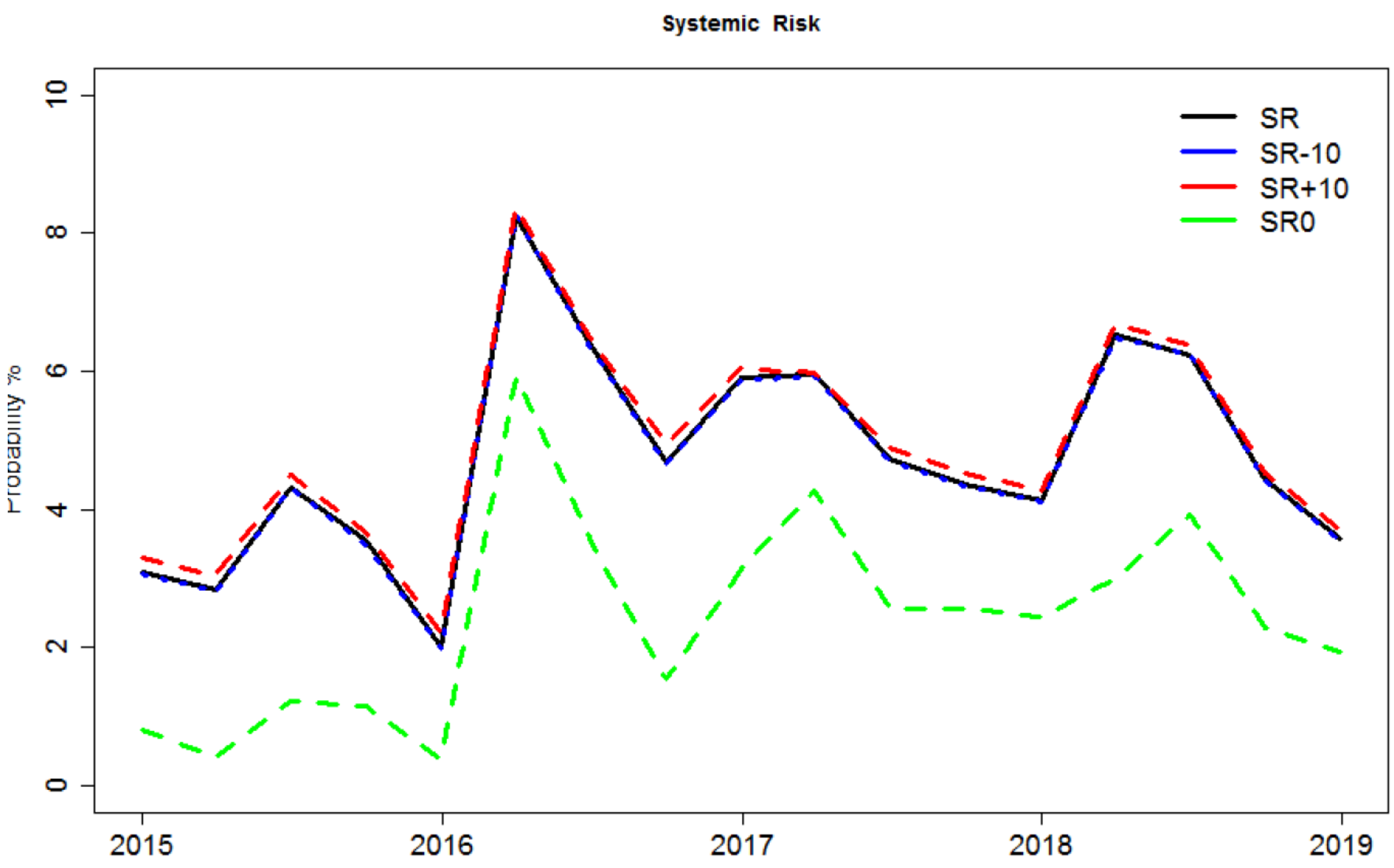
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00	0.99	0.76	0.72	0.99	0.94	0.92	0.77	0.90	0.98	0.86	0.99	0.90	0.92	0.78
2	0.99	1.00	0.81	0.70	0.98	0.94	0.93	0.74	0.88	0.96	0.84	0.97	0.85	0.88	0.86
3	0.76	0.81	1.00	0.33	0.79	0.75	0.86	0.43	0.58	0.69	0.53	0.69	0.47	0.55	0.75
4	0.72	0.70	0.33	1.00	0.71	0.86	0.53	0.63	0.68	0.71	0.97	0.78	0.73	0.72	0.59
5	0.99	0.99	0.79	0.71	1.00	0.95	0.94	0.77	0.90	0.97	0.85	0.97	0.87	0.91	0.94
6	0.94	0.94	0.75	0.86	0.95	1.00	0.85	0.71	0.83	0.91	0.95	0.94	0.81	0.85	0.78
7	0.92	0.93	0.86	0.53	0.94	0.85	1.00	0.69	0.81	0.89	0.71	0.87	0.75	0.80	0.81
8	0.77	0.74	0.43	0.63	0.77	0.71	0.71	1.00	0.92	0.78	0.71	0.79	0.81	0.80	0.7
9	0.90	0.88	0.58	0.68	0.90	0.83	0.83	0.92	1.00	0.91	0.80	0.92	0.93	0.93	0.79
10	0.98	0.96	0.69	0.71	0.97	0.91	0.91	0.78	0.91	1.00	0.84	0.97	0.91	0.94	0.84
11	0.86	0.84	0.53	0.97	0.85	0.95	0.95	0.71	0.80	0.84	1.00	0.90	0.83	0.84	0.85
12	0.99	0.97	0.69	0.78	0.97	0.94	0.94	0.79	0.92	0.97	0.90	1.00	0.94	0.96	0.88
13	0.90	0.85	0.47	0.73	0.87	0.81	0.81	0.81	0.93	0.91	0.83	0.94	1.00	0.99	0.85
14	0.92	0.88	0.55	0.72	0.91	0.85	0.85	0.80	0.93	0.94	0.84	0.96	0.99	1.00	0.79
15	0.78	0.86	0.75	0.59	0.94	0.78	0.81	0.70	0.79	0.84	0.85	0.88	0.85	0.79	1.00

- Banks' Total Loss Correlations

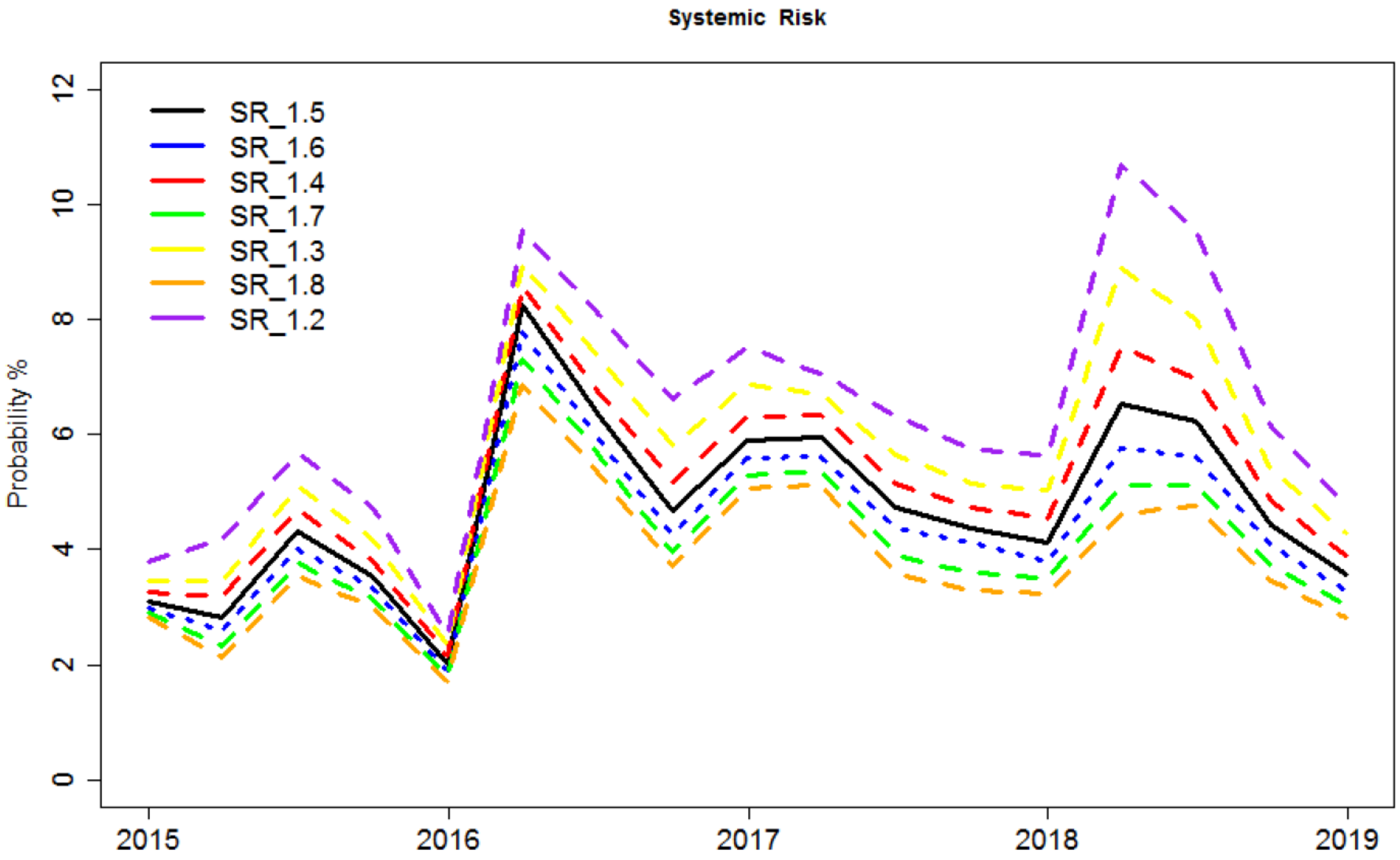
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00	0.81	0.84	0.47	0.77	0.80	0.84	0.62	0.79	0.82	0.61	0.86	0.81	0.59	0.62
2	0.81	1.00	0.75	0.43	0.68	0.72	0.73	0.60	0.72	0.73	0.51	0.78	0.73	0.51	0.60
3	0.84	0.75	1.00	0.39	0.75	0.74	0.81	0.54	0.71	0.79	0.50	0.77	0.69	0.46	0.62
4	0.47	0.43	0.39	1.00	0.43	0.64	0.40	0.42	0.46	0.44	0.57	0.53	0.55	0.40	0.30
5	0.76	0.68	0.75	0.43	1.00	0.70	0.72	0.54	0.68	0.72	0.50	0.73	0.70	0.51	0.55
6	0.79	0.72	0.74	0.64	0.70	1.00	0.73	0.60	0.73	0.74	0.65	0.79	0.77	0.55	0.57
7	0.83	0.73	0.81	0.40	0.72	0.73	1.00	0.57	0.73	0.78	0.53	0.76	0.71	0.49	0.61
8	0.62	0.59	0.54	0.42	0.54	0.60	0.57	1.00	0.64	0.57	0.47	0.65	0.68	0.51	0.42
9	0.79	0.72	0.71	0.46	0.68	0.73	0.73	0.65	1.00	0.73	0.54	0.77	0.77	0.58	0.57
10	0.82	0.72	0.79	0.44	0.72	0.74	0.78	0.57	0.73	1.00	0.56	0.79	0.76	0.54	0.58
11	0.61	0.51	0.50	0.57	0.50	0.65	0.53	0.47	0.54	0.56	1.00	0.65	0.64	0.47	0.35
12	0.86	0.78	0.77	0.53	0.73	0.79	0.76	0.66	0.77	0.79	0.65	1.00	0.87	0.65	0.57
13	0.81	0.73	0.69	0.55	0.70	0.77	0.71	0.68	0.77	0.76	0.64	0.87	1.00	0.78	0.53
14	0.59	0.51	0.46	0.39	0.51	0.55	0.49	0.51	0.58	0.54	0.47	0.65	0.78	1.00	0.36
15	0.62	0.60	0.62	0.30	0.55	0.57	0.61	0.42	0.57	0.58	0.35	0.57	0.53	0.36	1.00

- Banks' Default Correlations

Robustness (1) – No Correlations among Economic Shocks



Robustness (2) – Variations of Systemic Event Threshold



Robustness (3) – Variations of Number of Simulations