Losses due to cyber risk and concentration risks related to Cloud providers for the financial sector

Cyber Resilience: Managing the Consequences of Risk Contagion, 24 April 2020

Volatility and Risk Institute

Antoine Bouveret and Alexander Harris

Outline

Two main issues for financial institutions:

- How to estimate losses related to cyber risk?

- What are the concentration risks associated with increased reliance on cloud providers?
  - Work in progress

Introduction

Relevance of cyber risk for financial institutions

Threat: financial sector among the most targeted sector

Vulnerability: Reliance on IT, interconnected systems, critical infrastructures and legacy systems

Consequences: Direct and indirect losses, contagion

Types of cyber-attacks

Confidentiality: data breaches

Equifax data breach (145Mn records, USD 1.4bn)

Integrity: Fraud

Bangladesh central bank Swift heist (USD 81Mn)

Availability: Business disruption (FMIs, Cloud providers etc.)

NotPetya ransomware (USD 870Mn for Merck, USD 400Mn for Fedex)

Estimation of cyber losses

How to estimate losses due to cyber risk?

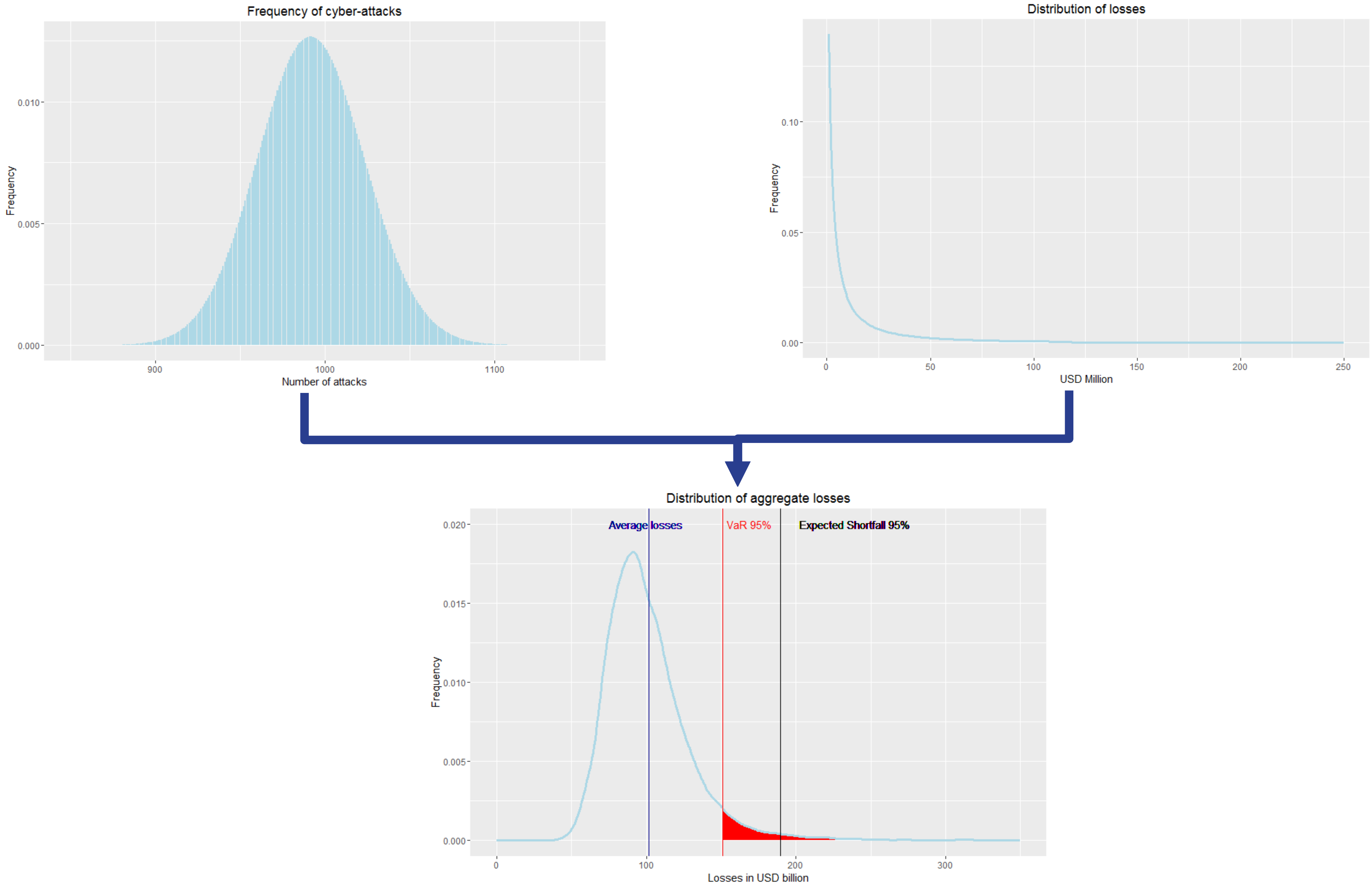
Objective: Raise awareness, consider cyber-insurance and manage operational risk

Method: Distribution of aggregate losses (actuarial science)

Data requirements: Frequency of cyber-attacks and losses

References: Bouveret (2019), Shevshenko (2010)

Overview of the method



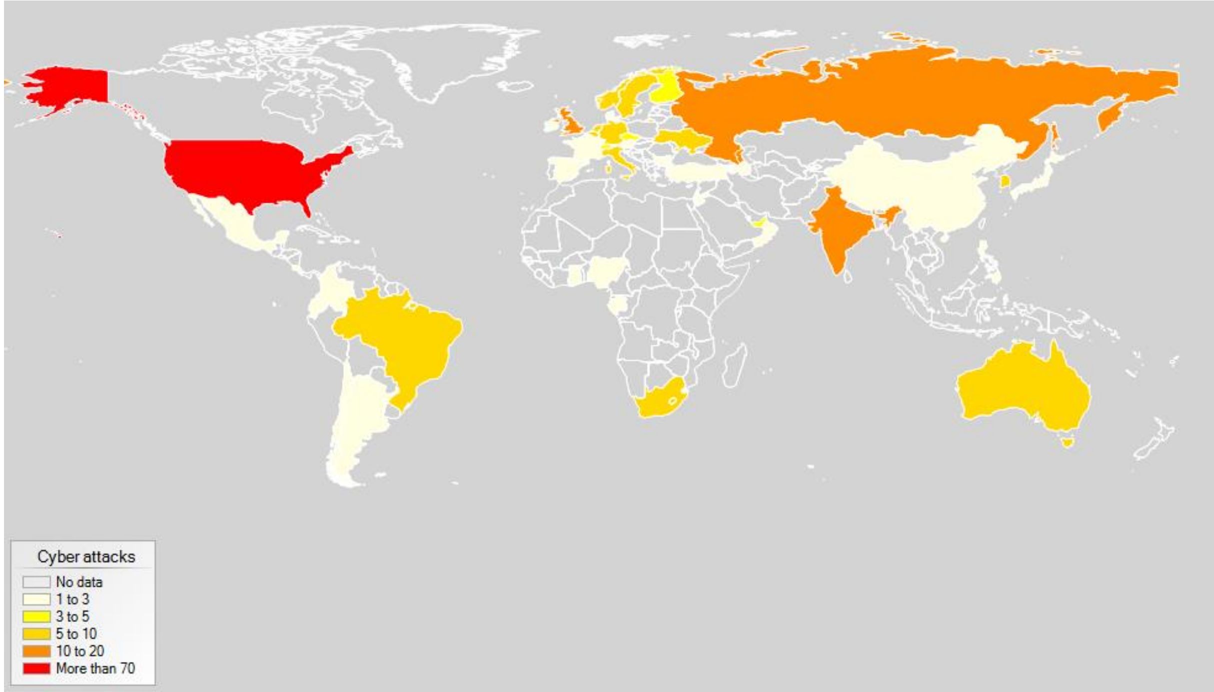
Data on cyber risk for financial institutions

OpRisk databases: SAS, IBM Advisen, ORX

Frequency: Average number of attacks (2011-2016)

Cyber attacks: 341 events (103 with losses), 50 countries

Number of attacks per country



Estimation of losses

Frequency distribution: Poisson ($\lambda = 992$)

Distribution of losses: Spliced distribution (lognormal for the body and GPD for the right tail)

Contagion:

- Either assume independence of losses
- Introduce contagion through multiple losses (each event can lead to more losses), geometric distribution ($p =$20%, calibrated on ORX data)

Estimation through Monte Carlo simulations

Main results

Two scenarios:

- Baseline
- Severe with 2x more attacks

Contagion effects

Results:

- Global losses around USD 100bn/year
- Possibility of very large losses

Annual losses for the financial sector

	in USD bn		In % of banks net income	
	Baseline	Severe scenario	Baseline	Severe scenario
Average	100	276	9	26
Median	88	254	8	24
95% VaR	167	405	16	38
95% ES	283	617	27	59
99% VaR	291	637	28	61
99% ES	599	1189	57	113
With contagion				
Average	124	345	12	33
Median	111	320	11	30
95% VaR	202	496	19	47
95% ES	324	736	31	70
99% VaR	343	762	33	72
99% ES	637	1372	61	130

Note: Aggregated losses from cyber attacks, assuming a Poisson distribution for the frequency and a spliced lognormal-GPD distribution for the losses. Estimates obtained by Monte Carlo simulations. Under the contagion scenario, each cyber attack has a 20% probability to affect two or more firms. Net income data based on a sample of 7,947 banks for 2016.
Sources: ORX News, SNL and author's calculations.

Concentration risk and cloud providers

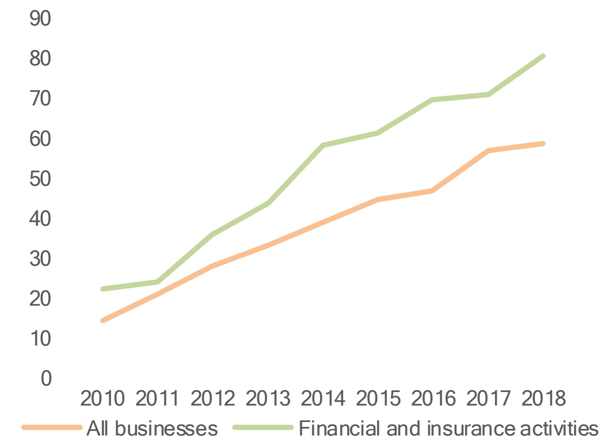
Increased reliance on cloud providers

Widespread use of Cloud services

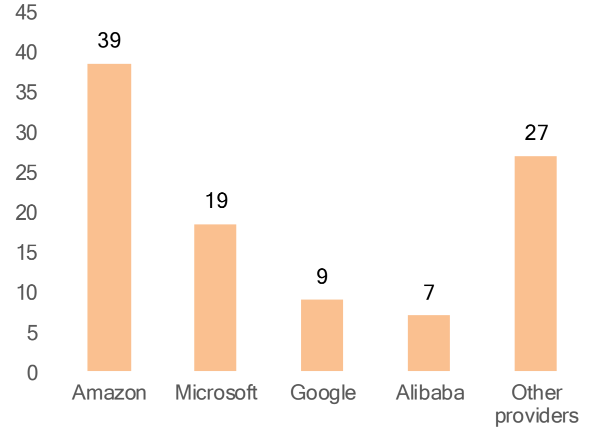
Highly concentrated market

Main issue:

- Concentration risk



Note: Share of businesses using cloud computing services, in %. Data for Japan.
Source: OECD.



Note: Market share (in % of world revenues) as of 2019Q3. Revenues for Public Infrastructure as a Service (IaaS) and Platform as a Service (PaaS), excluding Hosted/Managed Private Cloud.
Source: Synergy Research Group.

References: FSB (2019), Lloyd’s (2018)

Insights from a model of concentration risk

Main questions:

- Do Cloud providers reduce the risk of outages for firms?
- Under which conditions could cloud providers increase risk to financial stability?
- How to mitigate risks to financial stability?

Insights from a model of concentration risk

Framework and assumptions (1/2)

- Firms choose to rely (or not) on Cloud providers
- Firms and cloud providers are always in one of two states: {0, 1}, where 1 represents outage
- If firm does not rely on Cloud, moves from state 0 to 1 at 'incident rate' λ and moves from 1 to 0 at 'repair rate' μ
- Cloud providers are more efficient: less outages and of shorter duration $\rightarrow \lambda_{cloud} < \lambda$, $\mu_{cloud} > \mu$
- If firm relies on Cloud, then any Cloud outage causes all firms to suffer outage with probability q
- Outage states follow Markov process; enables closed-form steady state solutions, e.g. for average shares of time in outage (denoted τ and τ_{cloud})

Insights from a model of concentration risk

Framework and assumptions (2/2)

- Individual costs for firms equal total time in outage
- Cost externalities: if more than n' firms suffer an outage at the same time, where $n' \leq n$ is a model parameter, systemic cost of $\gamma n > 0$ arises
- Cloud providers charge fees

Insights from a model of concentration risk

Main theoretical results

- Unique equilibrium exists in which all firms use Cloud
- Reliance on Cloud providers can increase systemic risk due to concentration: more firms have simultaneous outages, even if outages are less frequent
- Cloud increases expected total net costs (excluding fees) when

$$\gamma(\beta - \alpha) > \tau - q\tau_{cloud}$$

where α, β are respective probabilities that a systemic event occurs if all firms do not / do use Cloud

- Systemic risk is mitigated when there is competition and portability among Cloud providers

Insights from a model of concentration risk

Main questions:

- Do Cloud providers reduce the risk of outages for firms?

→Yes because they are more efficient

- Under which conditions could cloud providers increase risk to financial stability?

→If systemic costs and probability of simultaneous outages are high

- How to mitigate risks to financial stability?

→Reduce probability of simultaneous outages and duration of outages (diversification)

Insights from a model of concentration risk

Next steps: Model calibration

- To calibrate model, need estimates of key parameters (duration and intensity of outage)
- Could also look at estimating parameters in relation to cyber-specific risks
- Data for estimation are scarce
- Our model and results above suggest what kinds of data collection would be policy-relevant

Main takeaways

1. Significant impact of cyber risk at entity-level and systemic risk
2. Reliance on cloud providers increases efficiency but could increase systemic risk due to concentration
3. Possible policy implications:
    1. Designation of Cloud providers as Critical Service Providers
    2. Diversification in terms of Cloud providers and/or service types (IaaS, SaaS etc.)
    3. Data portability and interoperability

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Additional slides

Technical details: Estimation of losses (1/2)

Aggregate losses:

$$Z = X_1 + \cdots + X_N$$

Where N is a discrete random variable (frequency) and X are random losses (severity).

Three components:

Frequency distribution of N

Distribution of losses for X

Correlation: under independence of events

$$E[Z] = E[N] \times E[X]$$

Avg. # of attacks

Avg. loss per attack

Technical details: Estimation of losses (2/2)

Aggregate losses:

$$Z = X_1 + \cdots + X_N$$
$$N \sim Poisson(\lambda)$$

For $x \leq u$, $X \sim LN(\mu, \sigma)$

$$f(x) = \frac{1}{x\sqrt{2\pi\sigma^2}} exp\left(-\frac{(\ln(x) - \mu)^2}{2\sigma^2}\right)$$

For $x > u$, $X \sim GPD(\xi, \alpha, \beta)$

$$f(x) = \frac{1}{\beta}\left(1 + \frac{\xi(x - \alpha)}{\beta}\right)^{\left(-\frac{1}{\xi}-1\right)}$$

Selected References

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