CYBER RISK MANAGEMENT

Domenico De Giovanni, Arturo Leccadito, Marco Pirra
Department of Economics, Statistics and Finance "Giovanni Anania"
Università della Calabria

Marco Pirra
marco.pirra@unical.it

23 June 2022

ACTUARIAL COLLOQUIA ORLANDO 2022

IAA AAI AFIR-ERM Finance, Investment & ERM

Agenda

- ✓ Introduction
- ✓ Methodology
- ✓ Results
- ✓ Conclusions

Cyber risk

https://www.thecroforum.org/

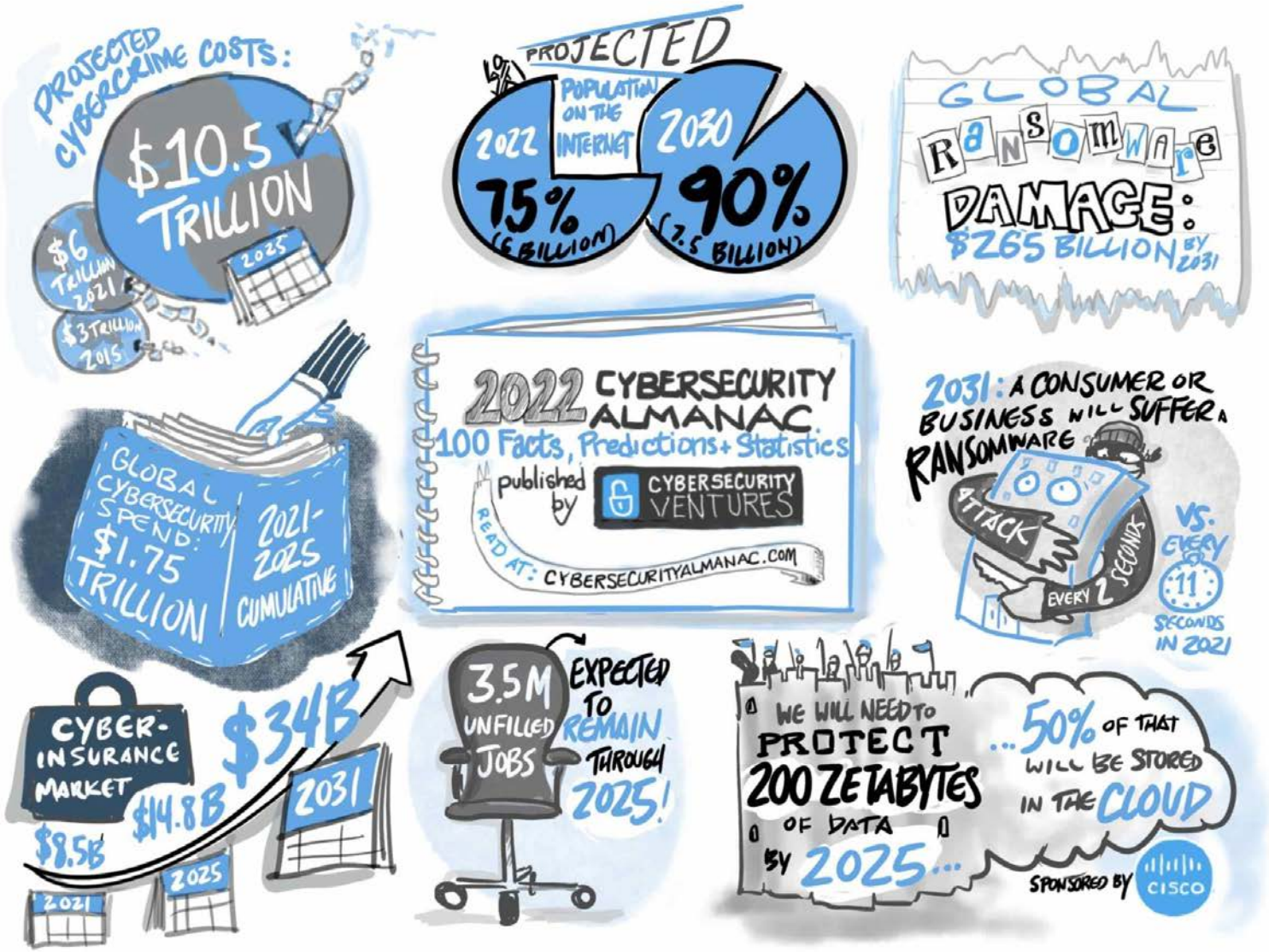
There is **no standardised definition** of the term "cyber risk."

The CRO Forum has broadly described "cyber risk" to mean: "*Any risks that emanate from the use of electronic data and its transmission, including technology tools such as the internet and telecommunications networks*.

It also encompasses physical damage that can be caused by cybersecurity incidents, fraud committed by misuse of data, any liability arising from data storage, and the availability, integrity and confidentiality of electronic information – be it related to individuals, companies or governments."

The cost of Cybercrime [*Cybersecurity Ventures*]

If it were measured as a country, then cybercrime — which was predicted to inflict damages totaling **$6 trillion USD** globally in 2021 — would be the world's third-largest economy after the U.S. and China.



The cost of Cybercrime [*Cybersecurity Ventures*]

Global cybercrime **costs expected to grow by 15 percent per year** over the next five years, *reaching $10.5 trillion USD annually by 2025, up from $3 trillion USD in 2015.*

Digital ad fraud is **rising sharply**.

Cybercrimes are **vastly undercounted** because they aren't reported — due to embarrassment, fear of reputational harm, and the notion that law enforcement can't help (amongst other reasons). Some estimates suggest as few as 10 percent of the total number of cybercrimes committed each year are actually reported.

Cryptocrime, or crimes having to do with cryptocurrencies, are predicted to cost the world $30 billion in 2025, up from an estimated $17.5 billion in 2021.

The **cyberinsurance market will grow** from approximately $8.5 billion in 2021 to $14.8 billion in 2025, and exceed $34 billion by 2031, based on a CAGR (compound annual growth rate) of 15 percent over an 11-year period (2020 to 2031) calculated.

Annual Cost of a Data Breach Study 2021 [Ponemon]

2021 Cost of a Data Breach Study: Global Overview

Benchmark research sponsored by IBM Security
Independently conducted by Ponemon Institute LLC

Key findings

The key findings described here are based on IBM Security analysis of the research data compiled by the Ponemon Institute.

10%
Increase in average total cost of a breach, 2020-2021

$1.07m
Cost difference where remote work was a factor in causing the breach

11
Consecutive years healthcare had the highest industry cost of a breach

The average total cost of a data breach increased by the largest margin in seven years.
Data breach costs increased significantly year-over year from the 2020 report to the 2021 report, increasing from $3.86 million in 2020 to $4.24 million in 2021. The cost of a data breach has increased by **11.9% since 2015**.

Figure 1
Average total cost of a data breach
Measured in US$ millions

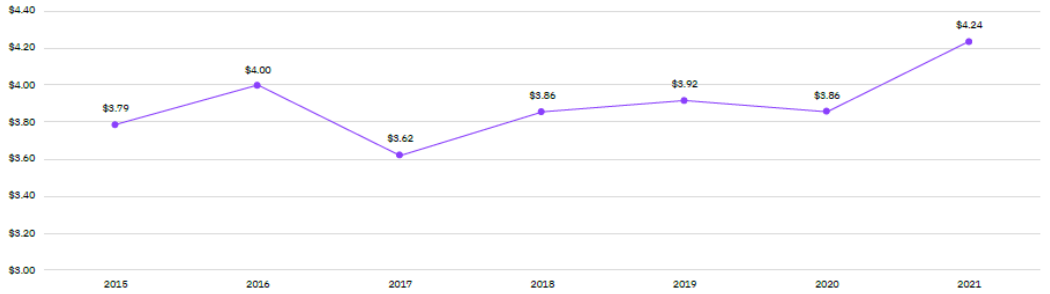
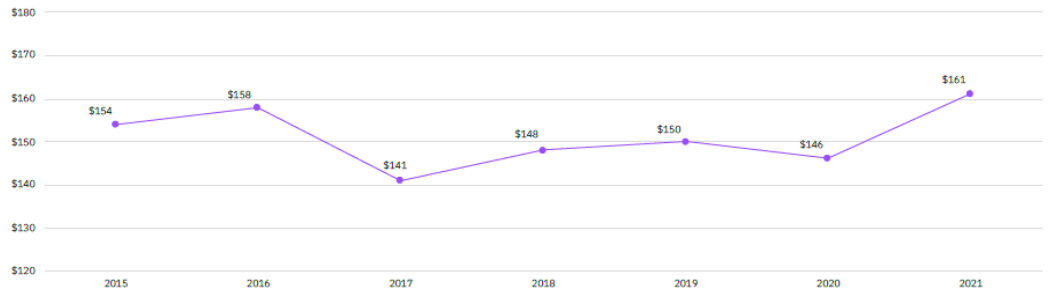


Figure 2
Average per record cost of a data breach
Measured in US$



Now in its 17th year, the Cost of a Data Breach Report has become one of the leading benchmark reports in the cybersecurity industry. The report offers IT, risk management and security leaders a lens into dozens of factors that can increase or help mitigate the rising cost of data breaches.

Economical Impact [Allianz Risk Barometer 2022]

Allianz

The 11th Allianz Risk Barometer incorporates the views of 2,650 respondents from 89 countries and territories.

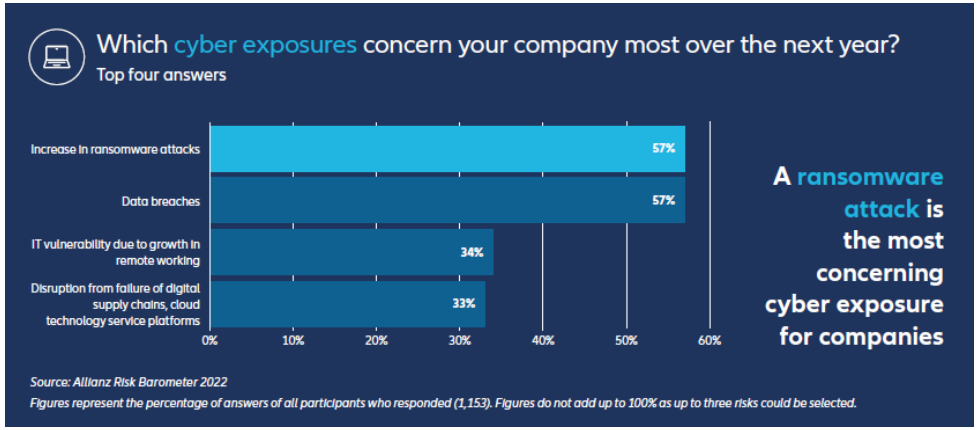
Cyber risk **hits the top spot** in this year's survey, with a series of high-profile ransomware attacks, combined with problems caused by accelerating digitalization and remote working, pushing it up from third in 2021, when it finished behind the closely related risks of business interruption and the Covid-19 pandemic.

"The role of insurance has always been to ensure good risk management and loss prevention," "Good cyber maturity and good cyber insurance go hand-in-hand. We buy insurance for our home, but this does not mean we leave the front door unlocked, and the same should be said for cyber security.

Cyber heads the rankings

1
↑ 44%
2021: 3 (40%)

Ranking history:
2020: 1
2019: 2
2018: 2
2017: 3



Demand for cyber insurance continues to grow, reflecting increased awareness of exposures associated with digitalization and remote working.

https://www.agcs.allianz.com/news-and-insights/news/allianz-risk-barometer-2022-press.html

IAIS - International Association of Insurance Supervisors

ISSUES PAPER ON CYBER RISK
TO THE INSURANCE SECTOR (2016)

IAIS
INTERNATIONAL ASSOCIATION OF INSURANCE SUPERVISORS

Concern over **cybersecurity** **is growing across all sectors of the global economy**, as cyber risks have grown and cyber criminals have become increasingly sophisticated. For **insurers, cybersecurity incidents can harm the ability to conduct business, compromise the protection of commercial and personal data, and undermine confidence in the sector**. The IAIS has noted that the level of awareness of cyber threats and cybersecurity within the insurance sector, as well as supervisory approaches to combat the risks, appear to vary across jurisdictions.

These factors prompted the IAIS to consider the area of cybersecurity in the insurance sector, **including the involvement of insurance supervisors in assessing and promoting the mitigation of cyber risk**. While many of the most widely publicised cybersecurity incidents involving consumer data have affected retailers, companies in the financial services sector, including insurers, have been victimised as well.

IAIS - International Association of Insurance Supervisors

All insurers, regardless of size, complexity, or lines of business, **collect, store, and share with various third-parties** (e.g., service providers, reinsurers) **substantial amounts of private and confidential policyholder information**, including in some instances sensitive health-related information.

Information obtained from insurers through cyber crime may be used for financial gain through extortion, identity theft, misappropriation of intellectual property, or other criminal activities. Exposure of private data can potentially result in severe and lingering harm for the affected policyholders, as well as reputational damage to insurer sector participants.

IAIS - International Association of Insurance Supervisors

The objectives of the Issues Paper are to **raise awareness** for **insurers and supervisors of the challenges presented by cyber risk**, including current and contemplated supervisory approaches for addressing these risks. As an Issues Paper, it provides background, describes current practices, identifies examples, and explores related regulatory and supervisory issues and challenges.

The Issues Paper focuses on **cyber risk to the insurance sector and the mitigation of such risks**, but does not cover IT security risks more broadly. It also does not specifically address insurers' underwriting of cyber risk (i.e., cyber insurance) or risks arising from cybersecurity incidents involving supervisors.

Data breaches

A **data breach** is an incident where information is stolen or taken from a system without the knowledge or authorization of the system's owner.

A small company or large organization may suffer a data breach. Stolen data may involve sensitive, proprietary, or confidential information such as credit card numbers, customer data, trade secrets or matters of national security.

The effects brought on by a data breach can come in the form of damage to the target company's reputation due to a perceived 'betrayal of trust.' Victims and their customers may also suffer ***financial losses*** should related records be part of the information stolen.

Literature Overview

Bessy-Roland Y., Boumezoued A., Hillairet C. (2020). Multivariate Hawkes process for cyber insurance. https://hal.archives-ouvertes.fr/hal-02546343

Betterley R. S. (2016). Cyber/privacy insurance market survey: A tough market for larger insureds, but smaller insureds finding eager insurers. The Betterley Report.

Böhme R. and G. Kataria G. (2006). Models and measures for correlation in cyber-insurance. Fifth Workshop on the Economics of Information Security (WEIS), University of Cambridge, UK.

Böhme R. and Schwartz G. (2010). Modeling cyber-insurance: Towards a unifying framework. Ninth Fifth Workshop on the Economics of Information Security (WEIS), Harvard.

Böhme, R., S. Laube and M. Riek. (2017). A Fundamental Approach to Cyber Risk Analysis. Variance 11, no. 2: 161–85.

De Giovanni, D., A. Leccadito and M. Pirra (2020). On the determinants of data breaches: A cointegration analysis. Decisions in Economics and Finance, 1-20.

Edwards B., S. Hofmeyr, and S. Forrest (2016). Hype and heavy tails: A closer look at data breaches. Journal of Cybersecurity 2(1), 3-14.

Eling, M. and W. Schnell (2016). What do we know about cyber risk and cyber risk insurance? The Journal of Risk Finance, 17(5).

Eling, M. and N. Loperfido (2017). Data breaches: Goodness of fit, pricing, and risk measurement. Insurance: mathematics and economics 75, 126-136.

Eling, M. and J. Wirfs (2019). What are the actual costs of cyber risk events? European Journal of Operational Research 272(3), 1109-1119.

Eling, M. (2020). Cyber risk research in business and actuarial science. European Actuarial Journal volume 10, 303–333.

Gordon, L. A., Loeb, M. P. and Sohail, T. (2003). A framework for using insurance for cyber- risk management. Communications of the ACM, 46(3):81–85.

Literature Overview

Herath, V. S. B. and Herath, T. C. (2011). Copula-based actuarial model for pricing cyber-insurance policies. Insurance Markets and Companies: Analyses and Actuarial Computations, 2:7–20.
Hillairet C., Lopez O., (2020) Propagation of cyber incidents in an insurance portfolio: counting processes combined with compartmental epidemiological models. https://hal.archives-ouvertes.fr/hal-02564462v2
Kosub, T. (2015). Components and challenges of integrated cyber risk management. Zeitschrift fur die gesamte Versicherungswissenschaft, 104(5):615–634.
Mukhopadhyay A., Chatterjee S., Saha D., Mahanti A. and Sadhukhan S. K. (2006). e-Risk management with insurance: A framework using copula aided Bayesian belief networks. In Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06), vol. 6, 126.1–126.6. Hoboken, NJ: IEEE.
Schwartz, G. A. and Sastry, S. S. (2014). Cyber-insurance framework for large-scale interdependent networks. In Proceedings of the Third International Conference on High Confidence Networked Systems, 145–154. New York: ACM.
Tatar U., Keskin O., Bahsi H., Ariel Pinto C., (2020) Quantification of Cyber Risk for Actuaries An Economic-Functional Approach, Society of Actuaries.
Wheatley, S., A. Hofmann, and D. Sornette (2019). Data breaches in the catastrophe framework & beyond. arXiv preprint arXiv:1901.00699 .
Wheatley, S., A. Hofmann, and D. Sornette (2020). Addressing insurance of data breach cyber risks in the catastrophe framework. The Geneva Papers on Risk and Insurance-Issues and Practice.
Wheatley, S., T. Maillart, and D. Sornette (2016). The extreme risk of personal data breaches and the erosion of privacy. The European Physical Journal B 89(1), 7.
Xu, M., and Hua, L. (2019) Cybersecurity Insurance: Modeling and Pricing, North American Actuarial Journal, 23, 220-249.
Yang, Z. and Lui, J. C. S. (2014). Security adoption and influence of cyber-insurance markets in heterogeneous networks. Performance Evaluation, 74:1–17.

Contribution of the research

The objective of our research is to contribute to the actuarial literature on cyber risk assessment in order to provide **possible solutions** for the reduction of the gap between supply and demand of cyber insurance.

In particular, the aim is to achieve a better understanding in quantifying, managing and pricing cyber risk by means of:

I. a **deeper awareness** of cyber risks and of the economic damages they produce;
II. the introduction and validation of new **actuarial techniques** to allow insurers a more effcient management of this new class of risk;
III. The design of **innovative insurance contracts** and alternative ways of risk transfers to reduce the costs of insurance premiums.

Privacy Rights Clearinghouse [*www.privacyrights.org*]

Records Breached: 11,575,804,706
from 8,804 DATA BREACHES
made public since 2005

The first dataset we analyze was obtained from the **Privacy Rights Clearinghouse (PRC)** which is one of the largest and most extensive datasets that is also publicly available.

PRC maintains the Chronology of Data Breaches as a source of information to assist in research involving reported data breaches from 2005 to present.

Many organizations are not aware they've been breached or are not required to report it based on reporting laws. PRC's Chronology is limited to data breaches reported in the U.S. If a data breach affects individuals in other countries, it is included only if individuals in the U.S. are also affected.

Privacy Rights Clearinghouse [*www.privacyrights.org*]

Year	Events	Records
2005	136	55,101,241
2006	482	68,580,749
2007	456	149,957,921
2008	355	130,896,900
2009	270	251,575,814
2010	801	140,937,393
2011	793	447,901,379
2012	886	298,766,833
2013	890	158,789,584
2014	869	1,313,623,927
2015	547	318,837,458
2016	826	4,815,012,420
2017	863	2,051,896,420
2018	828	1,371,001,705
2019	16	321,922

Types of data breach

CARD	Payment Card Fraud – fraud involving debit and credit cards that is not accomplished via hacking (e.g., skimming devices at point-of-service terminals)
DISC	Unintended disclosure – sensitive information either posted publicly on a website, mishandled, or sent to the wrong party via email, fax, or mail
HACK	Hacking or malware – electronic entry by an outside party, malware, and spyware
INSD	Insider – someone with legitimate access, such as an employee or contractor, intentionally breaches information
PHYS	Physical loss – lost, discarded, or stolen non-electronic records, such as paper documents
PORT	Portable device – lost, discarded, or stolen laptop, PDA, smartphone, portable memory device, CD, hard drive, data tape, etc.
STAT	Stationary device – lost, discarded, or stolen stationary electronic device, such as a computer or server not designed for mobility
UNKN	Unknown or other

Entity types

BSF	BSF Businesses – Financial and insurance services
BSO	BSO Businesses – Other
BSR	BSR Businesses – Retail/Merchant
EDU	EDU Educational institution
GOV	GOV Government and military
MED	MED Healthcare – Medical providers
NGO	NGO Nonprofit organizations

Type	Events	%	Records	%
CARD	68	0.75%	9,203,036	0.08%
DISC	1802	19.98%	2,815,845,013	24.33%
HACK	2584	28.65%	8,207,451,875	70.92%
INSD	608	6.74%	83,580,453	0.72%
PHYS	1735	19.24%	40,769,571	0.35%
PORT	1172	13.00%	185,650,895	1.60%
STAT	249	2.76%	16,235,932	0.14%
UNKN	800	8.87%	214,464,891	1.85%

Entity	Events	%	Records	%
BSF	788	8.74%	643,820,265	5.56%
BSO	1047	11.61%	8,990,170,575	77.68%
BSR	623	6.91%	1,383,161,417	11.95%
EDU	862	9.56%	66,376,099	0.57%
GOV	781	8.66%	227,483,420	1.97%
MED	4321	47.92%	242,968,015	2.10%
NGO	119	1.32%	8,444,531	0.07%
UNKN	477	5.29%	10,777,344	0.09%

Breach Level Index [*breachlevelindex.com*]

Data Breach Statistics
Data Records Lost or Stolen Since 2013
14,717,618,286 records
ONLY 4% of breaches were “Secure Breaches” where encryption was used and the stolen data was rendered useless.

The second dataset we analyze was obtained from the **Breach Level Index Data Breach Database** a centralized, global database of data breaches with calculations of their severity based on multiple factors.

The Breach Level Index not only tracks publicly disclosed breaches, but also allows organizations to do their own risk assessment based on a few simple inputs that will calculate their risk score, overall breach severity level, and summarize actions IT can take to reduce the risk score.

Gemalto is the world leader in digital security, helping the largest and most respected brands protect their data, identities, and intellectual property.

Breach Level Index [*breachlevelindex.com*]

YEAR	Events	Records
2013	1217	2,107,666,417
2014	1746	2,888,466,820
2015	1887	743,462,574
2016	1993	1,388,190,640
2017	1958	2,962,190,464
2018	1505	4,876,541,349

#	Source	Events	%	Records	%
1	**Accidental Loss**	2428	24%	4,532,637,539	30.3%
2	**Hacktivist**	164	2%	65,343,200	0.4%
3	**Lost Device**	5	0%	115,007	0.0%
4	**Malicious Insider**	1194	12%	306,945,069	2.1%
5	**Malicious Outsider**	6298	61%	9,430,616,718	63.0%
6	**Ransomware**	5	0%	-	0.0%
7	**State Sponsored**	130	1%	628,967,833	4.2%
8	**Stolen Device**	15	0%	59,069	0.0%
9	**Unknown**	67	1%	1,833,829	0.0%

#	Industry	Events	%	Records	%
1	**Education**	879	8.5%	126,843,836	0.8%
2	**Entertainment**	104	1.0%	502,594,229	3.4%
3	**Financial**	1301	12.6%	552,524,623	3.7%
4	**Government**	1418	13.8%	1,298,531,178	8.7%
5	**Healthcare**	2714	26.3%	291,675,274	1.9%
6	**Hospitality**	106	1.0%	527,606,802	3.5%
7	**Industrial**	138	1.3%	21,119,009	0.1%
8	**Insurance**	83	0.8%	12,700,290	0.1%
9	**Non-profit**	74	0.7%	410,488	0.0%
10	**Other**	1324	12.8%	3,110,303,702	20.8%
11	**Professional Services**	202	2.0%	147,140,489	1.0%
12	**Retail**	1131	11.0%	1,228,013,093	8.2%
13	**Social Media**	34	0.3%	2,758,853,076	18.4%
14	**Technology**	798	7.7%	4,388,202,175	29.3%

Framework

Count time series $\{Y_t : t \in N\}$. Y_t models the number of records stolen at time t.

Time-varying regressors $X_t = \left(X_{t,1}, \ldots, X_{t,r}\right)^T$

Conditional mean $E[Y_t | F_{t-1}] = \lambda_t$,
where F_t is the history generated by the joint process $\{Y_t, \lambda_t, X_t : t \in N\}$

General form:

$$\log(\lambda_t) = \beta_0 + \sum_{k=1}^{p} \beta_k \log(Y_{t-k} + 1) + \sum_{j=1}^{q} \alpha_j \log(\lambda_{t-j}) + \eta^T X_{t-1}$$

Specific form with p=q=1

$$\log(\lambda_t) = \beta_0 + \beta_1 \log(Y_{t-1} + 1) + \alpha_1 \log(\lambda_{t-1}) + \eta^T X_{t-1}$$

Distributions

Distributional assumption **Negative Binomial**

$$Y_t|F_{t-1} \sim NB(\lambda_t, \phi)$$

$$\text{with } P(Y_t|F_{t-1} = n) = p_n^Y = \frac{\Gamma(\phi+n)}{\Gamma(n+1)\Gamma(\phi)} \left(\frac{\phi}{\phi+\lambda_t}\right)^{\phi} \left(\frac{\lambda_t}{\phi+\lambda_t}\right)^{n}, n = 0,1, \ldots$$

Distributional Assumption **Poisson**

$$Y_t|F_{t-1} \sim Poiss(\lambda_t)$$

Zero-Inflated INGARCH models

Distributional Assumption **0-I Negative binomial** (*our own specification*)

$$Y_t|F_{t-1} \sim 0I - NB(\lambda_t, \phi, r)$$

$$\text{with } P(Y_t|F_{t-1} = n) = \tilde{p}_n^Y = \begin{cases} (1-r) + r\left(\frac{\phi}{\phi+\lambda_t}\right)^{\phi} & \text{if } n = 0 \\ r\, p_n^Y & \text{if } n > 0 \end{cases}$$

$$\tilde{Y}_t \sim NB(\lambda_t, \phi)$$

Y_t observed data breaches
$\tilde{Y}_t$ occurred data breaches

$$Y_t = I_t \tilde{Y}_t$$

$$I_t \sim Bern\,(r) \begin{cases} I_t = 1 & data\ breaches\ detected\ and\ reported \\ I_t = 0 & data\ breaches\ not\ detected\ or\ not\ reported \end{cases}$$

Explicative Variables

A data breach occurs when a cybercriminal successfully infiltrates a data source and extracts sensitive information.

Hackers search for these **data** because they can be used to **make money**

As part of their strategy, the attackers hold the information for ransom and demand a payment in order to have the data removed from the host website.
The motive of a cybercriminal defines what company he/she will attack. Different sources yield different information.

Criminal organizations now are treating this like a **business** “They’re going to plan, they’re going to make sure they understand how they’re going to execute and then they’re going to set out and see where they can execute.”

Bitcoins: Why do we care? What is the relationship with data breaches?

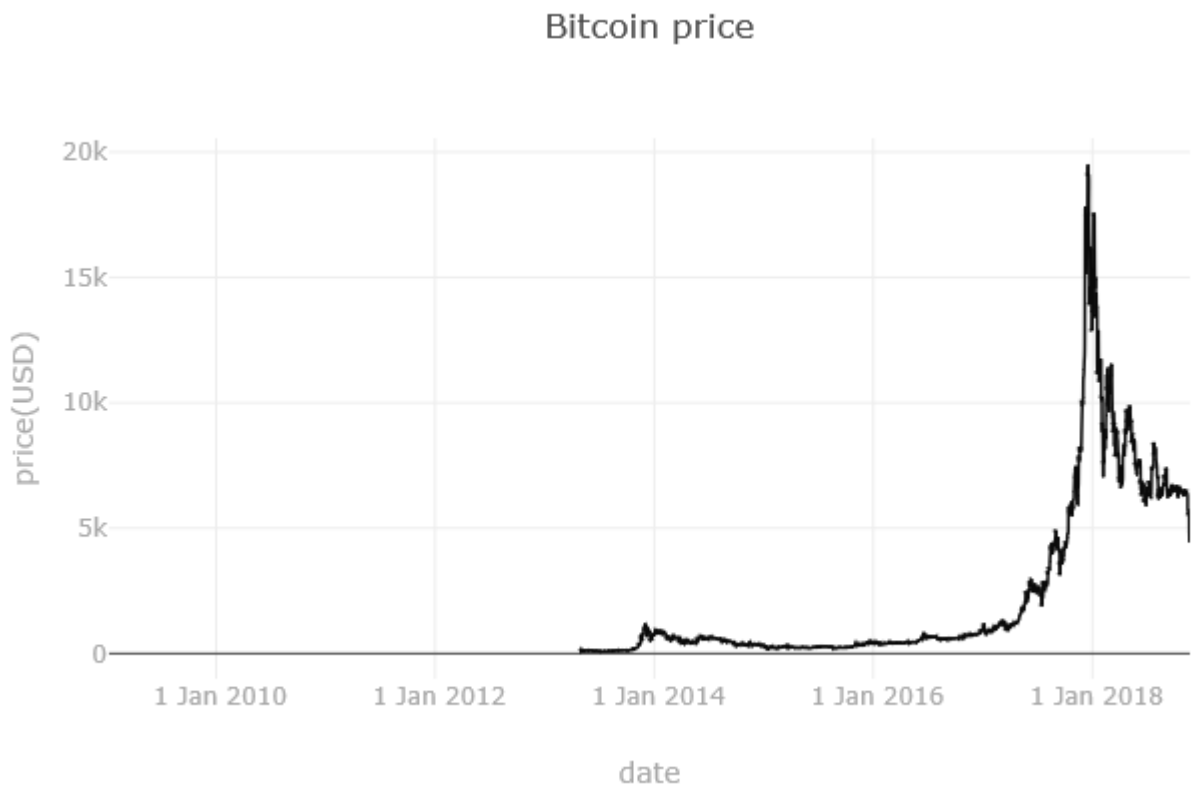
BitCoins

Bitcoin is a **digital payment currency** that utilizes cryptocurrency (a digital medium of exchange) and peer-to-peer (P2P) technology to create and manage monetary transactions as opposed to a central authority. The open source Bitcoin P2P network creates the bitcoins and manages all the bitcoin transactions.
Often referred to as "cash for the Internet," Bitcoin is one of several popular digital payment currencies along with Litecoin, Peercoin and Namecoin.

Bitcoin is considered the **biggest cryptocurrency**. It was first introduced in 2009 and is the most widely-traded cryptocurrency.

Bitcoin as an implementation of the cryptocurrency concept was described by Wei Dai in 1998 on the cypherpunks mailing list. Dai suggested a new form of money that uses cryptography to control its creation and transactions, rather than a central authority. In 2009, the Bitcoin specification and proof of concept was published in a cryptography mailing list by Satoshi Nakamoto. As noted in the Official Bitcoin FAQ, Satoshi Nakamoto left the project in late 2010 without revealing much about himself.

BitCoins [source datahub.io]



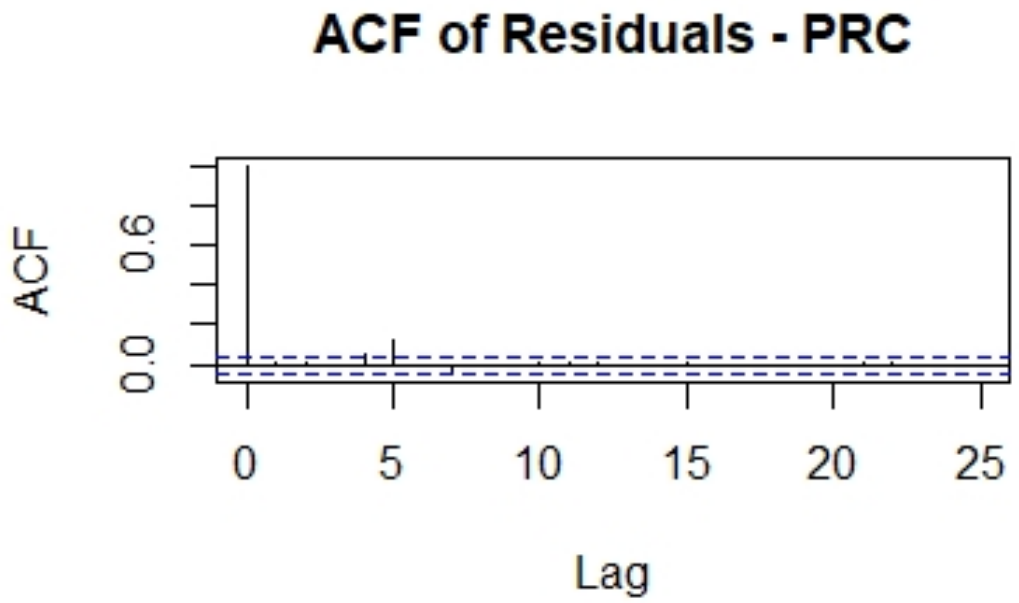
Field Name
date
txVolume(USD)
adjustedTxVolume(USD)
txCount
marketcap(USD)
price(USD)
exchangeVolume(USD)
generatedCoins
fees
activeAddresses
averageDifficulty
paymentCount
medianTxValue(USD)
medianFee
blockSize
blockCount

txCount - refers to the number of transactions happening on the public blockchain a day. Be aware that for low-fee blockchains, it's really easy to fabricate a whole bunch of transactions.

generatedCoins - refers to the number of new coins that have been brought into existence on that day. Actual number of newly-minted coins.

Results Database PRC

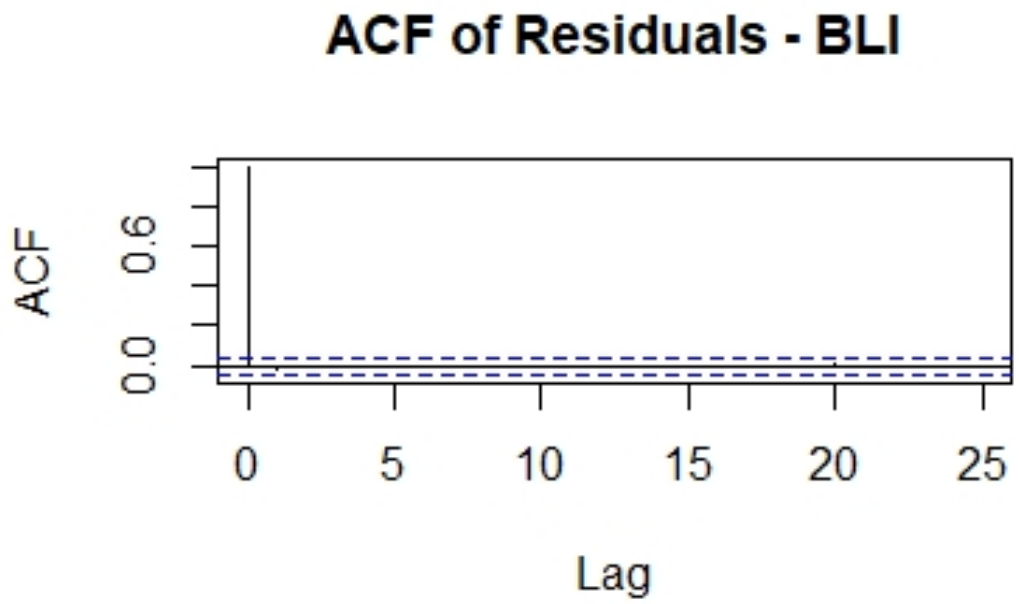
	Estimate	Std. Error	t value	Pr(>|t|)
gamma	- 0.15069	0.08290	-1.81777	0.06910
(Intercept)	4.16140	2.73801	1.51986	0.12855
beta_1	0.02239	0.02336	0.95840	0.33786
alpha_1	0.16208	0.14225	1.13938	0.25454
logGenerated	0.85439	0.31113	2.74611	0.00603
Return	-13.14767	3.84581	-3.41870	0.00063
interv_1	7.11124	5.49732	1.29358	0.19581
interv_2	6.23616	3.57748	1.74317	0.08130
interv_3	5.21903	5.58300	0.93481	0.34989
phi	0.07590	0.01001	7.58468	0.00000



In the PRC estimation the dynamics is NOT YET well captured. This is signaled by the non-significance of both beta_1 and alpha_1 and by the autocorrelation plot, where some lag is out of bounds.

Results Database BLI

	Estimate	Std. Error	t value	Pr(>|t|)
gamma	5.36868	658.19279	0.00816	0.99349
(Intercept)	0.02436	0.66901	0.03641	0.97096
beta_1	-0.00995	0.01186	- 0.83877	0.40160
alpha_1	0.72794	0.05380	13.53153	0.00000
logGenerated	0.45363	0.10871	4.17280	0.00003
Return	-4.35294	1.63529	- 2.66188	0.00777
interv_1	6.45844	2.34383	2.75551	0.00586
interv_2	5.48563	2.81723	1.94717	0.05151
interv_3	5.22553	2.55030	2.04899	0.04046
phi	0.05818	0.00174	33.47602	0.00000



In the BLI, the dynamics is fully captured. The value alpha_1 and its strong significance reflects a strong impact of the TODAY breach intensity on the TOMORROW intensity. The value of beta_1 is very close to zero. This means that the TODAY Size of the breach does not affect the TOMORROW intensity.

Comments

In both databases the value of the coefficients associated to *logGenerated* and *return* are **significant** and show the same **qualitative effect**.
An increase in log-generated rises the Tomorrow intensity.
An increase in the return reduces the Tomorrow intensity.

The value of phi is small; for this reason we have not considered the Poisson distribution (no good fit)

“Interventions” spike variables for outliers

Parametric Insurance

Parametric Coverage **simple and flexible**: if simple conditions are met [if the information commissioner has to be notified of the data breach - the GDPR legislation requires notification within 72 hours - that notification can be used for the assessment of the claim]

Providing **immediate payout** without the need to wait for loss-adjustment, designed to eliminate coverage gaps often found in other offerings, a parametric coverage offers broad parametric coverage with the following customer benefits: clear triggers, flexible limits, quick payout, affordable premiums

As a **first responder** for small and medium size entities the cover defends against cashflow shortages and reduced revenue immediately following a cyber event.

“Parametric” Insurance

A possible **insurance payout** could be based on a standard indemnity per lost or stolen record, whose value decreases as the size of the number increases in order to mitigate moral hazards

$$I = f(i_N | x, Tr, Ex) = x \times f(x) = \begin{cases} 1 & if\ i_N \leq Tr \\ \dfrac{i_N - Tr}{Ex - Tr} & if\ Tr < i_N \leq Ex \\ 0 & if\ i_N \geq Ex \end{cases}$$

if N	paym
< 10,000	$ 161.00
10,000-25,000	$ 128.29
25,001-50,000	$ 77.61
> 50,000	$ 53.24

figure 8 Average total cost of a breach by number of records lost (mln$)

#records	2019	2018	2017	2016	average
< 10,000	2.20	2.10	1.90	2.10	2.08
10,000-25,000	3.30	3.00	2.80	3.00	3.03
25,001-50,000	4.70	4.40	4.60	6.30	5.00
> 50,000	6.40	5.70	6.30	6.70	6.28

Demand's view

One approach for deriving an organization's optimal level of cybersecurity investment, which has received a significant amount of attention in the academic and practitioner literature, is referred to as the **Gordon-Loeb Model** [*Gordon, 2002 the original article*].

Skeoch (2022) demonstrates that the Gordon-Loeb model for investment in information security can be used to build a model for cyber-insurance based on maximizing the expected utility of an insurance buyer. The model suggests that when the Gordon-Loeb recommended optimum is invested in security measures, then utility is maximised at full coverage for reasonable insurance premium rates subject to a cash constraint that the total spend on security measures and insurance cannot exceed the maximum amount stipulated by the Gordon-Loeb model.

Conclusions

Feedbacks appreciated,
thank you for the attention!

marco.pirra@unical.it

Acknowledgements AFIR-ERM Research Grant