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The supply of cyber risk insurance

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ETH Risk Day, 13 September 2024

Cyber losses are large and growing

U.S. Agency for International Development, October 17, 2023

Why does cybersecurity matter for economic growth and trade? *Cybersecurity is critical to maintaining economic and financial stability.* At a macro level, the significant cost of recovering from a breach or hack of a Central Bank, Ministry of Finance, or any large commercial bank would cause financial harm to stakeholders ranging from national governments to small businesses and individuals. In a 2019 survey, *300 global CEOs cited the lack of cybersecurity as the single greatest threat to the global economy over the ensuing decade.* Analysis from cybersecurity industry groups suggests that cyber attacks have a great impact on the global economy. According to one estimate, *the global cost of cybercrime is estimated to top $8 trillion in 2023. This figure is larger than the national economies* of all but two countries—the United States and the People's Republic of China. And cybercrime is expected to continue to grow unabated over the coming years, with projections as high as $23.84 trillion by 2027.

Can cyber risk be insured?

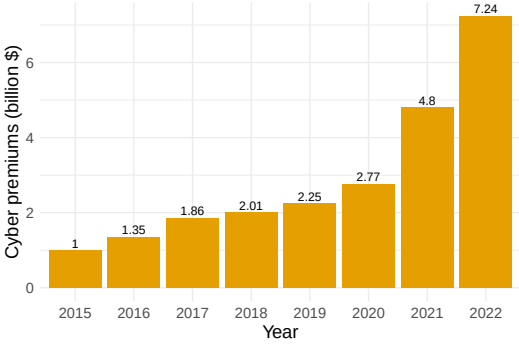


Figure: Cyber insurance market in the US

- The cyber insurance market is growing in the US
  - first-party coverage: data breach forensics, restoration services, extortion and ransom payments, etc
  - third-party coverage: the cost of defending against public or private litigation, and fines from the lawsuits, etc
- But cyber insurance volume amounts to only 0.8% of the property-casualty (P&C) insurance market in 2022
- Swiss Re (2022) estimates that 90% of losses are not covered

Special features of cyber risk

- **Heavy tails**
  - the loss distribution should be modeled by the family of heavy-tailed distributions
- **Risk uncertainty**
  - cyber risk remains largely unknown given its dynamic nature and complexities
  - the correlation of cyber losses with other insured risks is highly uncertain
- **Asymmetric information**
  - the underwriting results heavily depend on the information advantage and monitoring by the insurer
  - cyber insurance typically covers the cost of incident response service, which is provided by third parties and is hard to monitor

- **The combination of these factors creates a tension** between a need to raise substantial amounts of capital to finance heavy-tailed and uncertain risks and an expensive compensation demanded by investors due to information frictions
  - To circumvent asymmetric information costs, insurers use internal capital

Literature review

- Cyber risk and firms
  - the impact of cyber attacks on firms (Kamiya et al., 2021; Foerderer and Schuetz, 2022) and cyber risk exposure spillover effects (Crosignani, Macchiavelli, and Silva, 2023; Eisenbach, Kovner, and Lee, 2022; Jamilov, Rey, and Tahoun, 2023)
- Internal capital market
  - corporate finance (Gertner, Scharfstein, and Stein, 1994; Diamond, 1994; Stein, 2002) and insurer's capital structure (Garven and Lamm-Tennant, 2003; Plantin, 2006)
- Supply-side factors for insurance markets
  - how financial frictions affect insurance supply (Koijen and Yogo, 2015; Koijen and Yogo, 2022; Ge, 2022)
- Our contribution: the first paper to study cyber risk insurance supply to our best knowledge

Outline

Data on the US cyber insurance market

A model of risk financing

Does the cost of internal capital affect the cyber insurance supply?

Why is it more costly to raise external capital for cyber risk?

Data on the US cyber insurance market

A model of risk financing

Does the cost of internal capital affect the cyber insurance supply?

Why is it more costly to raise external capital for cyber risk?

Data

- The Cybersecurity and Identity Theft Coverage supplement from the National Association of Insurance Commissioners (NAIC) in the US
  - new template introduced in 2015
  - reporting components
    - premiums, losses, number of policies and reserves for each type of cyber insurance
    - policy type (standalone, package)
    - type of cyber coverage (cybersecurity, identity theft)
- NAIC regulatory reports on the balance sheet and income statement information of insurers from 2015 to 2022
- AM Best Financial Strength Rating File (from A++ to S)

Cyber insurance market in the US

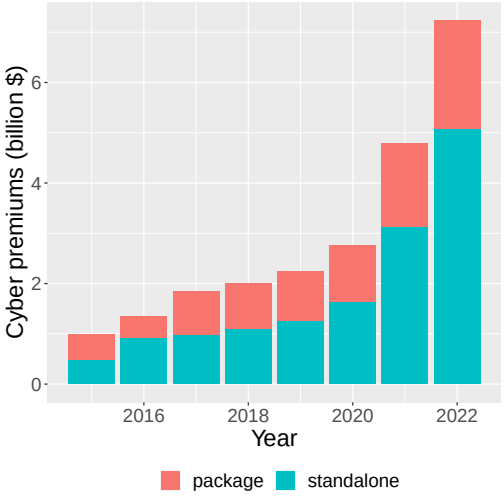


Figure: Market growth

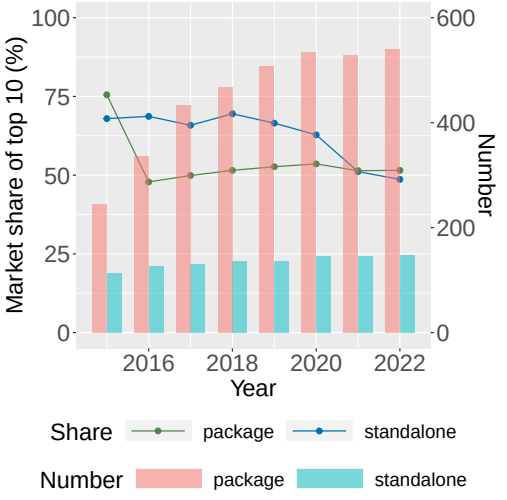


Figure: Market structure

Cyber insurers use more reinsurance than other lines of business

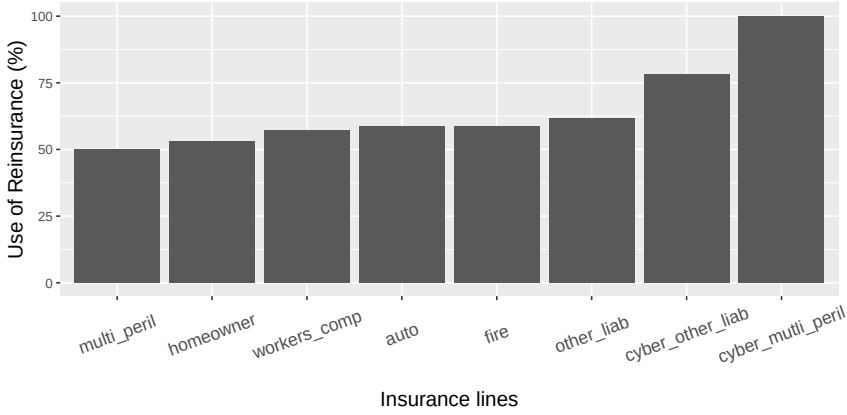
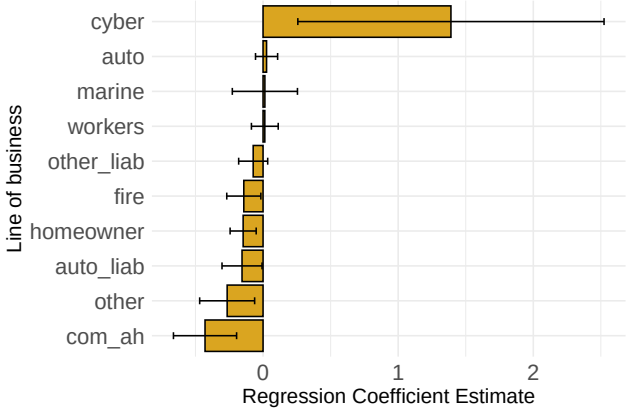


Figure: Use of reinsurance by insurance lines *("cyber_other_liab" and "cyber_multi_peril" use the subsample of insurers with* $\geq 50\%$ *cyber premiums in the corresponding lines)*

Cyber insurance correlates with the use of affiliated reinsurance

- Econometric specification
  $Affiliated\ Reinsuarnce_{it} = \beta_0 + \beta_1 cyber_{it} + \sum_j \beta_j line_{ijt} + X'_{it}\lambda + \epsilon_{it}$

- Strong correlation between cyber insurance and affiliated reinsurance but not for other lines



Cyber insurers maintain profitability despite premium growth

Premium growth is the product of price and exposures

Total Premiums = Average price × Number of exposures

Dependent Variables:	Change in loss ratio			Change in loss ratio		
Model:	(1)	(2)	(3)	(4)	(5)	(6)
Change in premiums	-0.3308**	-0.3896***	-0.5899***			
	(0.1356)	(0.1002)	(0.1649)			
Change in claims				0.2841***	0.2586***	0.2492***
				(0.0771)	(0.0754)	(0.0823)
Controls	No	Yes	Yes	No	Yes	Yes
Firm	No	No	Yes	No	No	Yes
Year	No	Yes	Yes	No	Yes	Yes
Observations	1,019	1,011	1,011	778	773	773
R^2	0.01265	0.02994	0.38544	0.01932	0.04602	0.45424

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A model of risk financing

Does the cost of internal capital affect the cyber insurance supply?

Why is it more costly to raise external capital for cyber risk?

A model of risk financing

- What is a pecking order of financing sources? How does it depend on the insurance liability portfolio characteristics?
- Model financing choices between internal capital market, external reinsurance, and outside investors
- Distinguishing characteristics of funding sources
  - information asymmetry
  - allocation of control rights and asset redeployment
  - managerial incentives

Model implications and hypotheses

- Does the internal capital market affect cyber insurance supply?
  - H0: The supply of cyber insurance decreases following the shock to the availability of affiliated reinsurance
  - H0: The supply of other types of insurance is less affected by the same shock compared to cyber insurance
- Why cyber risk is more costly to transfer outside of the insurance group compared to other risks?
  - Factor decomposition of external reinsurance price: heavy tail, information asymmetry, and risk uncertainty

Data on the US cyber insurance market

A model of risk financing

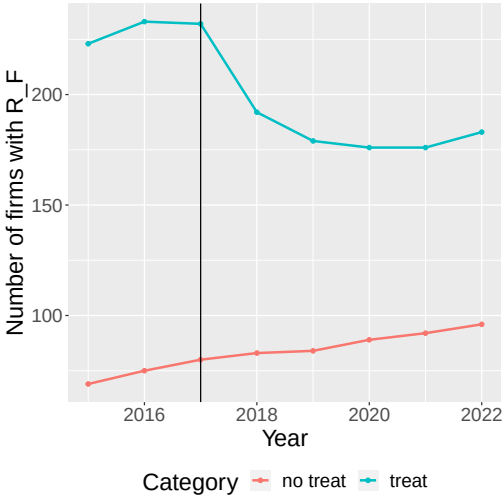
Does the cost of internal capital affect the cyber insurance supply?

Why is it more costly to raise external capital for cyber risk?

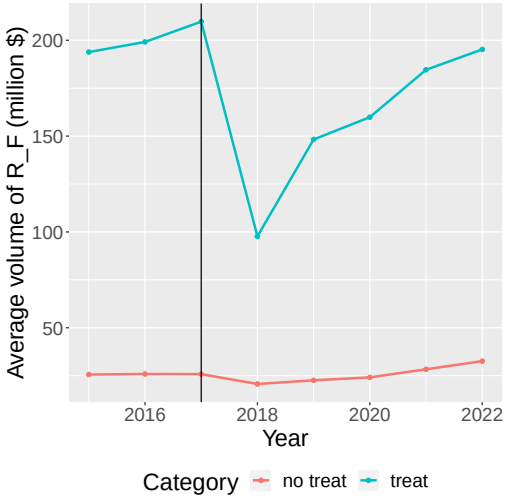
Identification: the BEAT reform

- In 2017, the U.S. Tax Cuts and Jobs Act introduced the base erosion and anti-abuse (BEAT) tax to more effectively limit profit shifting and curb base erosion
- Target group of the reform: multinational companies with average annual gross receipts of at least $500 million for the prior three tax years
- For insurers, the BEAT reform imposes a minimum tax of 10% on foreign-affiliated reinsurance transactions, which were tax-deductible before the reform
  - Typically, these reinsurers are located in Bermuda, which is historically a large reinsurance hub

Identification: the BEAT reform



(a) Extensive margin



(b) Intensive margin

Figure: The impact of BEAT on the use of foreign-affiliated reinsurance R_F

Does internal capital drive cyber insurance supply?

- H0: The supply of cyber insurance decreases following the shock to the availability of affiliated reinsurance
  H0: The supply of other types of insurance is less affected by the same shock compared to cyber insurance

- Difference-in-difference econometric specification

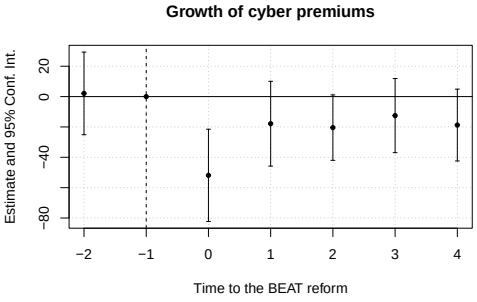
$$Y_{it} = \alpha + \beta_1 D_i + \beta_2 Post_t + \delta(D \times Post)_{it} + X'_{it}\lambda + \tau_t + \sigma_i + \epsilon_{it}$$

  - First type of D: 1 = treat, 0 = no treat
  - Second type of D: an intensity measure

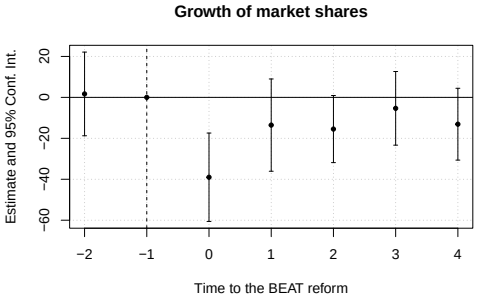
$$D = \underbrace{\frac{DPW_C}{GPW}}_{\text{cyber share}} \times \underbrace{\frac{R_F}{GPW}}_{\text{share of foreign affiliated reinsurance}}$$

  where GPW is gross premiums written, DPW_C is cyber premiums written, and R_F is premiums ceded to foreign affiliates

Event study 2016-2022



(a) All cyber insurers



(b) Cyber premiums $\geq$ 1st quartile

Figure: The impact of BEAT on growth rate of cyber premiums

Result 1: rising costs of internal capital constrain cyber insurance supply

Binary treatment variable (80%)						
Dependent Variable:	Growth of cyber premiums (%)			Growth of market share (%)		
Model:	(1)	(2)	(3)	(4)	(5)	(6)
Treat*2018	-16.08	-13.82	-14.00	-14.00	-11.74	-11.79
	(9.820)	(12.52)	(9.481)	(11.60)	(13.50)	(11.27)
Treat*2019	-28.20**	-26.84**	-30.36**	-27.65**	-26.37*	-30.74**
	(12.15)	(12.53)	(11.80)	(12.75)	(13.50)	(12.53)
Treat*2020	-15.34	-16.46	-22.05*	-12.82	-13.84	-19.43
	(13.41)	(12.71)	(12.86)	(13.82)	(13.70)	(13.56)
Insurer FE	N	N	Y	N	N	Y
Year FE	N	N	Y	N	N	Y
Control	N	Y	Y	N	Y	Y
Observations	288	288	288	288	288	288
R^2	0.06363	0.16072	0.42139	0.01807	0.10358	0.35378

- Compared to other affected insurers, insurers with exposures $\geq$ the 50th percentile
  - 30.36% decrease in the growth rate of cyber premiums
  - 30.74% decrease in the growth rate of market share

Result 2: internal capital is less relevant for other types of insurance

Growth rate of premiums (%)	Homeowner	Auto	Fire	Multi peril	Workers' comp	Other liability	Auto liability
Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treat*2018	-0.5896	0.0539	-0.0067	0.0061	0.0756	0.0048	-0.1344
	(0.7042)	(0.0606)	(0.0376)	(0.0345)	(0.0675)	(0.0061)	(0.1039)
Treat*2019	-1.036	0.0821	0.0043	-0.0129	0.0149	0.0075	-0.0557
	(0.8820)	(0.0523)	(0.0340)	(0.0356)	(0.0731)	(0.0068)	(0.0589)
Treat*2020	-0.8919	0.1542	0.0339	-0.0153	-0.1311	0.0004	0.1148
	(0.6785)	(0.2360)	(0.0406)	(0.0311)	(0.1698)	(0.0037)	(0.2289)
Insurer FE	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y
Control	Y	Y	Y	Y	Y	Y	Y
Observations	285	269	266	244	255	268	252
R^2	0.39832	0.27194	0.22653	0.38433	0.28620	0.42539	0.22041

- The continuous treatment variable is calculated similarly by replacing cyber premiums with the premiums of each corresponding line
- The BEAT reform has no significant effects on other lines of business

Data on the US cyber insurance market

A model of risk financing

Does the cost of internal capital affect the cyber insurance supply?

Why is it more costly to raise external capital for cyber risk?

Characteristics of cyber risk

- The key features of cyber risk include
  - heavy tail
  - risk uncertainty
  - information asymmetry, pre- and post-contractual

Heavy tail

- Heavy tail is an important property of cyber risk, and this affects the use of reinsurance (especially external) as cyber insurance might be exposed to more extreme risks than other insurance
- Cyber reinsurance is not reported separately, but we can use the share of cyber premiums as a proxy for reinsurance exposure
- **Empirical test:** as the tail for cyber risk is heavier than other risks in the same line, the share of cyber insurance is positively related to the price of reinsurance

Risk uncertainty

- The level of uncertainty in the cyber portfolio also affects the price of reinsurance
- Reinsurers may charge higher markups for insurers with less experience in cyber underwriting
- A proxy for the level of cyber knowledge/experience of one insurer is the update frequency of its cyber products
  - SERFF: The System for Electronic Rates & Forms Filing (all insurance product filings in the U.S.)
  - We use text mining and GPT API to identify the cyber products ($> 90\%$ accuracy in the training sample)
- **Empirical test:** the update frequency is negatively related to reinsurance price as higher frequency indicates more knowledge about cyber risk

Information asymmetry

- To limit moral hazard, reinsurers use price incentives and monitoring in the long term relationship (Doherty and Smetters, 2005)

- **Empirical test:** The reinsurance price $\frac{Reinsured\ premiums_t}{Reinsured\ losses_t}$ responds to the following variables:
  - Experience rating: measured by $\frac{Direct\ premiums_{t-1}}{Direct\ losses_{t-1}}$
    - reinsurers "experience rate" the past losses, high past losses lead to high current prices
  - Monitoring: measured by $\frac{Reinsured\ losses_{t-1}}{Direct\ losses_{t-1}}$
    - investment in monitoring is reflected in prices, monitoring increases in the share of reinsured losses
  - Direct price control: measured by Experience rating $\times$ $\frac{Reinsured\ losses_{t-1}}{Direct\ losses_{t-1}}$
    - the sensitivity of prices to past losses increases as more losses are reinsured

Econometric specification

- We combine all factors and their interaction terms into one regression to test the relationship to the reinsurance price

$$\textit{Reinsurance price}_t = \alpha + \underbrace{\beta \cdot \textit{cybershare}_{t-1}}_{\text{Heavy tail}} + \underbrace{\gamma \cdot \textit{non aff}_{t-1}}_{\text{Non-affiliated reinsurance}} + \underbrace{\lambda \cdot \textit{update freq}_{t-1}}_{\text{Risk uncertainty}}$$

$$\underbrace{\epsilon \cdot \textit{control}_{t-1} + \delta \cdot \textit{exp\_rate}_{t-1} + \omega \cdot \textit{monitor}_{t-1}}_{\text{Info asymmetry}} +$$

$$\underbrace{\textit{cybershare}_{t-1} \cdot \textit{non aff}_{t-1} \cdot (\epsilon 1 \cdot \textit{control}_{t-1} + \delta 1 \cdot \textit{exp\_rate}_{t-1} + \omega 1 \cdot \textit{monitor}_{t-1})}_{\text{Info asymmetry for lines with cyber insurance and non-aff reinsurance}} +$$

$$\underbrace{\lambda 1 \cdot \textit{cybershare}_{t-1} \cdot \textit{non aff}_{t-1} \cdot \textit{update freq}_{t-1}}_{\text{Risk uncertainty for lines with cyber insurance and non-aff reinsurance}} + \textit{other interaction terms}$$

Econometric specification

- Key variables:
  - non-aff (%): the share of non-affiliated reinsurance in total reinsurance
  - cybershare (%): the share of cyber premiums in total premiums
  - update_freq: the cumulative number of updates related to cyber products
  - exp_rate, monitor, and control are measures for information asymmetry

- The interaction terms are our focus
  - for example: non-aff×cybershare×monitor measures the sensitivity of reinsurance prices to monitoring efforts for a certain level of non-aff reinsurance and cyber premiums interpretation back

Result 3: Factor decomposition of cyber reinsurance price

Dependent Variable:	Reinsurance price					
	Other liability line			Commercial multi-peril line		
Model:	(1)	(2)	(3)	(4)	(5)	(6)
non-aff	0.0249**	0.0234***	0.0132	-0.0002	0.0003	0.0108
	(0.0102)	(0.0056)	(0.0204)	(0.0132)	(0.0087)	(0.0168)
cybershare	1.332	1.309	2.824***	-0.1275	-0.1387	0.0931
	(0.9208)	(0.9261)	(0.8556)	(0.1647)	(0.2535)	(0.1423)
exp_rate	1.676***	1.629***	0.3296	0.3903	0.3942	1.596
	(0.2185)	(0.1415)	(0.5106)	(0.8103)	(0.3714)	(1.177)
monitor	0.9114	0.7559	-0.1353	-1.094	-1.158	-0.7165
	(0.5984)	(0.5578)	(1.300)	(1.261)	(0.7838)	(1.960)
control	-1.368***	-1.306***	-0.1371	-0.2718	-0.2830	-1.242
	(0.3256)	(0.2410)	(0.6625)	(0.9290)	(0.4853)	(1.327)
update_freq	0.0103	0.0114	-0.0053	0.0215	0.0331	0.0676
	(0.0408)	(0.0353)	(0.0585)	(0.0294)	(0.0453)	(0.0622)
cybershare × update_freq	0.0049	0.0052	0.0212	0.0063	0.0034	-0.0057
	(0.0196)	(0.0501)	(0.0178)	(0.0045)	(0.0115)	(0.0060)
non-aff × update_freq	-0.0003	-0.0003	0.0001	-0.0041***	-0.0042***	-0.0011
	(0.0018)	(0.0009)	(0.0018)	(0.0015)	(0.0013)	(0.0013)
non-aff × cybershare × exp_rate	0.0265	0.0249*	0.0629*	0.0003	-2.22×10^{-5}	0.0011
	(0.0198)	(0.0138)	(0.0320)	(0.0015)	(0.0018)	(0.0009)
non-aff × cybershare × monitor	0.0421	0.0408	0.1172***	0.0014	0.0008	0.0012
	(0.0330)	(0.0350)	(0.0448)	(0.0024)	(0.0043)	(0.0017)
non-aff × cybershare × control	-0.0351	-0.0335	-0.0955**	-0.0016	-0.0009	-0.0016
	(0.0259)	(0.0220)	(0.0433)	(0.0021)	(0.0032)	(0.0013)
non-aff × cybershare × update_freq	-0.0003	-0.0002	-0.0004	7.11×10^{-5}	6.77×10^{-5}	5.26×10^{-5}
	(0.0004)	(0.0010)	(0.0003)	(7.08×10^{-5})	(0.0002)	(7.85×10^{-5})
Controls	No	Yes	Yes	No	Yes	Yes
Firm	No	No	Yes	No	No	Yes
Year	No	Yes	Yes	No	Yes	Yes
Observations	720	720	720	597	597	597
R^2	0.32849	0.34051	0.62496	0.14714	0.16715	0.56073

Result 3: Factor decomposition of cyber reinsurance price–summary

- External reinsurance
  - significantly increases overall reinsurance prices for cyber standalone policies
  - non-aff: $+$
- Heavy tail
  - significantly affects reinsurance prices for cyber standalone policies
  - cybershare: $+$
- Risk uncertainty
  - significantly affects reinsurance prices for package policies
  - non-aff $\times$ update_freq: $-$
- Information asymmetry
  - significantly affects reinsurance prices for cyber standalone policies, especially with higher levels of non-aff reinsurance and cyber premiums
  - non-aff $\times$ cybershare $\times$ monitor: $+$
  - non-aff $\times$ cybershare $\times$ control : $-$

Conclusions

- What limits the supply of cyber insurance?
  - supply of cyber insurance relies heavily on the internal capital of insurers
  - reliance on affiliated reinsurance limits the supply of cyber insurance
- Why cyber risk is more costly to transfer outside of the insurance group compared to other risks?
  - heavy tail, information asymmetry, and risk uncertainty all play a role in driving up the cost of external capital for cyber exposure

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Interpretation of variables for factor decomposition analysis

non_aff	how the overall reinsurance price reacts to the share of external reinsurance (+: **external reinsurance is more expensive**)
cybershare	how the overall reinsurance price reacts to the share of cyber insurance (+: **cyber reinsurance is more expensive**)
exp_rate	how the overall reinsurance price reacts to experience rating or past losses (-: **experience rating is used by reinsurers**)
monitor	how the overall reinsurance price reacts to the monitoring efforts (+: **monitoring is used by reinsurers**)
control	how the overall reinsurance price reacts to the direct control (-: **direct price control is effective as it increases the sensitivity of reinsurance price to experience rating**)
update_freq	how the overall reinsurance price reacts to update frequency (-: **higher frequency reduces reinsurance prices**)

interpretation back

Interpretation of variables for factor decomposition analysis

cybershare × update_freq	how the overall reinsurance price reacts to update frequency given the level of cyber share (**-: higher update frequency leads to a lower price when the cyber share is higher**)
non_aff × update_freq	overall reinsurance price reacts to update frequency given the level of non-affiliated reinsurance (**-: higher update frequency leads to a lower price when non-affiliated reinsurance is higher**)
non_aff × cybershare × exp_rate	how overall reinsurance price reacts to experience rating given the level of non-affiliated reinsurance and cyber insurance shares (**-: experience rating is used more intensively with more non-affiliated reinsurance and cyber insurance**)

Interpretation of variables for factor decomposition analysis

non_aff × cybershare × monitor	how overall reinsurance price reacts to monitoring efforts given the level of non-affiliated reinsurance and cyber insurance shares (+: **with more non-affiliated reinsurance and cyber insurance, the effect of monitoring on reinsurance price is higher**)
non_aff × cybershare × control	how overall reinsurance price reacts to direct price control given the level of non-affiliated reinsurance and cyber insurance shares (-: **with more non-affiliated reinsurance and cyber insurance, the sensitivity of price to direct price control is higher**)
non_aff × cybershare × update_freq	how overall reinsurance price reacts to update frequency given the level of non-affiliated reinsurance and cyber insurance shares (-: **with more non-affiliated reinsurance and cyber insurance, the update frequency of cyber insurer reduces more significantly the reinsurance prices**)