A re-examination of U.S. insurance market capacity to pay catastrophe losses

Georges Dionne and Denise Desjardins
Canada Research Chair in Risk Management, HEC Montréal

Preliminary

SCOR Foundation webinar
Paris, 8 November 2022

Preface

We thank the SCOR Foundation for Science for financial support. The Foundation is not responsible of the content and the conclusions of this study.

The study covers all losses by U.S. insurers net of reinsurance. The interpretation is often related to climate risk because it represents the major losses during the period of analysis.

Research document available at:
https://foundation.scor.com/sites/default/files/2022-05/ClimatRisk_22-05-11_paper%2Bonline%20appendix.pdf

Introduction

Our main objective is to update the study of Cummins, Doherty and Lo (2002) with new data available until the end of 2020. We also want to better integrate the roles of reinsurers and that of mergers and acquisitions in the analysis.

Cummins, Doherty and Lo (2002) presents a theoretical and empirical analysis of the capacity of the US property–liability insurance industry to finance insured catastrophic losses in the $100bn range.

They show that a sufficient condition for capacity maximization is for all insurers to hold a net of reinsurance underwriting portfolio which is perfectly correlated with aggregate industry losses.

Estimating capacity with insurers financial statement data from the NAIC, Cummins et al (2002) find that the U. S. insurance industry could appropriately fund a $100bn event in 1997.

But according to the authors, the prospect of a mega-catastrophe brings the real threat of insurer failures and unpaid claims.

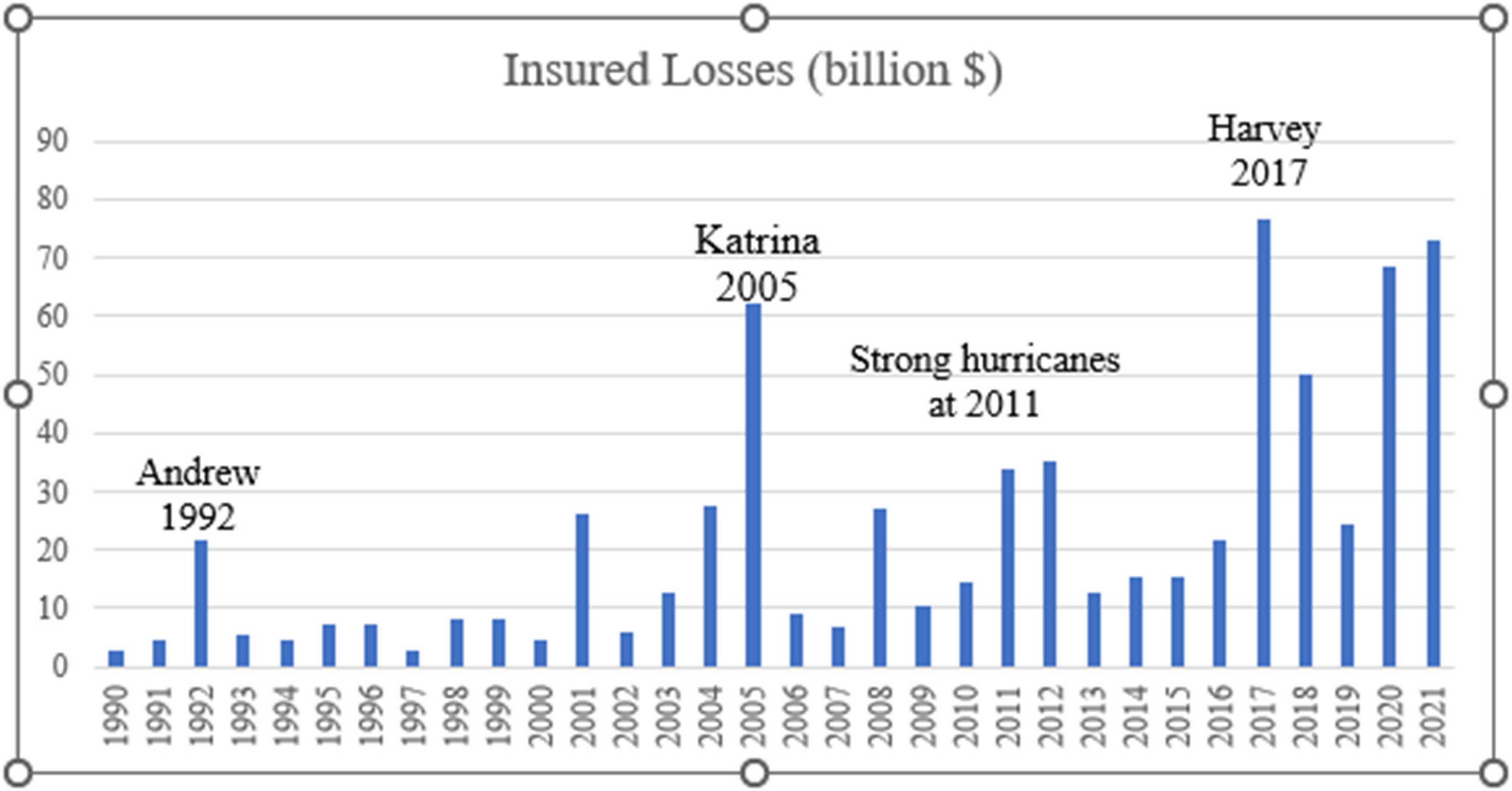
At that time, economic loss scenarios for one extreme event were:

- $76bn hurricane in Florida
- $72bn earthquake in California
- $101bn New Madrid earthquake

and the US property-liability insurance industry capacity was $370bn.

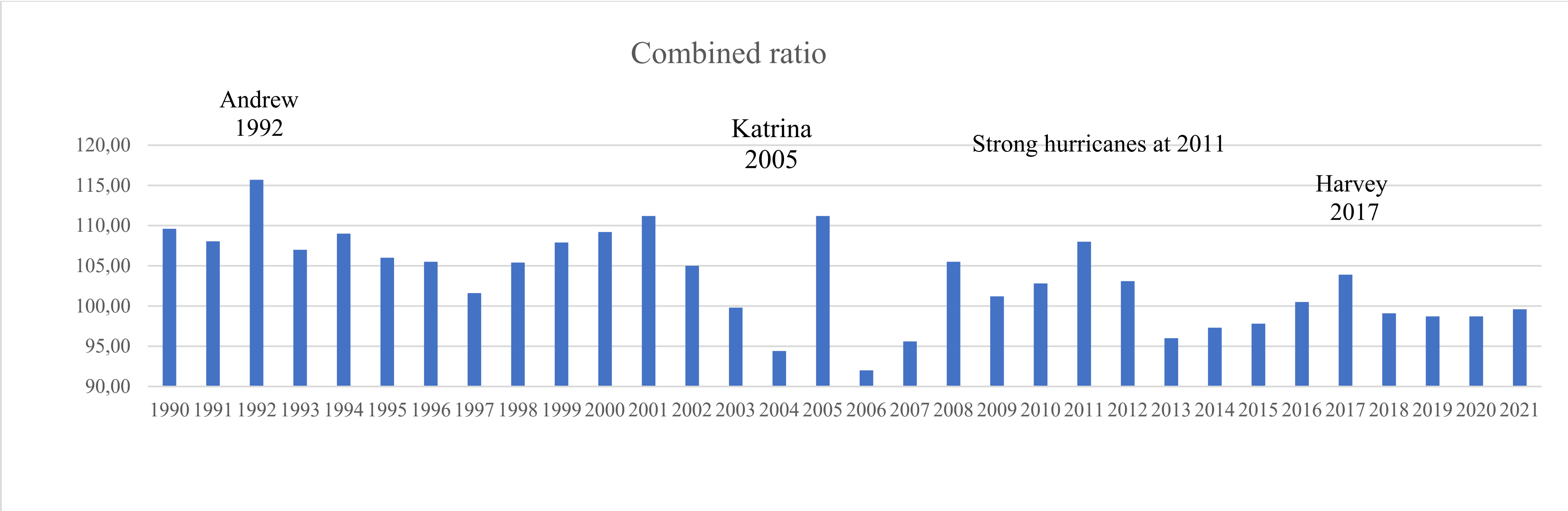
Recent economic costs and insurance costs

Hurricane	Economic cost (billion)	Insurance cost (billion)
Katrina (2005)	125	65
Sandy (2012)	70	28
Irma (2017)	67	30
Ida (2021)	70	36
Ian (2022)	70-120	30-60



Sources: Verisk and Dionne et al (2022).

Events of 25 million and more only.



Sources: NAIC data and Federal Insurance Office, U.S. Department of the Treasury, Annual Report on the Insurance Industry, and Statista data.

Sum of incurred losses and expenses divided by the earned premiums.

Climate finance

Climate finance is related to the sources of financing, supporting mitigation and adaptation actions that will address climate change (United Nations Framework Convention on Climate Change – UNFCCC – reported in Hong et al, special issue of *RFS*, 2020).

This financing is intended to change the world economy and to build resilience to climate change.

Yet no studies in finance and insurance have looked at the **causal** effects of climate change on the insurance industry even if different correlations are documented.

A crucial input for the analysis of climate change risks is the **causal impact** of climate events on economic activity, which is called the distribution of damages. This raises an important question about the modeling and sharing of extreme weather risks.

Do extreme weather risks, such as the impact of Hurricane Sandy in 2012 (economic cost: $70.2bn) or the 2018 California wildfires (economic cost: $148.5bn), have long-run causal effects on insurance markets? These events are also related to many deaths, at least 72 in USA for Sandy and 103 in California.

These distributions of damages depend on locational decisions by households and firms (self-protection), and technology (self-insurance) decisions in terms of mitigating the damage caused by disasters.

They also depend on market insurance coverage (including moral hazard and adverse selection effects).

By modeling these loss distributions adequately, the insurance industry should be able to play a critical role in facilitating risk-sharing and extending insurance coverage of extreme weather events. Public authorities must also improve their role. We may need more public resilience for society.

The frequency of events is also changing. In 2019, there were 33 events (20 in 2021) with more than 1 bn of **total losses** each in U.S. Nine events cost the **insurance industry** more than 1bn that year, and all of them were climate risk events (cyclones, storms with flooding, and tornadoes, National Centers for Environmental Information).

Moreover, in April 2020, severe weather events in the United States cost insurers billions of dollars with 14 tornadoes, the fifth highest month on record since 1950, according to the Aon Global Catastrophe Recap report.

In 2021, the weather and climate disasters cost $145bn in USA ($102bn in 2020, $346bn in 2017). During the last five years, the total cost was $742bn, which represents more than 33% of the total disasters costs of the 1980-2021 period (National Centers for Environmental Information). Recently, hurricane Ida cost $70bn (economic loss), which is not very far from the $100bn of the article.

The difference from recent experience is that we may have more than one “big one” event during a given year because of climate changes!

We can summarize the major issues related to climate risks as follows (Dionne, 2015):

- For many years the population has concentrated in high-risk areas.
- The demand for insurance coverage for climate risks among individuals is low, less than 40% coverage in many areas!
- On the supply side, a survey funded by the NAIC found that insurers were not really prepared to cover climate risks (NAIC, 2014). Are they better prepared in 2022?
- Natural hazard losses fluctuate radically. This is a long run issue. Insurers cannot only use the recent loss history to calculate premiums.
- Prevention is a long-run investment activity, yet insurance coverage is annual. There is a commitment issue here.

- Insurers can spread their liabilities through reinsurance. In principle, the effects of catastrophes can be diversified through the worldwide reinsurance market.

  Historically, the available capacity of reinsurers was limited but it has increased significantly since Hurricane Andrew, that cost $26bn in 1992 (Cummins and Weiss, 2000).
- Many insurers have reduced their exposure to such losses, and rating agencies seem to encourage such a move to maintain the current ratings of insurance companies (reinsurers?).
- Insurance-Linked Securities (ILS) are becoming important in the reinsurance market for catastrophe losses related to climate risk. They are not very prevalent in the insurance market.

According to 2014 data, reinsurance total capital is about $575bn ($625bn, 2019), including $62bn in ILS capacity other than traditional reinsurance.

We may think there is sufficient capacity because annual economic average long-run insured losses are below $150bn, but there are important recent exceptions in 2011 ($375bn) and 2017 (340bn).

Cummins et al (2002) study

Estimate industry capacity using insurers' financial statement data and find that the industry could adequately fund a $100bn insurance loss event in 1997 with data over the period 1983-1997, whereas US insurers' total equity capital was approximately equal to $370bn.

The estimated percentages paid for larger losses decline, however. For example, according to their parameter estimates, the industry would be able to pay about 96.4% of a $100bn loss. For a $200bn loss, the industry could pay 84.0%.

Nonetheless, such events may cause numerous insolvencies and severely destabilize insurance markets. For example, a $100bn catastrophe is projected to cause 30 insolvencies for the group sample.

Theory

Borch (1962) shows, in an EU framework, that value maximizing risk sharing transactions would leave all insurers holding losses net of reinsurance portfolios defined solely on the market aggregate loss and that insurance would be priced solely on the correlation with this aggregate portfolio.

An implication is that each insurer holds a proportion of the aggregate loss, and all insurers' portfolios are perfectly correlated with aggregate loss.

There is absence of market imperfections and market constraint in the model:

- pricing of insurance is actuarial;
- no limited liability;
- distribution of events is uniform across the territory;
- distribution of insurers is uniform across the territory.

So it is very important to compute the correlation of individual losses with the aggregate portfolio to obtain real capacity.

Cummins et al (2002) extended the Borch model to limited liability. Under limited liability, the ability of insurer *i* to pay the unexpected loss $L_i^p = \mathrm{Min}\left(L_i ; E\left(L_i\right) + Q_i\right)$ depends on its equity capital Q_i, and the collected premiums under competition $E\left(L_i\right)$ where L_i is the loss of insurer *i* and $E\left(L_i\right)$ its expected value.

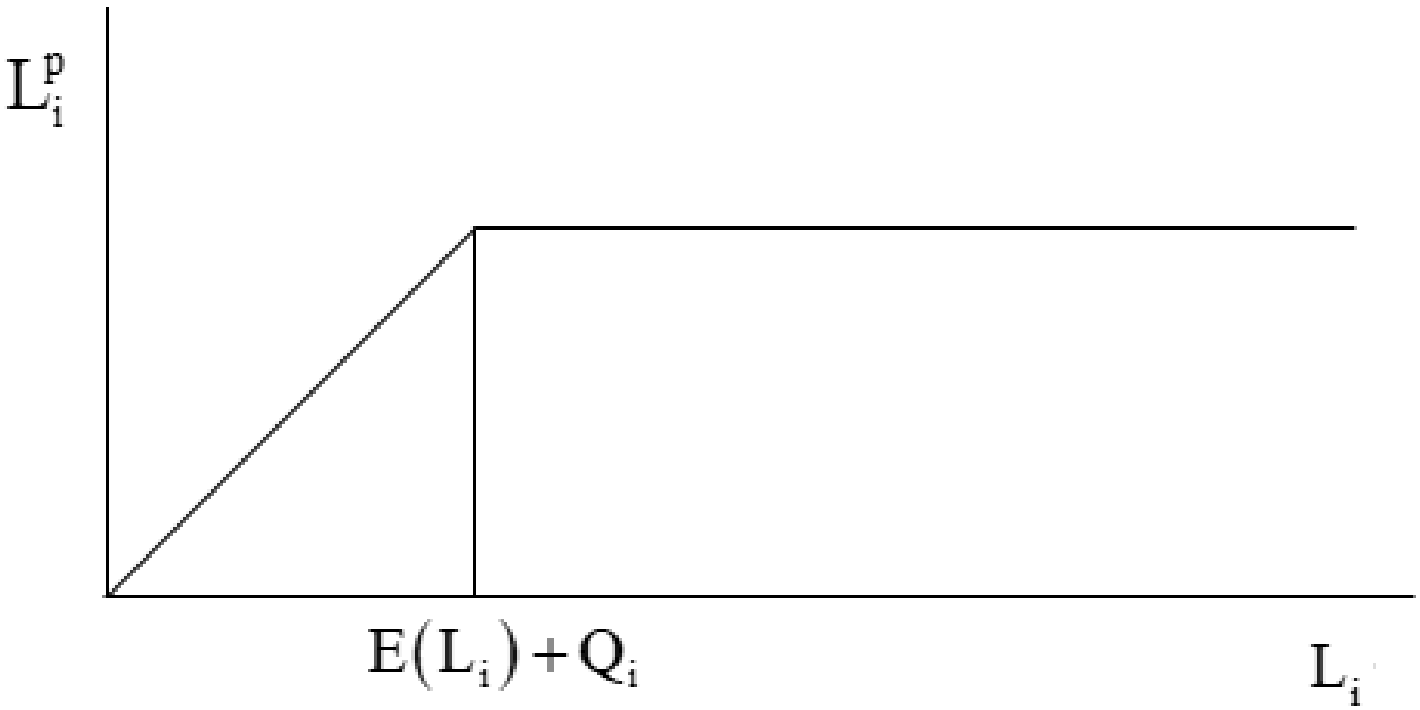


Figure 1

This is the main difference with Borch. In Borch modeling, all insurers can pay the total aggregate insurable loss. There is no capacity constraint.

By aggregation:

$$\sum_{i=1}^{N} L_i^P = \mathrm{Min}\left\{L; E(L) + \sum_{i=1}^{N} Q_i\right\} \qquad (1)$$

where N is the total number of insurers in the market and $E(L) + \sum Q_i$ measures the total resources in the industry for unexpected losses.

With respect to diversification, the industry acts as a single firm. No firm will become insolvent until the total industry capital is exhausted, which is a strong assumption.

Let's define the proportional payment of aggregate loss *L* by insurer *i* as:

$$L_i = \alpha_i L = c_i L_U + k_i D \qquad (2)$$

where:

α_i is the proportion of *L* paid by insurer *i*;

c_i is the proportion of the aggregate catastrophe risk L_U paid by insurer *i*;

k_i is the insurer *i* proportion of the aggregate industry diversifiable losses *D*.

They show that (2) is necessary (Proposition) to maximize industry capacity for a given industry surplus *Q*. This implies (Corollary) a perfect correlation between L_i and *L*.

Definition of the insurance industry payment capacity: For any configuration of losses for which insurers are liable, the payment capacity of the insurance industry is the proportion of those liabilities that is deliverable given the financial resources of firms on whom the losses fall and given all arrangements (such as reinsurance, guarantee funds, etc.) for reallocating those losses among insurers.

Capacity maximization: When the necessary conditions of maximization of capacity are satisfied, all insurers will hold losses net of reinsurance portfolios L_i, that are perfectly correlated with aggregate industry L. This provides a reference for measuring industry capacity.

Under the normality assumption, the capacity of the industry for any industry loss L is a function of two industry variables $\{E(L), \sigma(L)\}$ and four firm variables $\{E(L_i), \sigma(L_i), \rho_i, Q_i\}$ where ρ_i is the correlation coefficient between L_i and *L*. So the estimated correlations will give a good approximation to capacity utilization for a given Q_i.

But many frictions in the market can reduce the conditions described in the corollary on capacity maximization, such as small insurer size, reinsurance costs, losses distribution among insurers, states or counties, and other insurer diversification costs.

They estimated the average transaction costs $(\text{price} - \text{expected loss})/\text{expected loss}$ equal to 65% during the ten years preceding their study.

Cummins et al (2002) empirical results and our preliminary results

Let us define the expected terminal equity value.

$$E\left(T_i \middle| Q_i, L\right) = \left(E\left(L_i\right) + Q_i - \mu_{L_i|L}\right) N\left[\frac{E\left(L_i\right) + Q_i - \mu_{L_i|L}}{\sigma_{L_i|L}}\right]$$

$$+\sigma_{L_i|L} \frac{1}{\sqrt{2\pi}} e^{-(1/2)\left(\left(E\left(L_i\right)+Q_i-\mu_{L_i|L}\right)/\sigma_{L_i|L}\right)^2}$$

where

$$\mu_{L_i|L} = \mu_i + \frac{\rho_i \sigma_i}{\sigma_L}\left(L - \mu_L\right) \text{ and } \sigma^2_{L_i|L} = \sigma_i^2\left(1 - \rho_i^2\right)$$

and where T_i is the terminal equity of insurer *i*, $\mu_i = E\left(L_i\right), \mu_L = E\left(L\right)$, and ρ_i is the correlation coefficient between L_i and L.

In this section, we develop estimates of response functions for the US property–liability insurance industry by selecting three samples of insurers and estimating the parameters of Eq. (4) in Cummins et al (2002).

$$R_i \mid L = E(L_i) + Q_i - E(T_i \mid Q_i, L) =$$
$$(E(L_i) + Q_i)N(-C_i) + \mu_{L_i|L} N(C_i) - \sigma_{L_i|L} n(C_i), \qquad (4)$$

where:

$R_i \mid L$ is the response function of insurer *i*;

T_i is its terminal value of equity;

$N(\cdot), n(\cdot)$ are the standard normal probability and density functions;

C_i is the standard value of $E(L_i) + Q_i$.

The response functions are then calculated for various values of *L*, the total industry loss observed during different years.

The losses used in estimating capacity are net losses incurred, defined as direct losses incurred plus losses due to reinsurance assumed minus losses due to reinsurance ceded.

Direct losses incurred are losses paid or owed directly to policyholders, while net losses incurred reflect the netting out of reinsurance transactions.

The analysis thus implicitly takes into account the effects of reinsurance on capacity, but does not explicitly take into account of the reinsurance capacity.

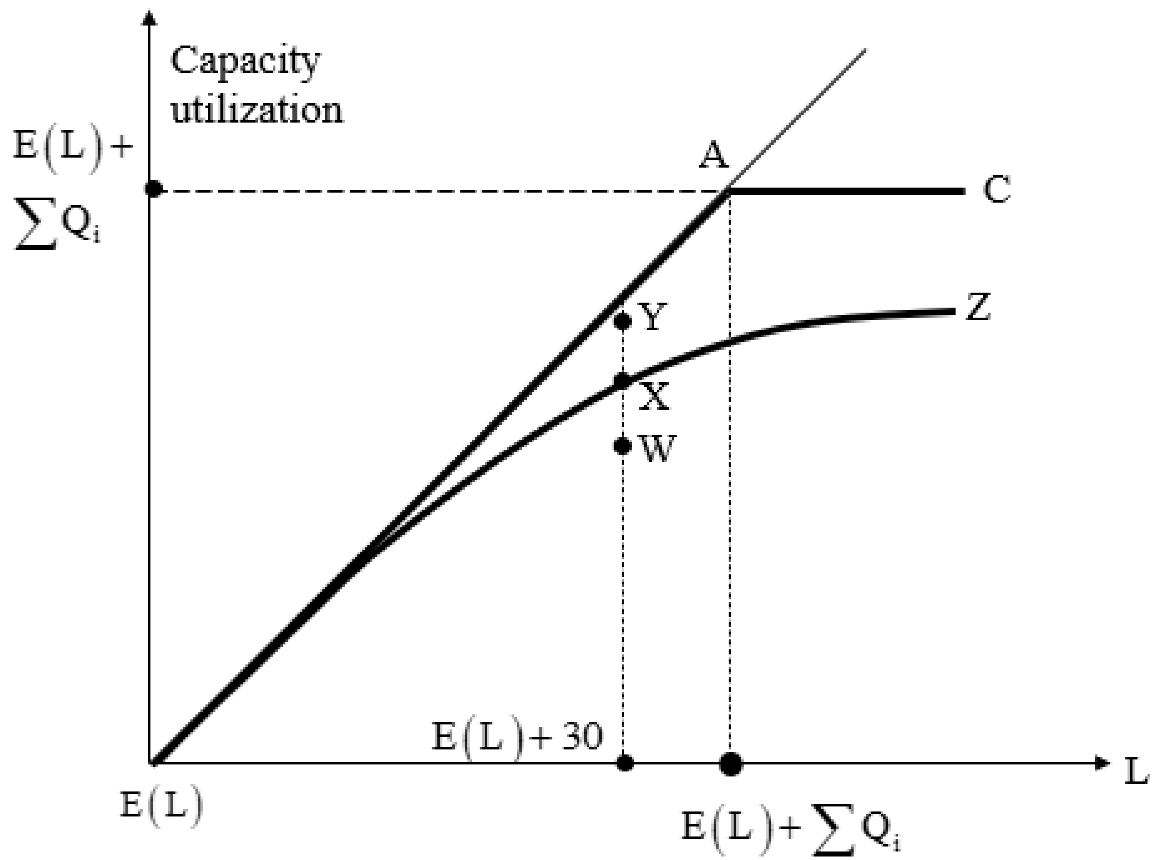


Figure 2: Capacity utilization

Note: The line $E(L)AC$ represents maximum capacity utilization.

The line $E(L)Z$ represents estimated capacity utilization. At value $E(L)+30$ billion, *X* is the estimated capacity of industry, *Y* is for a more diversified industry and *W* for a less diversified industry.

Three samples

- Data period 1990-2020.
- Parameters estimation over 10 years (Sample 1) with data from line 2 to line 11 of the NAIC reports instead of 15 years, as in Cummins et al (2002) 1983-1997 with line 11 only.
- Three 10-year periods in Sample 2: 1996-2005; 2005-2014; 2011-2020, with data from line 11 only. Effect of data source (lines 2 to 11 in Sample 1 versus line 11 only in Sample 2.
- Three 15-year periods in Sample 3: 1991-2005; 2001-2015; 2006-2020, with data from line 11 only. Effect of 10-years versus of 15-years.

Table 1 reports net losses and equity capital for the national sample, during the years 1997, 2005, 2014, 2020. FTS is for Full Time Sample.

Table 1: Net losses and capital for FTS
Summary statistics: Net losses and equity capital ($000 omitted)

Sample	Net losses incurred	Equity capital	Number of firms
1997			
Groups & unaffiliated companies	201,301,845	355,097,195	877
All companies	201,301,845	355,097,195	1,667
2005			
Groups & unaffiliated companies	301,274,767	496,797,400	853
All companies	301,274,767	496,797,400	1,578
2014			
Groups & unaffiliated companies	343,463,626	780,443,239	844
All companies	343,463,626	780,443,239	1,574
2020			
Groups & unaffiliated companies	455,137,413	1,085,524,198	841
All companies	455,137,413	1,085,524,198	1,509

Ratio of losses over capital is equal to 57% in 1997 and 42% in 2020.

Table 2 reports net losses and equity capital for the NFTS data for the same years. NFTS is for Non Full Time Sample.

Table 2: NFTS Sample 1
Summary statistics: Net losses and equity capital ($000 omitted)

Insurance industry	Net losses incurred	Equity capital	Number of firms
1997			
Cummins et al. 2002 study			
Groups & unaffiliated companies	201,905,979	370,993,421	1,248
All companies	201,905,979	370,993,421	2,256
Our database			
Groups & unaffiliated companies	209,800,900	373,035,693	1,179
All companies	209,800,900	373,035,693	2,286
2005			
Groups & unaffiliated companies	311,568,085	520,451,387	1,200
All companies	311,568,085	520,451,387	2,152
2014			
Groups & unaffiliated companies	349,123,503	803,479,225	1,064
All companies	349,123,503	803,479,225	1,923
2020			
Groups & unaffiliated companies	461,350,387	1,109,446,600	992
All companies	461,350,387	1,109,446,600	1,787

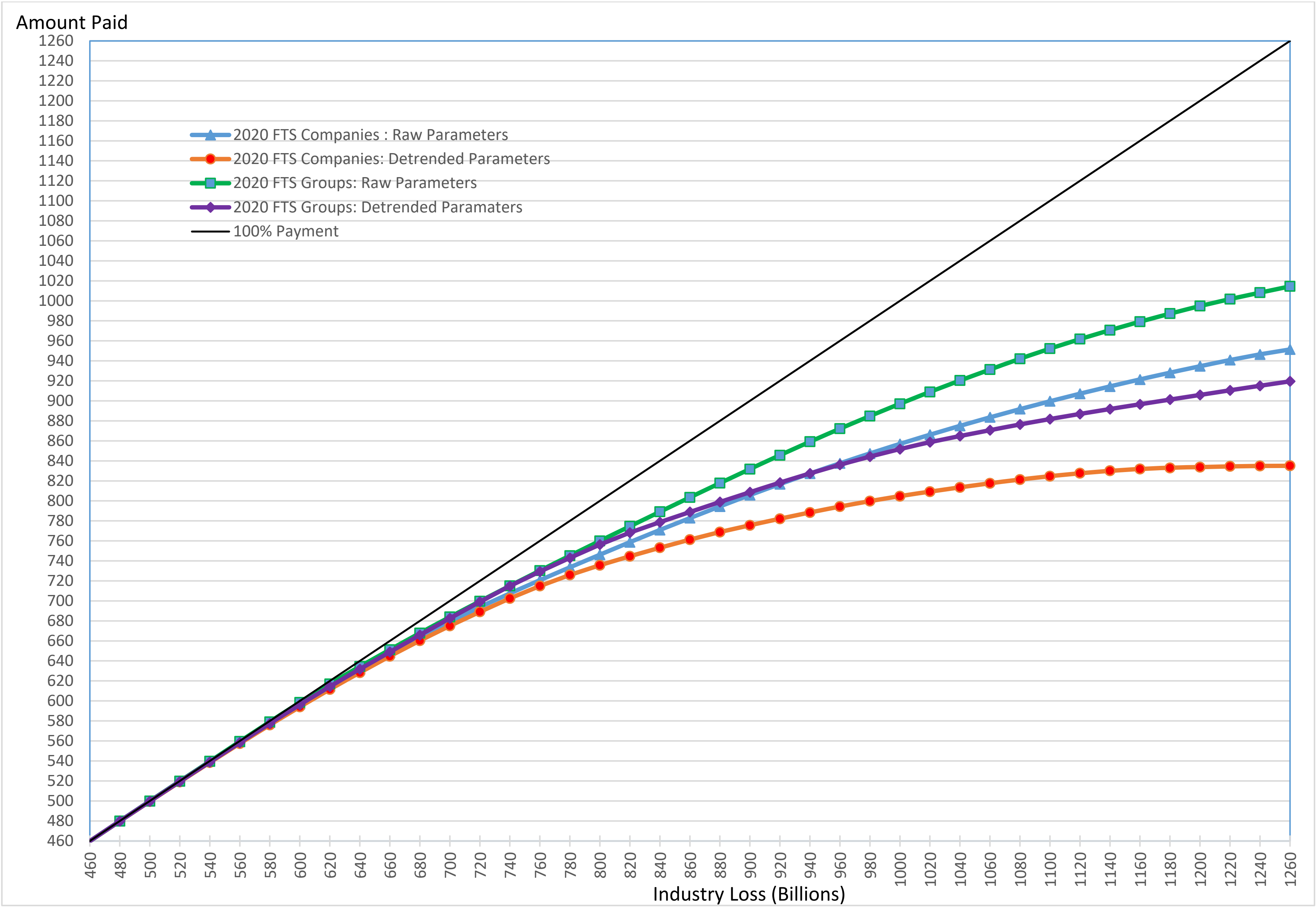


Figure 3: Response functions insurance industry net loss, 2020 (FTS)

Table 4 Capacity from Sample 1 with detrended values

	%			
1997	$100bn	$200bn	$300bn	$400bn
Insurance industry (FTS)				
Groups & unaffiliated companies	99.0	90.8	77.6	67.1
All companies	93.3	81.3	70.9	62.2
Insurance industry (NFTS)				
Groups & unaffiliated companies	94.7	87.9	77.3	67.0
All companies	94.6	82.8	72.4	63.5

	%					
2020	$100bn	$200bn	$300bn	$400bn	$500bn	$600bn
Insurance industry (FTS)						
Groups & unaffiliated companies	99.6	98.3	95.9	91.7	87.1	82.1
All companies	99.5	97.7	94.1	88.5	82.7	77.1
Insurance industry (NFTS)						
Groups & unaffiliated companies	98.9	97.3	94.9	91.2	86.6	82.1
All companies	99.9	98.8	95.9	91.0	85.8	80.8

Table 5: Summary statistics: Losses and equity capital ($000 omitted) Sample 2 and Sample 3

Sample	Insurance industry FTS		Number of firms
	Net losses incurred	Equity capital	
2020 Sample 2 FTS			
Groups & unaffiliated companies	455,145,860	1,087,840,856	877
All companies	455,145,860	1,087,840,856	1,570
2020 Sample 2 NFTS			
Groups & unaffiliated companies	461,350,387	1,109,446,600	992
All companies	461,350,387	1,109,446,600	1,787
2020 Sample 3 FTS			
Groups & unaffiliated companies	448,309,430	1,069,230,397	784
All companies	448,309,430	1,069,230,397	1,407
2020 Sample 3 NFTS			
Groups & unaffiliated companies	461,350,387	1,109,446,600	992
All companies	461,350,387	1,109,446,600	1,787

Table 6: Capacity from Sample 2 and Sample 3 with detrended values

	%					
2020 Sample 2	$100bn	$200bn	$300bn	$400bn	$500bn	$600bn
Insurance industry (FTS)						
Groups & unaffiliated companies	99.9	98.9	96.3	93.5	90.5	86.9
All companies	99.4	97.3	92.3	85.8	79.4	73.0
Insurance industry (NFTS)						
Groups & unaffiliated companies	98.8	97.4	94.8	90.9	86.2	81.4
All companies	99.4	97.5	92.8	86.3	79.9	73.5

	%					
2020 Sample 3	$100bn	$200bn	$300bn	$400bn	$500bn	$600bn
Insurance industry (FTS)						
Groups & unaffiliated companies	99.7	97.8	97.1	89.6	85.2	80.8
All companies	99.3	96.2	90.4	84.2	78.6	73.4
Insurance industry (NFTS)						
Groups & unaffiliated companies	98.3	96.4	93.1	89.6	85.3	81.6
All companies	99.5	96.9	91.4	85.2	79.6	74.4

Sources of capital

ILS products are not important in the insurance industry. $41bn issued in 2019.

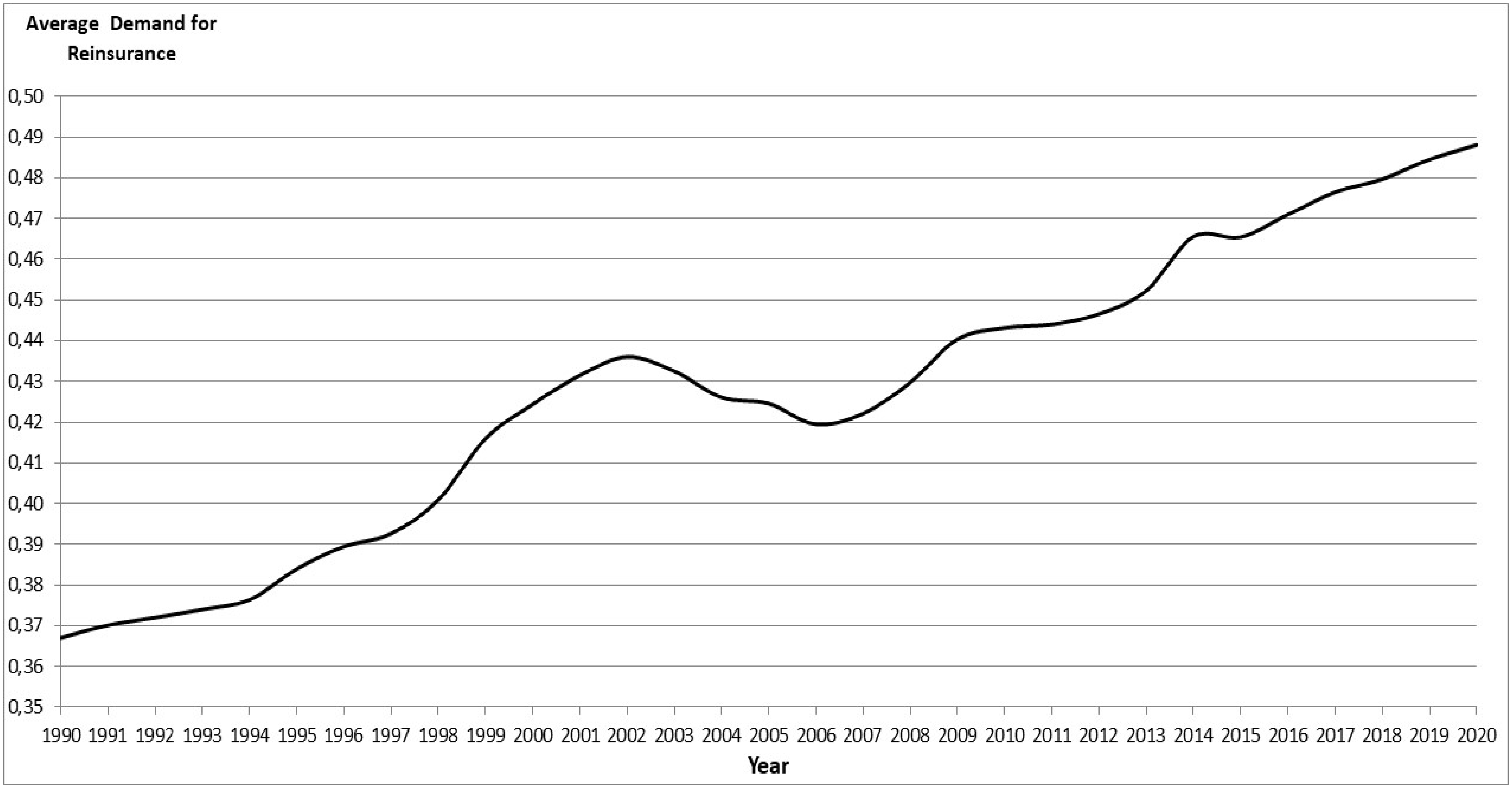


Figure 5: Demand for reinsurance for all insurers

Source: Desjardins et al (2022).

Reinsurance demand: Ratio of (affiliated reinsurance ceded + non-affiliated reinsurance ceded)/(direct business written + reinsurance assumed).

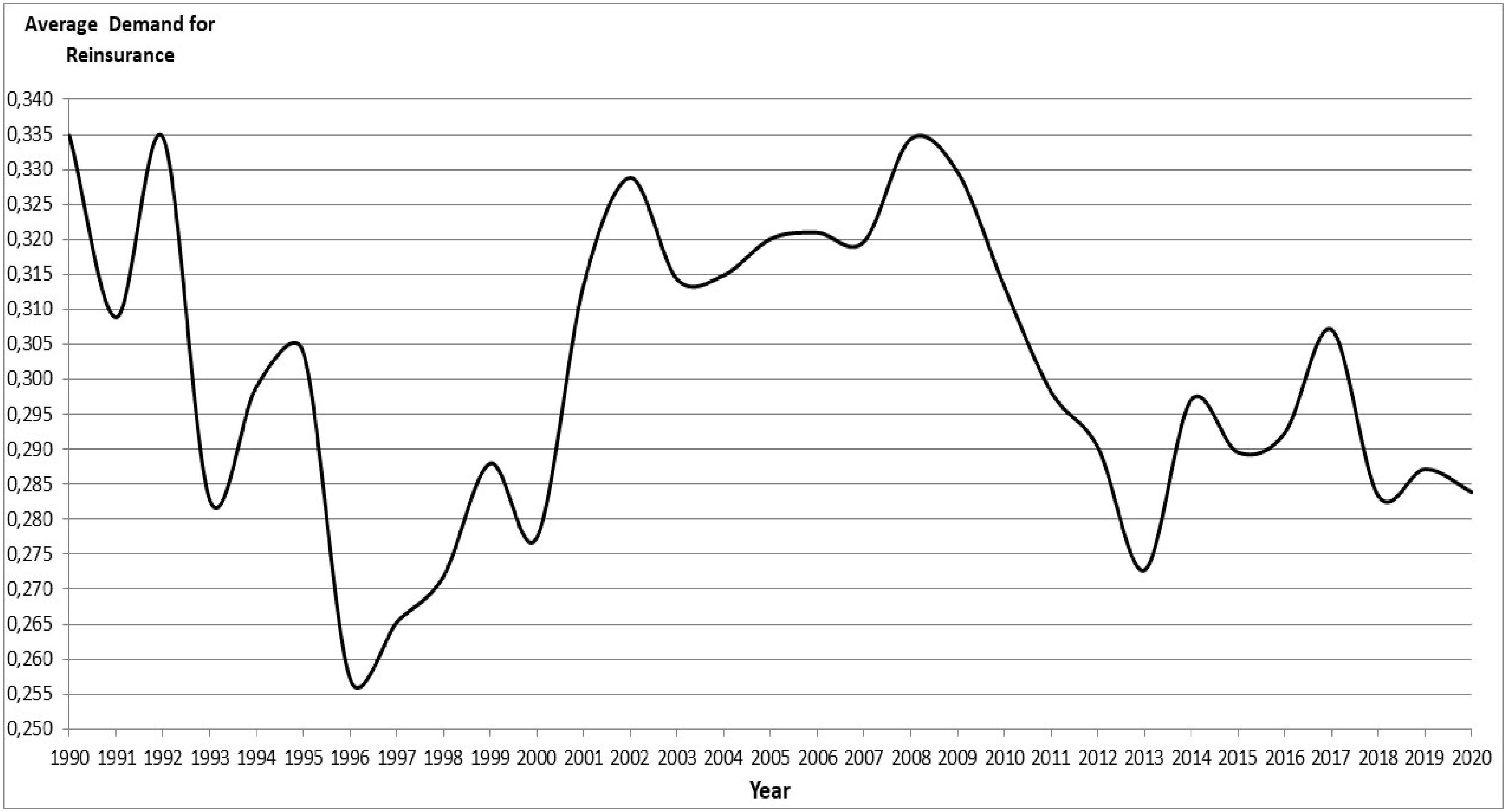


Figure 6: Demand for reinsurance for large insurers

Source: Desjardins et al (2022).

Large insurers constitute 60% of the premium earned in the industry while they represent 3% of the industry.

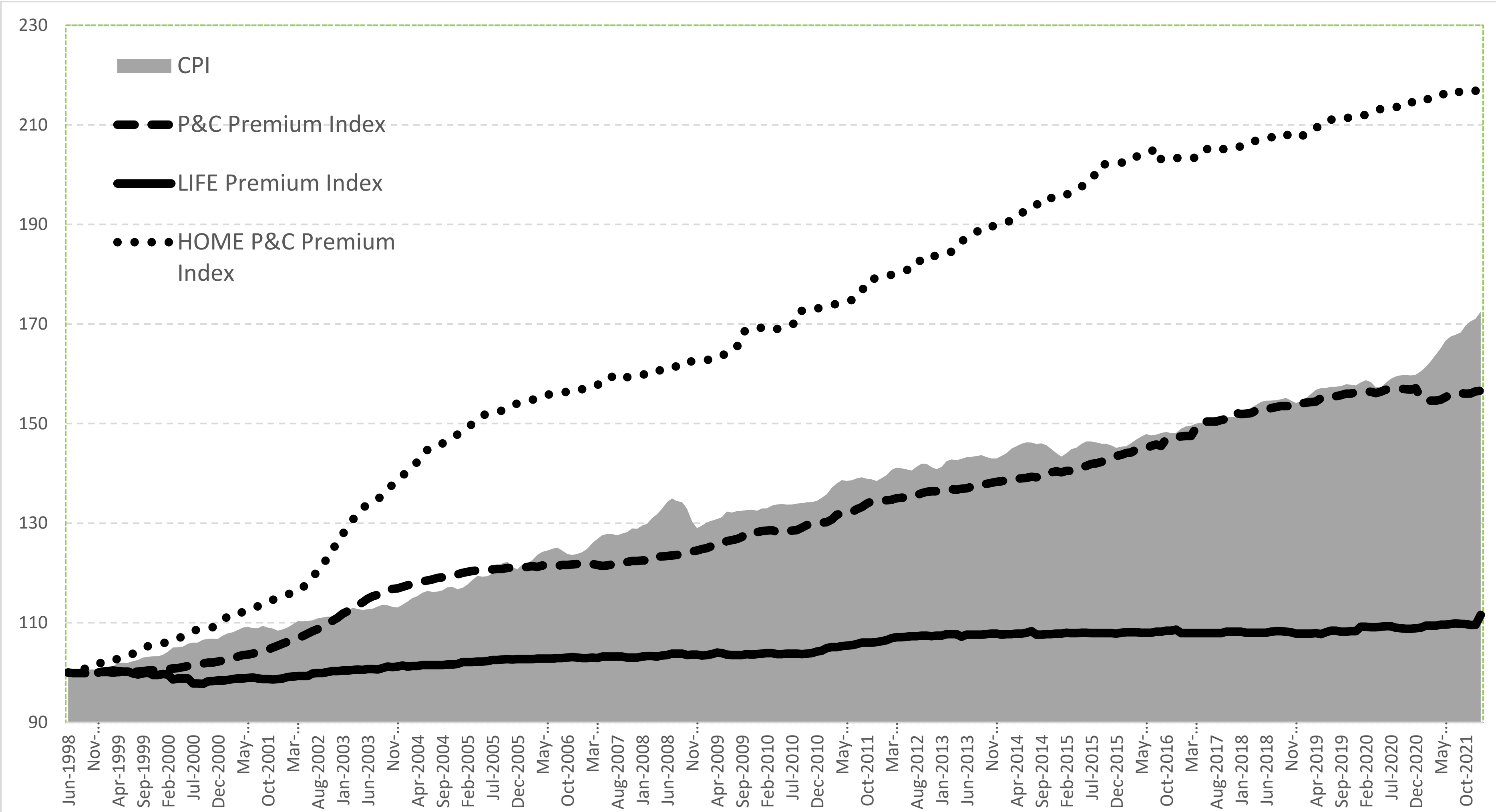


Figure 7: Different indexes of premiums increases during the 1998-2021 period

Source: Dionne et al (2022).

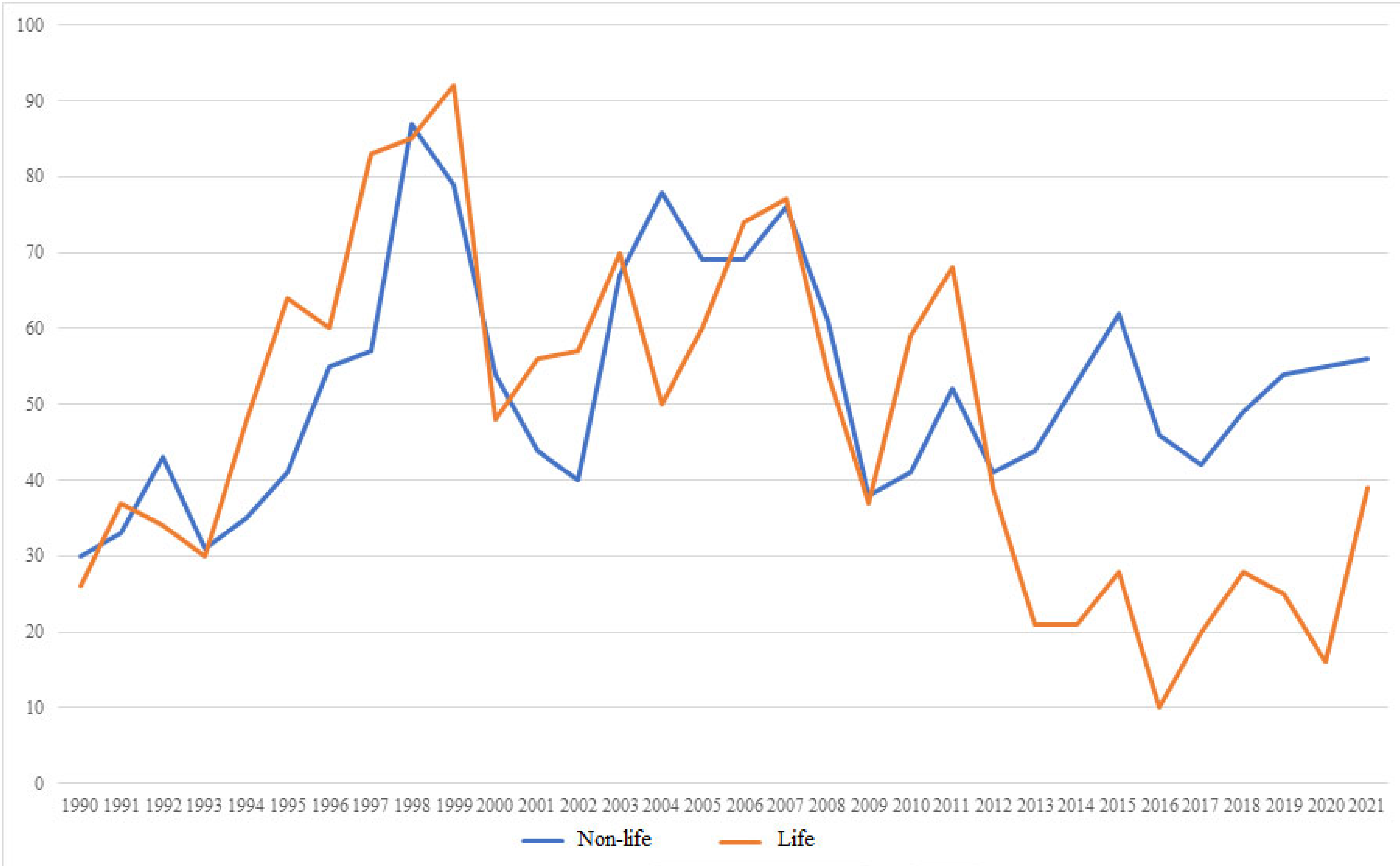


Figure 8: Mergers and acquisitions life and non-life industries 1990-2021

Source: Dionne et al (2022).

Extensions and conclusion

- Hypothesis of normality
- Capacity for multi events in a given year, not only the "big one"
- Causality?
- Long-term commitment from the financial markets?
- Explicit consideration of reinsurance demand for given insurer sizes
- Mergers and acquisitions or industry consolidation

Appendix

Table 3 reports the estimated sigma and correlation parameters.

Table 3
Detrended and raw parameter estimates: property-liability insurance industry

Case	Average				Number of firms
	Detrended sigma × 10^8	Detrended correlation	Raw sigma × 10^8	Raw correlation	
1997					
Insurance industry (FTS)					
Groups & unaffiliated companies	0.1766	0.1141	0.3703	0.5092	877
All companies	0.1311	0.1257	0.2536	0.4390	1,667
Insurance industry (NFTS)					
Groups & unaffiliated companies	0.2066	0.1243	0.4320	0.4899	1,179
All companies	0.0955	0.1004	0.2935	0.4376	2,286
2005					
Insurance industry (FTS)					
Groups & unaffiliated companies	0.3198	-0.0077	0.6241	0.5110	853
All companies	0.2157	0.0545	0.3969	0.4609	1,578
Insurance industry (NFTS)					
Groups & unaffiliated companies	0.3629	0.0352	0.7009	0.4765	1,200
All companies	0.1582	0.0409	0.4245	0.4399	2,152

Case	Average				Number of firms
	Detrended sigma × 10^8	Detrended correlation	Raw sigma × 10^8	Raw correlation	
2014					
Insurance industry (FTS)					
Groups & unaffiliated companies	0.3872	0.1162	0.6258	0.3927	844
All companies	0.2582	0.1621	0.3912	0.4039	1,574
Insurance industry (NFTS)					
Groups & unaffiliated companies	0.4202	0.1233	0.6817	0.3489	1,064
All companies	0.2113	0.1337	0.4156	0.3848	1,923
2020					
Insurance industry (FTS)					
Groups & unaffiliated companies	0.4135	0.1690	0.8693	0.4282	841
All companies	0.2804	0.2419	0.5348	0.4668	1,509
Insurance industry (NFTS)					
Groups & unaffiliated companies	0.4299	0.1716	0.9699	0.4138	902
All companies	0.2368	0.2093	0.5811	0.4487	1,787