Appendix A: Market overview of traded ILS products

Table 9: Multiples of traded cat bonds covering unmodeled risks

Name	Tranche Higher loss	Spread	E(L)	Multiple	Tranche Lower loss	Spread	E(L)	Multiple
Residential Reinsurance Limited (2019-2)	Class 1	24.00%	14.31%	1.68	Class 2	12.25%	5.87%	2.09
Residential Reinsurance Limited (2019-1)	Class 12	8.50%	3.61%	2.35	Class 13	4.50%	0.98%	4.59
Residential Reinsurance Limited (2018-2)	Class 1	20.25%	14.70%	1.38	Class 2	12.00%	6.45%	1.86
Caelus Re V Ltd. (2018-1)	Class D	11.50%	4.80%	2.40	Class B	5.25%	1.48%	3.55
Residential Reinsurance Limited (2018-1)	Class 11	13.25%	7.30%	1.82	Class 13	4.00%	0.82%	4.88
Residential Reinsurance Limited (2017-2)	Class 1	22.00%	15.75%	1.40	Class 2	13.50%	7.33%	1.84
Sanders Re Ltd. (2017-2)	-	3.75%	0.73%	5.14	-	3.75%	0.73%	5.14
Riverfront Re Ltd. (2017-1)	Class B	7.00%	3.72%	1.88	Class A	4.50%	1.08%	4.17
Caelus Re V Ltd. (2017-1)	Class C	7.25%	2.98%	2.43	Class A	3.75%	0.78%	4.81
Residential Reinsurance Limited (2017-1)	Class 10	17.50%	14.06%	1.24	Class 11	5.25%	2.11%	2.49
Sanders Re Ltd. (2017-1)	Class A	3.75%	0.86%	4.36	Class A	3.75%	0.86%	4.36
Residential Reinsurance Limited (2016-2)	Class 2	9.00%	5.55%	1.62	Class 4	4.75%	1.53%	3.10
Residential Reinsurance Ltd. (2016-1)	Class 10	12.75%	7.58%	1.68	Class 13	4.25%	0.98%	4.34
Espada Reinsurance Limited (2016-1)	Class 20	5.75%	1.93%	2.98	Class 20	5.75%	1.93%	2.98
Caelus Re IV Ltd. (2016-1)	Class A	6.25%	1.58%	3.96	Class A	6.25%	1.58%	3.96
Residential Reinsurance Ltd. (2015-2)	Class 3	7.75%	3.26%	2.38	Class 3	7.75%	3.26%	2.38
Residential Reinsurance Ltd. (2015-1)	Class 10	11.75%	6.20%	1.90	Class 11	6.00%	2.16%	2.78
Sanders Re Ltd. (2015-1)	Class C	3.88%	0.97%	3.99	Class C	3.88%	0.97%	3.99
East Lane Re VI Ltd. (2015-1)	-	4.00%	1.24%	3.23	-	4.00%	1.24%	3.23
Residential Reinsurance Ltd. (2014-2)	-	5.25%	1.61%	3.26	-	5.25%	1.61%	3.26
Residential Reinsurance Ltd. (2014-1)	Class 10	16.00%	9.86%	1.62	Class 13	3.50%	0.54%	6.48
FloodSmart Re Ltd. (2019-1)	Class B	14.50%	6.01%	2.41	Class A	11.25%	4.15%	2.71
Atmos Re DAC	Class B	10.50%	5.58%	1.88	Class A	3.50%	0.45%	7.78
FloodSmart Re Ltd. (2018-1)	Class B	14.25%	6.23%	2.29	Class A	12.00%	4.94%	2.43
Akibare Re Ltd. (2018-1)	Class B	2.50%	0.99%	2.53	Class A	2.50%	0.73%	3.42
Lion II Re DAC	-	4.00%	2.24%	1.79	-	4.00%	2.24%	1.79
Max				5.14				7.78
Min				1.24				1.79
Mean				2.45				3.63

Appendix B: Replication of Jacobs (2014) model

Table 10: Replication of Jacobs (2014) regression model with Advisen data
In line with the literature on the evaluation of data breach risk (Edwards et al., 2016), zero values for breached records have been removed. In addition, Model 2 and Model 3 only include events with at least 100 and 1,000 breached records, respectively.

	Dependent variable:		
	log(Loss)		
	(1)	(2)	(3)
log(Breached records)	0.323***	0.353***	0.405***
	(0.020)	(0.031)	(0.044)
Constant	10.223***	9.836***	9.112***
	(0.190)	(0.350)	(0.564)
Observations	621	439	326
R^2	0.306	0.234	0.207
Adjusted R^2	0.305	0.232	0.204
Note:			*p<0.1; **p<0.05; ***p<0.01

Appendix C: Derivation of Equation (12)

At time $t = 1$, the market values of equity and liabilities need to sum up to the market value of the assets: $\tilde{A}_1 = \tilde{E}_1 + \tilde{L}_1$. Rearranging yields: $\tilde{E}_1 = \tilde{A}_1 - \tilde{L}_1$. Under limited liability, the equity provides the familiar call option-payoff: $\tilde{E}_1 = \max(\tilde{A}_1 - \tilde{L}_1, 0)$ (Merton, 1974). Since both assets and liabilities are stochastic, the value of this call option is given by the Margrabe-Fisher formula (Margrabe, 1978; Fischer, 1978):

$$\tilde{E}_1 = A_0 \exp(\mu_a)\ \Phi(d_+) - L_0 \exp(\mu_l)\ \Phi(d_-), \tag{19}$$

with

$$d_\pm = \frac{\ln(A_0/L_0) + (\mu_a - \mu_l \pm \sigma^2/2)}{\sigma}, \tag{20}$$

and

$$\sigma = \sqrt{\sigma_a^2 + \sigma_l^2 - 2\sigma_a \sigma_l \rho_{a,l}}. \tag{21}$$

Φ is the standard normal cdf and $\rho_{a,l}$ denotes the asset-liability correlation. To obtain the CoE from the log-return $\tilde{r}_e$, we need to switch from continuous to discrete compounding:

$$\tilde{r}_e = \ln\left(\frac{E_1}{E_0}\right) \rightarrow CoE = \left(\frac{E_1 - E_0}{E_0}\right) = \exp(\tilde{r}_e) - 1. \tag{22}$$

Inserting (19) delivers:

$$CoE = \frac{A_0}{E_0} \exp(\mu_a)\ \Phi(d_+) - \frac{L_0}{E_0} \exp(\mu_l)\ \Phi(d_-) - 1. \tag{23}$$

Appendix D: Sensitivity analysis of liability portfolio input parameters

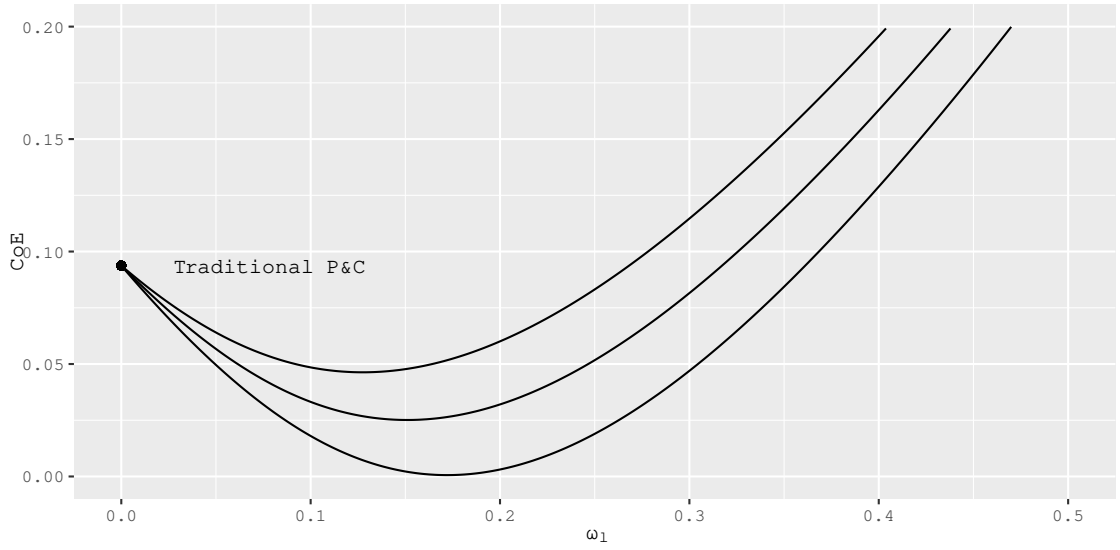

Figure 8: Sensitivity analysis of liability portfolio input parameter $\rho_{s,c}$
The portfolio costs are shown for different liability correlations $\rho_{s,c} \in \{0.1, 0.3, 0.5\}$ and $\rho^c_{a,l} = 0.3$. The portfolio costs increase with increasing $\rho_{s,c}$. The lowest curve refers to $\rho_{s,c} = 0.1$ and the diversification effect decreases for higher correlations $\rho_{s,c}$.