Preparing for the "Big One": Designing a Federal Backstop for Natural Disaster Risk

by Thorsten V. Koeppl

Online Appendix I

Methodology

Frequency Estimation

The estimation of the frequency of natural disasters fits a thinned Poisson process in two steps. First, the raw Poisson process expresses the number of events per year given by λ. Second, the probability of an extreme event, conditional on an event occurring in the first place, is modelled as a binomial distribution. This conditional probability is denoted by ρ. The estimated frequency of an extreme event is then given by $N = \lambda\rho$.

The Poisson process shows strong evidence of a time trend. The estimate of the log of its frequency based on a Generalized Linear Model (GLM) is given by

$$log\lambda = \beta_0 + \beta_1 t$$

with Table A1 reporting the estimation results.

Table A1: Estimated Coefficients for Poisson Arrival Rate λ of Natural Hazards

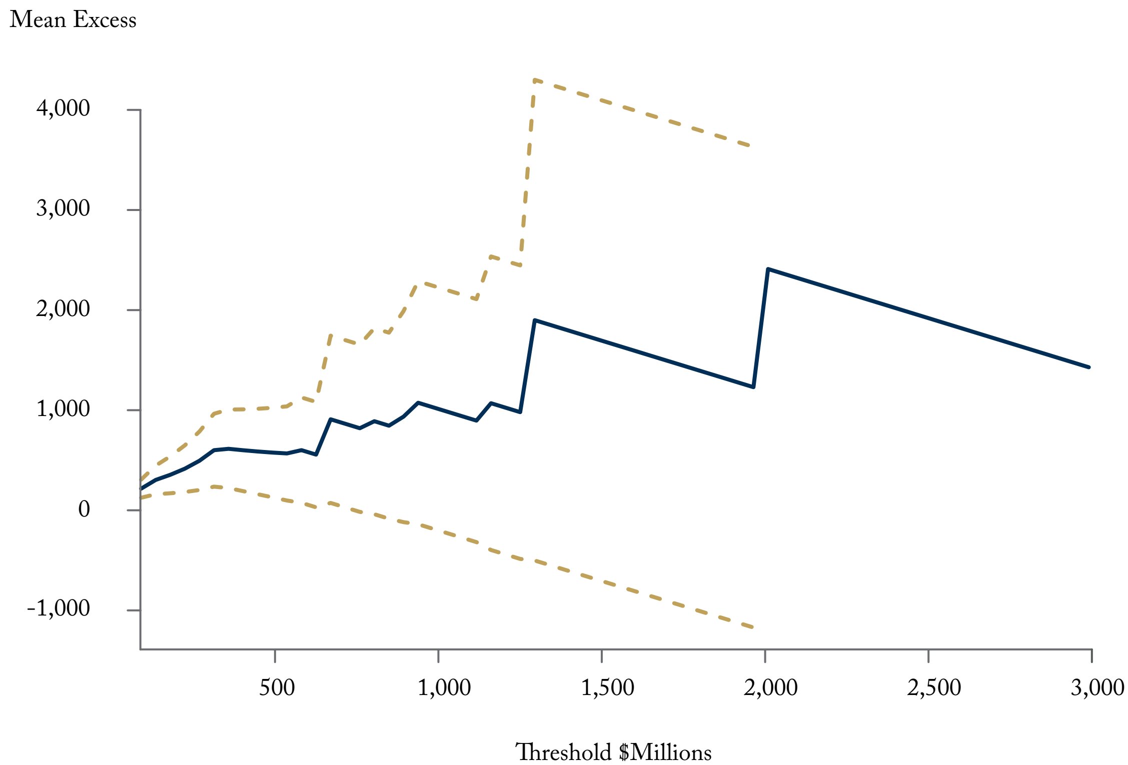
	Estimate	Std. Error	*z* value	*Pr*(>|*z*|)
β_0	1.57	0.15	10.21	2e-16
β_1	0.05	0.01	5.48	4.27e-08

There is no evidence for a time trend in the binomial distribution of extreme events. Hence, one can simply estimate the conditional probability as

$$\rho = \frac{\sum_{2000}^{2023} N_t \{\text{Loss} \geq 500\text{mn}\}}{\sum_{2000}^{2023} N_t} = 0.0693$$

where N_t stands for the number of events in period t.

Figure A1: Mean-Residual-Life Diagnostic Plot for Losses



Source: Author's calculations.

Severity Estimation

The estimation of the severity of tail losses that fall into the range of the XOL contract uses Extreme Value Theory (EVT). Figure A1 plots the mean excess over a threshold u or, equivalently, $E[x - u|x > u]$.

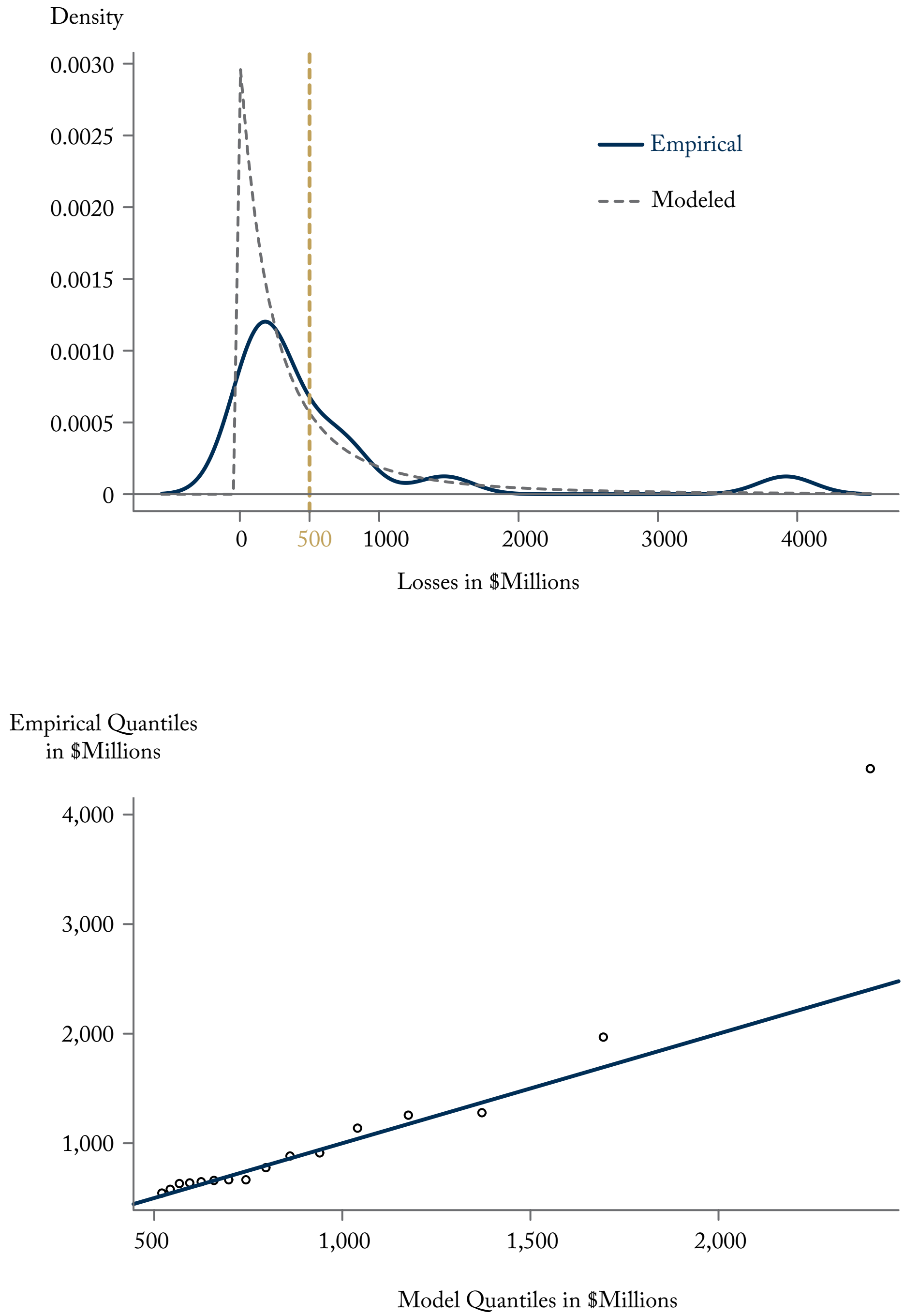
In the neighbourhood of $500 million, the mean excess function assumes roughly a linear trend with only moderate fluctuations, which is a good indication that losses follow a Generalized Pareto Distribution (GPD) above that threshold. Also, there are 16 observations with losses above $500 million, which is a small but reasonable number to estimate the parameters of a GPD. The estimation gives the following cumulative distribution function:

$$F(x|x>u) = \frac{1}{F(u)}\left(1-\left(1+\frac{\xi x}{\beta}\right)\right)^{\frac{-1}{\xi}}$$

with Table A2 reporting the numerical values of parameters together with their standard errors.

Figure A2 below shows a comparison of the empirical loss distribution and the estimated GPD on the left, as well as a comparison by quantiles on the right. The fit above the threshold seems to be reasonable, even though the relatively large standard errors point to weak power of the estimates.

Figure A2: Comparison Between Empirical and Estimated Loss Distribution



Source: Author's calculations.

Table A3 provides some risk measures commonly used in the insurance literature – value at risk (VaR) and the expected shortfall or tail value at risk (TVaR) – together with the estimated mean excess loss over $500 million and the mean excess loss under the XOL contract.

Simulation Primitives

The simulation creates a time series for natural disaster events exceeding the $2 billion threshold based on the estimated parameters in the previous two sections. The simulated frequency of events that exceed this threshold over a 25-year horizon is plotted in Figure A3. Figure A4 then shows the total losses above the threshold – together with the average loss per year – which correspond to the simulated payouts for the DRL over this horizon. For the simulated path, there is no single event with a total loss above $10 billion. The portion above those losses would fall into the CATL of the backstop.

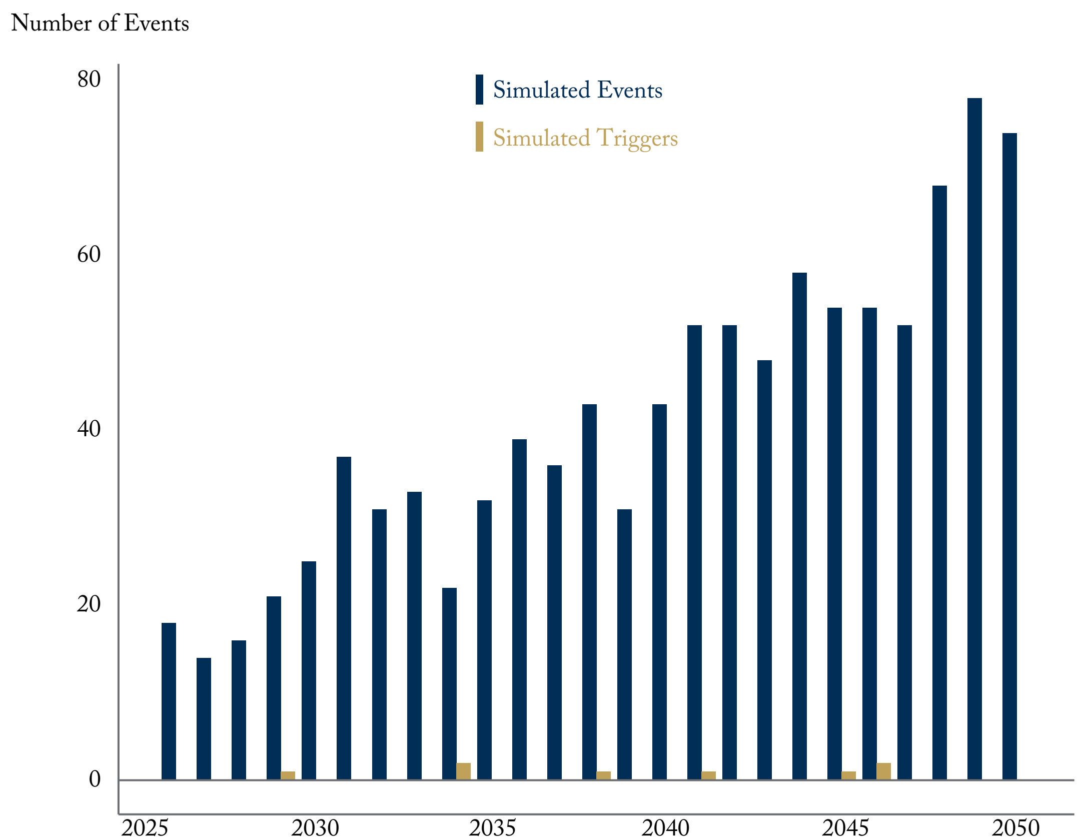
Table A2: Estimated Parameters of Generalized Pareto Distribution

	Estimate	Std. Error
Scale β	330.55	126.39
Shape ξ	0.45	0.33

Table A3: Estimated Mean Excess and Risk Measures

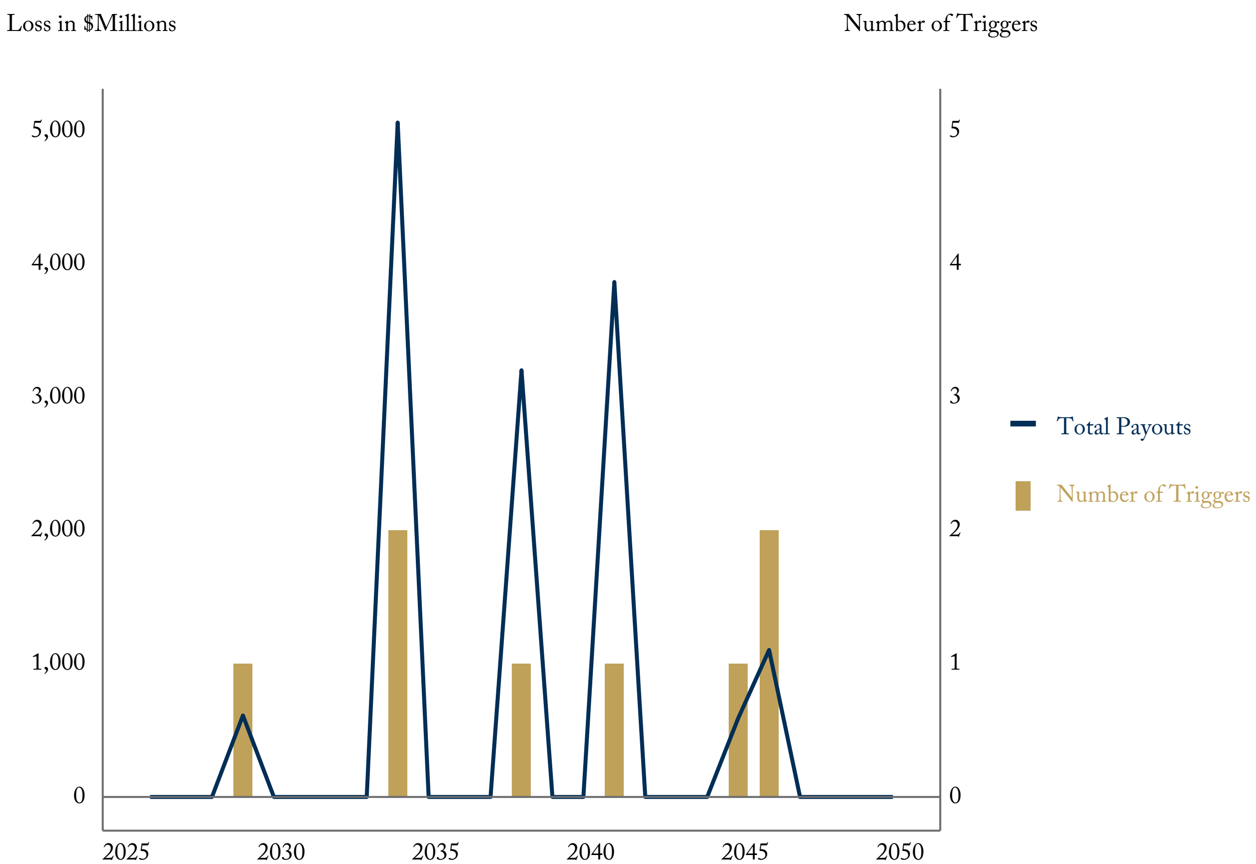
	$ Millions
$E[x - u \mid \vee x > 500]$	604.13
$E[x - 2000 \mid 10000 > x > 2000]$	2,664
VaR_{90}	1,841
VaR_{95}	2,604
VaR_{99}	5,645
$TVaR_{90}$	3,555
$TVaR_{95}$	4,950
$TVaR_{99}$	10,507

Figure A3: Simulated Frequency



Source: Author's calculations.

Figure A4: Simulated Severity



Source: Author's calculations.

Online Appendix II

Estimating the Costs of Public Funds for the Backstop[1]

There are three considerations when calculating the marginal costs of public funds (MCPF) for the backstop. First, the government does not issue debt permanently. It only does so temporarily to bridge the shortfalls that arise when payouts exceed revenue from insurance premiums. Similarly, the backstop will invest surplus funds in capital markets. It is not appropriate to tie the MCPF to a crowding out or in of private wealth through public debt, as the net capital position of the backstop varies across time and is zero on average by intention.

Second, the government incurs borrowing costs when providing capital, which need to be financed through current revenues. Since revenues are raised through taxation, the government incurs additional costs. Therefore, borrowing costs have to take into account these additional costs when calculating the MCPF.

Third, extra borrowing will raise interest rates for the government in financial markets. Borrowing for the backstop is likely to fall into periods where long-run interest rates may be larger, as natural disasters tend to be correlated with lower economic output. This correlation should be taken into account by adjusting the borrowing costs for the backstop through a risk premium.[2]

The opportunity cost for the backstop can then be approximated by adjusting long-term interest rates by both a factor representing the MCPF and an adjustment for a fiscal risk premium.

Opportunity cost = MCPF · long-term interest rates + fiscal risk premium

The current long-term yield on federal debt is around 4 percent. A conservative estimate for the MCPF in Canada is around 1.5. Using a fiscal risk premium of 1-2 percent, which also includes potential upward pressure in long-term yields due to an increase in federal debt, the opportunity cost for the backstop can be assumed to be around 7-8 percent.

1 For a comprehensive overview on the topic, see Dahlby (2008).
2 See Hanson et al. (2019).