Climate change uncertainty and risk management

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State of planetary emergency

Emergency and risk control mechanism (Lenton *et al.* 2020)

$$E = R \times U = P \times D \times \frac{\tau}{T}$$

Emergency

The product of risk R and urgency U

Risk

The probability P times the damage D of a bad outcome

Urgency

The ratio of the response time τ and remaining intervention time T

Risk control principle ($\frac{\tau}{T} < 1$)

The response time τ must be less than the remaining intervention time T

The damage from climate change is growing exponentially

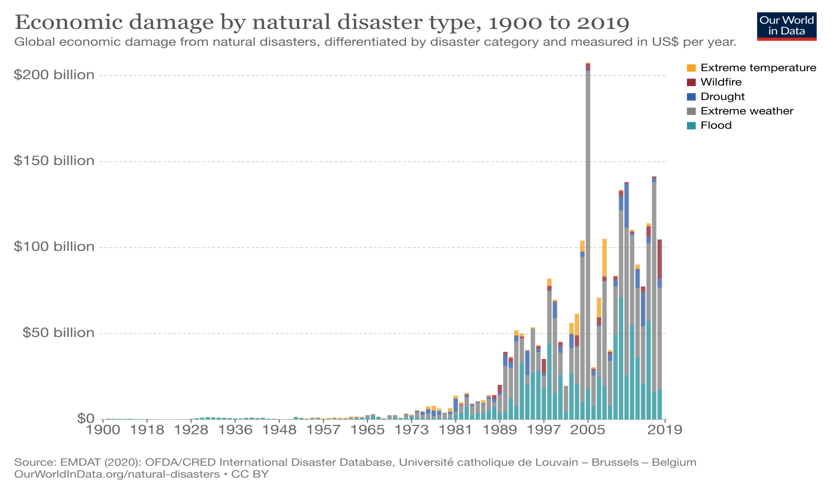


Figure 1: Global economic damage from climate change

While global carbon emissions are far from sufficiently taxed

Carbon Pricing Dashboard (The World Bank)

Today 64 implemented or scheduled carbon pricing initiatives cover 21.5% of global GHG emissions of which only 1% is ‘Paris aligned’

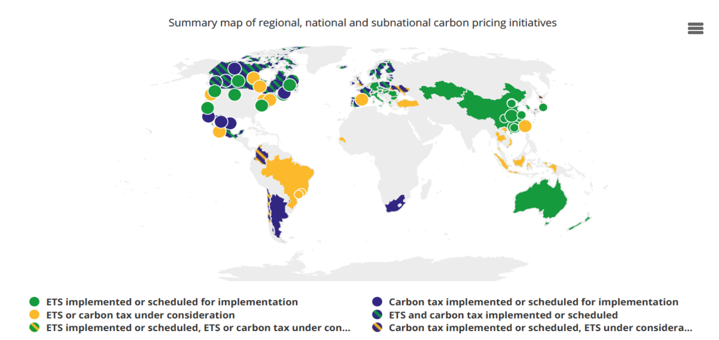


Figure 2: Carbon Pricing Dashboard 2021

Emissions of GHG's are free but impose costs on others

Definition

A fair carbon tax is the present discounted value of welfare damages resulting from an additional ton of Greenhouse Gas emissions today

Carbon tax is an insurance against bad states of the world

Table 1: Utility and states of the world

Investment	Carbon tax[♭]	Equities[♯]
Pay-off in good state	Low	High
Pay-off in bad state	High	Low
Today's value	High	Low
Expected return	Low	High
Character	Insurance	Anti-insurance

[♭] The benefits from taxing carbon emissions are highest in bad states of the world in which climate change has catastrophic consequences, leading to a high price for climate change mitigation today
[♯] The benefits from investing in equities are highest in good states of the world in which the economy is booming, leading to a low price for equities today

Climate bonds and the market price of climate change risk

- Bonds for which the notional value is linked to the realisation of a key climate related metric (e.g. average GHG emissions)
- Issued by sovereigns, such ‘climate bonds’ provide insurance to investors who are exposed to climate change risks
- The price differential with conventional bonds provides the market consensus about climate risk expectations and a risk premium

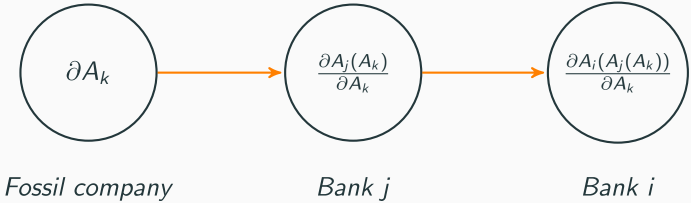
Financial institutions' direct and indirect climate exposures

- $\mathcal{A}$ is the set of climate-policy-relevant sectors {fossil, utilities, transport, energy-intensive, housing}
- $\mathcal{F}$ is the set of financial institutions {banks, insurers, investment funds, pension funds}
- The total exposure of bank i to climate-policy-relevant sectors is

$$A_i = \underbrace{\sum_{k \epsilon \mathcal{A}} \alpha_{ik}^{stocks} + \alpha_{ik}^{bonds} + \alpha_{ik}^{loans}}_{\text{direct exposure}} + \underbrace{\sum_{j \epsilon \mathcal{F}} \alpha_{ij}^{stocks}(A_j) + \alpha_{ij}^{bonds}(A_j) + \alpha_{ij}^{loans}(A_j)}_{\text{indirect exposure}}$$

Interconnectivity leads to a chain of exposures

- A large portion of total assets held by financial institutions are securities issued by other financial institutions
- About 40% for banks in the euro area (Battiston *et al.* 2017)
- Bank i has a claim on the assets of bank j, that in turn has a claim on the assets of fossil company k



Second round effects may amplify systemic risk

- Assume α_{jk}^{0} is the initial value of the securities held by bank j in fossil company k
- The ability of the issuer to pay either dividends or interest rates to its creditor increases with the issuer's total assets
- And $\frac{df_{jk(A_k)}}{dA_k} \geq 0$ is the change in securities value with respect a change in the collateral assets

$$\frac{\partial A_i(A_j(A_k))}{\partial A_k} = \frac{\partial A_i(A_j)}{\partial A_j}\frac{\partial A_j(A_k)}{\partial A_k} = \alpha_{ij}^{0}\alpha_{jk}^{0}\frac{\partial f_{ij}(A_j)}{\partial A_j}\frac{\partial f_{jk}(A_k)}{\partial A_k}$$

Dealing with climate change in risk management

MODEL KNOWN

Parameter risk

The risk that the parameters used in the model do not represent future outcomes

Risk

Stochastic variation within accurate model and representative parameters

PARAMETERS UNKNOWN

PARAMETERS KNOWN

Uncertainty

Outcomes and their probabilities of occurrences are unknown

Model risk

The risk that the model is not accurate in describing future states of the world

MODEL UNKNOWN

In case of risk an ARIMA model projects future trajectories

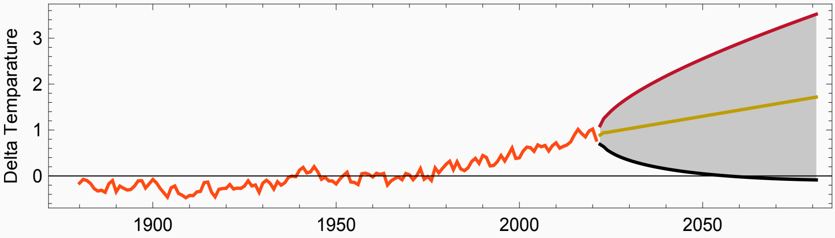


Figure 3: ISTEMP Team, 2021: GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies. Dataset accessed 2021-06-19 at https://data.giss.nasa.gov/gistemp/

Parameter risk and tail risk measures

- A well-known concept in option pricing is ‘vega’ or the rate of change of the option’s value with respect to volatility of the underlying asset
- This concept can be generalised to any truncated part of a return distribution to quantify the potential impact of large shocks
- We want to assess the impact of changes in the lower semi-deviation s^- on extreme climate related losses

Define measure ξ as the 'price of an option' with strike K

$$\xi(K, s^{-}) = -\mathbb{E}[X|X < K]\,\mathbb{P}[X < K]$$

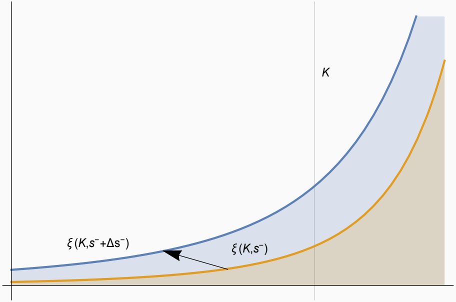


Figure 4: Impact of parameter risk on left tail

Let's take the critical value or strike to be $K = VaR_\alpha$

Following Taleb *et al.* (2014) we can write

$$\xi(VaR_\alpha, s^-) = \int_{-\infty}^{VaR_\alpha} (VaR_\alpha - r) f(r) dr - VaR_\alpha F(VaR_\alpha)$$

which simplifies to

$$\xi(VaR_\alpha, s^-) = -\alpha TVaR_\alpha$$

Vega is the sensitivity to parameter risk

$$\nu = \frac{\partial \xi}{\partial s^-}$$

Hurricane Irma caused a 20 sigma event in the cat bond market

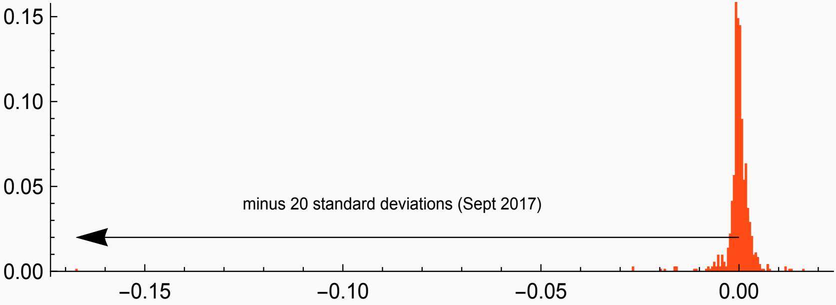


Figure 5: Swiss Re Global Cat Bond Performance Index

Impact of extreme events on risk measures

Table 2: Annualised risk measures for the Swiss Re Global Cat Bond Index

Period	Pre Irma	Post Irma	Full period
Observations	167	167	338
Standard deviation	1.6	2.3	8.1
Lower semi-deviation (s)	1.5	2.9	10.3
$VaR_{0.025}$	-2.0	-5.6	-4.7
$TVaR_{0.025}$	-5.1	-8.2	-20.4
ξ	0.127	0.205	0.510
$vega(\nu = \frac{\Delta\xi}{\Delta s})$		0.109	

Climate change is largely a case of uncertainty

Climate change uncertainty

The uncertain magnitude and impact of greenhouse gas emissions and climate policy on the economy and the financial system

These physical and transition processes involve many unknown unknowns

- Feedback loops
- Tipping points
- Non-linearities
- Interactions
- Timing

Human biases make it difficult to comprehend this uncertainty

- **Confirmation bias** → We look for data confirming our beliefs and ignore conflicting information, causing us to overlook new risks
- **Availability heuristic** → We estimate the likelihood of future events based on the ease with which past events can be recalled
- **Ambiguity aversion** → We tend to prefer known risks over risks where information is limited or unavailable
- **Illusion of control** → We overestimate the likelihood of being in control of risks to what is objectively realistic

Fundamental uncertainty will lead to potential surprises

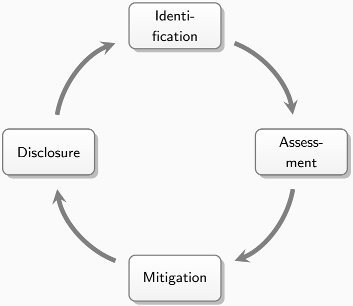
Uncertainty implies potential surprise

Human biases and the limitations of models together with uncertainty implies that there will always be potential surprises

How to cope with these potential surprises?

Structured risk management approach

The goal for financial institutions is to be less vulnerable to negative surprises through a structured risk management approach



Step 1: Identification methods for climate change uncertainties

- Be alert to early warning indicators and climate change related losses
- Run a pre-mortem to ‘imagine’ causes of an extreme climate event
- Expert elicitation

Expert elicitation is a rigorous way to get PD's from experts

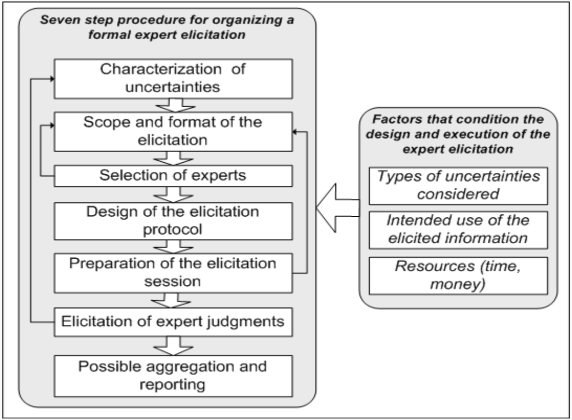


Figure 6: Protocol for expert elicitation (Knol *et al.*, 2010)

Step 2: Assessments methods for climate change uncertainties

- Prioritise climate change related uncertainties employing judgement
- Use quantitative models in case sufficient reliable data are available
- Work with scenario analysis in case reliable data are not available
  - Stress test
  - Reverse stress test

Assessment method: Reverse stress test

Reverse climate change stress test

A reverse stress tests explores climate change related scenarios that potentially lead to large losses and thus are useful in helping financial institutions to identify their core vulnerabilities

- Reverse stress testing aims to find combinations of climate change related risk factors (‘scenarios’) that cause a critical loss level
- The challenge is that there are infinitely many combinations of risk factors that yield the critical loss level
- Risk managers therefore need to demonstrate the plausibility of these climate change scenarios

Step 3: Mitigation methods for climate change uncertainties

- Apply the precautionary principle
- Prepare contingency planning
- Set tolerance levels

Mitigation method: Precautionary principle

Precautionary principle

The precautionary principle aims to anticipate and minimize potentially serious or irreversible events under conditions of uncertainty

Stronger prevention measures today are a hedge against the cost of

- Enduring temporary catastrophes
- Draconian interventions
- Inaccurate models

Step 4: Disclosure is a key part of effective risk management

Financial institutions and climate change disclosure

Disclosing material information on climate change uncertainties is important for meaningful decision making

Disclosing material information is also important for

- Developing best practices amongst market participants
- Issuing expectations to key stakeholders
- Creating incentives for market solutions
- Improving price discovery in markets

Climate change uncertainty and risk management

Table 3: Impact of climate change on the risk management toolbox

Feature	Old paradigm	New paradigm
Risk identification	Data driven	Monitoring losses
	Statistical tools	Pre-mortem analysis
Risk assessment	Parameter uncertainty	Expert elicitation
	Stress-test	Reverse stress-test
Risk control	Diversification	Precautionary principle
	Risk transfer	Contingency planning
	Insurance	Tolerance levels

Thank you for listening

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