An Economist Tries to Grapple with Catastrophic Climate Change

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A Black Swan is a highly improbable event with three principal characteristics: it is unpredictable; it carries a massive impact; and, after the fact, we concoct an explanation that makes it appear less random, and more predictable than it was – Nassim Taleb

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The climate system is an angry beast and we are poking it with sticks – Wally Broecker

Preliminary Probing and Basic Issues

- Climate change characterized by deep structural uncertainties and an inability to exclude catastrophes. Sample of worrisome aspects:
- 800K Antarctic ice core record of CO_2 and temperature.
- Methane hydrates in permafrost and continental shelves.
- Unlimited downside liability. All eggs in one planetary basket.
- How bad might it get? With what probabilities? Do bad consequences increase faster or slower than probabilities decline?
- Are conclusions from existing CBAs and IAMs robust to the modeling of climate extremes? Is policy advice robust?
- Spirit of these numerical exercises: They are a bit wild, and I am a bit wild in presenting them, but no sense in pretending false precision. Exercises motivated by the need to perform simple and transparent "stress tests" on climate-change CBAs and IAMs.
- Representative of a line of research. Major finding: "robustness of non-robustness" in big-picture climate change economics.

Climate Sensitivity as Prototype Example of Uncertainty

- What is equilibrium climate sensitivity? What are its strengths and weaknesses as an aggregate measure and as a prototype example?
- Why is climate sensitivity uncertain? What is its PDF? How should we extrapolate its tail probabilities?
- If climate sensitivity is an *example* of uncertainty, then what is the ultimate reduced-form PDF whose fat tail *really* concerns us? ... and the answer is ... lnD, where D≡B-W.
- Who knows how fat is the upper tail of the PDF of lnD? ... and the answer is ... Nobody. Very long chain of very uncertain links.
- Is climate change policy better conceptualized as warding off deterministic damages or as buying an insurance policy against bad damages from bad temperatures? What difference does it make?
- How should the upper-half tail of the PDF of climate sensitivity be calibrated? ... and the answer is ... consistent with IPCC-AR4, here I calibrate P[S≥3]=50% and P[S≥4.5]=15%.

Upper Tail of Climate Sensitivity PDF (two examples)

- *Fat*-tailed (polynomial or slower decline) **P**areto or **P**ower PDF:

$$f_{\mathbf{P}}(S) = 38.75958\, S^{-3.969362}$$

- *Thin*-tailed (exponential or faster decline) **N**ormal PDF:

$$f_{\mathbf{N}}(S) = \frac{1}{1.4473\sqrt{2\pi}} \exp\left(-\frac{(S-3)^2}{2\,(1.4473)^2}\right)$$

$\widehat{S} =$	3°C	4.5°C	6°C	8°C	10°C	12°C
$\text{Prob}_{\mathbf{P}}[S \geq \widehat{S}]$	.5	.15	.06	.027	.014	.008
$\text{Prob}_{\mathbf{N}}[S \geq \widehat{S}]$	.5	.15	.02	.003	7×10^{-7}	3×10^{-10}

- How do we know if tail is Normal or Power or any other form of PDF?
- Are there plausible mechanisms via which thin-tailed PDFs (like Normal) become fat-tailed PDFs (like Student-t)?
- Why does the economics of climate change seem especially vulnerable to fat-tailed uncertainty?

Probabilities of T as Function of G=GHG Concentrations

- Transformation of variables: $T = [\ln(G/280)\ /\ \ln 2] \times S$
- Transformation of PDFs:
  $\psi_{\mathbf{I}}(T \mid G) = f_{\mathbf{I}}(T/\ [\ln(G/280)\ /\ \ln 2])/\ [\ln(G/280)\ /\ \ln 2]$
  for $\mathbf{I} = \{\mathbf{P}, \mathbf{N}\}$
- Probabilities of exceeding temperature changes T =5°C and T =10°C for given G = ppm of CO_2e. (Why are T =5°C and T =10°C chosen as "iconic" temperature change examples?)

G:	**400**	**500**	**600**	**700**	**800**	**900**
Median T	1.5°	2.5°	3.3°	4.0°	4.5°	5.1°
$\text{Prob}_{\mathbf{P}}[T \geq 5°C]$	1.5%	6.5%	15%	25%	38%	52%
$\text{Prob}_{\mathbf{N}}[T \geq 5°C]$	10^{-6}	2.0%	14%	29%	42%	51%
$\text{Prob}_{\mathbf{P}}[T \geq 10°C]$	.20%	.83%	1.9%	3.2%	4.8%	6.6%
$\text{Prob}_{\mathbf{N}}[T \geq 10°C]$	10^{-30}	10^{-10}	10^{-5}	.1%	.64%	2.1%

What are Damages of Ruinous Climate Change?!?

- Typical multiplicative quadratic damages: $Y(T) = Y / \left(1 + \gamma T^2\right)$.
- Why may be OK for small T. Why may be questionable for big T.
- No one knows damages for high global-average temperature changes.
- For want of better analogue, try something *really* wild here.
- Suppose person pays ΔM for decreasing probability of death by ΔP.
- VSL=Value of a Statistical Life $= \Delta M / \Delta P$.
- Extremely rough empirical estimate: VSL $\approx$ 200 years of income.
- Crazily-tentatively identify "death of the planet" with T=10°C.
- Willingness to pay (income-years foregone) to keep G at 280 ppm.

G :	**400**	**500**	**600**	**700**	**800**	**900**
$W_{\mathbf{P}}[T \geq 10°C]$	.4	1.7	3.8	6.4	9.6	13
$W_{\mathbf{N}}[T \geq 10°C]$	≈0	≈0	≈0	.16	1.2	4.2

- Includes *only* willingness to pay to reduce tail catastrophe: $T \geq 10°C$.
- *Over*estimate: impact will be centuries hence. Discounting, anyone?
- *Under*estimate: death of Earth bigger than death of John Smith.

Concluding Questions and Comments

- Stress tests and sensitivity to how disasters are modeled and parameterized: is the glass half-empty or half-full?
- What about caveats, limitations? Will dynamics restore robustness?
- What about role of learning and mid-course corrections?
- What makes climate change so resistant to crisp policy conclusions?
- What is the appropriate role of climate change CBAs and IAMs?
- Should we inform policy makers about our inability to give robust policy advice in almost-unique case of climate change CBA?
- Beware of idea that a false impression of precision or robustness is required because "we have to recommend *something*"?
- Should we do more research about fatness of extreme tails of PDFs relative to more research about central tendencies? Is this "science"?
- Beware of fighting fat-tailed problems with fat-tailed solutions?
- Should we hope for the best but prepare for the worst by contingency planning for bad outcomes? Is there a possibly important niche role for last-resort options like geoengineering?