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How to (and not to) extrapolate climate damages

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“A false sense of security…”

- Climate scientist Tim Lenton (et al.), 2008:
  - “Society may be lulled into a false sense of security by smooth projections of global change.”
- Nordhaus *DICE Manual 2013* on damage functions and Lenton et al.
  - “The current version *assumes that damages are a quadratic function of temperature change* and *does not include sharp thresholds or tipping points*,
  - but **this is consistent with the survey by Lenton et al**.”

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“A variety of tipping elements … this century”

- Climate scientist Tim Lenton (et al.), 2008:
  - “**a variety of tipping elements could reach their critical point within this century** under anthropogenic climate change.
  - The greatest threats are tipping the Arctic sea-ice and the Greenland ice sheet,
  - and at least five other elements could surprise us by exhibiting a nearby tipping point.”
- Nordhaus *Climate Casino 2013* on tipping points and Lenton et al.
  - “**Their review finds no critical tipping elements with a time horizon less than 300 years until global temperatures have increased by at least 3°C**.”

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Water off a quadratic's back

- Other economists on using a quadratic to estimate damages:
  - "Our review of the literature uncovered no rationale, whether empirical or theoretical, for adopting a quadratic form for the damage function—although the practice is endemic in IAMs." (Stanton, Ackerman, and Kartha 2009)
  - "how much we might be misled by our economic assessment of climate change when we employ a conventional quadratic damages function …
  - we might be underestimating considerably the welfare losses from uncertainty by using a quadratic damages function." (Weitzman 2012)

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Water off a quadratic's back

- Pindyck: Nordhaus's damage function "is made up out of thin air. It isn't based on any economic (or other) theory or any data.
- Furthermore, even if this inverse quadratic function were somehow the true damage function, there is no theory or data that can tell us the values for the parameters or the correct probability distributions for those parameters, or even the correct means and variances." (Pindyck 2017)

- Nordhaus (2024) on quadratic damages:
  - "The damage function is a quadratic function of global temperature … iii) Damages are quadratic in warming, **in line with recent reviews** (13, 14)."

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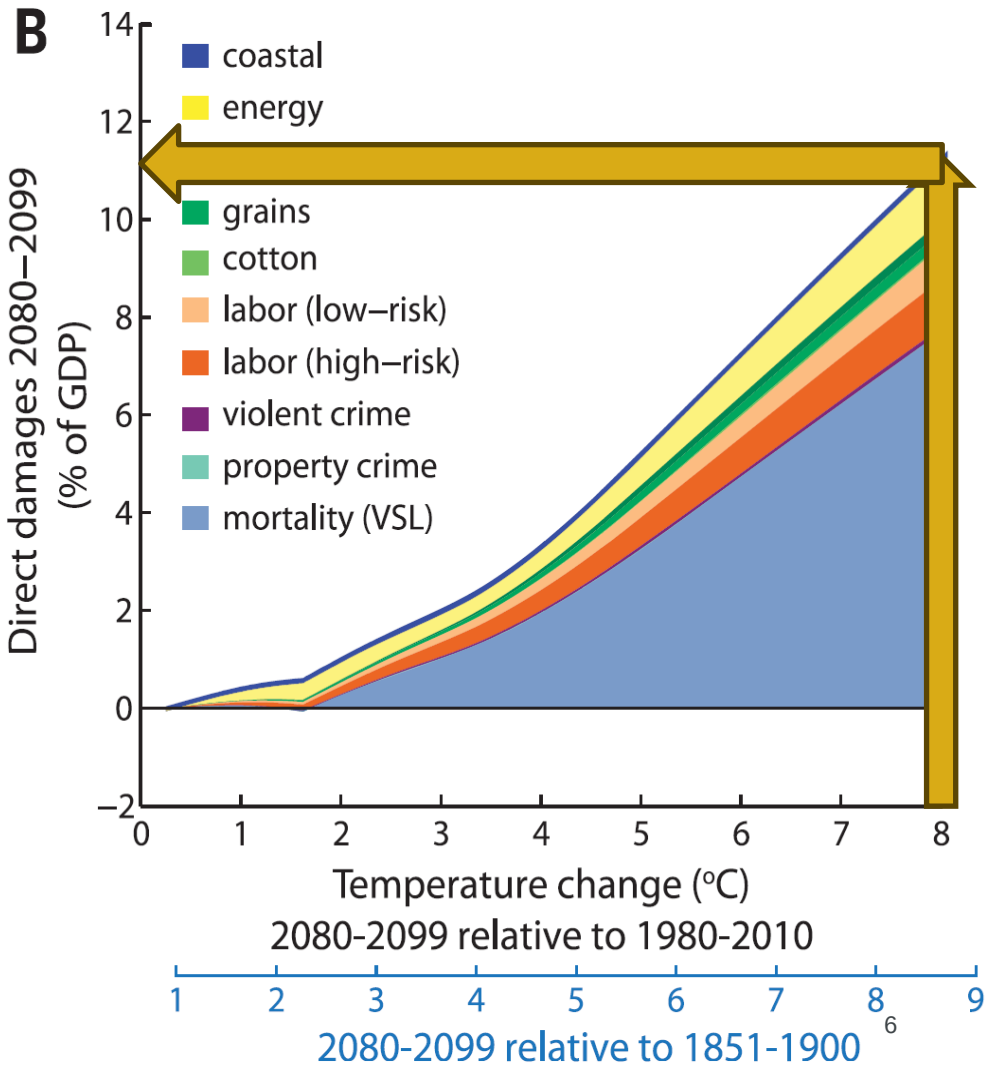
Trivial damage estimates

- Reference (14) is **not** a review, but yet another damage estimate paper:
  - "The combined value of market and nonmarket damage across analyzed sectors …
  - increases **quadratically** in global mean temperature, costing roughly 1.2% of gross domestic product per +1°C on average."
- Prediction of less than 12% damage to GDP from 8°C more warming…



Trivial damage estimates

- Reference (13) is **a review paper *by Nordhaus himself***, fitting functions to economists' damage estimates…
- These are the economic studies he fitted his function to:
- Of course a quadratic fits these numbers… But where did they come from?
- None of these temperatures **or damages** have happened yet…

Figure 1. Scatter of results of all studies[vii]

Figure shows the results of 36 estimates with positive weight. The area of each circle represents its weight.

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Trivial damage estimates

- Four ridiculous techniques
  - “Enumerative”—adding up damages while assuming that only weather-exposed industries will be affected by climate change
  - “Econometric”—assuming today’s temperature & GDP data can be used to predict the impact of global warming
  - “Elicitation”—asking other economists what they think the impact of global warming will be on GDP
  - “Equilibrium”—feeding the above estimates into CGE (“Computable General Equilibrium”) models, in which market adjustments reduce damages

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Enumerative

- “The most sensitive sectors are likely to be those, such as agriculture and forestry, in which output depends in a significant way upon climatic variables.
- At the other extreme are activities … which are undertaken in carefully controlled environments that will not be directly affected by climate change.
- Our estimate about **87% [of United States national output is produced] in sectors that are negligibly affected by climate change**.” (Nordhaus 1991)
  - This 1991 paper **includes mining** as “negligibly affected”
  - 1993 paper says “underground mining” & reduces “negligibly affected” percentage to 85%

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Enumerative

- IPCC 2014 Report
  - "FAQ 10.3 | Are other economic sectors vulnerable to climate change too?"
    - "Economic activities such as agriculture, forestry, fisheries, and mining are exposed to the weather and thus vulnerable to climate change
    - **Other economic activities, such as manufacturing and services, largely take place in controlled environments and are not really exposed to climate change**."

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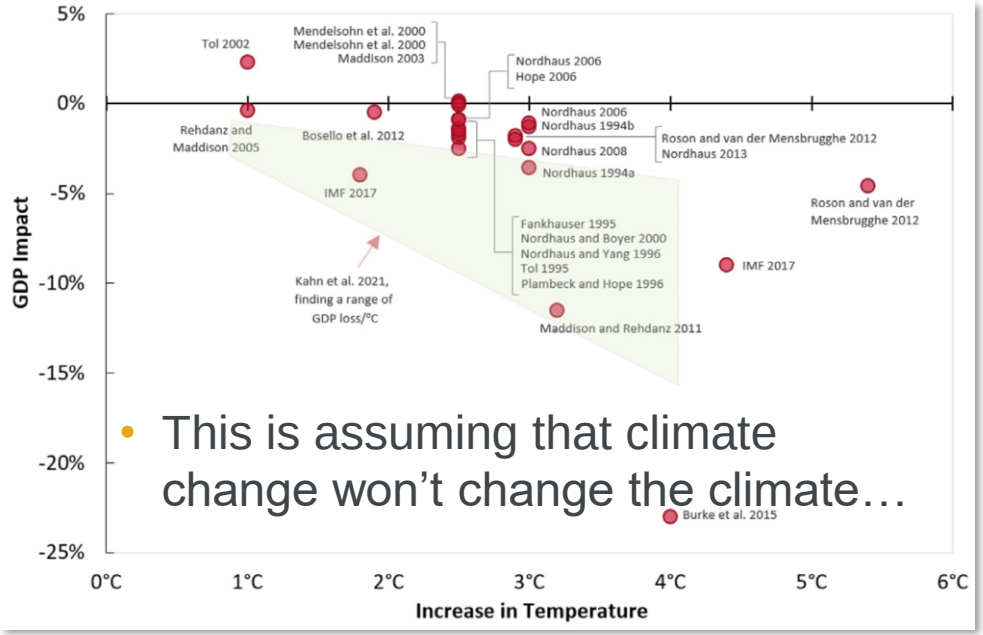
Econometric

- “Mendelsohn **assumes that the observed variation of economic activity with climate over space holds over time as well**; and uses climate models to estimate the future effect of climate change.” (Tol 2009)
- “if temperature rises (falls) above (below) its historical norm by 0.01℃ annually for a long period of time, income growth will be lower by 0.0543 percentage points per year. (Kahn et al. 2021)

- Linear extrapolation of 1960-2014 (0-1°C) relationship forward to 2100 (+4°C)



- This is assuming that climate change won’t change the climate…

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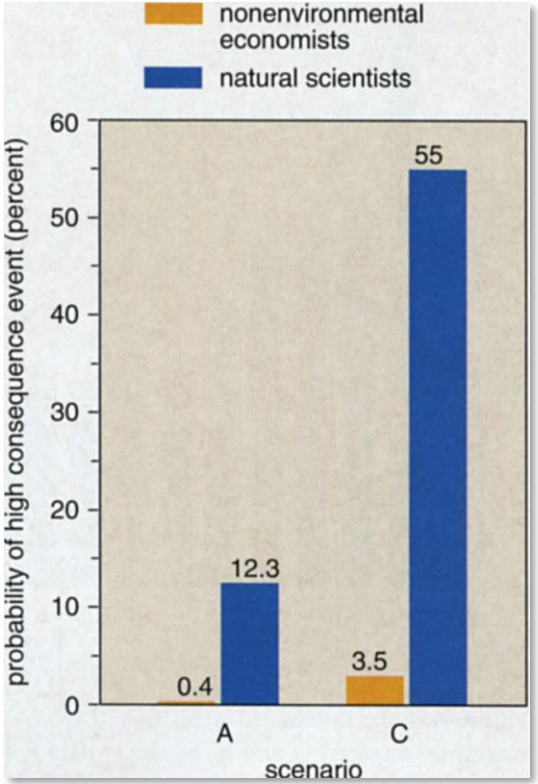
Elicitation

"For my answer, the existence value [of species] is irrelevant—I don't care about ants except for drugs"

- Nordhaus 1994: 19 people surveyed: 8 "nonenvironmental economists" vs 3 scientists. A) 3 °C; (C) 6 °C by 2090.
- "Natural scientists' estimates were 20 to 30 times higher than mainstream economists...
- This difference of opinion is on the list of interesting research topics…"
- Howard & Sylvan (2021) survey of >2000 "climate change economists"
- Median prediction for 7°C by 2220 causes a 20% fall in GDP, **relative to what it would have been without global warming**.



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Trivial damage estimates

- Economists even used quadratics to extrapolate damages from tipping points:
  - "**Using a second-order polynomial to fit the data**, 2°C warming in the absence of tipping points corresponds to 2.3°C warming in the presence of tipping points…
  - Tipping points reduce global consumption per capita by around 1% upon 3°C warming and by around 1.4% upon 6°C warming, **based on a second-order polynomial fit of the data**." (Dietz et al. 2021)

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Misleading statement of damages

- "x% of GDP" refers to a fall in future GDP, relative to no global warming
- To convert into a prediction for the decline in the annual rate of growth:
  - $\Delta g(Damage, Years) = \frac{ln(1+Damage)}{Years}$
- E.g., Howard & Sylvan survey: 7°C by 2220 causes 20% fall in GDP in 2220:
  - 20% fall over 200 years means $\frac{ln(0.8)}{200} = -0.11\%$ decline in annual economic growth
    - Say from 2% p.a. to 1.9% p.a.: i.e., economic growth still occurs at +7°C!

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Misleading statement of damages

- Economists are predicting minor falls in growth
- From temperature rises that scientists fear could drive humans extinct:
  - "The current risk category of dangerous warming is extended to more categories, which are defined by us here as follows:
    - >1.5°C as dangerous;
    - >3°C as catastrophic; and
    - **>5°C as unknown, implying beyond catastrophic, including existential threats**." (Xu & Ramanathan 2017)

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Misleading climate models

- All economic IAMs (“Integrated Assessment Models”) have their own climate modules: they don’t use scientists GCMs (“Global Circulation Models”)
- Tol’s IAM FUND predicts 1.3% ***increase*** in GWP from collapse of AMOC
  - “Integrated assessment models often **assume that other climate variables scale with temperature**, but the relationship may be different for greenhouse warming and THC cooling.” (Anthoff et al 2016)
  - “AMOC slowdown is expected to have physical effects other than temperature change, for instance **effects on precipitation and regional sea levels**, but these **have yet to be incorporated** in economic studies.” (Dietz et al. 2021)

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Why do economists do this???

- Academic disciplines develop paradigms
- Adherents to a paradigm respond defensively to anomalies
  - "Max Planck …sadly remarked that '*a new scientific truth does not triumph by convincing its opponents and making them see the light,*
  - *but rather because its opponents eventually die, and a new generation grows up that is familiar with it*.'" (Kuhn 1970)
- Generational change does not work in economics
  - Neoclassical vision of capitalism as a Utopia seduces new students
  - Paradigmatic anomalies are transient rather than permanent

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Why do economists do this???

- Limits to Growth (1972) was seen as a threat to the Neoclassical paradigm
- Climate change economics originated as an attack on LtG
- Nordhaus 1973 “World Dynamics: Measurement Without Data”
  - “The treatment of empirical relations in *World Dynamics* can be summarised as *measurement without data*…
  - *Not a single relationship or variable is drawn from actual data or empirical studies*”
  - “**there is some lack of humility toward predicting the future**. Can we treat seriously Forrester's (or anybody's) predictions in economics and social science for the next 130 years?”

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Why do economists do this???

- Half a century later, Nordhaus makes predictions for 2100:
  - "The updated results imply a **1.62%** GDP-equivalent loss at 3°C warming over pre-industrial temperatures, up from **1.22%** in the previous version…
  - Second, we have added the results of a comprehensive study of tipping points (Dietz et al. 2021), which estimates an additional 1% loss of global output due to 3 °C warming…
  - Including all these adjustments, damages are estimated to be around **3.12%** of output at a 3°C global warming over pre-industrial temperatures and **12.5%** of output with 6°C warming." (Nordhaus & Barrage 2023)
- **Predictions of the economy in 2100 to 2 decimal places…**

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~~More~~ realistic damage estimates

- A quadratic **cannot** represent the impact of global warming
  - The 2nd derivative of a quadratic is a constant
    - Acceleration remains constant as temperature rises
    - This function is inherently incapable of simulating tipping points
- 2 alternative functions
  - Exponential—acceleration always increasing
  - Logistic—acceleration, then deceleration as 100% destruction approached
  - Still smooth functions, but at least allow for accelerating damages

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~~More~~ realistic damage estimates

Extrapolate forward from current data:

- NOAA's "Billion Dollar Damages" database
- Fit to functions and extrapolate forward

- Work backwards from scientists:
  - Estimate temperature for total destruction of productive capacity
    - 5 times GDP as target level (since Capital stock ~ 4 times GDP)
  - Work backwards from estimate of total destruction to today's economy

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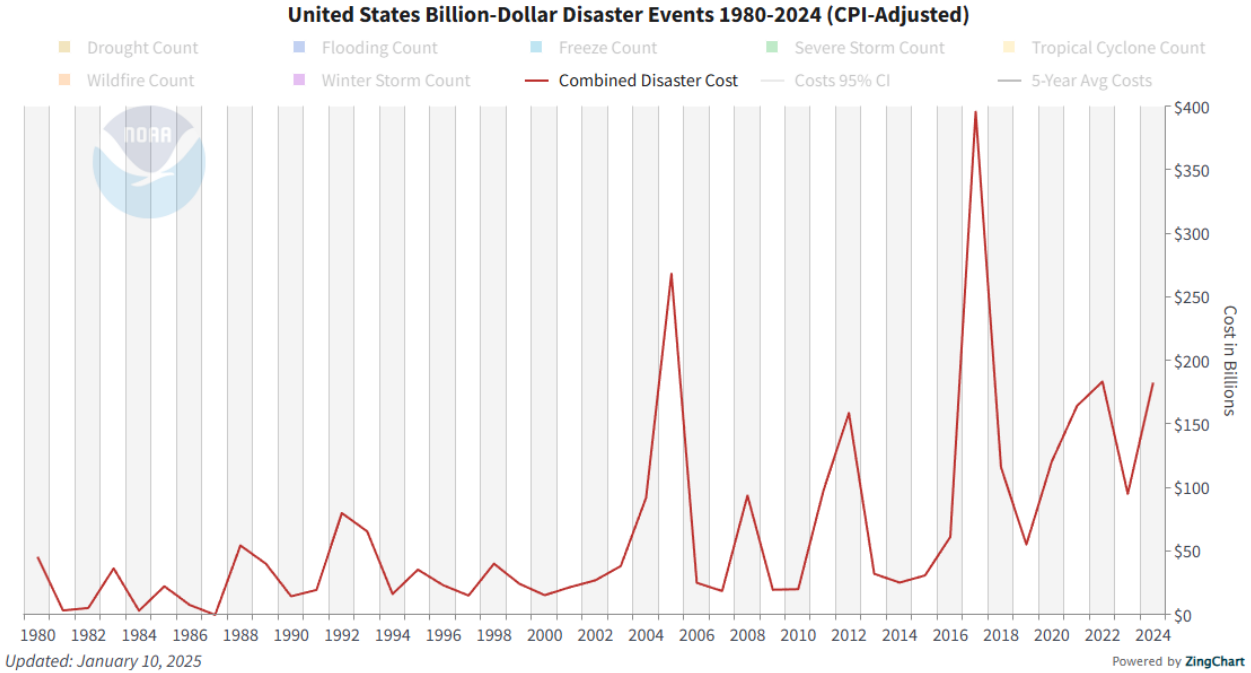
~~More~~ realistic damage estimates

- USA Billion Dollar Damages 1981-2024
  - Fit Quadratic, Exponential and Logistic functions to this data (Keen and Hanley 2024)



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~~More~~ realistic damage estimates

- Functions indistinguishable with current data…

$D(\Delta T) = a + b \times \Delta T^2$

a=0.0009644

b=0.004272

$D(\Delta T) = a + b \times e^{c \times \Delta T}$

a=0.0004023

b=0.0005223

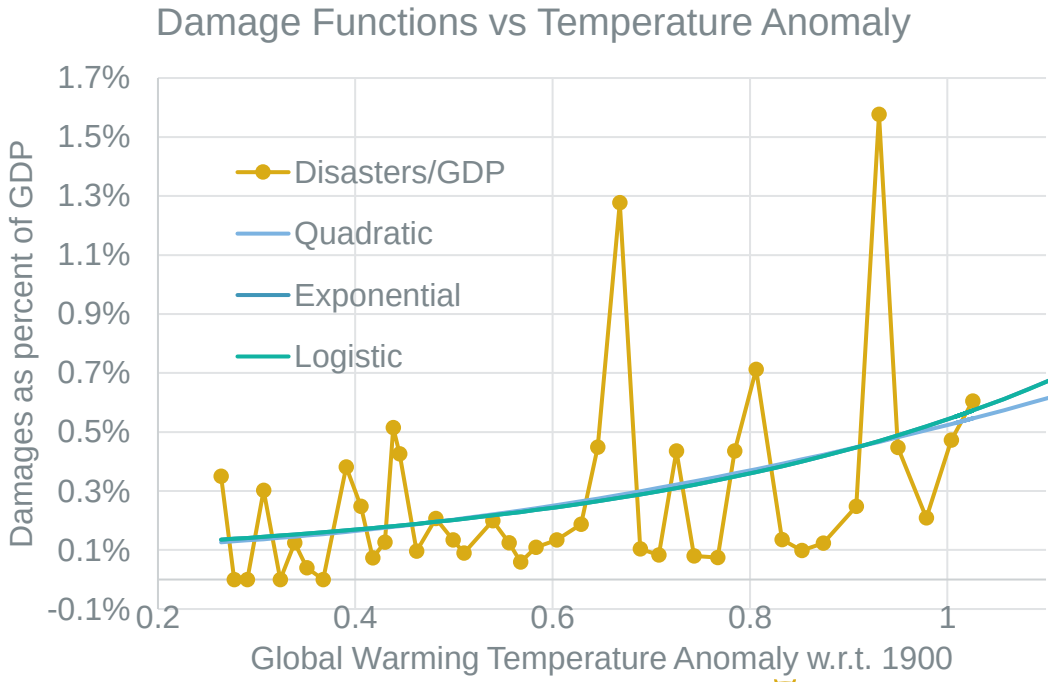
c=2.2635

$$D(\Delta T) = Min + \frac{1 - Min}{1 + e^{4 \times Slope \times \frac{Halfway - \Delta T}{1 - Min}}}$$

$Min = 0.001234$

$Slope = 0.6229$

Halfway=3.0277



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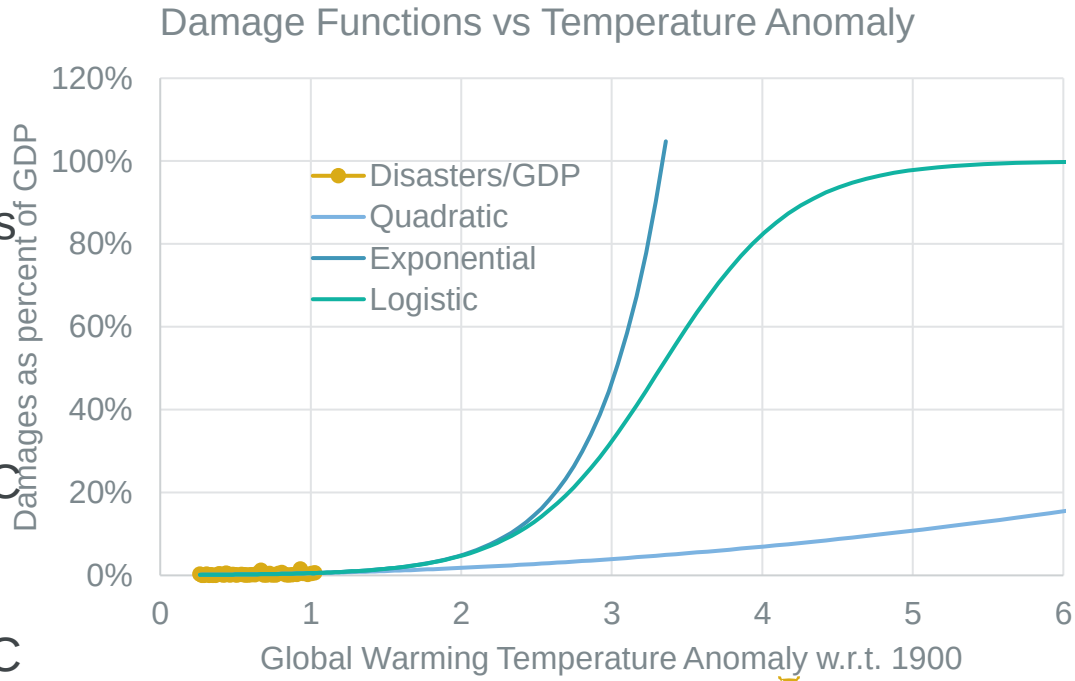
~~More~~ realistic damage estimates

- Utterly different projections…
- Quadratic:
  - Same ballpark as economists
  - Under 20% damages at 6°C
- Exponential:
  - Civilisation collapses at 3-4°C
- Logistic:
  - Civilisation collapses at 4-5°C



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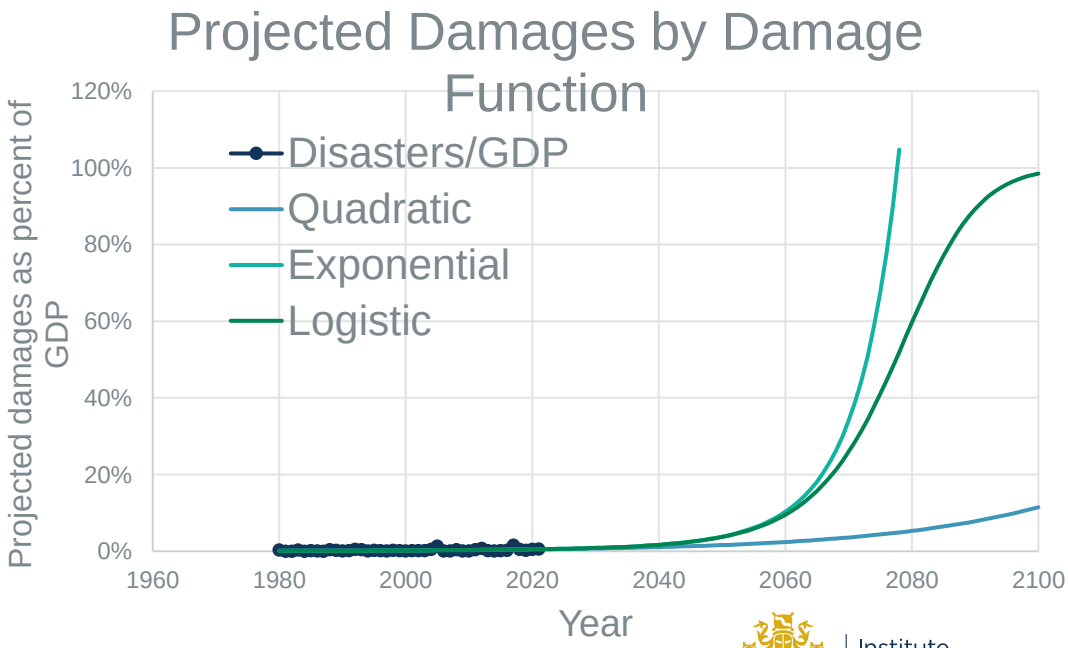
More realistic damage estimates

- More realistic functions infer an immediate crisis, versus economists “crisis? what crisis?”
- Quadratic—damages of 10% of GDP by 2100
  - $\frac{Ln(0.9)}{75} = 0.14\%$ fall in growth rate
- Exponential: civilization ends by 2080
- Logistic: civilization ends by 2100



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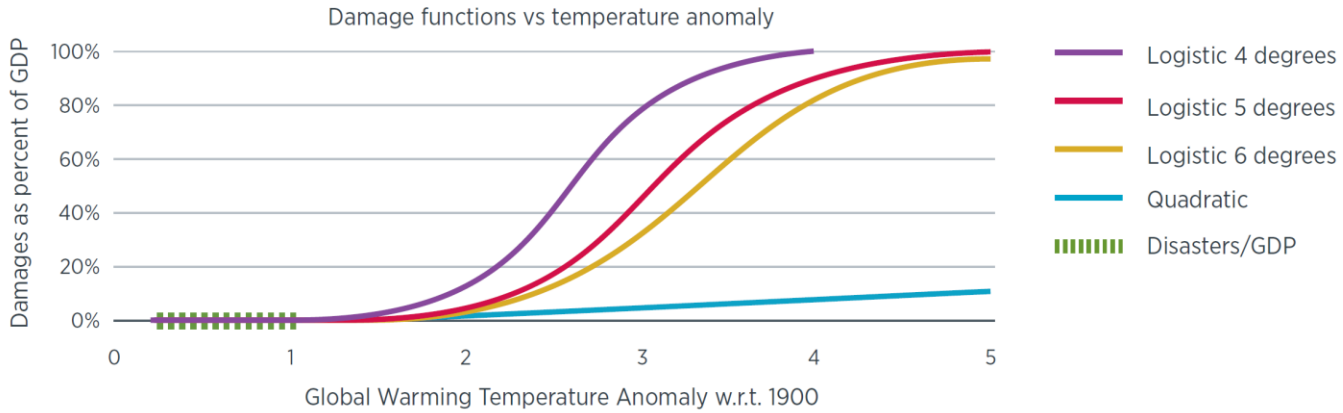
~~More~~ realistic damage estimates

- Survey scientists for estimates of temperature where civilisation is destroyed
- Work backwards from terminal temperature to today's. See IoFA Report ***The Emperor's New Climate Scenarios*** (Trust et al. 2023)

Figure 9: Climate damage functions – % GDP loss vs temperature



Source: Carbon Tracker (forthcoming), Keen et al, IFoA analysis. Reproduced with permission.

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Raise the alarm

- Economists have done sloppy, delusional work on the most significant threat that humanity has ever faced
- Refereeing process has lulled policymakers, media & public into believing this is quality work
- In fact, it has passed refereeing
  - Because it defends the Neoclassical paradigm
  - And because economists know **fuck-all** about climate change
- Economists must be removed from policy formation on climate change
- Policy must change from cost-benefit analysis to surviving an existential threat.

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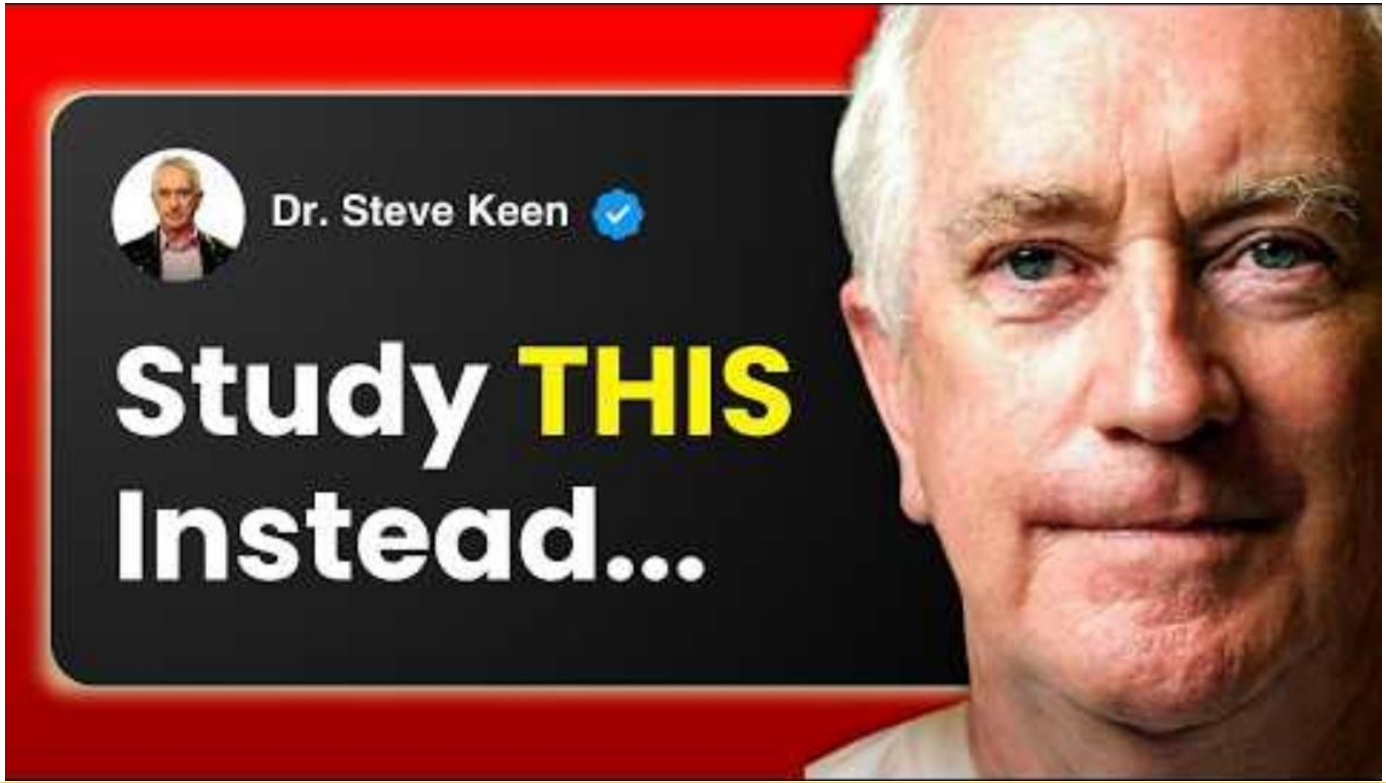
Please share this video widely (Yale University 2024):

https://www.youtube.com/watch?v=QGfaqALkc40



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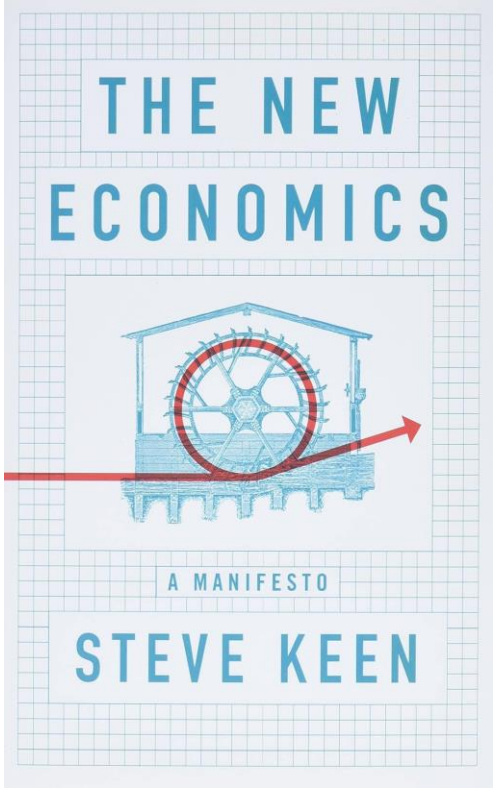

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Questions

Comments

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