Nordhaus's Nobel Prize is safe but the World isn't

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An economic analysis that won the highest of accolades and spawned influential followers has sharpened the threat from climate change, says Steve Keen.

One of the provisions of the Nobel Prize is that once awarded, it can never be revoked. This has led to some embarrassing gaffes with perhaps the worst to date being the award of the Nobel Prize for Chemistry in 1918. That went to Fritz Haber, who, as well as inventing what became an essential process in the manufacturing of fertilizer, had personally "supervised the first major chlorine gas attack at Ypres, Belgium, in 1915, which killed thousands of Allied troops," (Karl Ritter, 2016 *Five decisions that made the Nobel Prizes look bad*).

Writing for news agency AFP in 2015, journalist, Hugues Honore, reported a comment from Swedish chemist, Inger Ingmanson, who wrote a book about Haber's prize: "After Germany's defeat in the war, he didn't expect to win a prize. He was more afraid of a court martial."

So William Nordhaus's Nobel Prize in Economics"for integrating climate change into long-run macroeconomic analysis" is safe. But the world isn't. When future generations look back to try to determine why humanity delayed taking action against climate change for so long, Nordhaus's Dynamic Integrated model of Climate and the Economy (DICE) model will be regarded as one of the prime suspects.

I don't make this claim lightly. I have attacked mainstream economists in the past for making absurd assumptions in their models[1], but Nordhaus's transgressions are in a different, and lower, league altogether. His assertion that his "damage function" – a key component of his model – is consistent with the research of climate scientists, is incorrect, and he calibrates this function using data that has nothing to do with climate change itself.

And these errors are not merely of academic interest because the Intergovernmental Panel on Climate Change (IPCC) uses his model (and very similar models used by other economists following his approach) to advise governments about the economic impact of global warming.

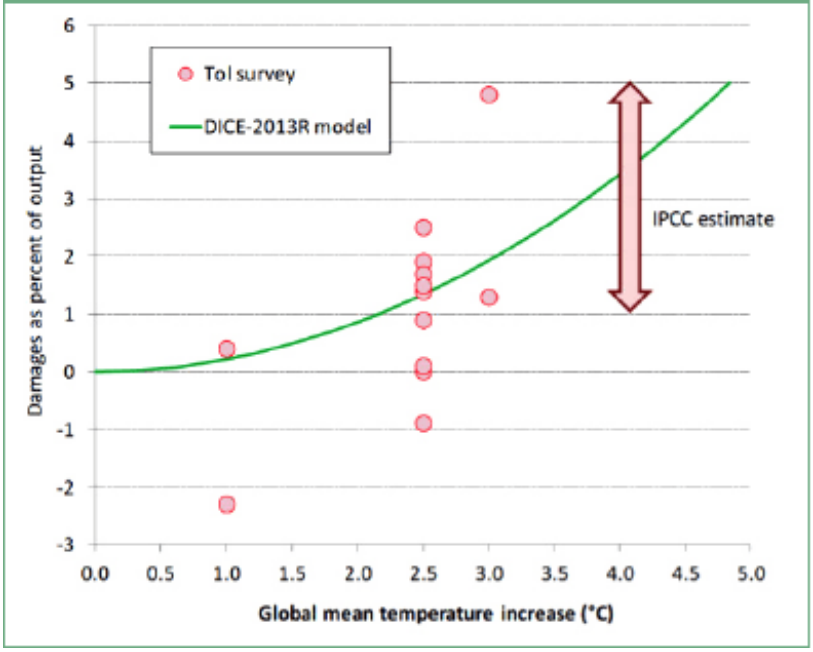
By provably ignoring the dangers of abrupt climate change, and by trivialising the impact of the higher temperatures that climate change will cause, Nordhaus (and his fellow mainstream climate economists) have seriously delayed action to avert severe damage from climate change.
The pivotal problem with his research is not the one often mentioned by critics — that

he applies a high discount rate to future damages from climate change. Instead, the problem is the function he uses to estimate damages attributable to global warming in the first place: his so-called “damage function”.

It is a simple quadratic: he asserts that an increase in the average global temperature over pre-industrial levels of, for example, 4°C, will reduce global gross domestic product (GDP) by a constant, multiplied by 16 (the square of the temperature increase), compared to what GDP would have been in the complete absence of global warming.

The constant itself is tiny. In his latest model, the coefficient he used is 0.227% [2]. Since his damage function is literally nothing other than this constant multiplied by the change in temperature squared, he asserts that GDP has been reduced by 0.227% by the 1°C of warming we have already experienced, that a 2°C temperature increase will reduce GDP by four times as much (just over 0.9%), a 3°C increase by nine times as much (just over 2%), and that a 6°C increase would reduce GDP by 36 times as much (just over 8%) — see figure 1.

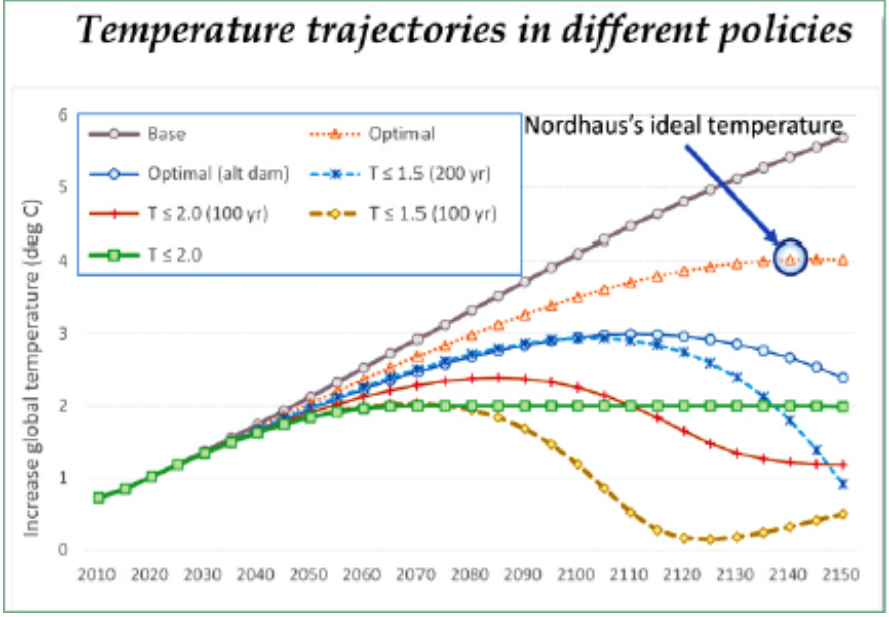
Figure 1: Nordhaus’s smooth “damage function” and the “data points” to which it was fitted (copied from page 12 of Nordhaus’s manual for his DICE programme).[3]



These are trivial changes in GDP, and by implication, in human welfare, caused by global warming. If it were true, there would be nothing to worry about. A 3.6% fall in GDP in one year is a very serious recession. But since, on Nordhaus’s calculations, it will take until 2140 to reach 4°C above pre-industrial levels (see figure 2), GDP growth over that period would have faded by a trivial 0.03% a year.

A sustained fall of 3.6% in GDP indefinitely every year from 2140 would add up to a lot as the centuries wear on. But this is where Nordhaus’s high discount rate comes in: it reduces today’s net present value of these falls to effectively zero.

Figure 2: Slide 6 in Nordhaus's 2018 Nobel Prize Lecture, annotated. Nordhaus stated that 4°C over pre-industrial temperatures was the "optimal" global temperature where the benefits of attenuating climate change balanced the costs of doing so



Climate scientists, meanwhile, are truly panicked about a 2°C increase over pre-industrial levels. A recent paper, jointly authored by 16 climate scientists, asserted that global warming must be kept to 2°C or below, because of the risk that "a 2 °C warming could activate important tipping elements, raising the temperature further to activate other tipping elements in a domino-like cascade that could take the Earth's system to even higher temperatures".[4]

Nordhaus's damage function doesn't have a discontinuity, but what climate scientists are saying is that there is a discontinuity ahead. In this sense, Nordhaus's function is like describing a canoe trip along a river with a waterfall by the statement that height above sea level falls seven metres for every kilometre paddled. That could describe the river section of the journey very well, but it would be cold comfort once you went over the waterfall.

> "Society may be lulled into a false sense of security by smooth projections of global change."

How did Nordhaus justify using a smooth function to describe the impact of Global Warming, when climate scientists are saying that there are "tipping elements" in the Earth's climate? How can he deny that a "damage function" must have a discontinuity? By, it seems, completely failing to understand climate research.

In the manual for his DICE model, Nordhaus claims: "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."[5]

That is just plain wrong. Lenton's paper, clearly entitled, *Tipping elements in the Earth's climate system*[6], concluded:

“Society may be lulled into a false sense of security by smooth projections of global change. Our synthesis of present knowledge suggests that a variety of tipping elements could reach their critical point within this century under anthropogenic climate change,” (my emphasis).

This is the exact opposite of what Nordhaus has claimed. Climate scientists have flatly rejected his function without a discontinuity. The gradual decline in GDP predicted by Nordhaus’s model, and all the “Integrated Assessment Models” produced by economists that are part of the IPCC’s reports, are completely at odds with what the climate scientists — also writing for the IPCC — have concluded.

Tim Lenton is a climate scientist at the University of Exeter, UK, where, to quote his university webpage “he and his group are focusing on … developing early warning of climate tipping points”. His 2008 paper was a first step in identifying what components of the Earth’s climate system might trigger runaway global warming. It provided a formal definition of a tipping point, and described components of the biosphere that could be pushed into a qualitatively different state by a sufficiently large increase in global temperature as “tipping elements.” Lenton says:
“In discussions of global change, the term tipping point has been used to describe a variety of phenomena… We offer a formal definition, introducing the term “tipping element” to describe subsystems of the Earth system that are at least subcontinental in scale and can be switched—under certain circumstances—into a qualitatively different state by small perturbations. The tipping point is the corresponding critical point—in forcing and a feature of the system—at which the future state of the system is qualitatively altered.”[7]

Lenton’s survey considered only large components of the planet’s climate (systems that were that of the order of 1,000km long), and which could be triggered by the increase in temperature expected this century. He concluded:
“The greatest (and clearest) threat is to the Arctic with summer sea-ice loss likely to occur long before (and potentially contribute to) GIS [Greenland Ice Sheet] melt. Tipping elements in the tropics, the boreal zone, and West Antarctica are surrounded by large uncertainty and, given their potential sensitivity, constitute candidates for surprising society. The archetypal example of a tipping element, the THC [Atlantic thermohaline circulation – part of which is the Gulf Stream that keeps Europe warmer than it otherwise would be] appears to be a less immediate threat, but the long-term fate of the THC under significant warming remains a source of concern.”[8]

How on Earth did Nordhaus read this paper and think that it justified using a smooth function, rather than one with tipping points? I can’t know of course,

but I believe he either didn’t read the paper at all or, at best, scanned it until he found a sentence that appeared to support the conclusion he wanted to reach, and then stopped. There is such a sentence, at the start of the paper’s third paragraph: “Many of the systems we consider do not yet have convincingly established tipping points.”[9]

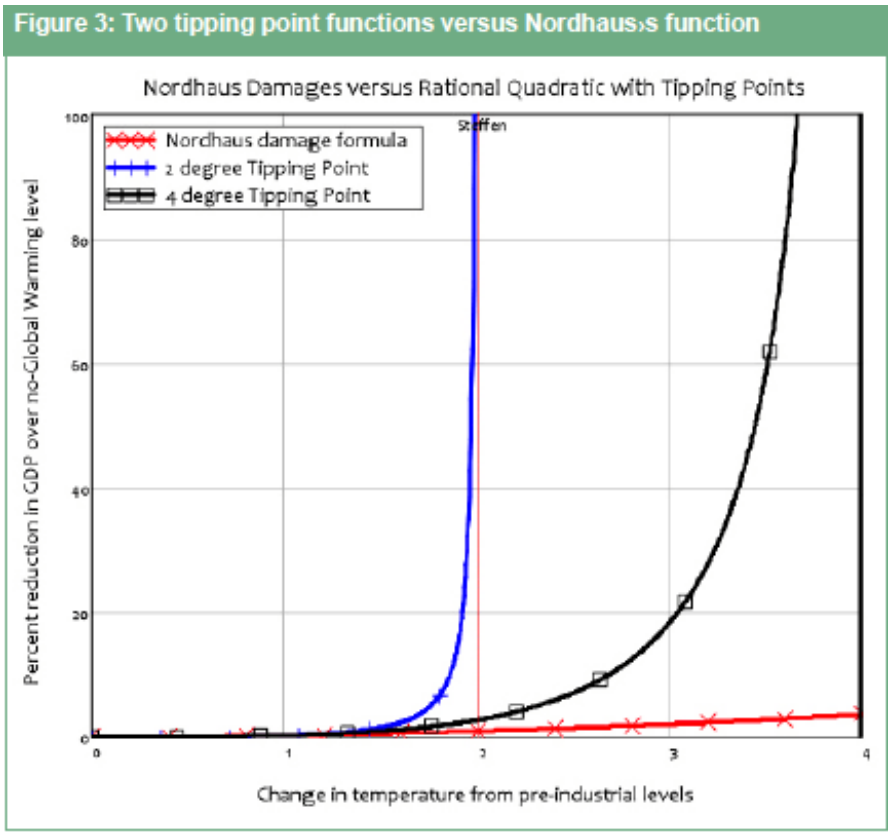
Read out of context, that sentence could imply that the existence of tipping points hasn't been proven—and that therefore a smooth function like a quadratic is fine. But everything else in the paper, including the sentences either side of that one, screams that a smooth function should not be used. Curiously, Nordhaus cites this paper in the DICE manual but does not quote from it. And the reference is not in his bibliography.

> "Many of the systems we consider do not yet have convincingly established tipping points."

It's simple to show just how misleading a smooth function is by using one that is otherwise very similar to Nordhaus's, but does have a tipping point. This is a function which coincides with Nordhaus's prediction about the damage from 1°Cof global warming, cubes the difference between the actual temperature and the pre-industrial level, and divides this by a tipping point temperature minus the actual temperature.

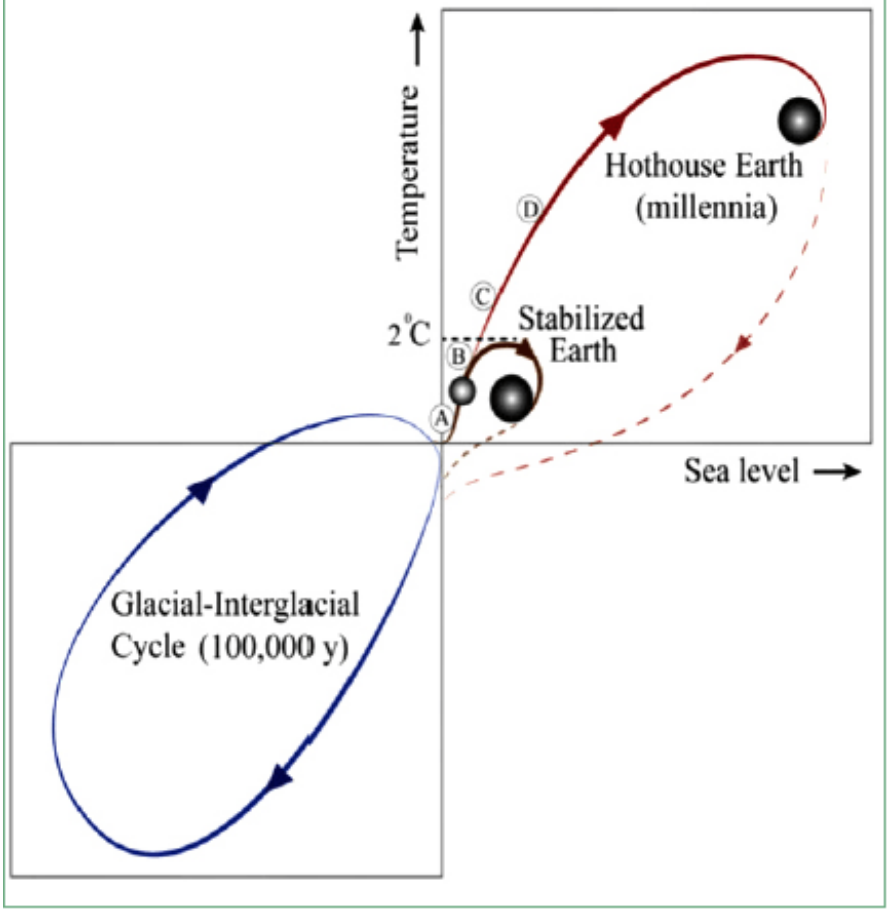
Figure 3 plots Nordhaus's function and two functions with tipping points, one at the 2°Cpoint chosen by climate scientists (Steffen et al. 2018)[9]as the danger point for the planet, the other at the 4°Clevel that Nordhaus sees as "optimal" for the planet. The difference between the stylised but realistic tipping point functions, and Nordhaus's unrealistic smooth function, are dramatic. Even if Nordhaus (and humanity) happens to be lucky, and the actual tipping point is twice as high as climate scientists fear it is, the 3°Cof warming that he predicts would only reduce GDP by 2% would instead reduce it by 18%. That is not some far-distant concern either: we are already at 1°Cwarming over pre-Industrial levels, and even Nordhaus predicts we will hit 3°Cof warming in 2070 (see figure 2). That's just five decades away, when today's Extinction Rebellion campaigners would hope to be entering retirement.

Figure 3: Two tipping point functions versus Nordhaus›s function



If the climate scientists are right, and 2°Cis the tipping point, then even on Nordhaus's calculations (see figure 2), we have just 25 years to avoid catastrophic damage to both the biosphere and the economy. This doesn't mean that the economy will cease to exist in 2045, but that the rate of temperature increase will accelerate at or around that date, driven by qualitative changes in the biosphere in addition to heat retention via greenhouse gases, and that these qualitative changes could push the biosphere to, or past, temperatures that have previously caused mass extinctions, and which will surely be incompatible with industrialised human society(see figure 4 taken from Steffen 2018).

Figure 4: The glacial-interglacial cycle plus the Hothouse Earth cycle we are now on.[9]



Not only has Nordhaus ignored these warnings by climate scientists, the only changes he has made to his damage function over the years have made it *less*able to handle tipping points[10] and *reduced* the already tiny coefficient he uses, from 0.35% in 1999, to 0.284% in 2008, 0.267% in 2013,[11]and 0.227% in 2018.[12]

This is the next mystery in DICE: how did Nordhaus get such tiny numbers for the impact of climate change in the first place? Here we have to delve into the source of the "data points" to which DICE is fitted: the 14 dots on figure 1, which originate in a survey of economists' predictions about the impact of climate change by Dutch economist, Richard Tol.[13]

There are many weaknesses in these predictions, but without a doubt the worst is an assumption, behind at least five of them, that the relative effect of climate on income in

different parts of the world today can be extrapolated to the effect of changes in climate on GDP across the whole planet over time. Under that assumption, temperature and income differences between, for example, Washington and Dallas, can be used to predict what will happen to global GDP if global temperatures rise by the gap between Washington and Dallas. In Tol's words, these data points are based on the assumption "that the observed variation of economic activity with climate over space holds over time as well."[14] He goes on to comment on specific studies:

"[Robert] Mendelsohn's work … can be called the statistical approach. It is based on direct estimates of the welfare impacts, using observed variations (across space within a single country) in prices and expenditures to discern the effect of climate. 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…

> "Like Mendelsohn, Nordhaus and Maddison rely exclusively on observations, assuming that "climate" is reflected in incomes and expenditures — and that the spatial pattern holds over time."

Nordhaus uses empirical estimates of the aggregate climate impact on income across the world (per grid cell), while [David] Maddison looks at patterns of aggregate household consumption (per country). Like Mendelsohn, Nordhaus and Maddison rely exclusively on observations, assuming that "climate" is reflected in incomes and expenditures—and that the spatial pattern holds over time.[14]

What does this mean? It means that these economists took data about the income and temperature levels in different parts of the USA today, performed regressions between them, and found a weak nonlinear relationship between income and temperature. Below an "optimum" average yearly temperature of 12°C[15], increasing temperatures are correlated with increasing income; above that average temperature, rising temperatures are correlated with decreasing income.

Since much of the world's inhabited landmass has a lower average temperature than 12°C, several of these economists concluded that an increase in global temperature over pre-industrial levels would actually increase global GDP.[16] For example the lowest point for a 2.5°C increase in figure 1 shows a negative damage – meaning an improvement – of 1% to GDP from a 2.5°C increase in temperature over pre-industrial levels (see also figure 5).

Figure 5: Mendelsohn's predictions of the impact of climate change on global GDP.[18]

R. Mendelsohn et al. / Comparing impacts across climate models

Table 3
Aggregate impacts in 2100 by GCM model Cross-sectional responses (billions of 1990 $/year).

GCM	Continent[a]							
	Total	Africa	Asia	LatAm	WEur	Comm	NAm	Ocean
BMRC	150	−10	32	−3	2	100	29	−1
CCC	152	−18	31	−6	5	108	33	−2
GF30	185	−5	35	3	6	106	41	−2
GFDL	184	−9	31	2	5	114	42	−1
GFQF	165	−12	35	0	6	98	41	−3
GISS	131	−15	17	−7	7	94	38	−2
HEND	97	−28	8	−10	5	95	32	−4
OSU	116	−15	0	−3	6	93	37	−1
POLS	173	−16	39	−7	6	101	53	−4
POLD	175	−10	21	−2	8	112	48	−2
UIUC	98	−31	−1	−14	5	99	42	−2
UKMO	136	−21	16	−5	6	104	39	−3
WANG	119	−22	1	−9	7	102	43	−3
WASH	143	−13	22	−2	5	96	38	−3
AVERAGE	**145**	**−16**	**21**	**−5**	**6**	**102**	**40**	**−2**

[a] The continents above are Africa, Asia, Latin America, Western Europe, the former Soviet Union and Eastern bloc, North America, and Oceania.

In their words:
"The results indicate that there will be large benefits from warming in the former Soviet Union and Eastern Bloc countries. The benefits in this region almost offset losses throughout the tropics in the experimental results. The Soviet benefits account for two-thirds of the net global benefits in the cross-sectional results. The results also suggest that there will be large benefits in North America and small benefits in Western Europe.

"The critical factor that these benefiting countries have in common is that they are currently cool so that warming is helpful."[17]
If anything, this assumption that income and temperature differences today can be used to predict the result of global warming over time is even more insane than Nordhaus's quadratic damage function itself. It is akin to assuming that the energy needed to move horizontally is equivalent to that needed to move vertically.

More seriously, it ignores the key issue in global warming: the impact of retaining much more energy in the biosphere. Once past the tipping point – which these economists ignore also – the energy level of the entire biosphere will rise enormously.

So while temperature and precipitation differs between places in the USA today, the amount of energy in the global atmosphere is unchanged. It may well be that incomes in parts of the world with average temperatures of 11°Ctoday are lower than in parts with average temperatures of 12.5°C today. But that tells you absolutely nothing about the impact on GDP of raising the temperature of the entire atmosphere of Earth by 1.5°C over time.

Furthermore, the global temperature range today is from minus 90°C in Antarctica to plus 70°C in the Middle East. If the temperature rises 1.5°C across the globe, the range will be from minus 68.5°C to plus 71.5°C. High temperatures that do not exist on the planet today will come into being; low temperatures that exist today will disappear. The impact this will have across the globe simply cannot be estimated by extrapolating from relationships between today's GDP and temperature ranges. The shift in the temperature range caused by global warming is simply ignored by the "spatial pattern holds over time" assumption.

The Integrated Assessment Models designed by other economists, used by the IPCC to predict the economic consequences of global warming, are no better informed.

They are the source of the IPCC's claims about the economic impact of climate change that trivialise the danger of extreme temperature changes. Examples include the 1996 IPCC Report claim that a 10°C increase in global temperature — well above levels that have caused mass extinctions in the past — would reduce GDP by a mere 6%[19]andanother from the latest IPCC report that a 2°C rise will reduce GDP by just 0.2-2%.[20]

These IPCC forecasts, derived directly from the work of Nordhaus, Tol and other mainstream economists, are so trivial that they are quoted and promoted by climate change deniers like Bjorn Lomborg. More importantly, these are the aspects of the IPCC's reports that are taken seriously by economic-growth-obsessed politicians, while the dire warnings of climate scientists are effectively ignored.

Given how irredeemably bad the work of economists on the economic impacts of climate change has been, that assessment should be left to climate scientists like Steffen, Lenton and Garrett.[21-24] They can be trusted to at least understand what global warming means.
And this is precisely what real climate scientists are saying but you have to read between the lines, which is possibly why economists like Nordhaus continue to ignore them. Here are Steffen and his 15 collaborators — including Lenton —from August of last year:

> "Given how irredeemably bad the work of economists on the economic impacts of climate change has been, that assessment should be left to climate scientists."

"With these trends likely to continue for the next several decades at least, the contemporary way of guiding development founded on theories, tools, and beliefs of gradual or incremental change, with a focus on economy efficiency, will likely not be adequate to cope with this trajectory. Thus, in addition to adaptation, increasing resilience will become a key strategy for navigating the future."[25]

They put it a lot more politely than I do. For me,Nordhaus's interventions on climate change have trivialised the dangers, and thereby helped delay critical action to prevent climate change. He and his fellow economists should be thrown out of the IPCC, and

replaced by scientists who have a far better understanding of the dangers of unleashing that much more energy on our sensitive biosphere.

Rather than "integrating climate change into long-run macroeconomic analysis", as his Nobel citation puts it, Nordhaus has led humanity up the garden path towards a possible slaughterhouse. He will take his Nobel Prize to the grave, but we should leave his death march, now. Hopefully, before it's too late. Climate scientists themselves are calling for the approach economists take to the mitigation of climate change to be abandoned. It is time their call was heeded.

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Steve Keen

Professor Steve Keen is both critic of mainstream economics and a developer of a modern complex systems approach to economics. Best known for the book Debunking Economics, he was a …

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