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The world before climate change

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William Nordhaus is best known today for his long career of path-breaking research on the economics of climate change, beginning in the late 1970s. It is intriguing to look back even farther in time, to his 1973 projection of long-term world energy futures (Nordhaus, 1973) – both for the successes and failures of that projection, and for the ways in which it foreshadowed the author's later work on climate change.

Now that the first 40 years of his 1973 forecast have slipped from the future into the past, it is impressive to see some striking successes. Who else predicted, back then, that shale oil supplies would eventually be developed, reducing US oil imports, by about 2020? Perhaps less remarkable, but clearly on the mark, was the anticipation of environmental restrictions on power plants, particularly those burning coal; it was, after all, several years after the passage of the Clean Air Act and the creation of the Environmental Protection Agency. The identification of natural gas as the least-cost fuel for US electricity production in the near term was also accurate in retrospect.

But prediction is especially difficult for the future, as the saying goes, because it has not happened yet. The young Nordhaus, as energy forecaster, failed to foresee the rapid rise of renewable energy, or the importance of the Organization of the Petroleum Exporting Countries (OPEC) and the heights which oil prices would soon reach. His assumption that coal, often liquefied, would be widely used in twenty-first century America does not currently look accurate. Writing years before Three Mile Island, let alone Chernobyl and Fukushima, he was remarkably sanguine about the prospects for nuclear power, discussing 'the inevitable transition from exhaustible fossil fuels to nuclear fuels… this basic pattern is all but invariant to such things as modifications in cost' (Nordhaus, 1973, p. 553).

It was, however, several years after Detroit Edison's disastrous attempt at building a fast breeder reactor, now largely forgotten but memorialized at the time in a book and a popular song titled 'We Almost Lost Detroit'. This experience may be reflected in Nordhaus' discussion of the risk that breeder reactor technology, often seen as the key to extending limited supplies of nuclear fuel, might not prove successful – even though his basic projections assumed that breeder reactors would become increasingly important in the twenty-first century and beyond (Nordhaus, 1973, p. 552, Table 5).

Nordhaus, as of 1973, also failed to anticipate the importance of the issue that he later became so well-known for studying – the economics of climate change. Indeed, almost no one was talking about global warming at the time. While the basic science underlying climate change is much older, widespread awareness of the urgency of the problem only surfaced in the 1980s. Yet on a deeper level, many of the themes of Nordhaus' later work are anticipated in his early work on energy futures.

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In both arenas, Nordhaus starts with a framework from conventional economic theory and applies it to an empirical problem of global scope and multi-century duration. An intentionally simple logical structure, combined with heroic extrapolation from limited available data, yields interesting estimates that are arguably better than complete ignorance, representing ambitious attempts at creating the best available or least bad forecasts. (When I was an undergraduate, the campus newspaper had a slogan on the wall in its editorial office: 'Something inaccurate is better than nothing at all'. This may be better guidance for some kinds of forecasting than for newspaper writing.)

In both cases Nordhaus offers a vision of the uncertain future that is imbued with technological optimism. For climate change this has often meant a comfortably modest estimate of the pace of climate change and the extent of the resulting damages; the assumption of a carbon-free backstop fuel, or complete decarbonization option, available at a moderately large but imaginable price; and, in some early analyses, over-reliance on cheap nuclear power,[1] and a geoengineering strategy that would solve the entire climate crisis at a very low cost.

The simplicity of Nordhaus' analyses, in climate change as in the 1973 energy forecast, may seem frustrating at times. It is, however, a conscious choice, designed for comprehensibility rather than completeness. His DICE (Dynamic Integrated Climate-Economy) model is one of the first and simplest of the integrated assessment models of climate economics. Even after decades of development, it still represents the entire long-run dynamics of the global economy, the climate, and their interactions, with only 18 equations and 44 parameters (Nordhaus, 2011). This offers a skeletal clarity about the assumed mechanisms, at the price of ruthless oversimplification. In defense of this approach, Nordhaus has argued that the complexity of more elaborate models implies that they will inevitably have a significant rate of errors, with unintended consequences for model results. My own work (Ackerman & Munitz, 2012), which identified a glaring algebraic error in a more complex integrated assessment model, provides one of his examples (Nordhaus with Sztorc, 2013, pp. 51–54).

The good news about this approach is that it has led to widespread understanding of DICE, and has created a community of users who have experimented with incremental changes to the model. Nordhaus' longstanding policy of making the code freely available, and making no attempts to police anyone else's use of it, has made DICE a *de facto* open-source standard for climate economics. Rigorous simplicity and intense public scrutiny ensure that there are no hidden errors or unintended glitches in the DICE software.

The bad news is that those 18 equations and 44 parameters leave out a lot of things about climate change that we know are very important. Particularly in its early, extremely optimistic versions, DICE could be, and often was, cited as proof that sound economic analysis shows climate change to be a minor problem, fully solvable without major expenditures or policy initiatives. The transparency of DICE has allowed critics, myself included, to rake over the model in search of the sources of this unwarranted optimism. Once the geoengineering and cheap nuclear power panaceas were abandoned, a while back, the principal remaining questions, from my perspective, concerned the discount rate, the near-absence of tipping-point risks of discontinuous or catastrophic outcomes, and the shape of the damage function. The discount rate may be the most important factor: in his widely cited critique of the Stern Review, Nordhaus emphasized Stern's use of a much lower discount rate as the root cause of their disagreement (Nordhaus, 2007). Regarding the damage function, a single equation in DICE projects a rather leisurely growth of total climate damages as global temperatures rise. Reasonable alternatives have very different implications for the costs and severity of climate impacts (Ackerman & Stanton, 2012).

Fortunately, the story does not end there. Fascination with the data and curiosity about what it implies, visible in Nordhaus' early work on energy futures, has continued to inform his latter-day work on climate change. For example, after Hurricane Katrina he demonstrated that hurricane damages rise extraordinarily rapidly as wind speed increases. Basic physics suggests that damages should be proportional to the cube of wind speed, a relationship that is assumed in many models.[2] Empirically, Nordhaus found, the relationship is much steeper, with damages proportional to the ninth power of wind speed (Nordhaus, 2010). This is plausible, he suggested, because many structures are little affected by strong winds up to a breaking point, at which point they experience large, discontinuous increases in damages. When wind speeds first exceed the breaking points of many structures, aggregate damages can rise quite steeply. Other researchers have found similar, if not quite as extreme, patterns in hurricane damages as a function of wind speed (Bouwer & Wouter Botzen, 2011).

In the bigger picture, Nordhaus has gradually shifted his estimates of the severity of climate risks, nudging the damage function upward with each revision. There is also a larger, noteworthy change in his latest book, *The Climate Casino* (Nordhaus, 2013). As well as presenting a new revision of DICE, he emphasizes that there are critical impacts of climate change that cannot easily be quantified or monetized, and hence cannot be incorporated into a model of this type. The title of the book reflects his focus on unpredictable, extreme risks as the most serious problem of climate change, justifying policy responses beyond those literally recommended by the DICE model. It is still not the book I would have written on these issues; Martin Weitzman's appreciative critique seems to me to strike many of the right notes (Weitzman, 2015). But *The Climate Casino* is more than just an update of earlier books by Nordhaus. In public debate, Nordhaus appears to have concluded that the Stern Review and others calling for more drastic action are less of a threat than the rising tide of climate science denial in American politics. He has spoken out forcefully to emphasize that the problem is real, and inaction is not a survivable option (Nordhaus, 2012).

Finally, more than 40 years on from the publication of his global energy forecast, Nordhaus provides an exemplary model of scholarly activity. We all have met people who, by this stage in their careers, are so absorbed in pride or defensiveness about their past accomplishments that they are no longer really open to discussion of new and different perspectives. Nordhaus, despite his fame, remains impressively humble and curious about the views of others, seeking out some of his harshest critics (I am speaking from personal experience here) to be sure he understands where they disagree with him. This sort of behavior threatens to give academic careers a good name. In the words of a television show that was popular when Nordhaus published his early energy projections, 'Live long and prosper'.

Disclosure statement

No potential conflict of interest was reported by the author.

Notes

1. He commented in one of his first analyses of climate change that prohibition on nuclear power would make the cost of meeting carbon constraints about five times as large (Nordhaus, 1977, p. 346).
2. The kinetic energy of an air molecule is proportional to the square of wind speed. The number of molecules striking a fixed structure per unit of time is proportional to wind speed. The impact on a fixed structure per unit of time is the product of these two factors.

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