Non-optimal optimization

Most natural scientists have a limited understanding of how economists think about the world and, in particular, how they conduct their analyses about it. The ignorance goes the other way too, and this isn't good now that scientists and economists interact with increasing frequency — most notably in offering analyses aimed at supporting wise decisions on issues such as environmental protection and climate change.

Economists bring some rather alien points of view to the table. The economists' baseline for thinking about climate change, for example, is well explained in a 2004 paper by Kenneth Arrow and colleagues (*J. Econ. Perspect.* **18,** 147–172; 2004). Economists, readers learn, traditionally see the issue as a problem of optimization. The aim, roughly speaking, is to choose the policy that will reduce costs and increase benefits, in an optimal way, not only now, but summed over the entire future yet to come.

Economists don't like speaking 'roughly', however, and so they turn this idea into a specific mathematical recipe. The thing to be optimized is $V(t)$, the 'social welfare' at time t, written out as the integral over the infinite future

$$V(t) = \int_{s=t}^{\infty} U[C(s)]e^{-\delta(s-t)}ds$$

with $C(s)$ being the rate of consumption at time s, and U is an increasing function of its argument. Consumption reflects all the economic activities that we carry out, and it is assumed (through U) that more is naturally better. The exponential factor in the equation enters because economists assume — partially in keeping with actual human behaviour — that something in the future does not have the same value as that same thing now. Investments (generally) grow, for example, so future benefits should be reduced or 'discounted' by an exponential factor dependent on a parameter δ.

Hence, dealing optimally with climate change or any other issue is considered to be equivalent to solving this mathematical optimization: making $V(t)$ as big as possible. Actually, the task is a little more complicated, as, with an uncertain future, the target of the optimization is really the expected value of $V(t)$. Reducing consumption now to reduce climate change is, in this view, a good idea only if the sum of expected future benefits that such a move brings, after

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their discounting, will outweigh the costs. Good policy is reduced to the calculus of variations — just maximize this variable!

If this seems a little incredible, then you haven't been trained as an economist. Most natural scientists, I expect, would suggest that the problem is far too complex to be reduced to an exercise in mathematical optimization, and that any conclusions following from such an analysis would most likely be misleading. The answers would be far too vulnerable to errors in the estimation, especially as the true likely costs and benefits of any policy action are wildly uncertain. But there are other worries to add to this.

One is that simple exponential discounting does not make sense in an uncertain world. Interest rates (at least in an approximate, short-term sense) should reflect people's collective views on how the future should be discounted. But such rates fluctuate, often quite strongly, and there is little evidence that they fluctuate in a statistically stationary way: you can't assume that a fixed probability distribution predicts what we'll see next year. This implies, studies show, that we should expect, over time, that periods of unusually low interest rates (and therefore low effective discounting) should dominate any average, being exponentially more significant than other episodes (J. Doyne Farmer *et al.*, *Discounting the Distant Future*; Cowles Foundation for Research in Economics, 2014; http://ssrn.com/abstract=2465953). One consequence is that the future should be valued far more strongly than the standard economic formula would suggest.

Other serious problems have been widely discussed by economists themselves. Prominently, even within the exponential framework, the right discount factor cannot be established in any certain way. And different choices lead to wildly divergent analyses. In 2006, UK economist Nicholas Stern, using one form of discounting, concluded that the long-term risks of climate change demanded a strong and immediate reduction in emissions. Meanwhile, US economist William Nordhaus, using a stronger form of discounting, came to the opposite conclusion — we should do little about climate change now, and more later. These are simply differences of opinion.

A still deeper problem, suggested not too long ago by US economist Martin Weitzman, is that our uncertainty over the future is likely to be so significant that proper estimates of future potential losses may well be effectively infinite (*Rev. Environ. Econ. Policy* **5,** 275–292; 2011). In that case, no summing up and attempting to maximize expected returns makes any sense. The optimization approach is just the wrong way to look at the problem.

Yet questions over the 'maximize consumption' scheme go even further, as Arrow and others in their 2004 article acknowledged. For example, an alternative criterion to maximization might be sustainability — the demand, in mathematical terms, that the expected value of the future consumption stream never decrease, so that future generations are expected to be at least as well off as we are. This might be satisfied in ways that do not maximize the present value. So, slightly different ways of thinking about the infinite sum yield utterly different recommendations for policy.

It may just be a bad idea to try steering humanity in the right direction by optimizing a one-dimensional measure. Most of us do not try to calculate our way to the best decision when we face complex problems, such as deciding which job to take or house to buy. We gather information, widely perhaps, but don't reduce it all to a one-dimensional sum. In fact, psychologists agree that individuals facing complex problems generally make better decisions using simple heuristics or rules of thumb, rather than falsely precise calculations. Often we cannot even list all the possible alternatives and consequences, let alone their probabilities. Rather than aiming for some illusory 'optimal,' we would be better off trying to avoid the worst outcomes that we know are possible.

Natural scientists need to learn about this debate over how to make wise policy decisions. The discussion is now dominated by economists, but the matter is too important to be left to any one group or narrow analytic method. ❐

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