

## Climate Policy: A Note

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I'm trying to do a popular writeup of debates over climate change policy, which meant that I had to get a grip on the big dispute over the timing of action – Nordhaus and other modelers calling for a “climate policy ramp” in which carbon prices start fairly low and rise only gradually, Stern and others calling for a quick rise in prices. I found the discussion hard to follow, so I did what I usually do in such cases – tried to write down a toy model that hopefully clarifies the issues. This note describes this toy model; it's basically a note to myself, but some other people may find it useful.

Here's my approach: I think of climate policy as being like an optimal investment model upside down, where you accumulate a bad – atmospheric carbon concentration – rather than a good. In this setup, the price of carbon acts like an upside-down Tobin's  $q$ : the higher this price, the lower are emissions, and hence the lower the rate at which you add to the atmospheric concentration.

For simplicity, I think of damages as being driven by contemporaneous carbon concentration – no lags in the effects of CO<sub>2</sub> on temperature. I also think of carbon in the atmosphere as “depreciating” at a constant rate  $\delta$ , although I'm well aware that the actual process by which excess carbon would leave if we stopped all emissions is a lot more complicated than that.

If you think about things this way, you get a picture like Figure 1. In the figure,  $\lambda$  is the price of emissions,  $K$  the atmospheric carbon concentration. The line  $dK/dt=0$  shows the steady-state

level of  $K$  for any given carbon price. It's downward-sloping, but I've drawn it fairly flat, since as I read it all the models suggest that eventually we'll have to bring carbon emissions down to very low levels, almost regardless of where we hope to stabilize.

The line  $d\lambda/dt=0$  is the upside-down analogue of the  $dq/dt=0$  line that comes from a standard optimal investment model. Think for a minute in discrete time about the “payoff” – actually harm – imposed by adding one unit of carbon to the atmosphere this period, which must be equal to  $\lambda$ . It's

$$(1) \quad \lambda_t = \frac{\partial W}{\partial K} + \frac{1 - \delta}{1 + r} \lambda_{t+1}$$

where the first term represents the damage done by an additional unit of carbon concentration now, and the second term represents the cost of contributing to future carbon concentration; in this term,  $\delta$  is the rate at which carbon leaves the atmosphere, and  $r$  is the discount rate. If you rearrange this, take linear approximations, and then express it in continuous time – or, if you're less quick-and-dirty than I am, you derive the whole thing from continuous time to begin with – this becomes:

$$(2) \quad r + \delta = \frac{\partial W / \partial K}{\lambda} + \frac{\dot{\lambda}}{\lambda}$$

So the  $d\lambda/dt$  line is the locus of points at which the price of emissions is equal to the current cost of an additional unit of carbon concentration, divided by the sum of the discount and disappearance factors – that is,

$$(3) \quad \lambda = \frac{\partial W / \partial K}{r + \delta}$$

You can get above that line if the price of emissions is going to rise, below it if it's going to fall.

The solution, as shown in Figure 1, is a saddle path, with both the price of carbon and the concentration converging on steady state. Again, this is just like an optimal investment model in which Tobin's  $q$  and the capital stock converge to the steady state.

OK, now I think I'm in a position to understand the timing debate.

Nordhaus and other modelers, making their best possible estimates, come to the conclusion that while emissions must eventually be brought way down and carbon concentration stabilized, it's not worth doing this until  $K$  has risen a long way above current levels. So it's a mega-St.

Augustine: O Lord, make us carbon-neutral, but not yet. In effect, we're starting at  $K(0)$  in Figure 1, with a long way to go up the saddle path, and hence a low carbon price is appropriate now. This is the "climate policy ramp".

You can change this conclusion by moving either locus in Figure 1. In practice, though, there doesn't seem to be much disagreement about the economic costs of carbon abatement, so  $dK/dt=0$  doesn't figure much in the argument.

Instead, it's about  $d\lambda/dt=0$ . Now, it's obvious if we've gotten this far that there are two ways to argue that this locus should be set higher, and hence imply a lower long-run level of atmospheric carbon: you can either increase the numerator in equation (3) or reduce the denominator.

What Nicholas Stern did was reduce the denominator, arguing that we should use a much lower discount rate than the private sector appears to. I'm still wrapping my head around what I believe about that.

But what about the numerator? This actually depends on the product of two things: the sensitivity of temperatures to carbon concentration, and the sensitivity of welfare to temperature. And there are things happening on that front. Lately, climate models have begun suggesting a lot more sensitivity to concentration, with a number of groups doubling their predicted temperature rise. As for the welfare sensitivity: Marty Weitzman has managed to scare me, by pointing out that there's a pretty plausible case that a rise of 5 degrees C – which is no longer an outlandish prediction – would be utterly catastrophic. You don't have to be sure about this; just a significant probability is enough.

So where does this all leave us? It's a toy model, but it seems to help me think about the issues. And it leaves me both understanding and worried about the climate policy ramp.

Figure 1

