

Climate through the eyes of an economist

From energy balance to a stock that is costly to lose

A short learning note

September 2026

While learning the basics of climate, I kept seeing familiar economic ideas: two flows that must balance, a variable that adjusts until they do, and a stock whose depletion changes tomorrow's conditions. The graphs make that connection first. The equations then give those intuitions a precise form.

1 From the physics to an equilibrium diagram

Energy comes in. The Sun sends mostly short-wave radiation; Earth absorbs some and reflects the rest. The reflected share is called *albedo*. Clouds, the atmosphere and bright surfaces contribute to it; roughly 30% of incoming sunlight is reflected back to space [1]. Snow and ice are useful mirrors, whereas the darker surfaces exposed by their loss usually absorb more sunlight [4].

Energy goes out. Earth emits long-wave infrared radiation. A hotter body emits more energy. Greenhouse gases absorb and emit infrared; more CO₂ reduces the energy escaping to space at a given surface temperature, after fast atmospheric adjustments [2,3]. Earth then warms until outgoing energy can balance absorbed sunlight again.

That is enough to draw the first graph. Hold sunlight, reflectivity and atmospheric composition fixed. Absorbed sunlight is a horizontal line; outgoing energy rises with temperature. Below the crossing, Earth absorbs more than it loses and warms. Above it, Earth loses more than it absorbs and cools. The crossing is a stable equilibrium.

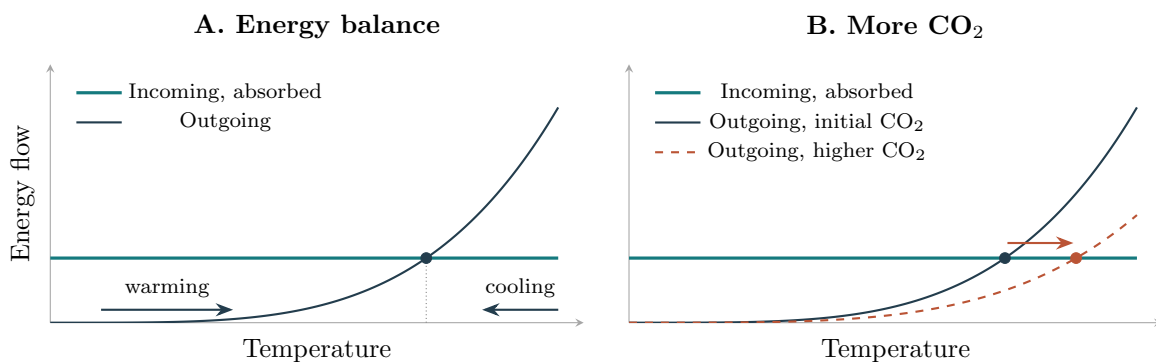


Figure 1: Equilibrium and a rise in CO₂. A: temperature moves towards the crossing. B: more CO₂ shifts outgoing energy down, moving the crossing towards a higher temperature. Incoming energy is held fixed in this first approximation. Curves are schematic.

This looks like supply and demand: temperature plays the adjusting role of price, aligning two flows. The comparison is about the *structure* of equilibrium; there are no actual buyers or sellers. The useful economic question is now familiar: what shifts either curve, and how does the equilibrium respond?

2 From ice loss to a dynamic problem

The incoming line need not stay put. Warming can melt reflective ice, exposing darker surfaces and increasing absorbed sunlight. That shifts the incoming line upward and adds to warming [3,4]. Ice is therefore like *reflective capital*: an inherited stock that helps keep the planet cool, and that heat can run down.

There are two reasons time matters. First, ice cover takes time to adjust. Two otherwise identical planets with the same temperature and CO₂ today can have different ice cover because of their histories. The one with less reflective cover absorbs more sunlight, so it warms faster or cools more slowly.

Second, *loss and recovery can be asymmetric*. For large ice sheets, rebuilding lost mass and geometry can take a very long time; model experiments find that restoring an earlier climate can lead to slow or incomplete recovery [5]. Seasonal sea ice can regrow each winter [4]. To isolate the asymmetry, I assume a stock that melts relatively quickly above an effective temperature threshold and rebuilds slowly below it. The strength of that asymmetry is a modelling choice, not a universal constant for all ice.

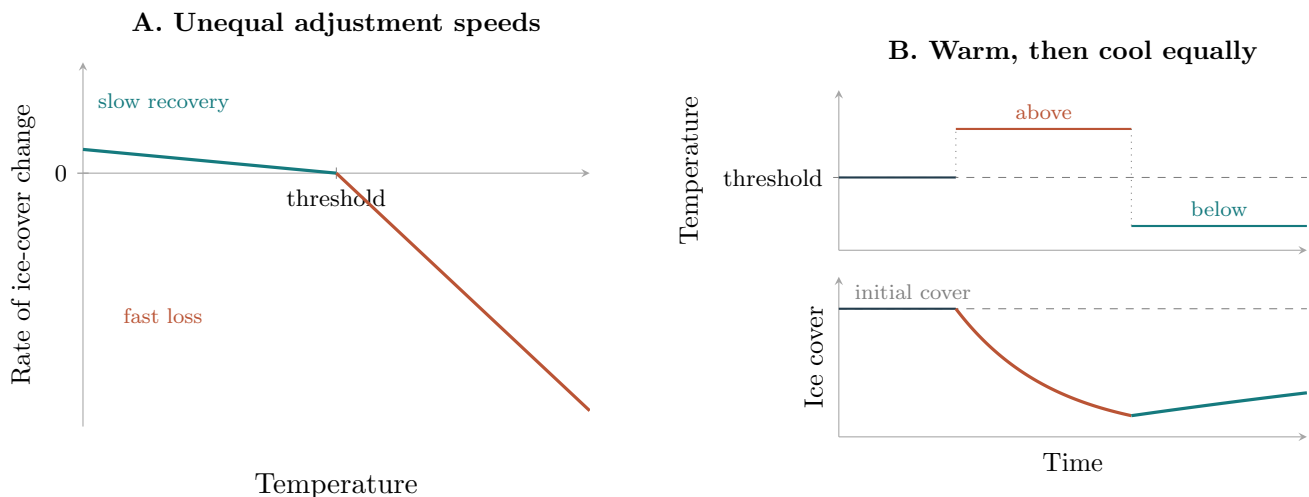


Figure 2: Asymmetric ice adjustment. A: rates at half the maximum ice cover. B: temperature is held above and below the threshold by equal amounts for equal durations; cover falls sharply and recovers only partly. The curves follow equation (3), with temperature prescribed to isolate the ice response.

Cooling below the threshold starts rebuilding the stock in this illustration, but it does not undo the loss at the same speed. While reflective cover remains depleted, extra sunlight continues to be absorbed. This combines a stock inherited from the past with an unequal speed of destruction and repair.

Warming today can worsen tomorrow's energy balance. A later reversal of temperature need not restore the protective stock on the same timetable.

3 Turning the mechanisms into a model

Two energy flows. Let T be global temperature, c atmospheric CO_2 , E average incoming solar energy per unit area and time, and $K \in [0, \bar{K}]$ effective reflective ice cover. Since more ice reflects more sunlight, write $\alpha'(K) > 0$. Since warming increases outgoing radiation and CO_2 reduces it, write

$$\text{In} = [1 - \alpha(K)]E, \quad \text{Out} = f(T, c), \quad f_T > 0, \quad f_c < 0. \quad (1)$$

Since an energy surplus accumulates, an effective heat capacity $C > 0$ gives

$$C\dot{T} = [1 - \alpha(K)]E - f(T, c). \quad (2)$$

Temperature measures the thermal state; stored energy is the stock. With K fixed, equilibrium sets the right-hand side to zero. The familiar comparative static is $dT^*/dc = -f_c/f_T > 0$, and $f_T > 0$ makes that fixed-ice equilibrium stable.

A stock with asymmetric adjustment. Since the illustrative stock shrinks above the threshold and rebuilds more slowly below it, choose

$$\dot{K} = \begin{cases} -m(T - T_f)K, & T > T_f, \\ 0, & T = T_f, \\ g(T_f - T)(\bar{K} - K), & T < T_f, \end{cases} \quad m > g > 0. \quad (3)$$

T_f is an effective threshold for this stock, not a universal freezing point for global temperature. The stock terms keep cover bounded. At equal temperature distances from the threshold, $m > g$ makes the characteristic recovery time longer than the loss time; actual rates also depend on the remaining stock and room for regrowth. Lower K reduces albedo and raises the inflow in (2). These equations capture the feedback and asymmetry without establishing real-world tipping thresholds.

The economic question this opens. Can the additional consumption and investment from a more emissions-intensive growth path justify extra warming, once we account for lost reflective ice, slow recovery and asymmetric rebuilding costs? The relevant comparison is with feasible cleaner growth paths. It must include current gains, future damages, the costs of achieving and sustaining cooling, and damages incurred while ice recovers. Greater future wealth does not by itself guarantee timely physical restoration.

That is an *intertemporal optimization* problem. Answering it would require adding production, emissions, mitigation and welfare to these climate constraints, including discounting, uncertainty and who bears the costs. The model here motivates that question; it does not yet solve it or assign a monetary cost to rebuilding ice.

Figure 2 details. Illustrative units: $\bar{K} = 1$, $m = 0.6$, $g = 0.06$. Panel A holds $K = 0.5$. Panel B starts at $K = 0.8$, holds $T = T_f$ until time 2, then $T = T_f + 1$ until time 5, then $T = T_f - 1$ until time 8. Its cover curve solves (3) conditional on that temperature path. Other climate feedbacks are held outside this small model.

Sources

- [1] NASA Earth Observatory (2009), *Climate and Earth's Energy Budget*.
- [2] NASA Science, *Causes of Climate Change*.
- [3] IPCC (2021), *AR6 WGI, Chapter 7: Energy Budget, Feedbacks and Sensitivity*.
- [4] NSIDC, *Science of Sea Ice*, especially albedo and the seasonal cycle.
- [5] Gregory, George & Smith (2020), *Large and irreversible future decline of the Greenland ice sheet*, The Cryosphere 14, 4299–4322, especially Section 4.