

Rethinking the Discount Rate as Natural Capital Declines

The discount rate for long-term environmental policies should start from a positive value and then tend negative in the far future. This is because we routinely miscalculate g in the Ramsey model by ignoring the environment and positing infinite growth.

In the Ramsey framework, the discount rate r for long-term environmental policies is given by

$$r = \rho + \eta g$$

where ρ is the pure rate of time preference, η measures the marginal utility of consumption, and g is the expected growth rate of welfare in the future. Ramsey (1928) defines welfare to be the sum of enjoyment of every individual in the society, where the enjoyment of an individual is defined as the total satisfaction a person derives through consumption.

Much of the debate over discount rates in the past has focused on the appropriate values for ρ and η , while g is typically proxied by GDP growth models. For example, Stern relies on the PAGE2002 baseline growth without climate change of 1.3% (2006, 161) while Nordhaus uses the DICE model to estimate growth of 1.9-2.1% (2018, 346) based on projected long-run GDP growth.

These models explicitly assume that GDP growth is a valid proxy for welfare growth. However, GDP is an incomplete measure of what contributes to our welfare, since it systematically excludes environmental services such as clean air, fresh water, or arable land. Hermann Daly (1996) has pointed out that this is the result of economists treating nature simply as an input to the economy, a source of raw materials, and a sink for waste, located at the periphery of the circular flow of economic activity. Daly argues that the economy is not an independent system operating on top of the environment, but rather a sub-system within the broader biosphere. From his perspective, the environment should be considered as natural capital: the “foundational stock”. The amount and kind of this foundational stock impose long-run constraints of welfare growth.

So instead of using GDP to directly substitute welfare growth, we should take both the growth of produced capital and the change of natural capital into account.

Dasgupta (2001) has adopted a similar approach using the concept of inclusive wealth. He defines a nation’s total productive base as the sum of produced capital, human capital, and natural capital, and evaluates these forms of capital at their shadow prices

rather than market prices or GDP flows. This framework shifts attention from current market values to the true cost of the different forms of capital that sustain welfare.

He draws on the estimates of Wackernagel and Rees (1996) to understand the current state of inclusive wealth. Wackernagel and Rees outline the ecological footprint framework, a quantitative tool for measuring humanity's total demands for ecological services. They convert all human consumption of ecosystem services into a common unit (global hectares). Then, they apply equivalence factors and yield factors to account for the difference in relative productivity across different ecosystem types and different nations. They also define the planet's "sustainable regeneration capacity" by estimating the rates at which these ecosystem types are restored. When only considering the provisioning services of the ecosystem, Wackernagel and Rees find that humanity has a total annual ecological footprint of 17.3 billion hectares, which is approximately 1.7 Earths, meaning that humanity is exceeding the planet's sustainable regenerative capacity by over 70%. They point out that even this is an underestimate of the true depletion of natural capital, because they do not include any maintenance and regulating services other than carbon capture.

By their measure, the growth of natural capital is already negative. In Dasgupta's estimates (HM treasury 2021) which include human capital, since 1992, although global per capita production and human capital increased, this was offset by a significant decline in natural capital. As a result, while global GDP per capita rose over the same period, inclusive wealth per capita stagnated or declined.

If growth has stagnated or been negative in previous years, how can we reasonably predict significant positive growth?

Furthermore, the declining amount of natural capital inevitably leads to a constrained trajectory of future welfare growth. As natural capital is progressively depleted, the ecological systems that underpin economic production are weakened, reducing the economy's underlying capacity to generate future output. As a result, even if current levels of production can be maintained in the short run, this maintenance of production will definitely increasingly rely on depleting the natural capital base rather than sustaining it, thereby limiting the economy's long-run growth potential.

At this point Nordhaus and even Dasgupta might object. They argue that dematerialised growth such as art, software, or artificial intelligence could allow welfare to grow indefinitely without consuming natural capital. While it is true that they can become more efficient in their use of natural capital, these industries do and probably will depend on a physical substrate. For instance, software development and training AI models requires the construction of data centers, maintenance of internet infrastructure, and electricity production that are far from complete dematerialization: indeed our use of natural capital seems to be growing. It would involve a significant exercise in science fiction to imagine this changing.

In response to Sterner & Persson's (2008) objection that once a natural resource becomes scarce, the price of this resource will increase, Nordhaus (2007) argues that this will drive entrepreneurs to find cheaper alternatives or restore natural capital through investing produced capital. For instance, when whale oil was depleted in the early 20th century, lighting product manufacturers were forced to adapt new illumination methods such as kerosene lamps (Messinger 2025). Since human imagination is unlimited, Nordhaus believes that the market could also eventually find a solution to avoid the consequences of resource depletion on productivity.

Yet it is not obvious that all such forms of natural capital can be substituted by produced capital or technological innovation, nor is there any guarantee that this will occur before these supporting services pass recoverable thresholds. Consider the ocean, one of the biggest carbon sinks, absorbing roughly 25% of annual CO₂ emissions (IPCC 2021). No matter how much produced capital is invested, no human engineering is ever likely to replace its function on a planetary scale. It is also inconceivable for people to extract CO₂ from it to restore this functionality.

Therefore, it is impossible that production growth could be sustained under the scenario where natural capital is irreversibly declining. There will eventually be one day, no matter soon or late, the produced capital will inevitably decline once natural capital depletes beyond threshold points. Since welfare is a combination of produced capital and natural capital, the parallel decline in both capitals in the distant future indicates an overall decline of welfare in the long run: a negative g.

Moreover, we can expect that the reduction of produced capital due to natural capital decline will happen soon. This is due to the non-linear and state-dependent dynamics of climate change.

Burke et al. (2015) argue that economic systems experience more severe and exponentially accelerating reductions in productivity once a particular critical temperature boundary is reached. These boundaries are unevenly distributed across the globe because of the variation in temperature between states. The wealthiest countries have lower temperatures and are further away from this boundary, while developing nations are significantly closer to this boundary.

Burke et al. also argue that temperature itself is only one such threshold, although correlated to others. The exact timing of the surpassing of these thresholds and their relation to one another remain highly unforeseeable. Therefore, we cannot reliably predict the impact of climate change on welfare; we can only conclude that it is very possible welfare will decline after we exceed these thresholds.

Weitzman (1998) claims that if we cannot predict the precise growth of welfare in the future, we should use a discount rate that reduces over time. This is because over a long period of time, the lower growth estimate tends to have a more significant effect on how significantly the future is valued, while high growth estimates tend to have a negligible effect. Western governments have already operationalised this through

declining step schedules. For instance, the UK official guidance (HM Treasury 2026) discounts super long-term constructions starting at moderate positive rates (3.00%) for the first 30 years and declining over longer horizons, reaching low discount rates (0.86%) after 300 years.

Implementing Weitzman's logic, we should adopt a discount rate that is somewhat higher for the first few decades and then transition to a negative discount rate gradually, just like the UK government did. In spite of my arguments for a negative discount rate, the reason we should still start with a positive discount rate is because we expect that a lot of welfare growth is still possible in the short term in underdeveloped countries, as the rapid development of China and the broader Asian Miracle has shown.

Why should this growth matter even if we are consuming excess natural capital? The simplest answer is that we can expect to obtain this growth without significant addition to our ecological footprint while it involves ensuring that people in those economies have basic human rights including food and healthcare. Easterlin (1974) argues that when an economy grows beyond a certain threshold of produced capital, additional economic growth does not increase self-reported wellbeing anymore because there are absolute limits on both consumption and wellbeing. In 1974 when Easterlin wrote, he already believed these limits had nearly been reached in developed countries. In fact, since then most of the rise in carbon footprint per person has come from developed countries (Hickel and Sullivan 2024), suggesting that achieving near limit levels of welfare only constitutes a small portion of a nation's ecological footprint. Indeed a recent LSE review (Oparina 2025) of Easterlin's paradox suggested that it had held true on a national level since the time of writing. It is possible and morally right to pursue this, especially given that these nations will be most affected by climate change. An initial positive discount rate recognizes this welfare growth of developing countries.

What are the consequences of adopting a negative rate?

The table below shows the present value of \$10 trillion in environmental damages occurring in 100 years which could be prevented with a policy that cost \$100 billion. Comparing six different discount rate assumptions, including market-based, benchmark, and negative long-run rate calibrated to historical economic contractions (using Stern's assumptions of ρ and η), it shows how the choice of rate, and in particular the transition to a negative discount rate, transforms the policy conclusion from inaction to overwhelming justification for immediate intervention.

Discount rates adapted	Rate structure	Present value of damage	Ratio (benefit/cost)	Policy decision
Market rate	7% flat	\$11.5 billion	0.115	don't act
Nordhaus	4% flat	\$200 billion	2	just about act
Stern	1.4% flat	\$2.49 trillion	25	obviously act
Slow negative growth	1.4%, then -1%	\$13.3 trillion	133	act immediately
Black Death	1.4%, then -6.6%	\$153.7 trillion	1537	act immediately
Great Depression	1.4%, then -8.4%	\$369.5 trillion	3695	act immediately

Based on the table, the first response might be that the results of negative discount rates overrepresent the distant future, thereby ignoring present welfare and implying that we should sacrifice most of our present welfare for future benefits. Furthermore, counterintuitively, a negative discount rate suggests that the more distant damage is in the future, the greater the present value is.

This presents an occasion to remind ourselves why we use discount rates: to make decisions about whether to take actions or not in the present. I have argued that persistent negative growth has become a reasonable prospect due to climate change and its threshold effects generating irreversible natural capital loss and productivity reduction. This would mean that people of the future would be catastrophically poorer than us.

When used to evaluate whether one environmental project should be pursued rather than another, a negative discount rate does not provide a meaningfully distinctive message, although this slightly improves with higher negative discount rates. The numbers in both cases are comically large, the better reference point would be the threshold levels of the natural capital being protected. What a negative discount does is to send a single message clearly: act now. This is not a bug, but a feature.

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