

Sustainability and the solar constraint

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Good evening.

It's an honor to follow Ed Lentz, who's done so much in Otsego county both to raise awareness of environmental issues—global warming in particular—and to actually get something *done* about them.

I'd like to start with a pair of definitions of sustainability, an intuitive one and one that is keyed more to how an economist thinks.

The intuitive one says that an activity is sustainable if you can keep doing it forever.

The economic conception says that something is sustainable if you can do it without compromising the ability of future generations to be as well-off as we are.

The problem with the economic one is that it's a lot harder to define.

- We have imperfect knowledge about the effects of our actions on the environment.
- We have VERY imperfect knowledge about future technological developments and what they might do to enable continued well-being even in a depleted environment.
- We have imperfect knowledge about what future generations will consider important.
- We have imperfect knowledge about the future economic effects of environmental depletion.¹

The most prominent example right now is the issue of global warming, where there's a real possibility that continuing on our current path will quite severely reduce future generations' ability to be as well off as we are.

So the economic conception is tricky to apply at best, but it still gives some useful insights. Think in particular about fossil fuels.

The intuitive conception suggests that we can't use fossil fuels at all. Forests, fields, and fish stocks have *sustainable* yields, amounts that we can harvest forever, even if in practice we often reduce them through overharvest. Fossil fuels are inherently nonrenewable, exhaustible—there is no rate at which we can use them in perpetuity, so there is no rate at which their use can be “sustainable” under this definition.

¹ This is separate from uncertainty about technology, because imperfect knowledge about future economic effects has to do with the lack of consensus on how much we depend on the environment even under current technology.

Given that, how do you satisfy the economic definition of sustainability, when use of fossil fuels now inevitably means less in the future?

There's actually a rough guide for this, and oddly enough it's called the Hartwick Rule. (It has nothing to do with the town of Hartwick or Hartwick College, it's named for the economist John Hartwick.)

Using a nonrenewable resource makes you rich. The Hartwick Rule says you should take this wealth and use it to create something that will be just as valuable as the nonrenewable resource you depleted. Fossil fuels make us rich, in the sense that they give us the ability to do more than we could do without them. The Hartwick Rule says we should use some of that wealth to build up our means of getting along when the fossil stuff is gone.

What would that actually mean?

First, we need to understand what it is that fossil fuels do for us, in order to know what we have to replace. Take an imaginary journey back 200 years, when coal use is still small and oil and gas are unknown as fuels. Human societies were subject to the solar constraint. Metal implements, from ploughs to swords, were tremendously expensive, because it was human and animal labor that pulled the ore from the ground and trees that provided the heat for turning the ore into metal. Other than metal and stone, the materials for industry, such as it was, and day-to-day life were all derived from plants, or from animals that ate plants. So their quantities were limited by how much solar energy the plants could capture. Fertility came from leguminous plants and from animals that ate plants. Traction power and much industrial power came from humans and animals, both of which ate plants. The whole thing was driven by sunlight that plants captured. Everywhere you turn you find the solar constraint, and the solar constraint is a hard master.²

² *The Lord of the Rings* was an entertaining film, but one aspect of it really stuck in my craw. The bad wizard creates this massive army of orcs, all outfitted with metal armor and armament. The movie shows you the endless warren of underground spaces where the wizard's slaves are busy creating orcs and smithing out weapons. And the whole enormous metallurgical operation is powered by—trees! Tolkien is invoking a mediaeval world, but mediaeval metallurgy was woefully inefficient, and there simply aren't enough trees in Middle Earth to support the scale of operations that the movie depicts (presumably following the book relatively closely). And what of the orcs themselves? They are biomass, and as such must feed on other biomass. And they seem to be carnivores, so they're at least two trophic levels up from the plants, the "primary producers" that capture the sun's energy; in other words, the orcs don't eat plants, they eat creatures that eat plants. Each time you go up a trophic level, you keep only about 10% of the energy embodied in the lower level; the rest is dissipated in the higher organisms' simple daily existence. There's just no way that the plants of Middle Earth can capture enough solar energy to forge all the metal *and* support all the orcs that the movie shows. I don't mind the walking trees, or the wizard returning from the dead, or a ring that can make people evil. I'm cool with all that magic stuff. But don't go violating the first and second laws of thermodynamics, and don't ignore the basic rules of energy flows in ecological systems. Don't create a world apparently subject to the solar constraint and then pretend that that constraint doesn't exist.

Then along came coal, followed by oil and natural gas, and we had energy to burn, as it were. We left the solar constraint behind and were able to make 6.5 billion people far more prosperous, on average, than 1 billion had been before (though of course we still have a couple billion in abject poverty). Fossil fuels helped us get ores—and eventually more fossil fuels—from the ground. They replaced the animals that had been important in industry and transport, so the land that had fed the animals could be used to feed us or to hold our houses and businesses. They provided more nitrogen than the legumes ever could on their own, increasing yields on those same lands that no longer had to provide the motive power for industry. They allowed us to move vast numbers of people and things over tremendous distances, freeing most of us in the rich countries from any meaningful dependence on our immediate surroundings. They accustomed us to heat in winter and cool in summer, all at the push of a button. This is the industrial cornucopia that we have come to take for granted as the normal state of affairs. We treat it as the simple playing out of human progress. We have not absorbed into our bones how much this has depended on the geological gift of fossil fuel which has allowed us to escape the solar constraint.

So how do we apply the Hartwick Rule to this miraculous stuff, fossil fuel?

The Hartwick Rule says we have to use the wealth it gives us to allow our descendants to be as well off as we are. And given the likely implications of climate change, we have to start decreasing *now*; it's not good enough to keep using the stuff at increasing rates, even if we are setting everything in place to be able to function when it's gone.

In other words, we have to use a diminishing allotment of fossil fuel to do things now that will help us fit most of the way back inside the solar constraint soon.

Biofuels have their proponents and their detractors, but regardless, they're a perfect example of having to fit inside the constraint. Before, we used sunlight and soil to grow crops for animals so that we could have transportation and traction power. Now we propose to use sunlight and soil to grow crops and turn them into ethanol. Since we're used to driving, that may well be a worthwhile thing to do, but we shouldn't harbor any illusions about how it's freeing us from dependence on petroleum. Coal and oil freed us from dependence on the sun. Biofuels are returning us to that dependence, and the biggest bottleneck is simply the quantity of solar energy that plants are capable of capturing.

Other alternatives are photovoltaics, hydropower, and wind. They all have their pluses and minuses, but they are all directly or indirectly forms of solar power. The one major source that isn't solar is nuclear. While it has its advocates, there are obviously concerns about construction cost, waste storage, safety, and even the total quantity of fuel available. Without trying to settle that debate right now, I'll ask you to accept for the sake of argument that nuclear is not going to be a practical, large-scale, long-term solution. (If that statement turns out to be wrong, we can just go ahead and build lots of reactors. And disregard everything I've been saying.)

So where does that leave us? Our 200-year shopping spree has left us with some distinct advantages and disadvantages when it comes to tucking ourselves back under that solar constraint.

On the plus side, our understanding of ecology is far more sophisticated and global than it was then: we understand a lot more about how the individual parts of the system work and how those parts fit together as a whole. Our technological prowess is obviously greater, from nuclear physics to genetic engineering to nanotechnology to materials science to computational power: we can do all sorts of things that our ancestors couldn't even imagine. Politically, we have more or less functioning democracies in many parts of the world; call me an optimist, but if a populace that's even semi-informed understands the constraint it's working under, I have more faith in them to do something viable that makes their lives decent than I do in a benign dictator, and most dictators and kings are not benign.³

We also have three major disadvantages I'd like to point out. First, there are more than six times as many of us than the last time we had to take the solar constraint seriously, so we'll have to be six times cleverer in our use of the sun, merely to be as poor as most of the world was 200 years ago; something approaching current prosperity requires us to be a lot more than six times as clever. Second, our burgeoning population, throwing its weight around in the way that fossil fuels allowed, has done serious damage to ecosystems around the world, so that the web that sustains us in the absence of fossil fuels is more frayed than when there were only 1 billion of us. Third, a portion of the world's population has gotten used to material abundance, and another portion has learned what that abundance looks like, so their yearnings have concrete shape.

What then of the Hartwick Rule? I don't see how we provide our descendant the same *material* standard we've become accustomed to in the rich countries. If we use our technology and our democracy wisely, the solar budget can probably support a life that would have looked wonderfully rich to a French peasant groaning under the Bourbon monarchy or a yeoman farmer fighting in the American War of Independence. But humans are creatures of habit, and what would have looked luxurious to our ancestors looks cramped and impoverished to us.⁴ Still, we must try. The work Ed is doing on energy conservation and local food is a step in exactly the right direction.

The Hartwick Rule also poses an inner challenge, another tool for meeting its requirements that complements the outer, technological challenges. It asks us to help our descendants be as well off as we are. But what is well-being? Beyond basic material needs, well-being is largely a psychological condition. If we can learn to get more of our

³ Ironically, those scientific advances have partly been made possible by the prosperity that we built using the gift of fossil fuels. Some political theorists contend that the relative spread of democracy in the modern world depends on the same conditions. It would be nice if the scientific and political advantages we've gotten from abundant fossil fuels could be used to help us get along without them.

⁴ I don't mean to extol the virtuous thrift of a bygone era. Deprivation sometimes made people hard and often led to tragedy. The thrift of our ancestors was not some inner virtue but a product of necessity. We are their children and are no more inherently incapable of it than they were.

satisfactions from our dealings with others, that is something we can pass on to our children that doesn't depend on fossil fuel.

Postscript

Someone who heard the remarks was generally appreciative but concerned that the Hartwick Rule doesn't seem to address the existing extent of poverty. Leaving posterity as well off as we are doesn't seem like such an impressive standard: you can leave two to three billion people in abject poverty, and you've still satisfied the Rule because, though they're miserably poor, they're no worse off than their grandparents.

This is an important concern, and the Hartwick Rule itself doesn't require us to do anything about it. Indeed, plenty of people are willing to use the plight of the poor as an argument why we shouldn't be spending a lot of effort on environmental problems. The real tragedy, in this view, is the billion or more people who lack access to clean drinking water, so we should be focusing on that rather than worrying about a decidedly secondary issue such as global warming. (See, for instance, various works by Bjorn Lomborg.)

It was not my intention to endorse such a position, and two counterarguments come immediately to mind, one pragmatic and one ethical. The pragmatic one points out that environmental problems are not "boutique" concerns of well-to-do Westerners who have nothing better to worry about. The notion that they *are* an elitist issue comes from aesthetic aspects such as the visual blight of a clear-cut; people who are undernourished or worried about keeping their jobs may be less worried about a view they never see than a person who has the time and income to travel to places being despoiled. But poor populations everywhere, and especially in poor countries, tend to have a more direct dependence on environmental resources than more affluent people do, and the water problems stemming from global warming highlight this particularly well.

Rich populations usually get their water from highly engineered systems that gather large quantities, move it large distances, and purify it to tolerable levels. As increased consumption and shifting climate patterns stretches those sources thin, we can (in principle) extend our engineering and bring in more distant sources. Our high consumption also gives us considerable room for reducing our use and still being OK. In contrast, poor populations more often rely on nearby water sources without recourse to filtration, and because of the difficulty of obtaining water they use very little—often less than is ideal just for basic health and hygiene. As shrinking glaciers deplete their rivers, the world could expend huge resources building massive engineered solutions to keep them hydrated. (This would also entail burning lots more fossil fuel ...) Or we could just not provoke such severe climate change and thus preserve the water resources they're already using. But this involves restraint rather than bold engineering, so it's not sexy. And it doesn't allow advocates of economic growth to pose as the true friends of the poor while depicting environmentalists as heartless elitists, so it's not politically useful to people with a disproportionate stake in continued growth.

The ethical argument picks up on why we care about sustainability in the first place. Basic survival would seem to be reason enough, but a satisfying life would actually be far

more compelling than mere existence. (This idea is central to the project *Envisioning a sustainable and desirable America*, at <http://www.uvm.edu/giee/ESDA/>.) It may be possible to continue with widespread global poverty (after all, poverty is nothing new and the world hasn't ended), but it's not particularly desirable. If "sustainability" means a third of the world has to remain undernourished, it's not a very appealing concept. The challenge for those of us with the good fortune to be rich (which on a global scale means the great majority of people in wealthy countries) is to help poor populations improve their lot while minimizing their increased impact on the Earth and significantly reducing our own. Preserving ecosystems and the viability of future generations doesn't *have* to mean keeping the poor and their descendants in poverty, and it *shouldn't* mean that.

Sources

The economic conception I presented is based on Robert Solow's definition: "an obligation to conduct ourselves so that we leave to the future the option or the capacity to be as well off as we are."⁵ This isn't necessarily a definition that all economists subscribe to, but in the focus on how people are doing rather than on any particular state of the world, it is fairly representative of economists' habits of thought.

The Hartwick Rule was introduced in Hartwick, John M. (1977), "Intergenerational equity and the investment of rents from exhaustible resources," *American Economic Review*, vol 67, December, pp. 972-74.

The idea of the "solar constraint" is distilled primarily from three works. The first of these is *Environment, Power, and Society*, by Howard T. Odum, which tracks energy flows through ecosystems and human activities. In *The entropy law and the economic process*, Nicolai Georgescu-Roegen ties together energy and non-energy resources, by observing that part of the value to humans of well-functioning ecosystems and high-grade mineral ores is that we don't need to use a lot of energy to get something useful from them. Finally, *Energy and resource quality: the ecology of the economic process*, by Charles A.S. Hall, Cutler Cleveland, and Robert Kaufmann adds to the insights of Odum and Georgescu-Roegen, in part by drawing on M. King Hubbert's model of bell-shaped extraction curves for fossil fuels.

⁵ Robert Solow, "Sustainability: an economist's perspective," 18th J. Seward Johnson Lecture to the Marine Policy Center, Woods Hole Oceanographic Institution, at Woods Hole, MA, June 14, 1991. Reprinted in *Economics of the environment: selected readings*, 4th edition, Robert N. Stavins, ed.