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COMMENTARY

FORUM: THE ECOLOGICAL FOOTPRINT

The dynamics of the ecological footprint concept

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1. Background

Ecological Economics publishes fora in order to stimulate substantive discussion of topical issues as an alternative to confrontational debate. Commentaries included in each forum are invited, with an eye toward presenting a balanced and interesting discussion of the issue at hand. In inviting and reviewing the commentaries, we are therefore not seeking merely critiques or support of particular works (although this can certainly be included), but rather thoughtful discussion and interpretation of the issues they raise, and creative extensions into new areas.

The issues of 'indicators' and 'biophysical limits' in their various guises have been central ones for *Ecological Economics* since its inception. There has been much recent interest in and discussion of one particular indicator, known as the 'Ecological Footprint' (EF), including a book (Wackernagel and Rees, 1996) and two recent articles in *Ecological Economics* (van den Bergh and Verbruggen, 1999; Wackernagel et al., 1999).

The EF for a particular population is defined as the total "area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes that the population produces, wherever on Earth that land and water may be located" (Rees, 2000). The EF has been widely praised as an effective heuristic and pedagogic device for presenting current total human resource use in a way that communicates easily to almost everyone. Although there are ongoing debates about specific methods for calculating the EF (cf. Herendeen, 2000; Simmons and Lewis, 2000), everyone, it seems, understands land area as a numeraire — even those who have trouble with money or energy as a numeraire.

The controversy comes when one moves from simply stating the results of an EF calculation to interpreting it as an indicator of something else. The EF has been proposed as an indicator of biophysical limits and sustainability, i.e. if one's EF is bigger than the land area under one's direct control then 'overshoot' has occurred and one has exceeded one's sustainable resource use. In other words, can the EF be used as a "guideline to achieving sustainability" as the Dutch environment minister inquired of Hans Opschoor (Opschoor, 2000) or is it merely an interesting attention getting device?

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The commentaries included in this forum look at the EF from several different perspectives, and in particular address the issues of its proper interpretation and use. Some argue in favor of its broad use for policy questions about sustainability (Rees, 2000; Templet, 2000; Wackernagel and Silverstein, 2000), while others, acknowledging the EF's pedagogic value, see a much more limited use for policy-making (Ayres, 2000; Opschoor, 2000; van Kooten and Bulte, 2000) or see it as being useful in a different way for policy-making (Deutsch et al., 2000; Moffatt, 2000; Rapport, 2000). I have tried to summarize these perspectives, while adding a few of my own ideas to the mix.

2. The costs and benefits of aggregate indicators

Assessment of human resource use has been going on for a very long time. The power of the EF is that it aggregates and converts typically complex resource use patterns to a single number — the equivalent land area required. As such, it shares certain costs and benefits with all aggregate indicators (such as gross national product (GNP), index of sustainable economic welfare (ISEW), environmental space, embodied energy, etc.). The obvious and substantial benefit of an aggregate indicator is its production of a single number, which makes using it for decision-making relatively straightforward. For example: if ISEW goes up, its a good thing; if it goes down, its a bad thing. Ultimately, in order to make a decision, we must go through this process of reducing a number of criteria to a simple comparison. We do this either explicitly or implicitly. Even 'multi-criteria' analysis does this using any of a number of different aggregation methods.

The costs of an aggregate indicator are that, if one is not careful and informed, one can be ignorant of where the numbers came from, how they were aggregated, the uncertainties, weights, and assumptions involved, etc. It's not that one 'loses' the more detailed information — usually it is possible to look at the details of how any aggregate indicator has been constructed — but rather that decision-makers are too busy to deal with these details. The beauty of the aggregate indicator is that it does that job for them. Even given this advantage of aggregate indicators, no single one can possibly answer all questions and multiple indicators will always be needed (Opschoor, 2000), as will intelligent and informed use of the ones we have.

3. Biophysical limits and sustainability

Another important issue is whether the EF is an indicator of sustainability. The contention that it is rests on the assumption that if biophysical limits are exceeded (using current technologies), then we are not sustainable and the EF is an indicator of the degree to which biophysical limits have been approached or exceeded (at least at the global scale; see later). Of course, the important caveat here for technological optimists is 'using current technologies'. They would argue that the current path of development is, in fact, sustainable because technology will be able to overcome any biophysical constraints it may encounter. This is true if and only if the underlying assumptions about technical progress are true. If they are not and we pursue policies based on their being true, then we will most likely end up in big, unsustainable, trouble (Costanza, 1999). Since we are in a situation of true uncertainty about whether the assumptions underlying the technological optimist position are true, we should at least provisionally assume that they are not true (since the costs of their being wrong are potentially so high). The more rational strategy from the point of view of society as a whole is to assume that biophysical limits cannot be overcome, unless and until it can be shown that they can be (Costanza, 1999). This strategy makes the EF a useful provisional indicator of sustainability at the global scale, but it should be cast in these terms; as a technologically skeptical indicator, one that assumes that technology will not save us. Alternately, one can think of the EF as a measure of how much faith in technology is required in order to consider current consumption patterns sustainable.

4. Self-sufficiency versus sustainability

Another issue that this forum brings out is the distinction between self-sufficiency and sustainability. EF proponents tend toward the view that self-sufficiency is a necessary condition for sustainability (Wackernagel and Silverstein, 2000), while critics argue that the two are not necessarily related (Ayres, 2000; Opschoor, 2000; van Kooten and Bulte, 2000). This question is related to whether the EF has any interpretation vis-à-vis carrying capacity at scales lower than the global, and whether international and interregional trade can be part of a sustainable world. I think it is clear that sustainable trade is at least possible (Costanza et al. 1995), and that the proper interpretation of the EF at national and regional scales is simply as a measure of the net input from outside the region converted to equivalent land area units. It tells us little if anything about the sustainability of this input over time, although it may tell us something about the 'fairness' of consumption (Wackernagel and Silverstein, 2000). No city has ever existed that did not depend on its hinterland for support (Folke et al., 1997), and even hunting and gathering tribes rely on inputs from a much larger area than that of the village itself. However, the fact remains that many people are simply unaware of this relationship between cities (or nations) and their hinterlands, and the EF communicates this fact effectively.

On the other hand, the current system of international trade, which ignores environmental externalities and differences in labor laws and conditions, is probably neither sustainable nor is it necessarily fair (Costanza et al., 1995). For example, to be fair, the decision of the Netherlands to import carrying capacity would have to be balanced by a willingness of other countries to export carrying capacity. But the amount voluntarily exported may exceed long-run sustainable carrying capacity and the export may not in fact be voluntary. To the extent that the EF cannot distinguish between sustainable and fair, and unsustainable and unfair trade, the critics who argue that certain interpretations of the EF are 'biased against trade' (van den Bergh and Verbruggen, 1999; Simmons and Lewis, 2000; van Kooten and Bulte, 2000) have a point.

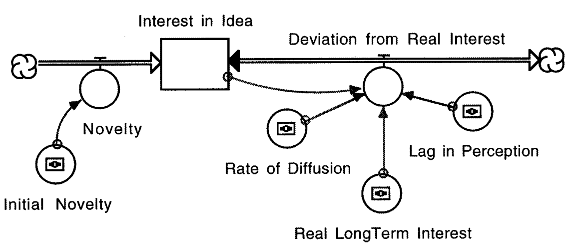

Fig. 1. STELLA diagram of the model. Boxes are state variables, double line arrows with circles are flows, single line arrows are functional relationships, and circles with small boxes inside are parameters.

5. The dynamics of interest in ideas

Finally, the EF is, I believe, caught in a dynamic that is common to many, if not most, new ideas. Have you ever noticed that interest in a new idea takes off rapidly at first, with expanding claims of applicability, but then peaks and often a 'backlash' occurs with plummeting interest levels? There may be a resurgence of interest at some later time, followed perhaps by another decline in interest, and this cycle may continue for quite a while.

Fig. 1 is a simple model of this dynamic. The interest in a new idea, I (the box in Fig. 1) is fed by its novelty (N), but this input degrades quickly with time. It is also affected by its degree of deviation from the real long-term interest in the idea, R (think of this as the 'carrying capacity' of the idea). This deviation is corrected with a certain rate of diffusion (r). There is also a lag in perception (L) such that the interest in the idea several time steps ago is what is being perceived rather than the current interest. The model equations are:

$$\mathrm{d}I/\mathrm{d}t = N - \Delta I$$

$$N = \max(N^0 - t^2), \quad 0$$

$$\Delta I = r[\mathrm{lag}(I) - R]$$

where I is the interest in the idea, N the novelty of the idea, N^0 the initial novelty, t the time, r the rate of diffusion, and R the real long-term interest in the idea.

This model produces output of the type shown in Fig. 2. Fig. 2a shows output with rate of

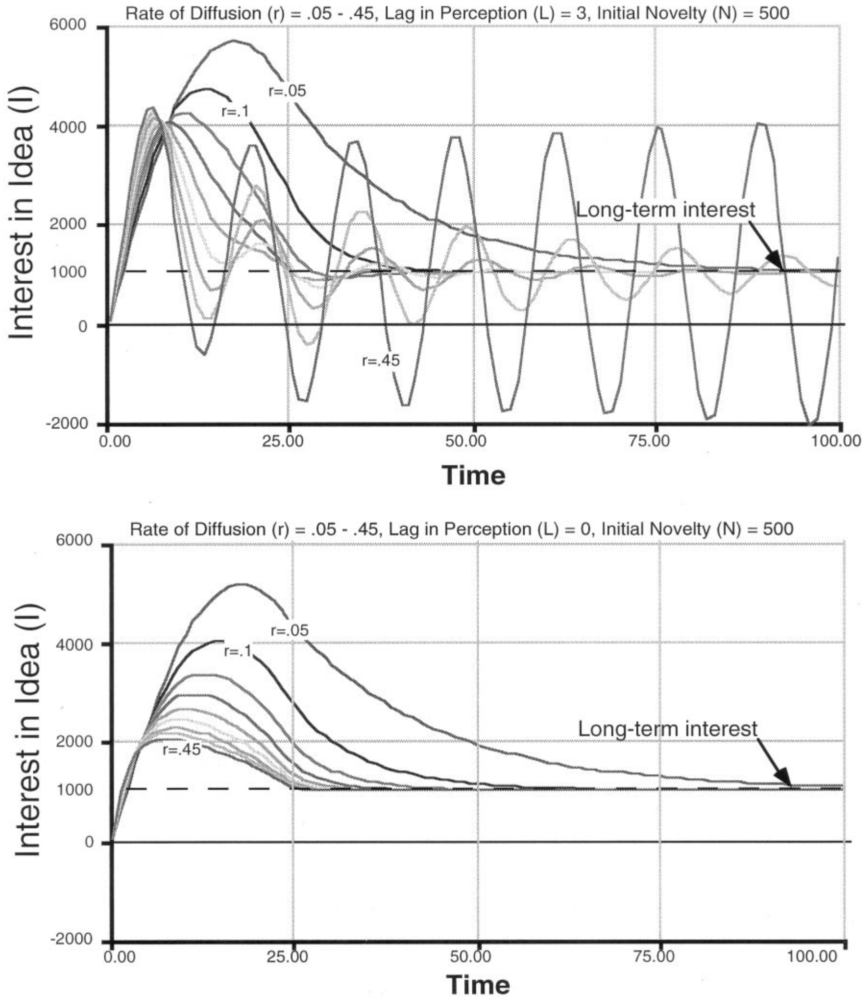

Fig. 2. Model runs with parameter values as shown.

diffusion (r) varied over the range from 0.05 to 0.45 with intervals of 0.05, lag in perception (L) = 3, real long-term interest (R) = 1000, and initial novelty (N) = 500. At low diffusion rates, the idea overshoots R significantly, and eventually peaks and gradually returns to R. As the rate of diffusion is increased, the idea peaks sooner and at a lower level, and returns to R sooner. As the diffusion rate increases further still, the interest in the idea becomes oscillatory, damped at first but becoming less damped as the rate of diffusion is increased, and finally entering a parameter space where the amplitude of the oscillations are increasing with time. Fig. 2b shows the situation with the lag in perception set to 0. In this case, the oscillations never set in and the magnitude of overshoot is reduced as the diffusion rate is increased.

The objective of scientific discussions is to achieve the real long-term interest level as quickly as possible with as little overshoot (or undershoot) as possible, and avoiding time-consuming and disruptive oscillations in interest levels, especially those with increasing amplitude over time. To do this, one needs to reduce the lag in perception of interest in the idea, reduce the effects of initial novelty, and increase the rate of diffusion to at least a moderately high level. Scientific journals (including *Ecological Economics*) unfortunately introduce significant lags in perception, reward novelty, and diffuse ideas at a rather low rate. It is little wonder, then, that new ideas such as the EF may experience the kind of dynamics outlined in this paper. Hopefully, fora of the type we are presenting here will help alleviate this situation by increasing discussion and diffusion, and reducing lags in perception.

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