ELSEVIER

Ecological Economics 29 (1999) 61–72

ECOLOGICAL
ECONOMICS

TENTH ANNIVERSARY INVITED PAPER

Spatial sustainability, trade and indicators: an evaluation of the 'ecological footprint'

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Received 21 September 1998; received in revised form 12 February 1999; accepted 17 February 1999

Abstract

The search for frameworks and indicators of sustainable development has taken a prominent place in this journal. However, some specific aspects have received little or no attention, notably the spatial dimension and the role of international trade in indicator development. Moreover, many sustainable development indicators comprise implicit valuations, weighting schemes and policy objectives, which are insufficiently recognised as such. This contribution tries to highlight these issues by means of a review of a recently proposed indicator for ecological–economic analysis, namely the ecological footprint, that has been developed by Wackernagel and Rees. Its concept and calculation procedure are criticised on a number of points, and it is concluded that the Ecological Footprint is not the comprehensive and transparent planning tool as is often assumed. In explaining our position we will argue that spatial sustainability and regional sustainable development have not been precisely discussed so far, neither in the literature on trade and environment, nor in that on sustainable development. We will defend the view that trade can contribute positively and negatively to environmental unsustainability. Consequently, indicators and models are needed that allow for analysing interactions and trade-offs between such opposite effects.

Keywords: Carrying capacity; Indicators of sustainable development; Interregional trade; International economics; Regional sustainability; Trade theory; Land use; Sustainable trade

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PII: S0921-8009(99)00032-4

1. Introduction

The search for indicators of sustainability or sustainable development is a recurrent theme in this journal. Recently, the ecological footprint (abbreviated as EF hereafter) is suggested to offer a concept and method that can generate one of the most objective, non-biased, aggregate, single-dimension indicators for evaluating sustainability:

> In summary, by putting sustainability in simple but concrete terms, the Ecological Footprint concept provides an intuitive framework for understanding the ecological bottom-line of sustainability. This in turn stimulates public debate, builds common understanding and suggests a framework for action. The Ecological Footprint makes the sustainability challenge more transparent—decision makers have a physical criterion for ranking policy, project or technological options according to their ecological impacts. (Wackernagel and Rees, 1996, p. 57).

These claims are substantiated by the formulation of an indicator expressing the ecological impact of human activities in terms of (hypothetically) required land areas to sustain these activities. The question that will be addressed in this contribution is to what extent the EF fulfils these pretensions. This is needed because the EF concept and indicator seems to be accepted almost without any critique by many scientists and policy makers, and especially by environmental organisations.[1] The rapid increase of its popularity and influence over a short period of time provides the motivation to systematically examine its pros and cons.

Our evaluation bears in mind that the search for operational indicators for sustainable development should be guided by a number of specific criteria. The calculation procedure should be, among others, objective and scientifically sound; indicators should relate to clear policy objectives; they should have a clear interpretation and be understandable to non-scientists; they should cover the functioning of a system as a whole; and they should be based on parameter values that are stable over a long period of time (see Kuik and Verbruggen, 1991). It will subsequently be argued that the EF suffers from serious shortcomings regarding all these criteria. As a result, it may provide a wrong direction for our intuition, i.e. give rise to unsustainable, inefficient or even immoral policy options.

The organization of this article is as follows. Section 2 provides a short explanation of the EF concept and calculation procedure. Section 3 offers a critique, focusing on methodological and policy issues, the notion of land use, the transformation of energy use, the spatial and regional dimension, and the implications for trade. Section 4 discusses some alternative views on spatial sustainability and sustainable trade. Section 5 suggests improvements in the EF and alternative indicators. Section 6 concludes.

2. A short explanation of the ecological footprint

Wackernagel and Rees (1996) have introduced the EF concept and method (a short account is

[1] Some indications are as follows. The original 1996 book on the EF has been translated in various languages. The inventors of the concept and method, Rees and Wackernagel, are both often asked by media about the EF, and travel around the world to promote the concept. In the Netherlands, for instance, various newspaper articles have appeared that positively evaluate the EF; in the 10 May 1997 edition of the highest-quality newspaper in the Netherlands, NRC Handelsblad, an entire page was devoted to an interview with Rees on the EF. Interestingly, in the Netherlands the minister for the environment has shown an interest in the concept as well. Wackernagel (1998, note 4) states that he and colleagues have had direct contact with academics in 24 countries that use the EF concept in their teaching or research projects. An environmental organisation in the Netherlands, de ‘Kleine Aarde’, is stimulating the application of EF to cities throughout the country (see http://www.pz.nl/dekleineaarde). Also others have shown an interest in this type of application (see Folke et al., 1997; IIUE, 1998). Bicknell et al. (1998) apply the EF at a country level. A final indicator of the popularity of the EF is the large number of internet websites devoted to it. The only critical evaluations of the EF we have come across are Levett (1998) and (very shortly) Pearce et al. (1998).

Wackernagel and Rees, 1997). The basic idea is that every individual, process, activity, and region has an impact on the earth, via resource use, generation of waste and the use of services provided by nature. These impacts can be converted to biologically productive area. This should be accounted for.

The EF is presented as a simple operational indicator to aid in monitoring progress towards (un)sustainability, i.e. maintenance (loss) of natural capital. It accounts for the flows of energy and matter to and from a specific economy or activity, converted into corresponding land and water area needed to support these flows. Six land categories are included in the procedure, namely consumed/degraded land (built environment), gardens, crop land, pasture land and grasslands, productive forest, and energy land. EF analysis is suggested to be useful in determining the human appropriation of ecological production, measured in area units. The power of the method is the fact that all human exploitation of resources and environment is reduced to a single dimension, namely land and water area needed for its support.

An EF can be assessed for persons, activities or regions, from a city to the world at large. How is it calculated? First, consumption is determined in a particular spatial domain for each relevant category. This includes food, housing, transportation, consumer goods and services. Next, the land area appropriated by each consumption category is estimated for different land categories. This includes land appropriated by fossil energy use, built environment, gardens, crop land, pasture/grassland and managed forest. This is based on both resource and waste flows, and leads to a consumption/land-use matrix. Summing all the area figures in this matrix gives an estimate of the EF of the region considered.

Application of the method on a per capita basis shows that the world average EF is estimated at 1.8 ha/person. Many developed countries have an EF in the range of 3–5 ha/person, with the USA ranking highest. The EF of a developing country like India is 0.4 ha/person. Wackernagel and Rees also calculate available ecological space, i.e. the actual productive area for regions. For the world at large it is estimated that the latter has decreased from approximately 6 to 1.5 ha since the beginning of the century. Next, it is possible to compare (per capita) EFs with the (per capita) available ecological space. According to the previous indicators, mankind nowadays overshoots the Earth's carrying capacity by approximately 0.3 (= 1.8–1.5) ha/person. In addition, an EF/actual-productive-area ratio can be calculated for regions as an indication of their (un)sustainability. Especially small developed countries and densely populated cities score high on this ratio measure. For instance, Belgium and the Netherlands score between 10 and 20, and London 120.[2]

Note that an EF larger than a region's actual productive land area is possible due to the EF representing hypothetical instead of concrete land use. In addition, trade may of course cause the EF to exceed land availability at a regional level. These features will be considered in detail later on.

3. Critique on the EF concept and method

3.1. Aggregation, weighting and policy relevance

A first objection against the EF has to do with the supposed attractiveness and strength of the EF, namely that it provides a one-dimensional indicator by summing up all consumption related direct and indirect ecological impacts—of a region, activity or person—in terms of land use. This requires that different consumption categories are translated into land area. Evidently, this conversion is necessarily incomplete, while no account is taken of regional and local features of land types and land use. But the main problem is that physical consumption–land conversion factors are used that function as implicit weights in the conversion as well as the aggregation. The physical weights used

[2] Wackernagel and associates have continued working on the footprint, and improved some of the weaknesses of its initial calculation procedure. The figures presented here draw on the published book by Wackernagel and Rees (1996). Later work has lead to a much lower EF for particular countries (see Wackernagel and Rees (1997); http:/www.edg.net.mx/~mathiswa).

are regarded by the authors as consistent with ecological principles and thermodynamic laws, but they do not necessarily correspond to social weights. In other words, they reflect neither relative scarcity changes over time nor variation over space. This problem is magnified by the choice of a fixed weighting scheme. This means that a fixed rate of substitution is supposed between different categories of environmental pressure. Worse even, some categories receive identical weight, even if it is clear that their environmental impacts are very distinct. For instance, in the EF procedure land use by infrastructure has the same weight as land use by agriculture, although designating land for road infrastructure clearly is more environmentally destructive than designating it for pasture. In view of these assumptions, the EF procedure may produce odd results that are unwanted from both an environmental and a socio-economic point of view.[3] This becomes problematic when the EF is meant to serve as a criterion for ranking policy options.

In spite of this, Wackernagel and Rees refer to EF analysis as offering "…a planning tool that can help to translate sustainability concerns into public action" (1996, p.3). However, for any planning approach a clear objective, constraints and instruments should be defined. This has not been done for the EF. In this respect, neither minimizing land use nor maximizing regional land productivity are explicitly mentioned. Both objectives would be in line with the EF approach.[4]

In sum, one cannot infer much on the basis of the EF alone, neither what is the main problem nor what might be adequate policy solutions to the problem. For this reason a decomposition type of approach is needed, which distinguishes between population density, consumption and production of goods and services (per capita), and unsustainable land use associated with each type of good or service. This implies a logical and complete system of multiple, complementary indicators, based on a systems perspective of interconnected environmental problems (e.g. 'Industrial Metabolism'; see Ayres, 1998). Moreover, a single, aggregate indicator like the EF does not allow for trade-offs among the three central dimensions of ecological economics' evaluation, i.e. efficiency, equity and sustainability.[5]

3.2. Hypothetical and unsustainable land use

A second objection against the EF relates to the land use dimension. To begin with, although the EF denotes hypothetical land area there is a serious danger that it will be interpreted as actual or at least realistic land use, not only by the general public and politicians, but also by environmentalists and academic researchers. This can be regarded as a case of 'false concreteness'. The hypothetical nature of the EF means, for instance, that the world's EF can exceed the world's total available productive land; even worse, the EF's value is unbounded from above.

Next, the EF does not distinguish between sustainable and unsustainable use of land, however defined. In order to measure the degree of unsustainability of an economy or activity indicators are needed that focus on processes that contribute to unsustainability, such as unsustainable resource use and soil degradation, rather than just an overall (and hypothetical) land area measure.

[3] Of course, these problems are not unusual for aggregate indicators, which are often based on the choice of a fixed and physical aggregation scheme. An example of another such indicator is 'materials inputs per service unit' (MIPS), in which kg of any type of material are added to arrive at an aggregate indicator of material intensity per service. As a result, heavy metals and sand thus receive equal weights (see von Weizsäcker et al., 1997).

[4] The idea of minimising land use (as an approximation of the human impact on the environment), both globally and regionally, can be regarded as consistent with the precautionary principle—as opposed to the traditional economic approach which focuses on optimizing welfare and thus optimizing (not minimizing) environmental externalities.

[5] Victor (1994) argues that aggregate indicators are only useful if one believes in a high degree of substitution among manufactured, human and natural 'capital'. If there are limits to substitution among these types of 'capital' then each should be represented by a specific indicator. His argument is based on the idea that non-subsitution (or complementarity) is the clue for deriving indicators of sustainable development. This is a general shortcoming of aggregate indicators (like GDP, MIPS, Exergy, Net Primary Product Use, Genuine Progress Indicator, ISEW).

Thus indicators need to reflect both the quality and the quantity of renewable resource use. A distinction between sustainable and unsustainable land use seems a minimum condition for any procedure aimed at determining to what extent an activity or region is contributing to (un)sustainable development. This is not to say that such a procedure can easily be implemented, as it is not always easy to determine what sustainable land entails.[6] Nevertheless, ignoring this question, as the EF procedure does, is worse.

An implication of this point is that the EF does not allow for a trade-off between environmental sustainability and intensive/extensive land use, notably in agriculture. Evidently, this is an important issue for policy and science to examine, but it is completely lost in the EF procedure. In agricultural production, for instance, intensive land use, which would translate to a small contribution to the EF, is usually associated with high environmental pressure: use of pesticides and fertilisers, groundwater control and irrigation.

Another important issue neglected by the EF calculation procedure is that land use is regarded to be associated with single functions only. However, in many cases land use (and land cover) provides multiple services or functions, and land is subject to multiple use regimes. This has received ample attention in the study of ecosystems under stress (e.g. Bowes and Krutilla, 1985; van der Ploeg 1990; Braat, 1992). Neglecting multiple use associated with land use will bias the EF upwards.[7]

[6] Serrão et al. (1996) are able to indicate for a range of current land use systems in the Brazilian Amazon the degree of sustainability, distinguishing even between agronomic, ecological, economic and social components. Others have tried to come to grips with this issue by relating economic activities, demography and other variables to land use and land cover patterns (see Darwin et al., 1996). Global modelling (‘integrated assessment’) has also devoted much attention to (un)sustainable land use (see, e.g. Rotmans and de Vries, 1997).

[7] This point was noted by Helias Udo de Haes of Leiden University, The Netherlands.

3.3. Sustainable energy use scenario

A third objection against the EF has to do with the measurement and aggregation procedure used to address environmental impacts associated with energy use. The land appropriated by fossil energy use makes up more than 50% of the EF estimate for most developed countries. This component consists of estimating the land area needed to catch (assimilate) the CO_2 emissions from burning fossil fuels, i.e. ‘carbon sink’ land. The idea behind this is that sustainability is realized if the carbon sink is not exceeded (thereby focusing only on the emission and not on the resource scarcity side of fossil energy use). This is questionable: CO_2 assimilation by forests is one of many options to compensate for CO_2 emissions, and indeed a very land-intensive option.

This approach faces three problems. First, there may simply not be sufficient land available that is suitable for forests. In other words, the suggested sustainable energy scenario is not even technically (or environmentally) feasible. Second, the solution would depend on the availability and cost of land as well as the productivity of reforestation. All these are likely to differ between countries or regions, as they depend on the level of development, the technological expertise available, and geographical circumstances (including climate and soil type)—compare, for instance, Denmark with Australia. Third, the EF is not consistent with marginal cost thinking of economics, and therefore unnecessarily unrealistic from an economic perspective.

To explain the latter, note that even if ‘carbon sink land’ would at present be the cheapest sustainable option at the margin, the EF concept calls for such large reductions in CO_2 emissions that these cannot be realized with marginal economic and societal adjustments. Consequently, it is extremely unlikely that the cheapest option to realize sustainable energy use will remain ‘carbon sink land’. The most straightforward effect is that the more land will be (re)forested, the more expensive this option will become, due to increased scarcity of appropriate land. Other sustainable solutions, less land-intensive and thus less sensitive to increasing land prices, may become attractive then. These include shifts to other fuels, less fuel use, increasing energy efficiency of processes, restructuring of the economy at various levels (input mix, sector structure, demand), or other ways to prevent CO_2 build-up in the atmosphere, such as CO_2 removal and underground storage. The EF neglects the selection of such economically rational options, and will thus be biased upwards.

It should be noted that at a more abstract level the EF is based on the idea that the present unsustainable economic configuration is translated to a sustainable system. It does this by applying a single sustainability scenario to the present configuration. A way to improve the EF procedure in this respect consists of two steps. First, instead of fixing the sustainable energy use scenario, multiple sustainable energy use scenarios should be allowed for. Such alternative scenarios should meet some minimum technical, environmental (available and suitable land) and economic feasibility (cost-effectiveness) conditions. In addition, a model instead of an mere accounting procedure is required to calculate the indirect effects of nonmarginal changes. This should take account, where relevant, of changes in income, production and consumption brought about by increasing costs of energy use that result form particular sustainability-oriented policies. It is very likely that EFs calculated according to such an approach will be much lower than the ones calculated by Wackernagel and Rees.[8]

Concluding this point of critique, the EF is too much dominated by energy use. This is largely due to the hypothetical conversion of energy to land use, which implicitly assumes only one strategy to reduce CO_2 build-up in the atmosphere, namely forestation. Other strategies are ignored which causes an upward bias of the EF.[9]

3.4. Space and regions

A fourth objection relates to the arbitrariness of the spatial scales at which the EF is calculated. Wackernagel and Rees calculate EFs at global, regional, national and local (cities) scales, both on a total and on a per capita basis. However, from an environmental point of view, regional EF estimates are rather arbitrary. National boundaries are of a geo-political and cultural nature and have no environmental meaning.[10] As a matter of fact, country borders often cut right through natural areas or interconnected ecosystems. If one wishes to focus on regional footprints, then it would make more sense to define the regions from an environmental perspective, i.e. using environmental (hydrological, ecological) boundaries. One may thus end up with EFs of, for instance, continents, climate zones, larger connected ecosystems and river catchments. This is consistent with ‘Bioregionalism’ and ‘Deep Ecology’ perspectives on ‘sustainable trade’ (Perkins, 1994).

Regions show large discrepancies in accessibility, environmental and resource endowments, soil characteristics and climate conditions. Such differences have largely determined human settlements and the location of industrial activities and agriculture. For instance, presently a very large proportion of the world population resides in coastal zones, near harbours and (intersections of) waterways. Humans have concentrated in space for a number of reasons. These include economies of scale and scope, agglomeration effects, and

[8] The problem is somewhat similar to the confusion about optimal environmental taxes. These should not be based on the present (nonoptimal) level of marginal externalities, but instead be equalized to the marginal externalities in the optimal economic configuration. If this procedure is not followed, environmental taxes will be set too high. Also the derivation of the optimal taxes requires an economic model that can calculate the new economic configuration that is consistent with their implementation.

[9] By contrast, the EF is downward biased as regards the environmental impact of energy use because of its incompleteness. No account is taken of, for instance, SO_2 an NO_x emissions related to fossil energy use that contribute to acidification. Of course, one cannot simply assume that the downward and upward biases compensate each other. In other words, the sign of the net bias is unclear.

[10] Wackernagel (personal communication) has argued that it is useful to analyze EFs at the national level and compare the results with the national capacity because nations are the largest decision-making body and there is no world government.

compact city advantages. The fact that densely populated countries, regions and cities show large EFs is thus not so much a sign of unsustainability, but rather the outcome of particular spatial allocation factors and specialisation patterns. To focus on regional EFs neglects the positive impact of spatial concentration of people on environmental sustainability. Indeed, a comparison is possible between per capita EF at high and low population densities. This implies that conceptually an optimal trade-off of population density and per capita EF is feasible. In other words, from a global perspective a spatial distribution of people can be determined that minimizes the EF of the world population.[11]

Consequently, in comparing the per capita EF among regions or countries, its value appears in essence to be a reflection of the global distribution of wealth. The per capita EF is neither very informative about the spatial distribution of the impacts nor the causes of environmental pressure. There are better indicators for all three types of distributions. Only an inter-temporal comparison for a particular country, region or city can be informative. Likewise, the comparison of the total EF with available productive land area per country or region is rather meaningless for the above-mentioned reasons. It simply does not seem fair to compare large—in terms of economic activity or land area—and small countries. And similarly, the comparison of sparsely populated, large countries, such as Australia, Canada and the USA, with densely populated, small countries in Europe, is a bit like comparing cities with continents. The latter category of countries necessarily shows a greater openness and trade dependency. Indeed, it holds in general that the smaller is the region the more it will trade with other regions: the global economy is one extreme (no trade) while a city is another (100% trade). This brings us to the next weakness of the EF.

3.5. Trade between regions and countries

A fifth objection against the EF is that it has an anti-trade bias, and can, therefore, not be regarded as an objective indicator. The relationship between trade and regional sustainability is unclear, since the latter is undefined in the EF context. Implicit in comparing the EF with the available productive land in a region, however, is the interpretation that some form of self-sufficiency (autarky) is the most desirable situation.[12]

The concept of 'ecological deficit' is introduced by Wackernagel and Rees (1996, 1997) as an indicator of unsustainability. It is defined as the difference between the ecological footprint and the available ecological capacity, i.e. productive land (both in ha or ha/person). In order to assure global ecological stability, trade should not exceed a level such that an ecological deficit results (i.e. its value < 0). In other words, trade is allowed, but arbitrarily only up to the point where the sum of (hypothetical) land use domestically and abroad equals the available productive land in the region.

The EF completely neglects comparative advantages of countries and regions related to endowments of environmental and ecological resources, or simply in terms of space and population density, e.g. the Netherlands versus Canada. Moreover, the EF does at present not even distinguish between imports based on sustainable and unsustainable land use (following from the discussion in Section 3.2).

In our view, trade can in principle spatially distribute the environmental burden among the least sensitive natural systems. Since it is not realistic to expect the historically developed spatial distribution of human societies to change significantly over a short period of time, and

[11] The optimization or trade-off problem can be formulated as minimizing the global EF, which for a world split up in two regions can be written in mathematical form as follows: choose P_1 to minimize $P_1^* EF_1(P_1/A_1) + P_2^* EF_2(P_2/A_2)$ subject to $P_1 + P_2 = P$; here P is the given world population, P_i is the population size in region i, A_i is the (productive) area of region i, EF_i is the regional (average) per capita EF which depends on the population density P_i/A_i, and $i = 1{,}2$ denotes the region.

[12] The most explicit statement seems to be as follows: "A shift [is needed] from the present emphasis on global economic integration and inter-regional dependence toward greater regional autonomy and self-reliance" (Wackernagel and Rees, 1997, p.21).

because natural resources are immobile, a spatial matching of consumption, production and resource use is only feasible on the basis of trade of commodities and resources. Of course, making trade sustainable requires correct national and international incentives or regulations to be operative, preferably at sources of environmental pressure. Such regulations should also cover the environmental impacts of transport. Only then full ecologically comparative advantages (including climate and geo-physical conditions) can be enjoyed. Section 4 sketches a more desirable approach to study sustainable trade.

4. Sustainable trade

4.1. Spatial sustainability and regional development

The most important objection we have against the use of the EF is that it creates much confusion about spatial sustainability, regional sustainable development, and sustainable trade. The spatial dimension of environmental sustainability and sustainable development has been largely neglected by environmental and ecological economists alike (see, e.g. Costanza and Patten, 1995). One reason for this may be that its study requires some integration of insights from such diverse fields as international economics, regional economics, transport economics, economic development and growth theories, ecology and environmental science. There are at least three important perspectives to be recognized in arriving at a comprehensive view on sustainable trade and spatial or regional sustainability. These will subsequently be discussed.

4.2. Neoclassical economics

A mix of insights from economic theories of long-run growth, international trade and environmental sustainability has so far been lacking in the standard approach to environmental economics. To some extent this is due to the fact that the externality concept of welfare economics has not been clearly linked to the concept of sustainability. The latter is usually approached by economics from the perspective of (macro) economic growth theory, whereas trade theory is closer to welfare (and micro) economics (see for critical evaluations: Folke et al., 1994; van Beers and van den Bergh, 1996). A more complete neoclassical economic theory of international trade and environment should include a number of additional elements: endogenous locations; international imperfect and missing markets; policy competition between countries; and international transboundary pollution flows (e.g. Anderson and Blackhurst, 1992; Markusen et al., 1993; Beladi, and Frasca, 1996; Kox and van der Tak, 1996; Verhoef and van den Bergh, 1996).

On the basis of the traditional mechanism of (Ricardian) comparative advantages, environmental gains can be realized through trade and specialization. Essential in this respect is that natural resources are immobile and not uniformly distributed, i.e. heterogeneous over space. Hence, there are comparative advantages that allow for allocative efficiency gains. The argument raised by Daly and Cobb (1989) and Daly and Goodland (1994), that capital being mobile nowadays implies the gains of trade suggested by traditional trade theory do not apply anymore, is not very convincing. True, in a static context factor mobility substitutes for trade. However, natural and environmental resources are completely immobile. Therefore, the insights from traditional trade theory hold in any case with regard to unique and immobile natural and environmental resources. Of course comparative advantage also holds because capital is not completely and perfectly mobile (e.g. investments in plants), and knowledge and labour characteristics differ between countries.

4.3. Ecological economics

An important issue raised by Wackernagel and Rees (1997), as well as by van den Bergh and Nijkamp (1991, 1994, 1995), is that trade seems to increase regional carrying capacity, whereas it may actually harm it. This problem has to be analyzed from a dynamic perspective. A logical starting point is a model that poses the existence of a finite natural carrying capacity (CC), acting as a limiting factor to the scale of the economy. This may subsequently be extended to address open regions and trade. This gives rise to two qualitative patterns of economic scale and CC over time (see Fig. 1): (1) without trade, i.e. a closed or autarkic system with carrying capacity (CCautarky) completely dependent on regional environmental factors; and (2) with trade, i.e. an open system with carrying capacity dependent on both regional environmental factors and potential trade (CCtrade). The 'density dependent growth' pattern, where the growth rate is dependent on the stock and restrained by some limiting factor (resource), is represented by curve 1 for the autarky situation, and by curve 2 for the trade situation. Through trade with other regions the carrying capacity CCtrade of the region's consumption is lifted upwards. The result can be regarded as the sum of CCautarky and a part dependent on potential trade (Fig. 1).

Two-way interactions between economic and ecological systems may cause variations in a region's carrying capacity over time. For instance, due to trade regional production and consumption can increase such that the regional carrying capacity (CCautarky) is exceeded ('overshooting'), as shown by curve 2. Subsequently, environmental degradation—collapse of regional ecosystems and resources—of factors that compose the CCautarky may occur due to excessive waste and toxic emissions to the region's environmental systems.

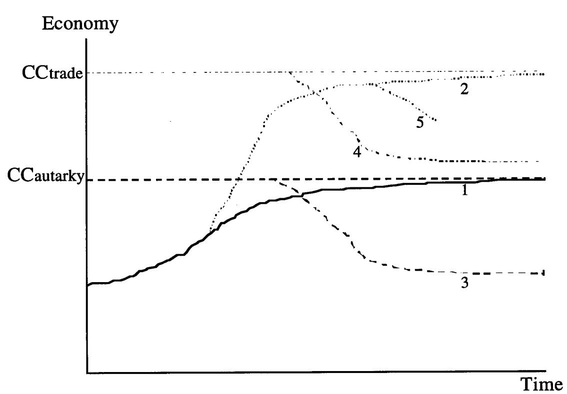

Fig. 1. Development and carrying capacity under autarky and trade.

This results in a lower level of CCautarky after some time, as indicated by curve 3. This in turn can affect the CCtrade in the same direction (curve 4), as it is partly dependent on CCautarky (curve 3). The collapse of the CCtrade (right part of curve 4) affects economic change with some delay, i.e. curve 2 is replace by curve 5.

It should be realized that curve 3 is not a necessary consequence of trade, as long as environmental policy and management are adequate and aimed at long-run sustainability of regional carrying capacity CCautarky. This may of course require such strict environmental policies that trade will be reduced. For instance, exported goods associated with regionally pollutive production may be charged, while imported goods whose consumption creates much pollution in the region may be taxed or even banned.

This simple picture provides a general conceptual framework for studying the interaction between growth and environment on global and regional scales.[13] It recognizes that overshooting in a regional, open system can easier occur than in a global, closed system.

4.4. Social–political issues

It should be recognized that trade can have various negative impacts in social–cultural and political respects, such as weakening community structures, changing landscapes (e.g. types of agricultural crops), confusing human perception through a distant ecological impact of consumptive decisions, and magnifying domestic environmental externalities of production. Trade can even be evaluated negatively from the perspective that environmental policy in very open economies is severely hampered by the objective of stimulating international competitiveness of domestic sectors. All in all, there are many reasons to be critical about foreign and interregional trade.

As opposed to this, one can foresee various negative consequences of minimizing trade between regions, notably given the historical path mankind is on: worsening of international rela-

[13] van den Bergh (1993) has analysed a formal model of variable carrying capacity feedback for a closed system.

tions between country groups, destabilising international trade agreements and institutions (notably the GATT/WTO), trade wars and related conflicts, stagnating diffusion of knowledge and information, and widening of the gap between rich and poor regions in the world. The latter can result from reduced growth perspectives of poorer regions due to less international trade.

Such fundamental issues should be discussed in frameworks that are aimed at supporting a balanced evaluation of advantages and disadvantages of trade. As indicated, the EF is unsuitable for this purpose, as its application to regions incorporates an ex ante, normative bias against trade.

5. Suggestions for improvement and alternative indicators

After so many critical points, we would like to provide a few constructive suggestions for alternative, but closely related, approaches to the EF. A first improvement would be to calculate actual instead of hypothetical 'footprints' of two types, namely sustainable and unsustainable actual land use per capita. Especially the latter is relevant for environmental policy, while the sum would be relevant for equity evaluation among persons.

In addition, more flexibility needs to be allowed for in the EF calculations. One should be careful in trying to find a single, absolute value for the EF, and instead follow a scenario approach, which allows to deal with complex processes in the case of large, nonmarginal changes. Moreover, a modelling rather than an accounting approach should be followed to realize economically feasible outcomes.

Allowing for multiple scenarios essentially reflects the impossibility of a one-to-one mapping of the unsustainable present situation to a hypothetical sustainable world. Moreover, different conceptions of sustainability may also imply different footprints. Each of these involve political choices, which should perhaps be made explicit, e.g. changing prices, implementing standards, and the pursuit of 'autarky'.

'Ecological deficit' calculations are only useful for 'Bioregions', and generally not for politically bounded regions or nations. In this way, carrying capacity has a real meaning and can be made more concrete. Of course, one does not need to aggregate various environmental impacts into a single EF but may focus on particular types that are most critical for the ecological context considered. Regional carrying capacities are so different, and hence, actual land use in a region should be compared with available land and its quality or capacity, an approach many ecologists would probably feel more comfortable with.

'Ecological deficit' calculations for political regions should be approached differently, e.g. based on genuine savings indicators (Pearce et al., 1998). For surveys of alternative indicators, see Kuik and Verbruggen (1991), Ayres (1996), Rennings and Wiggering (1997), Pearce et al. (1998), Gilbert and Kuik (1999). The regional and spatial dimensions still need to be fully integrated in the process of indicator development.

6. Conclusions

We are in sympathy with Wackernagel and Rees in their concern about the impact of humans on natural systems, as well as with their effort to construct an indicator using an explicit accounting framework and a detailed database.

Nevertheless, we cannot subscribe to the view that EF analysis provides sufficient information about the ecological impact and 'appropriation', and we do not think that the EF as it is presently constructed can serve as an indicator for assessing (regional) (un)sustainability. Application of the EF on a global level provides no new insights: it is well-known that the human species threatens environment, nature and biodiversity, and exhausts many natural resources. Moreover, application of the EF on a regional level provides information that is easily misinterpreted. The main reasons are that the EF is too aggregate, uses a fixed sustainable energy scenario, represents hypothetical rather than actual land use, makes no distinction between sustainable and unsustainable land use, does not recognize advantages of spatial concentration and specialization, and is in certain applications biased against trade. Such a trade bias can easily lead to the odd conclusion that the 'ecological deficit' can only be reduced by expansion (more land) or an extremely restrictive population policy (as in China). In conclusion, the EF is unsuitable as a tool for informing policy-making: it can support unsustainable, inefficient and even immoral policy options.

We have argued that trade can in principle spatially distribute the environmental burden among the least sensitive natural systems, a point which does not seem to have attracted much attention in the literature so far. But this requires that correct incentives or regulations are operative, preferably at sources of environmental pressure, and international policy coordination for transboundary environmental issues. Spatial sustainability and sustainable trade need to be approached from a dynamic and non-biased perspective, paying due attention to insights from neoclassical economics, ecology, and social-political sciences. Spatial or regional sustainability should focus on 'bioregions' rather than political regions. Indicators should provide information useful to making trade-offs between economic efficiency, spatial equity, and environmental sustainability.

Acknowledgements

We are grateful to Klaus Hubacek, Mathis Wackernagel and an anonymous referee for helpful comments. They are not responsible for any errors and, of course, do not necessarily support our opinions.

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