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Working Paper

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Discussion Paper Series, No. 412

Provided in Cooperation with:
Alfred Weber Institute, Department of Economics, University of Heidelberg

Suggested Citation: Baumgärtner, Stefan; Becker, Christian; Faber, Malte; Manstetten, Reiner (2004) : Relative and absolute scarcity of nature: Assessing the roles of economics and ecology for biodiversity conservation, Discussion Paper Series, No. 412, University of Heidelberg, Department of Economics, Heidelberg

This Version is available at:
https://hdl.handle.net/10419/127234

University of Heidelberg

Department of Economics

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September 2004

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September 2004

Abstract. Our aim in this essay is to identify and analyze some of the difficulties with interdisciplinary integration of economic and ecological contributions to the study of biodiversity loss. We develop our analysis from a widely accepted definition of economics which is based on the concept of scarcity. Taking a closer look at this notion, we find that economics actually limits itself to a very particular aspect of scarcity, which we denote as *relative scarcity*. We describe in what respect the economic approach towards biodiversity is based on this notion, and also reflect on the specific understanding of the relation of humans and nature behind the economic approach. We then turn to *absolute scarcity* as another notion of scarcity, and show that this is not within the scope of economics, but has been a theme of ecology and ecological economics. We describe in which way ecological and ecological-economic approaches towards biodiversity are based on the idea of absolute scarcity, and also reflect on the specific understanding of the human-nature relationship behind this notion of scarcity. Against this background, we discuss the roles of economics and ecology for nature conservation. We conclude that the interdisciplinary integration of ecology and economics requires a philosophical underpinning, and suggest a framework for further research.

JEL-classification: Q57, Q20, Q30

Keywords: absolute and relative scarcity, biodiversity, economics, ecology, interdisciplinary integration, philosophy

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1. Introduction

Biological diversity, which has been defined as 'the variability among living organisms from all sources ... and the ecological complexes of which they are part' (CBD 1992), is currently being lost at rates that exceed the natural extinction rates of the past by a factor of somewhere between 100 and 1,000 (Watson et al. 1995). This is one of the most eminent environmental problems of our time (Wilson 1988). Biodiversity, its role for ecosystem functioning and human well-being, its sustainable use, and the various causes for its current loss are multifarious and involve very different aspects (Ehrlich and Ehrlich 1981, Soulé 1986, Barbier et al. 1994, Perrings et al. 1995). By its very nature, this issue cannot be analyzed or solved by one academic discipline alone. It is the subject of many disciplines, such as ecology, economics, environmental science, agricultural science, forestry, regional planning, political science and others.

All these disciplines make valuable contributions. In order to develop an encompassing understanding of, and find sustainable solutions to, biodiversity loss, one requires interdisciplinary integration. As with other large-scale environmental problems, a crucial difficulty arises at this point from the fact that disciplinary analyses start from, and are based on, fundamentally different procedures and perspectives (Norton 1991, Norton and Ruse 2002, Norgaard 2004). To a large extent, this underlying basis is only implicit. As a result, it remains unclear exactly what the respective contributions of each discipline is, what their potential and limits are, and how exactly one should integrate the different disciplinary contributions.

Our aim in this essay is to point out and analyze these difficulties, and to suggest a philosophical approach for successful interdisciplinary integration. We focus on the procedures and perspectives of two disciplines which are essential in the biodiversity context: *ecology*, as the relevant natural science, and *economics*, as an important social science. This includes the field of *ecological economics*, which incorporates the insights from the natural sciences into the study of economy-environment interactions.

When analyzing the perspectives by which these disciplines approach the issue of biodiversity, we focus on the notion of *scarcity*, which is the crucial concept in economics and also plays an important role in ecology and ecological economics. A general and intuitive understanding of scarcity is as follows: Something is *scarce*, if people want to have more of it than is available (Mankiw 2000: 3). Thus, scarcity describes a certain relation between

subjective needs and given possibilities to satisfy them. Generally speaking, the concept of scarcity describes a relation between humans and nature.

We show that this general notion of scarcity is understood in different specific ways in economics on the one hand, and ecology or ecological economics on the other hand. We argue that this reveals different, particular (implicit) perspectives on humans, nature, and the relationship between them. The questions 'What is a human?' and 'What is nature?' are essentially philosophical questions. And so, we conclude that the interdisciplinary integration of ecology and economics ultimately requires a philosophical foundation.

The essay is organized as follows. We develop our analysis from a widely accepted definition of economics which is based on the concept of scarcity. In Section 2, we take a closer look at this notion to find that economics actually limits itself to a very particular aspect of scarcity, which we denote as *relative scarcity*. We describe in what respect the economic approach towards biodiversity is based on this notion, and also reflect on the specific understanding of the relation of humans and nature behind the economic approach. In Section 3, we turn to *absolute scarcity* as a different notion of scarcity. We show that this is not within the scope of economics, but has been a theme of ecology and ecological economics. We describe in which way ecological and ecological-economic approaches towards biodiversity are based on the idea of absolute scarcity, and also reflect on the specific understanding of the human-nature relationship behind this notion of scarcity. In Section 4, we pull together the arguments and discuss the roles of economics and ecology for biodiversity conservation. In the concluding Section 5, we reflect on the philosophical conditions of an interdisciplinary integration of ecology and economics.

2. Relative scarcity

2.1 Economics as the study of relative scarcity

According to a classic definition, economics 'studies human behaviour as a relationship between ends and scarce means which have alternative uses' (Robbins 1932: 15). This definition has a wide scope and consequently economics has approached a wide range of issues. Here, the notion of *scarcity* holds a crucial position, separating the economic dimension from other dimensions of purposeful human behavior involving the utilization of means to achieve ends. This has lead to the understanding that economics is essentially about optimization under constraints, with constraints as an expression of scarcity.

In economics, a means of production or a consumption good is said to be *scarce* if it carries opportunity costs (Debreu 1959: 33, Eatwell et al. 1987). In order to obtain one additional unit of the good one must give up something else – some amount of another good, or an opportunity to do something – or pay a monetary price. Thus, scarcity is defined in a relative way: a good is scarce in relation to other scarce goods. This definition is one of *relative scarcity.*[1]

Such a relative notion of scarcity relies on one particular assumption about (i) the objective possibilities of consumption and (ii) peoples' subjective preferences over these options, namely *substitutability.* First of all, the idea of relative scarcity presupposes the existence of alternative consumption bundles. Usually, there exists a wide spectrum of consumption possibilities which can all be produced from a number of elementary resources. Giving up one particular consumption bundle allows the production of a substitute consumption bundle from these resources, if the resources can be used in alternative ways to produce different consumption bundles.[2] Furthermore, the concept of relative scarcity presupposes that peoples' preferences are characterized by substitutability. Saying that people are willing to give up something else in order to obtain one additional unit of a scarce good, rests on the implicit assumption that people consider these two goods to be substitutes. Giving up one unit of good A and receiving in exchange a certain amount of good B will leave them equally well of in utility terms. Only then does it make sense to say that one is willing to pay for one good by giving up another. The concept of relative scarcity thus rests on the implicit assumption of substitutability both on the production side and on the preference side. In economics, it is generally assumed that continuous substitution is always possible, at least on the margin.[3]

As an illustration consider the following example. Bread is a scarce good. Nonetheless, all of us have enough bread to eat. Scarcity of bread solely refers to the fact that obtaining bread

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[1] The distinction between relative and absolute scarcity employed here goes back to Faber and Manstetten (1998) and Faber et al. (1994).

[2] Technically, this idea is captured in the concept of a *production possibility curve* (Mankiw 2000: 5), which denotes the locus of all output combinations (bundles) that can be produced from a set of resources with a given technology. The *technical rate of substitution* then indicates the rate at which it is possible to transform output A into output B, by producing one unit less of A and using the resources thus saved for producing as much additional output of B as possible.

[3] Although it is possible to formulate preferences for complementary, rather than for substitutable goods, and lexicographic preferences, the commonly employed economic framework always assumes substitutability, e.g. by assuming convexity and continuity of preferences (Debreu 1959, Mas-Colell et al. 1995).

carries opportunity costs. Obtaining one additional unit of bread implies that we have to give up something else. This is relative scarcity as defined above. Bread is scarce in relation to other goods, for instance other food, CDs, gasoline etc., which are relatively scarce as well. Furthermore, at the margin – and given the current average income level in developed countries – all these goods are substitutes for bread in satisfying preferences. At the same time, it is assumed that with increasing demand for bread it is possible to produce more bread by reallocating resources (flour, labor, electricity etc.) from other sectors of the economy to bread-production.

2.2 The study of biodiversity in environmental and resource economics

Based on this understanding of scarcity, economics has addressed environmental and resource issues which have been viewed as problems of relative scarcity with respect to the satisfaction of human needs. According to Fisher (2000), the aspect of scarcity allows one to define the field of environmental and resource economics as a sub-discipline of general economics. For environmental and resource economics studies those areas of optimizing human behavior subject to constraints imposed by the natural world. Examples include the limited stock, concentration and spatial distribution of mineral resources; the natural growth and mutual interaction of biological resources such as populations of different species; the diffusion, transformation and decay of a pollutant in an environmental medium; and so on.

In particular, environmental and resource economics has also addressed the issue of biodiversity loss and conservation. This includes, inter alia, the analysis of

- the measurement of biodiversity (e.g. Weitzman 1992, 1998, Solow et al. 1993, Weikard 1998, Nehring and Puppe 2002, 2004, Brock and Xepapadeas 2004),[4]
- the valuation of biodiversity or individual components thereof (e.g. Randall 1988, Pearce and Moran 1994, Watson et al. 1995, Costanza et al. 1997, Goulder and Kennedy 1997),
- the optimal selection of specific plant genetic traits for the development of pharmaceutical substances (e.g. Polasky and Solow 1995, Simpson et al. 1996, Rausser and Small 2000),

[4] See Baumgärtner (2004) for an overview).

- the use of biodiversity as an insurance of the provision with certain ecosystem services, for instance in agriculture or medicine (e.g. Perrings 1995, Weitzman 2000, Schläpfer et al. 2002, Swanson and Göschl 2003),
- different use and ownership regimes of biodiversity (e.g. Sedjo and Simpson 1995, Lerch 1998, Swanson and Göschl 2000b),
- the relation between biodiversity loss and poverty or, more generally, the distribution of wealth and income (e.g. Munasinghe 1992, Dasgupta 1995, Myers 1995, Swanson and Göschl 2000a), and
- the design of cost-effective and efficient measures of nature conservation (e.g. Polasky et al. 1993, Solow et al. 1993, Weitzman 1993, Swanson 1994, Metrick and Weitzman 1996, 1998, Wu and Boggess 1999, Baumgärtner 2002).

All these economic contributions are based on the idea of relative scarcity of biodiversity.

2.3 The economic view of the relationship between humans and nature

Looking at biodiversity from the point of view of relative scarcity, economics features a specific, implicit understanding of humans, nature, and the relationship between them. In the view of economics, both human preferences and real production possibilities, including production by nature, are characterized by substitutability. The human actor is seen as a rational decision-maker, who makes choices based on his own preferences over goods (*homo economicus*). These goods are held to be substitutes for each other with respect to his preferences. Besides consumption goods, this also includes environmental goods and services.[5] Thus, nature is seen as consisting of substitutable and reproducible environmental goods which serve the purpose of satisfying human preferences. The relationship between humans and nature in economics, therefore, appears as a relation between *homo economicus* and nature as a collection of goods and services which are, in principle, like any other economic goods and services. Other aspects of the relation between humans and nature are not within the scope of economics.

[5] Most of current analyses in environmental and resource economics depend on the assumption of substitutability (Turner 1999).

3. Absolute scarcity

3.1 The notion of absolute scarcity

If a certain good is neither substitutable against others on the production side nor on the preference side, a relative notion of scarcity will not capture the scarce nature of this good. As an illustration consider again the example of bread. As argued above, at the margin and at sufficiently high income levels bread is scarce only in a relative sense. Now imagine a besieged town. There is only a limited amount of flour, bread and other food available. This amount cannot be increased. What will happen? Bread and other food will become ever more scarce as the siege continues, but the scarcity will be of a different kind than the relative scarcity discussed above. The scarcity of food will be of a fundamentally different kind than the also existent scarcity of CDs or gasoline because, at some point in time, it cannot be put into a meaningful relation to other, less essential goods any more. Firstly, at a certain point – when the entire stock of flour has been depleted – it is not possible to produce more bread by reducing the output of other goods. Second, bread, as other food and water, is essential for survival, while gasoline and CDs are not. Therefore, at a certain level of consumption people are no longer wiling to substitute bread with other goods. In such a case, when scarcity concerns a non-substitutable means for the satisfaction of an elementary need and cannot be levied by additional production, one may speak of *absolute scarcity.*

This aspect of absolute scarcity is not within the scope of economics.[6] The very definition of economics (Robbins 1932: 15) presupposes that scarce means have alternative ends, in other words, that there is a possibility of substitution and that there is room for choice.[7] Choice, thus, is the true substance matter of economic analysis. For this reason, absolute scarcity, which implies that there is no choice, is generally beyond the horizon of economic analysis. Problems stemming from the possibility that there is no substitute for essential goods such as bread in a besieged town are typically not considered as economic problems.

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[6] The focus of modern economics on relative scarcity stands in contrast to pre-neoclassical economics, which also addressed issues of absolute scarcity (Biervert-Held 1994, Schefold 2001).

[7] Robbins (1932: 13), when introducing his modern definition of economics, recognizes the fundamental contrast of absolute scarcity and relative scarcity, and limits the range of economics to the latter: "If means of satisfaction have no alternative use, then they may be scarce, but they cannot be economized [i.e. they are not scarce in a relative sense]. The Manna which fell from heaven may have been scarce, but, if it was impossible to exchange it for something else or to postpone its use, it was not the subject of any activity with an economic aspect."

The example of bread in a besieged town may seem far-stretched and absolute scarcity hardly relevant for standard economic problems. But the idea of absolute scarcity is very relevant for the issue of nature conservation. From ecology, it is well known that the extinction of one species can lead to the extinction of another species if the former is an essential ressource for the latter and cannot be replaced (Begon et al. 1998, Ricklefs and Miller 1999). Thus, absolute scarcity is an essential characteristic of biological life. The questions are, to what extent can humans be reduced to being a purely biological species, and how relevant, as a result, is absolute scarcity for humans? In the following, we will discuss the meaning of absolute scarcity for the human being. We will first address non-substitutability on the preference side and then on the production side, before we turn to a discussion of absolute scarcity of biodiversity.

Non-substitutability on the preference side

In the history of economic thought, a distinction has been made between two classes of human needs, which may be called 'elementary needs' and 'imaginary needs' following Schlosser (1784; cf. Binswanger 1991). This distinction goes back to the ancient Aristotelian distinction between the 'natural economy' and the 'artificial economy' (Roscher 1874: 529).[8] This Aristotelian perspective shows up in various forms over time among various scholars preceding the neoclassical era in economics. For example, Thoreau ([1854]1998) employs a similar distinction based on whether the satisfaction of needs is 'necessary of life' or not, when discussing man's relation to nature. And even today, the United Nations make a distinction between basic needs and non-basic needs when assessing progress in worldwide poverty alleviation (ILO 1976, Boltvinik 2001).[9]

More specifically, we denote by *elementary needs* everything that is necessary to sustain human life and reproduction; for example eating, drinking, sleeping, shelter, heating and basic health care. They characterize the human existence as that of a biological animal. *Imaginary*

[8] Schlosser was the first one to translate Aristotle's *Politics* into German. Obviously, he was inspired by the economic ideas expressed therein (Riedel 1962).

[9] "Basic Needs … include two elements. First, they include certain minimum requirements of a family for private consumption: adequate food, shelter and clothing are obviously included, as would be certain household equipment and furniture. Second, they include essential services provided by and for the community at large, such as safe drinking water, sanitation, public transport, and health and educational facilities … Basic needs for health and the closely related field of nutrition can be set on the basis of scientific findings, although these are still being constantly improved" (ILO 1976: 32-33).

needs extend to everything beyond that. If elementary needs are not satisfied, a human cannot survive. In contrast, if imaginary needs remain unsatisfied an individual may feel very much unsatisfied, but will still be alive.

In economics it is presupposed that elementary needs can be satisfied and that they are, indeed, satisfied. This follows from the definition of economics as the study of choice among different alternatives. One may justly suppose that, as far as the satisfaction of elementary needs is concerned, there is no free choice. Someone at the verge of starving to death, when offered a choice between one slice of bread and a CD, is not free to make a choice. Such a person will take the slice of bread, and not even consider the value of a CD. This means, whether one satisfies basic needs or not, given the opportunity to do so or not, is not a matter of choice. Therefore, economics as an academic discipline has confined itself to the study of imaginary needs.

There is a correspondence between the distinction between elementary needs and imaginary needs on the one hand, and the distinction between absolute scarcity and relative scarcity on the other. As far as elementary needs are concerned, absolute scarcity may arise, since people are usually unwilling to trade-off the means for their survival. And as far as imaginary needs are concerned, people will typically hold different goods to be substitutes. In this case, scarcity is a relative one. Since elementary needs refer to the biological condition of human existence, absolute scarcity may be dubbed 'objective scarcity' and relative scarcity 'subjective scarcity'.

There are other aspects of human being beyond elementary needs, which might also be regarded as essential of human life and thus as absolutely scarce. Human life is not fulfilled by mere survival, but by striving for aims beyond mere survival. In this regard some fundamental values might be regarded as absolutely scarce. For example, ethical laws in a Kantian sense, can be regarded as universally and absolutely valid.[10] The same holds for

[10] We refer to Kants *Groundwork of the Metaphysics of Morals* (*Grundlegung zur Metaphysik der Sitten*, [1785]1996: 84): 'In the kingdom of ends everything has either a price or a dignity ("Würde"). What has a price can be replaced by something else as its equivalent; what on the other hand is raised above all price and therefore admits of no equivalence has a dignity. What is related to general human inclinations and needs has a market price; that which, even without presupposing a need, conforms with a certain taste, that is, with a delight ("Wohlgefallen") in the mere purposeless ("zwecklosen") play of our mental powers, has a fancy price ("Affectionspreis"); but that which constitutes the condition under which alone something can be an end in itself has not merely a relative worth, that is, a price, but an inner worth, that is, dignity.'

human rights, freedom or justice. Such values can be seen as absolutely scarce with regard to a fulfilled human existence. There is no substitution conceivable without a degradation of human being. In this perspective, ethical categories are not within the scope of economics. But they constitute a form of absolute scarcity which is not within the scope of ecology either.

Non-substitutability on the production side

When we want to know whether a certain bundle of goods and services can be replaced by another bundle, by reallocating resources from one production process to another production process, we have to make recourse to the objective natural and engineering sciences. Resource availability and transformation (by production) has to obey the laws of nature. For that reason, geology, ecology, physics, chemistry, mechanical and chemical engineering, etc. tell us about the potential and limits of producing goods and services from primary resources.

The natural and engineering sciences provide evidence that the potential for substitution between goods and services by reallocating resources in the economic transformation process is actually limited:

- The laws of thermodynamics specify the *minimal energy and material input required* to produce a certain product (Kondepudi and Prigogine 1998, Bejan 1997).
- Ecology tells us that in using a biological resource as a factor of production, e.g. a stock of fish, cattle, forest or rangeland, the dynamics of the respective ecological system is essentially governed by *different scale effects, discontinuities, thresholds, minimum viable population sizes, limited resilience intervals*, etc. (Begon et al. 1998, Ricklefs and Miller 1999)
- Both thermodynamics and ecology stress the importance of *irreversibility* in a system's dynamics and evolution. This means, it is not always possible to substitute one production result by another one, by just undoing the former and starting anew. An extreme example is species extinction, which cannot be reversed.

From these arguments it becomes obvious that, in as far as production is governed by the laws of nature, the possibilities for substitution between producing alternative consumption bundles are generally limited. In particular, non-substitutability on the production side holds for the goods and services produced directly by nature, as the laws of ecology play a key role here. There are more or less restrictive limits to producing more or less natural goods and services in exchange for the production of manufactured goods and services. Nature provides a lot of

factors for agricultural and industrial production, e.g. water, nutrients, sunlight, pollination and mineral as well as fossil resources. While some of these factors may be replaced by manufactured substitutes, this is not possible for all of them in their entire amount. As a consequence, these services of nature are indispensable – at least to a certain extent. Overall, nature has a number of characteristics, which are systematically neglected when treating nature's goods and services as ordinary economic goods, services or production factors.

3.2 Absolute scarcity in ecology and ecological economics

As argued above, the objective natural and engineering sciences play a key role in the study of absolute scarcity. For the natural and engineering sciences analyze the feasible potential and the limits of production, including relations of substitutability between different production plans. In the realm of biological resources and their diversity, the relevant natural science is ecology, and its contribution to the study of absolute scarcity of biodiversity will be further explicated below (Section 3.3).

The research field of ecological economics, which 'addresses the relationship between ecosystems and economic system in the broadest sense' (Costanza 1989: 1),[11] aims at incorporating the insights of the natural sciences into the study of the relationship between humans and nature. While neoclassical environmental and resource economics, just like economics at large, focuses on relative scarcity of environmental goods and services; ecological economics, by taking into account the natural sciences, recognizes and emphasizes the relevant absolute scarcities as imposed by the biogeophysical environment (Underwood and King 1989). In the view of ecological economists, many environmental goods and services are not only scarce in a relative sense but also in an absolute sense. This is part of the underlying 'vision' of ecological economics, where the term vision is used, following Schumpeter (1954: 41), to denote a 'preanalytic cognitive act'. As Herman Daly (1980: 8), one of the founders of ecological economics put it: '[N]ature really does impose an inescapable general scarcity.' Viewing environmental goods and services as absolutely or relatively scarce thus constitutes a basic difference in vision between neoclassical environmental or resource economics, and ecological economics.

[11] Similarly, Faber et al. (1996: 1ff), Proops (1989: 60) and Edwards-Jones et al. (2000: 3).

3.3 The study of biodiversity in ecology and ecological economics

Ecologists and ecological economists have stressed that biodiversity has an important value in so far as it is instrumental for ecosystem functioning and ecosystems' capability of providing essential life-supporting ecosystem services for humankind. In making this claim, the 'division of labor' between ecologists and ecological economists is the following. Ecology studies biodiversity and its role for ecosystem functioning and evolution in a descriptive way and independent of subjective human valuations. One result of this research is that biodiversity is essential for ecosystem functioning (e.g. Schulze and Mooney 1994, Holling et al. 1995, Tilman 1997, Brown et al. 2001, Kinzig et al. 2001, Loreau et al. 2001, 2002),[12] and for the provision of a number of ecosystem services (e.g. Perrings et al. 1995, Daily 1997, Mooney and Ehrlich 1997). Examples for ecosystem services include biomass production, nitrogen fixation, nutrient cycling, control of water runoff, purification of air and water, soil regeneration, pollination of crops and natural vegetation, partial climate stabilization.

Ecological economists go on to argue that these ecosystem services are essential to support the human existence on Earth. Up until today, no man-made substitutes are known which could replace these ecosystem services – or even only some – at the scale at which we currently depend on them. Ecological economists therefore argue that the ultimate value of biodiversity consists in safeguarding ecosystem functioning and the provision of a number of essential life-supporting ecosystem services for humankind (Perrings et al. 1995, Daily 1997, Mooney and Ehrlich 1997).

3.4 The ecological view of the relationship between humans and nature

Ecologists, and not few ecological economists, tend to regard humans mainly as a biological species like all others, i.e. the human being is regarded as a *homo biologicus*. In this view, and in contrast to the economic perspective, an elementary and absolute dependence of human beings on nature and its biodiversity becomes obvious.[13] This insight refers to the perspective of absolute scarcity, since it presupposes that humans have elementary and non-substitutable needs (such as water, food, fresh air) which have to be satisfied for their mere survival. In this respect, it is the achievement of ecological economics and the natural sciences to recognize

[12] These surveys also stress the large extent of uncertainty about the functioning of ecosystems.

and express the essential and inescapable dependence of human life on nature. Thus, the relationship between humans and nature in ecological economics appears as a relation between *homo biologicus* and nature as an absolutely scarce entity, essential and necessary for survival. Thereby, ecological economics recognizes an aspect of the relationship between humankind and nature which cannot be regarded within economics (Becker 2003: 48-70).

4. The relationship between relative and absolute scarcity

In Sections 2 and 3, we have introduced a categorical distinction between relative and absolute scarcity. But this distinction is not as clear-cut as it seems. It depends on several qualifications and conditions. Whether there exist possibilities of substitution for a certain good or service, depends on a number of factors, such as e.g. the time-scale, the spatial scale, the institutional setting, the organization of interaction, and the hierarchical level of analysis of the problem under study.

- *Time-scale:* Technical progress may yield new technologies over time, which allow the production of substitutes for previously absolutely scarce goods, which then become scarce only in a relative sense. For example, with progress in cardiac transplantation and the development of an artificial heart, the absolute scarcity of the life-supporting function of the natural heart has been transformed into a relative one. As an example of the reverse, in the besieged town considered above, bread may be relatively scarce at the beginning, but may become absolutely scarce as the siege continues.

- *Spatial scale:* A good, which is absolutely scarce on a given spatial scale, may be relatively scarce on a larger spatial scale. In the example of the besieged town, bread is absolutely scarce only within the town, but it may be relatively scarce when considering the country at large.

- *Institutional setting:* Institutions, such as e.g. markets and mechanisms of (international) trade, which foster interaction and exchange between economic agents, introduce or enlarge possibilities of substitution. For example, a subsistence farmer absolutely depends on his own food production. If this person has access to, say,

[13] While humans are, to some extent, different from other animals, for instance, in that they have a consciousness and a free will, to a considerable extent they are just animals. That is, they are characterized by elementary biological dependencies (e.g. MacIntyre 1999).

markets for food and labor, he can transform the absolute scarcity of food into a relative one, by trading his own labor force for food.

- *Organization of interaction:* Interactions and exchange between individuals, and the institutions which govern these interactions, may be organized in an efficient or in an inefficient way. Inefficiency means that resources or consumption goods are wasted, such that individuals and society at large fall short of reaping the maximum benefits from a given resource endowment. If social processes are organized in an inefficient manner, the full potential of substitution is not exhausted, and a certain good may be absolutely scarce, which could be relatively scarce if process were organized in a more efficient manner.

- *Hierarchical level*: An individual's possibilities of substitution are, in general, more limited than societies'. As a consequence, what is absolutely scarce for an individual may be relatively scarce for society at large. As an extreme example, individual freedom and survival are non-substitutable for the individual. However, society at large may consider these as substitutable, for instance in times of war, when the freedom and survival of military personnel are traded-off against the freedom and survival of other members of society and society at large.

As a consequence, the question of substitutability, and the question of relative versus absolute scarcity, cannot be answered in a general way, once and for all, but needs to be addressed in a particular context. It requires detailed knowledge about ecosystem functioning, technological possibilities for substitution, human preferences, organization of interaction, institutional setting, etc. However, all these aspects are subject to dynamic change: evolution of nature, technology, preferences and institutions over time. These dynamic developments are uncertain and cannot be predicted in detail. An additional difficulty arises from the fact that the qualifications and conditions listed above essentially reflect a number of subjective decisions by scientists, e.g. the choice of a particular spatial and temporal scale and the hierarchical level of organization of the system under study.[14]

[14] Technically speaking, a scientist always studies a particular *system representation* of a given system, and not the system itself (Baumgärtner 2000: 165-177, Schiller 2002: Chap. 2). The choice of a system representation (i.e. system boundaries, time-horizon, system elements as well as internal and external relations under study, etc.) introduces a subjective element into all natural and social sciences.

5. Summary and conclusion

5.1 The roles of economics and ecology in the study of relative and absolute scarcity of biodiversity

As we have seen in Section 2 above, economics deals with relative scarcity. Thus, economics is useful and important as far as the relative scarcity of biodiversity is concerned. The aspect of relative scarcity becomes apparent when considering the current situation of species extinction. The *Global Biodiversity Assessment* (Watson et al. 1995: 2) makes the following assessment:

> Because of the world-wide loss or conversion of habitats that has already taken place, tens of thousands of species are already committed to extinction. It is not possible to take preventive action to save all of them.

If it is true that it is not possible to save *all* species, then we face a problem of choice. We have to decide which species to save, and which species to let go extinct. Put this way, biodiversity conservation is clearly an economic problem: how to use limited means, say, a given nature conservation budget, in an optimal way. Economics as a discipline provides the methods and tools to solve this problem. Neglecting economics in the discussion of biodiversity conservation runs the risk of addressing this problem in an inefficient way.

By suggesting efficient allocation rules and institutional designs, economic analysis can help promote efficient strategies for biodiversity conservation. Thus, economics can help to transform, to a certain extent, problems of absolute scarcity into problems of relative scarcity.

However, economics regards the problem of biodiversity loss *merely* under the aspect of relative scarcity. As argued above, the aspect of absolute scarcity cannot be within the scope of economics. Accordingly, economists tend to subsume absolute scarcity under relative scarcity.[15] Yet, as illustrated in Section 3 above absolute scarcity is an important aspect of biodiversity loss. In order to come to grips with this aspect, one needs a different approach.

Ecology and ecological economics provide such an approach, in that they stress the essential and non-substitutable role of biodiversity for human survival. Thus, they recognize one

[15] Typically, in the example of bread in a besieged town economists would recommend to increase the relative price of bread in order to achieve an efficient allocation of bread. As a consequence, demand for bread would drastically decline and everyone who could not afford bread anymore would have to look for substitutes for bread, existing and new ones. The possibility that all inhabitants of the town may starve to death is not a problem amenable to the methods of economics.

specific aspect of absolute scarcity of biodiversity.[16] However, they regard the problem of biodiversity loss predominantly under this aspect of absolute scarcity.

The discussion so far has shown that both the economic perspective and the ecological perspective when applied to the scarcity of biodiversity yield important insights. Each perspective highlights an aspect which the other one does not focus on, such that the two are complementary. As a consequence, a single-discipline approach to the analysis of biodiversity loss and protection is not sufficient, but ecology and economics need to be combined for this purpose (Barbier et al. 1994).[17]

However, the integration of the two perspectives – in order to gain a full and comprehensive view of biodiversity, and its role for human well-being – is difficult for two reasons:

(i) As discussed in Section 4, it is impossible, based on the knowledge of individual natural and social sciences, to clearly distinguish whether biodiversity is relatively or absolutely scarce. Therefore, on these grounds it is impossible to clearly assign roles for economics and ecology in the study of biodiversity loss and conservation.

(ii) As discussed in Sections 2.3 and 3.4, the distinction between relative and absolute scarcity is essentially grounded in a difference in the underlying philosophical views of humans, nature, and their interrelation.

Both of these reasons lead to the conclusion that assessing the roles of economics and ecology for biodiversity conservation is not possible merely on the level of economics and ecology. It requires transcending the natural and social sciences, and explicitly entering into a philosophical discussion.

5.2 Beyond economics and ecology: the philosophical dimension

In the end, a comprehensive discussion about biodiversity loss and protection comes down to a discussion of our images of humankind and nature, as well as their relationship. Both economics and ecology provide us with one particular dimension of this image. In economics, the relationship between humans and nature appears as a relationship between *homo economicus* and nature as a diverse bundle of substitutable consumption goods and production

[16] Remember (from Section 3.1) that there could be further dimensions of absolute scarcity which are not based on biological reasons; e.g. an ethical dimension of absolute scarcity.

[17] In a similar vein, Norgaard (1989, 2004) argues for methodological pluralism in ecological economics, and discusses different modes of `learning and knowing collectively'.

factors, which are not essentially different from manufactured goods and factors. In ecology, this relation appears as a relationship between *homo biologicus* and nature as an entity which is essential and necessary for his survival. Both disciplines and perspectives address important dimensions of the human being and its relation to nature: The human being obviously shows both essential dimensions – *homo economicus* and *homo biologicus* – and nature is both a set of objects, which are subject to rational choice, as well as an entity, which is essential for human survival.

However, it is not sufficient to just consider these two perspectives. Even taken together, the economic and the ecological perspective do not give a full and comprehensive picture of the interrelation between humans and nature. There are additional dimensions of the human being and its relation to nature (Becker 2003, Becker and Manstetten 2004). The difficult question, what is the meaning of nature for humankind beyond her economic function and beyond her necessity for biological survival, cannot be fully discussed within economics and ecology. Human life is more than biological survival and rational economic choice. It also defines and fulfils itself essentially in an ethical dimension, for example, in the horizon of what has been called a 'good life' (e.g. Aristotle 1925). In this sense, the relation between humans and nature also has an ethical dimension, which can only be discussed in philosophical terms (e.g. Cafaro 2001, Spaemann 1989).

Thus, assessing the roles of ecology and economics for biodiverity conservation ultimately requires the integration of the ecological and the economic view on humankind and nature into an encompassing philosophical understanding of the relationship between humans and nature. This should allow for an integrated view of the human being, which solves the possible tension between the different human dimensions, and determines the meaning of each one as well as their relation. The same holds for the different views of nature and for the relation of the human being with nature.

In conclusion, a philosophical approach can achieve at least four tasks:

(i) clarify the preconditions, potential and limits of ecology and economics for the analysis of biodiversity protection;

(ii) identify the dimensions of the problem which are beyond the scope of these two disciplines;

(iii) formulate and analyze the ethical dimension of the problem;

(iv) provide a philosophical framework in which the different underlying perspectives of disciplines such as ecology, economics and ethics, as well as their relation can be identified and integrated.

Biodiversity loss and conservation is a complex and multifarious problem. There are already a large number of fruitful contributions to the analysis and solution of this problem from a large number of different academic disciplines. What is on the agenda now, is an interdisciplinary integration along the lines of (i) through (iv). This goes beyond biodiversity research in the traditional, disciplinary sense, and shows the need for a philosophy of science that deals with the foundations of interdisciplinary research.

Acknowledgements

We are grateful to Geir Asheim, Karin Frank, Andreas Lange, Birgit Müller, Konrad Ott, Martin Quaas, Irene Ring, Johannes Schiller, Ralph Winkler and conference participants at the *8th Biennial Conference of the International Society for Ecological Economics* (Montreal 2004) for critical discussion and helpful comments; to Eva Kiesele for research assistance; to Maximilian Mihm for assistance with language and style; and to the *Volkswagen Foundation* for financial support under grant II/79 628. S.B. gratefully acknowledges financial support by the *Deutsche Forschungsgemeinschaft (DFG)* under grant BA 2110/1-1 and the hospitality of the *Energy and Resources Group* at the *University of California, Berkeley* where the first draft of this manuscript was written.

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